Swedish Environmental Research Institute

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LCA – NTR treated wood decking and other decking materials

Report nr. 715202
IVL report C 302

Title:
LCA on NTR treated wood decking and other decking materials

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(report also published as ISBN 978-91-88787-37-8, IVL report No C302)

March 2018
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Table of Contents

Summary

An evaluation of the environmental impact of an NTR Class AB terrace construction was done in a life cycle perspective. NTR (Nordic Wood Preservation Council) is an industrial trade organization comprising the wood preservation councils of the Nordic countries. Wood preservation plants which fulfil the requirements set forth by NTR can label their products with the NTR label. This study concerns NTR class AB, for products intended for outdoor use, above ground. Main focus was on the global warming potential (GWP). All parts of the terrace were considered including foundation and substructure. Results were compared with alternative terrace materials, Siberian larch, Ipé, WPC (Wood Polymer Composites), and Concrete. Of the different terrace alternatives, NTR Class AB showed the lowest global warming potential (GWP) while WPC showed the highest. The full 30-year life cycle GWP of the 30 m^2 NTR AB terrace was 172 kg CO_2-eqv corresponding to the CO_2 emissions caused by driving an average sized car 1433 km.

1. Introduction

The ever-increasing focus from consumers and lawmakers on environmental sustainability, has led to “environmental friendliness” becoming an important sales argument for any consumer product along with more traditional parameters such as quality, durability, price, etc. While many products claim to be “environmentally friendly”, “eco-friendly”, “green”, or similar it is not always easy for the consumer to judge the validity of these claims. Life cycle assessment (LCA) is a methodology established to objectively quantify, evaluate and compare environmental impacts from products and processes.

Pine wood is an abundant resource in Scandinavia. While pine heartwood is moderately durable, the sapwood is susceptible to fungal attack (rot) which limits the service life when used in outdoor applications. To increase the durability and thus prolong the service life of pine sapwood, it can be treated with chemicals. NTR (Nordic Wood Preservation Council) is an industrial trade organization comprising the wood preservation councils of the Nordic countries. NTR maintains systems for approval of wood preservatives and for quality control of impregnated wood products. Wood preservation plants which fulfil the requirements set forth by NTR can label their products with the NTR label. The NTR labelling system is widespread and covers about 90% of the Scandinavian market for impregnated wood products. The NTR label is divided into subcategories depending on impregnation class and the intended final use of the product. This study concerns NTR class AB, for products intended for outdoor use, above ground (Figure 1).

Figure 1. *The NTR class AB label for impregnated wood products for outdoor use, above ground.*

NTR class AB is a common material choice for decking. Alternative materials include amongst other things different wood species such as Siberian larch and tropical timber species, but also composite materials such as Wood Plastic Composites (WPC) and concrete.

Siberian larch is used for terrace decking and other outdoor applications. The heartwood of Siberian larch is moderately durable without impregnation. The wood is felled and processed in Siberia.

Ipé is a representative for the tropical timber species commonly used for decking. Other typical decking species include Cumaru, Bankirai, Jatoba, Teak, Massaranduba, etc. Ipé is a heavy hardwood species with a high durability without impregnation. The wood is felled and processed in South America.

WPC are composites made from plastic polymers and milled wood or bamboo (sawdust). The wood to polymer ratio can vary but is typically 50% wood, 50% polymer. The polymer part is typically High Density Poly Ethylene (HDPE) but other polymers can be used as well. The HDPE-part is typically virgin or pre-consumer recycled plastic although some producers claim to use a certain percentage of post-consumer recycled plastic. China is a major producer of WPC but European producers also exist. WPC is often marketed as “maintenance free”.

Concrete decking is produced as concrete blocks or tiles with different geometry. Concrete is typically produced locally.

2. Scope

This report evaluates the environmental impact of a wooden terrace made from pressure treated wood (NTR class AB). The environmental impact is compared to alternative materials – Siberian larch, tropical wood (Ipé), Wood-Plastic Composites (WPC), and concrete. The full life cycle is considered (cradle-to-grave). The assessment includes the entire terrace i.e. both decking layer and substructure and/or foundation.

The study was conducted according to the guidelines found in ISO 14040 and ISO 14044 and includes 1) Goal and scope definition; 2) Inventory analysis; 3) Impact assessment; and 4) Interpretation.

