House Pyörre, National Housing Fair at Lohja 2021

Material and climate declaration

3.7.2021 Matti Kuittinen

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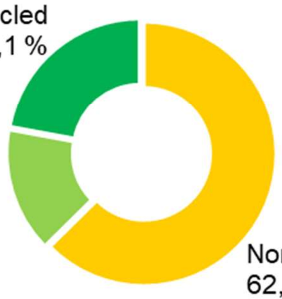
House Pyörre

Finnish housing fair at Lohja, 2021

Aalto University
School of Arts, Design
and Architecture

Circular economy

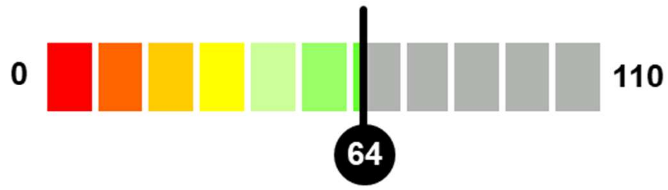
Origin of materials



Materials	tonnes
Soil, gravel and rocks	67
Concrete	42
Timber	19
Metals	16
Gypsum	11
Thermal insulation materials	7
Glass	2
Ceramics	1
Other materials	7
	172

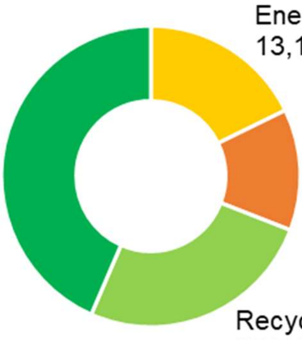
Flexibility and adaptability

DGNB ECO2.1



Utilisation potential of materials after their use

Building Circularity



Climate

Caused harms

CO_2e

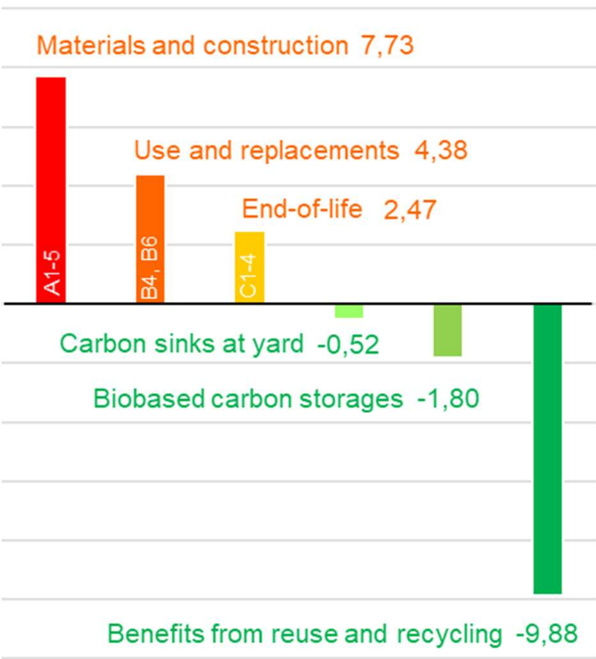
Carbon footprint
+ 14,6 $kgCO_2e/m^2/a$

Potential benefits

CO_2e

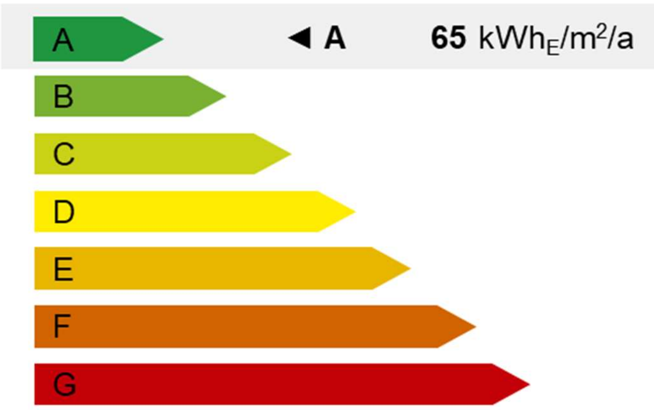
Carbon handprint
– 12,0 $kgCO_2e/m^2/a$

Distribution of climate impacts ($kgCO_2e/m^2/a$)



Energy

Energy class



1 Description of the building

Building	
Address	Palkkikatu 9, Lohja, Finland
Building type	Single-family house
Year of completion	2021

Technical information	
Number of floors	1
Gross floor area	227 m^2
Heated floor area	160 m^2
Net floor area	197 m^2
Volume	895 m^3
Number of rooms	3 room + kitchen + laundry + wc + garage
Number of users	2
Material of loadbearing frame	Steel
Construction type	On-site
Foundation type	Steel piles
Energy systems	Air-to-water heat pump, solar PV panels
Energy class	A (65 $kWh/m^2/a$)
Amount of purchased energy	54 $kWh/m^2/a$
Design service life	100 years

Project team	
Client	Timo Ranta and Jukka Turunen
Main constructor	Leena Lundell / Aulis Lundell Oy
Principal designer and architect	Matti Kuittinen
Structural designer	Sami Huttunen
HVAC designer	Markku Sainio
Garden designer	Matti Kuittinen
Interiour designer	Client, main constructor, architect
Main material provider	Saint-Gobain Finland Oy
Landscaping	Uudenmaan Pihamestarit Oy

2 Background

The purpose of the material and climate declaration is to evaluate the potential for circular economy and the climate impacts of the building. The evaluation was carried out during the design and construction phases, before taking the building into use.

At the time of the evaluation, there was no official method for assessing the circular economy of buildings. There are very few methods in Europe either, that would be suitable for quantitative assessment of circularity. Therefore, the assessment of circularity is based on combination of three complementary assessment methods: EU´s Level(s)[1], German DGNB[2] and Building Circularity Tool of OneClickLCA software[3].

The climate declaration of this report is based on the method published by the Ministry of the Environment of Finland in 2021 for public hearing. This method was tested at the national housing fairs at Lohja for all buildings. It is based on EU´s Level(s). With the method, it is possible to quantify both climate burdens (carbon footprint) and potential climate benefits (carbon handprint).

This report consists of three main chapters: material efficiency (chapter 3), adjustability (chapter 4) and climate impacts (chapter 5).

Estimated impacts	*Used methods*
Origin of materials	Level(s)
Classification of materials	Level(s)
Share of recycled materials	Building Circularity, EPDs
Adjustability of the building	Level(s)
Scoring for the adjustability	DGNB
Utilisation of materials after the use of the building	Building Circularity
Carbon footprint	Ministry of the Environment 2021
Carbon handprint	Ministry of the Environment 2021

[1] https://ec.europa.eu/environment/levels_fi
[2] https://www.dgnb-system.de/en/buildings/new-construction/criteria/index.php
[3] https://www.oneclicklca.com/fi/rakennushankkeisiin/rakentamisen-kiertotalous/

3 Material efficiency

3.1 Assessment of material efficiency

The assessment includes materials and products used in the building and on its site. Their inventory is based on data from main constructor´s logs, on architect´s Building Information Model, and on inquiries from the construction site. The materials have been estimated separately for each life cycle stage. Estimation of losses at the construction site and expected replacements during a 50 year use period of the building are included.

3.2 Materials used

Origin of materials	total tonnes	kg/m^2	share
Renewable	29	181,25	15,3 %
Non-renewable	119	743,75	62,6 %
Recycled	42	262,5	22,1 %
Reused	0	0	0,0 %
Total (incl. losses and replacements)	**190**	**1187,5**	

Distribution of materials	total tonnes	kg/m^2	share
Soils and gravel	67	418,75	39,0 %
Concrete	42	262,5	24,4 %
Timber	19	118,75	11,0 %
Metals	16	100	9,3 %
Gypsum	11	68,75	6,4 %
Thermal insulation materials	7	43,75	4,1 %
Glass	2	12,5	1,2 %
Ceramics	1	6,25	0,6 %
Other materials	7	43,75	4,1 %
Total (only for the building ”as built”)	**172**	**1075**	

Product groups with highest shares of recycled materials	share	weight (t)
Thermal insulation materials	51 %	3,57
Soils and gravel	47 %	31,49
Metal parts	28 %	4,48
Gypsum products	19 %	2,09
Concrete products	6 %	2,52
Other products in total	33 %	2,31

3.3 Utilisation of materials after use

	total tonnes	kg/m^2	share
Can be reused	83	518,75	43,5 %
Can be recycled as materials	49	306,25	25,7 %
Can be recycled as energy	25	156,25	13,1 %
Left for landfilling	34	212,5	17,8 %

The figures above describe the potential for utilisation. Real utilisation rates in the future will depend on e.g. legislation and markets at the time of the disassembly of the building.