Data collection for the different terraces has been limited to published data supplemented by data base input.

3. Inventory analysis

For all terraces, an inventory analysis was made covering all identified input and output flows to and from the environment for the full life cycle of the products (cradle to grave). The inventory was carried out for the functional unit of 30 m^2 of terrace (5m x 6m). The terraces were assumed to be constructed in Stockholm, on more or less level, soil terrain. The analysis includes all materials and operations necessary for the construction of the terrace, i.e. site preparation, foundation, substructure, and decking. For the wooden terraces, maintenance by application of water based product at regular intervals was assumed. Application of water based product by brush every 5 years from year 1, volume needed per application 15 m^2/l = 2 l. The water based product was modeled to have the composition as given in EN152:2011. No maintenance was considered for the WPC and concrete terraces. The following end-of-life scenarios were calculated for the different terraces; NTR class AB: incineration. Siberian larch, Ipé and WPC: incineration. Concrete: backfilling. Carbonation of the concrete is accounted for both in the use phase and at the end of life (appendix A).

3.1. NTR AB

The lifetime of the terrace is assumed to be 30 years. The wood, Scots pine (*Pinus sylvestris*) is grown, harvested, processed and impregnated in Sweden. The bulk density is about 550 kg/m^3 (i.e. the raw density at delivery). The underlying LCA (Erlandsson 2013) is based in specific data and can be assumed to be representative for countries like Norway and Finland. Data was collected in 2013 and no significant changes in the process etc. have been introduced, why they are representative also for the current production. The data from Erlandsson (2013) is used but the uptake of wood preservative was updated to take into account the new NTR uptake requirements and the result was divided in NTR AB and NTR A. No major site preparation is needed and the terrace is constructed using small electrical power tools.

3.1.1. Description

The terrace consists of substructure and decking. The decking layer of the NTR Class AB terrace consists of pine wood (Scottish pine) treated with wood impregnation chemicals according to the NTR Class AB classification.
The substructure consists of a series of parallel wood struts (NTR Class A, 45x195 mm) placed 60 cm apart to support the decking. The struts themselves rests on 3 load bearing struts (NTR Class A, 45x195 mm) which again rests on concrete cubes (10x10x7 cm) to keep the wood struts out of ground contact and to provide a level and stable substructure. The cubes per strut are used i.e. 9 in total. The wood struts are heavy and wide enough to be placed directly on the concrete cubes without further fixation. The decking boards (NTR Class AB, 28x120x3000 mm) are placed on top of the substructure and fixed with stainless steel screws to the substructure struts. 2 screws per board/strut crossing. The distance between each board is 5 mm.

3.1.2. Materials

Decking

Boards (incl. 10% waste): NTR Class AB terrace boards. Dimensions: 28x120 mm. Quantity: 264 m (e.g. 88 boards of 3.0 m). Volume: 0.887 m^3. Origen: Scottish pine, grown, felled, sawn, and impregnated in Sweden. Transport distances: Forest to sawmill (logs - truck) – 30 km, sawmill to impregnation facility (boards - truck) – 50 km, impregnation facility to hardware store (boards - truck) – 100 km.
Screws: Stainless steel, 4.0x60mm, 880 pieces (11x40x2), 4.09 g/piece = 3599 g total.

Substructure

Struts, support (incl. 10% waste): NTR Class A. Dimensions: 45x195. Quantity: 19.8 m. Volume: 0.17 m^3.
Struts, decking (incl. 10% waste): NTR Class A struts. Dimensions: 45x195. Quantity: 60.5 m. Volume: 0.53 m^3. Origen: Scottish pine, grown, felled, sawn, and impregnated in Sweden. Transport distances: Forest to sawmill (logs - truck) – 30 km, sawmill to impregnation facility (boards - truck) – 50 km, impregnation facility to hardware store (boards - truck) – 100 km.
Screws: Stainless steel, 4.0x60mm, 66 pieces (11x3x2), 4.09 g/piece = 270 g total.
Concrete cubes: Dimensions 100x100x70 mm. Weight: 1.55 kg. Quantity: 9. Total weight: 13.95 kg.