4 Adjustability and ease of disassembly

The adjustability of spaces and the ease of disassembly have qualitatively been estimated based on the design documents. Quantitative scoring has been carried out according to German DGNB framework.

4.1 Adjustability of spaces

The building is designed to be used for residential purposes. During its service life the following changes may be done without the need to change loadbearing structures:

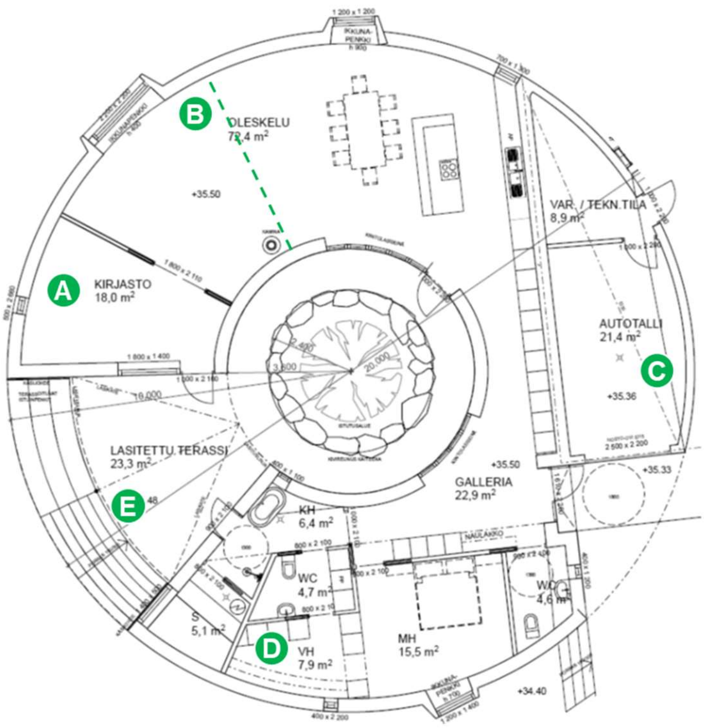
A. Library can be converted into bedroom. Change requires that the door will be changed to have better acoustic value.

B. Living area can be divided into two separate spaces.

C. Garage can be converted into residential use. It is half-warmed and additional thermal insulation can be installed. In such change, the garage door would be replaced with solid wall with a window. Such change may require building permit.

D. The walk-in closet next to bedroom can be converted into small working space or into an alcove for e.g. an infant.

E. The terrace can be insulated into an indoor space. This would add two more rooms to the building without increasing the footprint of the building. Such change would require building thermal envelope around the loadbearing structures, as well as a building permit.



4.2 Scoring of flexibility and adjustability

The assessment is based on German DGNB framework´s criteria ECO2.1. DGNB was one of the very few methods that included scoring at the time of the assessment. However, even this method is clearly not intended for single-family homes. The assessment was done based on design documents.

Criteria	*Requirement*	*Assessment of the house*	*Score*
1. Space efficiency	• Ratio of floor area to gross area. • Range of ratio in residential buildings: ≤ 0,60 ratio ≥ 0,80 • Scores: 1…20	Floor area: 197 m^2 Gross area: 227 m^2 Ratio: 0,87	20 / 20
2. Ceiling height	• Higher space improves flexibility and offers room for post-installation additional building service systems. • Range in residential buildings: ≥ 2,5m … ≥ 2,75m • Scores: 7…10	Measure (average): 2,93 m	10 / 10
3. Depth of floor plan	• Wider space improves flexibility. • Scoring in residential buildings: • 5,75m ≤ frame ≤ 6,75m = 5p • 6,25m ≤ frame ≤ 6,75m = 10p	Measure: 5,87 m	5 / 10
4. Vertical access	(Indicator not used for residential buildings)		
5. Floor layout	• Dimensions of rooms ensure their neutral use. Standard-sized rooms (4x4m or 3x3m) are multifunctional (10 points) • Separating the loadbearing frame from internal partitions enables adjustability (5 points)	Rooms can be used for multiple purposes, as described in section 4.1 of this report. However, the rooms are not rectangular (5 points). Internal dividers of the house are not loadbearing (5 points).	10 / 15
6. Structure	• If loadbearing structures do not prevent flexibility, this eases the multifunctionality of spaces (2,5 points). • Building service shafts can	Space-dividing structures are not loadbearing, there are no loadbearing beams or columns. (2,5 points).	2,5 / 5

	enable flexible adjustments of kitchen and wet spaces (2,5 points).	Building service shafts are designed for the current location of wet spaces only (no points).	
7. Building services	Adjusting parts of the building service systems without having to a open surfaces eases flexibility. Scoring: • 1 point, if possible with considerable structural changes • 7 points, if possible with marginal structural changes • 10 points, if possible without structural changes		
	Ventilation system	Ducts built inside the ceiling. Changes require partial disassembly of the wooden slats of the ceiling. Slats are attached with screws for easing this.	7 / 10
	Cooling system	Cooling is done partially with ventilation and partially with the indoor unit of the heat pump.	7 / 10
	Heating system	Floor heating with water circulation that is cast inside a concrete top floor.	1 / 10
	Water and sewage system	Pipes are placed inside the ground floor structure, but can be accessed from the crawl space below.	1 / 10
	Electricy and automation (not assessed in residential buildings)		
8. Use of building	Extra scores, if use rate can be increased at least in half of the spaces.	The house is a private residence, thus not suitable for increasing use rate.	0 / 10
		Total score	**63,5** / 110

4.3 Ease of disassembly

Assessment for the ease of disassmebly and for the utilisation of disassembled products and materials has been made based on design documents. Although the utilization would take place in the future, its potential has conservatively been estimated according to today´s practices. In reality, recycling and reuse policies are evolving and would possibly allow for greater decrees and higher hierarchies of utilization.

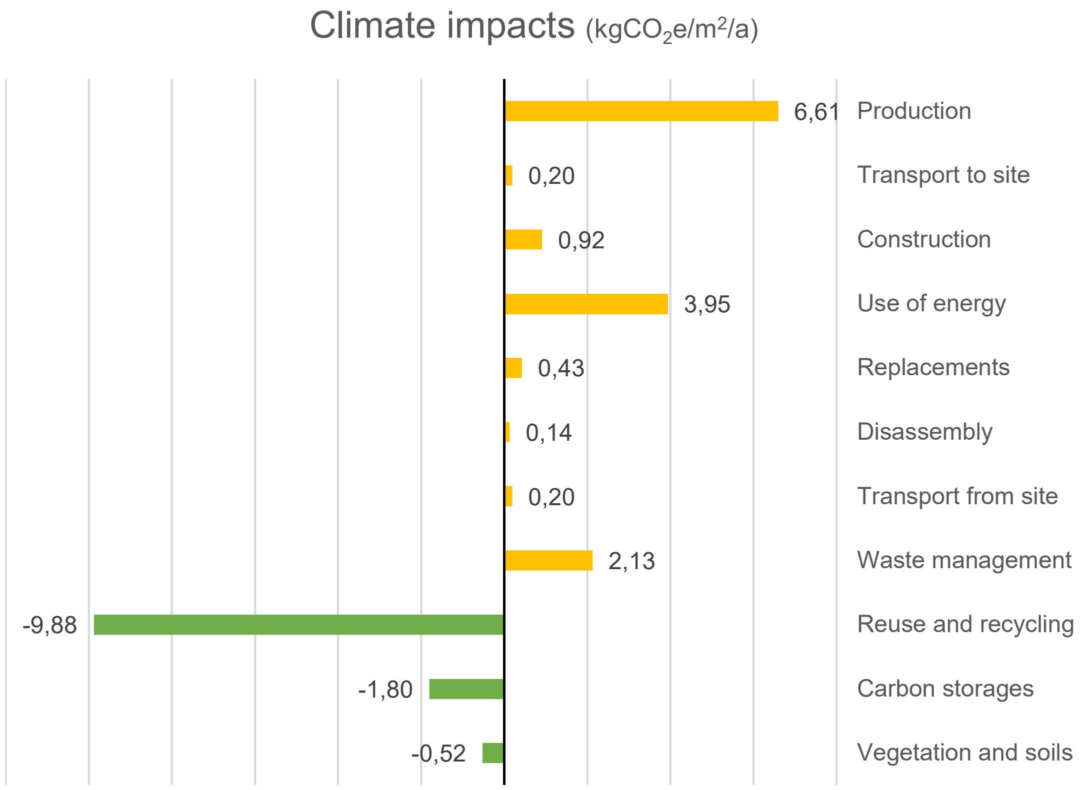
Component	*Materials*	*Ease of disassembly*	*Utilisation potential*
Loadbearing frame	Steel, gluelam timber, timber	Parts are attached to each other with screws and attachment plates.	- Reuse of components - Recycling of steel - Energy recovery of wood
Roofing	Bitumen	-	- Recycling as material - Energy recovery
Foundation	Steel screw piles, steel beams	Piles can be unscrewed from the sandy soil	- Reuse - Recycling of steel
Floor slab	Concrete	-	- Recycling as material
Thermal insulation	Glass wool	-	- Recycling as material
Internal dividers	Steel framing and gypsum boards	-	- Recycling as material
Doors and windows	Wood, glass, rubber, metal hinges	Doors and windows attached to frames with screws. Fixed glazing attached to frame and seamed with detachable elastic compound.	- Reuse of components - Recycling of metals and glass - Energy recovery of wood and rubber
External and internal claddings	Corrugated metal sheet, timber	Attached with screws	- Reuse - Recycling of steel - Energy recovery of wood
Paving	Concrete	Not fixed, can be disassembled	- Reuse - Recycling as aggregate
Ventilation pipes	Plastic	Fixed with metal components	- Energy recovery