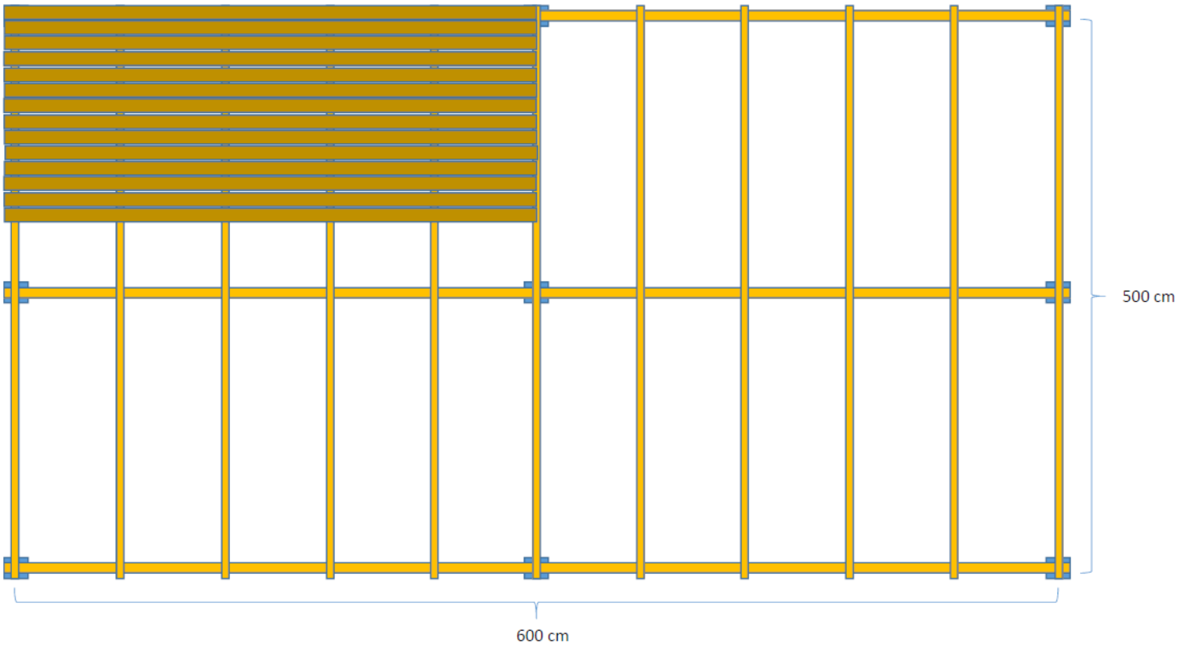

Figure 1. *Schematic drawing of the NTR AB terrace, showing the substructure and part of the decking. See text for details.*

3.2. Siberian larch

The lifetime of the terrace is assumed to be 15 years. A bulk density of 660 kg/m^3 is used in the calculations affecting mainly the environmental impact from transportation. The wood is grown, harvested, and processed in Siberia. Transport of logs and processed boards by truck until Irkutsk. Transport from Irkutsk to Sct. Petersburg by railroad. Transport from Sct. Petersburg to Stockholm by ship. No major site preparation is needed and the terrace is constructed using small electrical power tools. The underlying LCA is based on an earlier work by Erlandsson (2013) and several assumptions are made for forest and sawmill operations (see reference for further details). However, these assumptions affect production (A1 and A3) and are not significant for the overall result since the major contribution to environmental impact is from transportation to Scandinavia.

3.2.1. Description

The terrace construction is identical to the NTR Class AB terrace, the only difference being the wood material of the decking layer. The terrace consists of substructure and decking. The decking layer of the Siberian larch terrace consists of Siberian larch. The substructure consists of a series of parallel wood struts (NTR Class AB, 45x195 mm) placed 60 cm apart to support the decking. The struts themselves rests on 3 load bearing struts (NTR Class AB, 45x195 mm) which again rests on concrete cubes (10x10x7 cm) to keep the wood struts out of ground contact and to provide a level and stable substructure. The cubes per strut are used i.e. 9 in total. The wood struts are heavy and wide enough to be placed directly on the concrete cubes without further fixation. The decking boards (Siberian larch, 28x120x3000 mm) are placed on top of the substructure and fixed with stainless steel screws to the substructure struts. 2 screws per board/strut crossing. The distance between each board is 5 mm.

3.2.2. Materials

Decking
Boards (incl. 10% waste): Siberian larch terrace boards. Dimensions: 28x120 mm. Quantity: 264 m (e.g. 88 boards of 3.0 m). Volume: 0.887 m^3. Origen: Siberian larch, grown, felled, and sawn in Russia. Transport distances: Forest to sawmill (logs - truck) – 50 km, sawmill to Irkutsk (boards – truck) – 200 km, Irkutsk – Skt. Petersburg (rail – boards) – 5500 km, Skt. Petersburg to Stockholm (boat – boards) – 750 km, Stockholm to hardware store (boards – truck) – 30 km.
Screws (incl. 10% waste): Stainless steel, 4.0x60mm, 880 pieces (11x40x2), 4.09 g/piece = 3599 g total.

Substructure
Struts, support (incl. 10% waste): NTR Class AB. Dimensions: 45x195. Quantity: 19.8 m. Volume: 0.1737 m^3.
Struts, decking (incl. 10% waste): NTR Class AB struts. Dimensions: 45x195. Quantity: 60.5 m. Volume: 0.5309 m^3.
Origen: Scottish pine, grown, felled, sawn, and impregnated in Sweden. Transport distances: Forest to sawmill (logs - truck) – 30 km, sawmill to impregnation facility (boards - truck) – 50 km, impregnation facility to hardware store (boards - truck) – 100 km.
Screws: Stainless steel, 4.0x60mm, 66 pieces (11x3x2), 4.09 g/piece = 270 g total.
Concrete cubes: Dimensions 100x100x70 mm. Weight: 1.55 kg. Quantity: 9. Total weight: 13.95 kg.

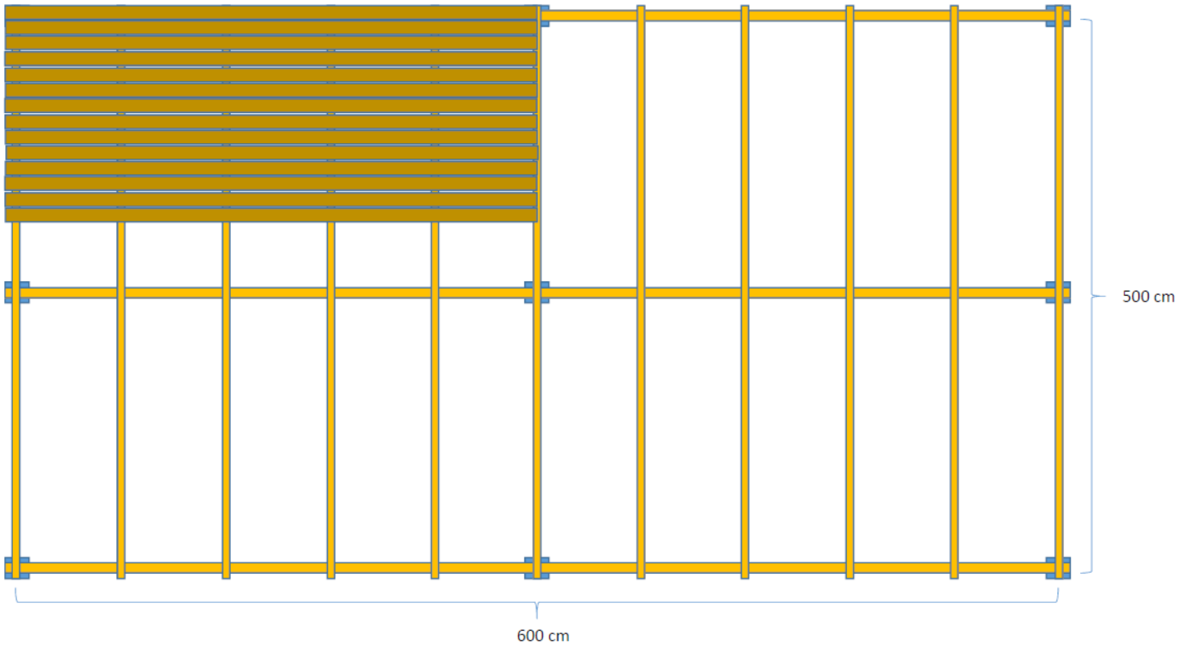

Figure 2. *Schematic drawing of the Siberian larch terrace, showing the substructure and part of the decking. See text for details.*