5 Climate impacts

5.1 Summary

Majority of climate impacts arise before the use of the building. Production of building products and materials, their transport and assembly causes around 53% of the carbon footprint. As the building has highest energy class, the carbon footprint during 50 year use is only around 30%. After the use, disassembly, transport and handling of waste cause around 17% of emissions.

The carbon handprint of the building is almost as high as its carbon footprint. This is due to the good recyclability potential of the chosen building materials, especially regarding steel components.



Climate impacts have been estimated according to the draft Decree on Climate Declaration (2021) by the Ministry of the Environment of Finland. Inventory is based on main constructor´s data and on Building Information Model of the architect. Amount of purchased energy is based on the “as built” version of building´s energy performance certificate. Data on the carbon footprints and handprints of individual products are based on their EPDs or on the national emission database (www.CO2data.fi).

5.2 Carbon footprint

Carbon footprint describes the total sum of greenhouse gas emissions over the life cycle of the building. Its calculation includes those building parts and life cycle stages that are included in the assessment method of the Ministry of the Environment. Reference study period is 50 years.

Production stage (A1-3) is the most dominant part of building´s carbon footprint. It constitutes 45% of the emissions of the entire life cycle. Most of these emissions are associated to the production of external walls and loadbearing frame.

The building is highly energy-efficient and consumes only 54 kWh/m^2 of purchased energy per annum. In addition, solar panels on the roof produce up to 1 500 kWh of electricity annually. Due to these factors the building requires only small amounts of grid electricity and therefore the carbon footprint from operational energy use remains at 27% of life cycle emissions.

A	**Carbon footprint before use**	kgCO_2e/m^2/a
A1–3	Production of building products	6,61
A4	Transport to site	0,20
A5	Construction site activities	0,92
	Total	**7,73**

B	**Carbon footprint during use**	
B1	Use of products	(not included)
B2	Maintenance	(not included)
B3	Repairs	(not included)
B4	Replacements	0,43
B5	Refurbishments	(not included)
B6	Operational energy use	3,95
B7	Operational water use	(not included)
	Total	**4,38**

C	**Carbon footprint after use**	
C1	Demolition	0,14
C2	Transport to waste management	0,20
C3–4	Waste management and final disposal	2,13
	Total	**2,47**

A+B+C	**Total carbon footprint over full life cycle**	**14,58**

5.3 Carbon handprint

Carbon handprint describes such climate benefits that would not occur without the building project and that can be quantified with European EN standards or international ISO standards. Included building parts follow the assessment method of the Ministry of the Environment (2021).

Most of the potential climate benefits are associated to the reuse and recycling of building components. They and energy recovery from building materials total 82% of carbon handprint.

Carbon storages in the building are considered for those wooden building parts that have design service life of 100 years. They account for 15% of the carbon handprint. Wood and bio based products that have shorter design service life have been excluded from the assessment. However, there is as much carbon content in such short-lived wood products as in those that have a design service life of 100 years.

Regarding the assessment of cement-based products, it has been conservatively assumed that after their end-of-life, only part of the concrete rubble could be used in applications where the rubble is in contact with air. The assumption is based on Government Decree VNa 843/2017 that specifies the conditions under which concrete rubble can be used in infrastructure works. Following these assumptions, most of the concrete rubble would not be in touch with ambient air and hence could not undergo noteworthy carbonation during an assessment period of 100 years. If concrete rubble could in future be used e.g. in gabions, it would carbonate faster and absorb more CO_2 from the atmosphere.

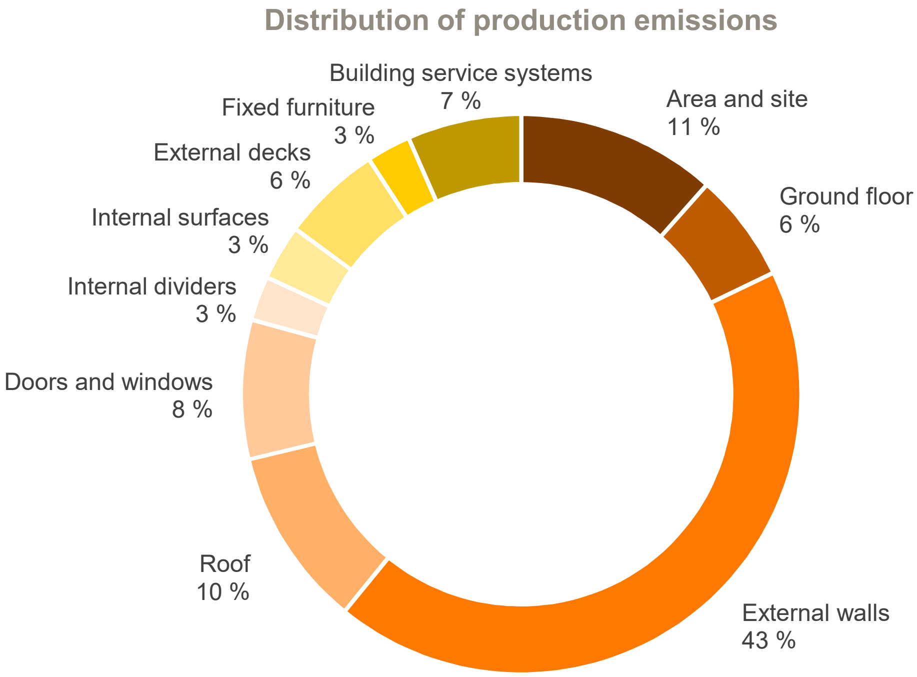
Although the assessment method of the Ministry of the Environment does not include carbon uptake potential of vegetation or soils, these impacts were calculated as an additional information. The quantity and type of vegetation and growing media were gathered from garden design documents. Majority of the sequestered carbon after a 50 years of photosynthesis and soil organic carbon uptake is found in apple and cherry trees planted on the site. Their carbon contents were assessed based on their growth algorithms. In addition, shrubs, lawns and contents of soil organic carbon were estimated based on ongoing research on the topic at Aalto University.

Carbon handprint		$kgCO_2e/m^2/a$
D1+D2	Reuse, recycling and energy recovery	− 9,88
D3	Surplus renewable energy	0
D4	Longterm carbon storages	− 1,80
D5	Carbonation of cement-based products	− 0,19
	Total	**− 11,96**

Additional	Carbon uptake into vegetation and soils	− 0,33

5.4 Distribution of carbon footprint into building parts

The emissions from the production phase (A1-3) were also studied in relation to building parts.



Majority of the emissions are related to the production of the external wall and the loadbearing frame (45%). These building parts include high degree of metals that still have moderate amounts of recycled raw materials. Had they higher recycled scrap content in the future, the emissions from the production of such components would be lower.

Structures on the site and the foundations account for 11% of emissions. Most of these emissions come from the production of concrete paving on the yard. The share of emissions is low, because steel screw piles are used instead of traditional foundations.

Roof structures cause around 10% of the emissions. Most of these are related to the production of the bitumen roofing. The chosen bitumen product is low in its manufacturing emissions, but as it did not have an EPD, these benefits could not be taken into account.

6 Innovations and experiments

Geopolymer concrete has been utilised in the floor slab of the garage. Part of the aggregate of the concrete has been replaced with recycled foundry sand. Paving concrete on the yard is made from mix that includes recycled foundry sand and biochar. In both experiments the weight of recycled materials is around 40%.

Biochar has been mixed into the growing medium on the site. The aim was to improve water retention of the soil, as well as boost vegetation growth. The biochar was preloaded with organic fertilizer.

Nanocarbon technology is being tested in one of the sliding doors of the building. The nanocarbon component in the door acts also as a heating source.