3.3. Ipé

The lifetime of the terrace is assumed to be 30 years. The wood is grown, harvested, and processed in Brazil. The underlying LCA data is based on Jankowsky (2015). A bulk density of 1100 kg/m^3 is used in the calculations. Transport from forest to sawmill by truck. Transport from sawmill to shipping port by truck/boat. Transport from shipping port to Hamburg by ship. Transport from Hamburg to Stockholm by truck.

3.3.1. Description

The terrace construction is identical to the NTR Class AB terrace, the only difference being the wood material of the decking layer. The terrace consists of substructure and decking. The decking layer of the Ipé terrace consists of Ipé. The substructure consists of a series of parallel wood struts (NTR Class AB, 45x195 mm) placed 60 cm apart to support the decking. The struts themselves rests on 3 load bearing struts (NTR Class AB, 45x195 mm) which again rests on concrete cubes (10x10x7 cm) to keep the wood struts out of ground contact and to provide a level and stable substructure. The cubes per strut are used i.e. 9 in total. The wood struts are heavy and wide enough to be placed directly on the concrete cubes without further fixation. The decking boards (Ipé, 21x145 mm) are placed on top of the substructure and fixed with stainless steel screws to the substructure struts. 2 screws per board/strut crossing. The distance between each board is 5 mm. The area of the terrace is adjusted slightly to 4.95 x 6.04 m to get an integer number of boards (33) on the width of the terrace.

3.3.2. Materials

Decking
Boards (incl. 10% waste): Ipé terrace boards. Dimensions: 21x145 mm. Quantity: 219 m. Volume: 0.667 m^3. Origen: Ipé, grown, felled, and sawn in Pará state, Brasil. Transport distances: Forest to sawmill (logs - truck) – 30 km, sawmill to Santarem (boards – truck) – 50 km, Santarem – Belem (boards - boat) – 700 km, Belem to Hamburg (boat – boards) – 8210 km, Hamburg to Stockholm (truck – boards) – 1000 km.
Screws (incl. 10% waste): Stainless steel, 4.0x60mm, 726 pieces (11x33x2), 4.09 g/piece = 2969 g total.

Substructure
Struts, support (incl. 10% waste): NTR Class AB. Dimensions: 45x195. Quantity: 19.8 m. Volume: 0.1737 m^3.
Struts, decking (incl. 10% waste): NTR Class AB. Dimensions: 45x195. Quantity: 60.5 m. Volume: 0.5309 m^3.
Origen: Scottish pine, grown, felled, sawn, and impregnated in Sweden. Transport distances: Forest to sawmill (logs - truck) – 30 km, sawmill to impregnation facility (boards - truck) – 50 km, impregnation facility to hardware store (boards - truck) – 100 km.
Screws: Stainless steel, 4.0x60mm, 66 pieces (11x3x2), 4.09 g/piece = 270 g total.
Concrete cubes: Dimensions 100x100x70 mm. Weight: 1.55 kg. Quantity: 9. Total weight: 13.95 kg.

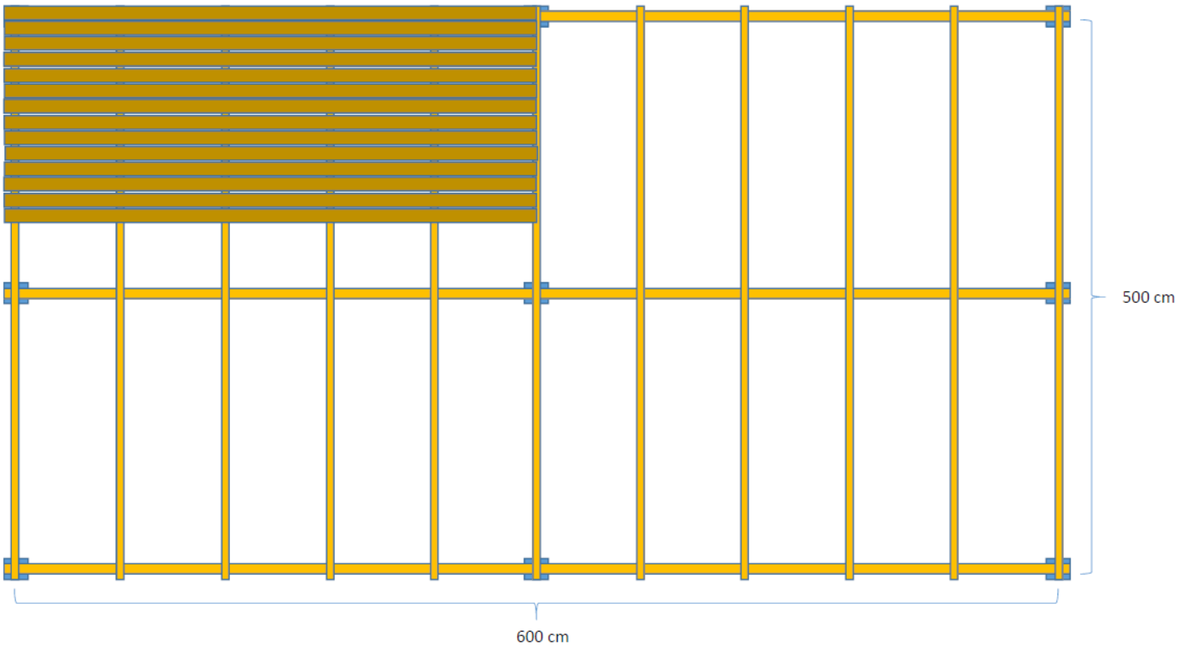

Figure 3. *Schematic drawing of the Ipé terrace, showing the substructure and part of the decking. See text for details.*

3.4. WPC

The lifetime of the terrace is assumed to be 30 years. The WPC lifetime is not well established due to a lack of long term field test results. It is possible that the expected lifetime could be longer. No major site preparation is needed and the terrace is constructed using small electrical power tools.

The LCA data for WPC is based on Philipp et al (2016) that is compared and validated with the EPD published by VDH (2015). Based on these sources different scenarios have been calculated including different manufacturing sites in Germany and China. Different material combinations are also validated. The different scenarios are described below. WPC is a variable product and the environmental impact is influenced by e.g. origin of the production site, transport distance from production site to consumer, wood/polymer ratio in the final product, type of polymer, virgin/recycled ratio in the polymer part, and end-of-life aspects (incineration, land-fill, recycling, etc.).

Origen: Two places of origin are examined: China (Zhejiang Province) and Germany (Sachsen-Anhalt). Most of the WPC terrace boards available on the Scandinavian market seems to be of Chinese origin. However, the German scenario was included to show the influence of production place in the final analysis.

Wood-polymer ratio: declared wood-polymer ratios vary. A common ratio is about 50% wood, 50% polymer. However, since some producers claim up to 75% wood, we have included to scenarios in this assessment: 1) 50% wood/50% polymer, 2) 70% wood/30% polymer.

Type of polymer: The polymer part is assumed to be High-Density Poly-Ethylene (HDPE).

Virgin/recycled ratio in the polymer part: Two scenarios are examined, 1) the polymer part consists of 100% virgin material, 2) the polymer part consists of 50% virgin material and 50% post-consumer recycled plastic. At present, the majority of the products on the market will contain 100% virgin material, however the fifty-fifty scenario was provided to show the potential environmental impact from adjusting the virgin/recycled polymer ratio.

Summing up, a representative WPC product on the Scandinavian market, would be imported from China and consist of 50% wood (or bamboo) and 50% virgin HDPE. Other scenarios are assessed to show the potential influence on environmental impact from changing the assumptions.

3.4.1. Description

The decking layer – as well as the substructure struts – of the WPC terrace consists of Wood Polymer Composites. The WPC material consists of 50% wood fibers and 50% polymers, additives etc.

The terrace construction differs to the wood terraces above in that the WPC terrace uses WPC struts in the substructure. The terrace consists of a substructure and the decking. The substructure consists of a series of parallel struts (WPC 30x40 mm) to support the decking. The struts themselves rests on a grid of concrete cubes (10x10 cm) to keep the struts out of ground contact and to provide a level and stable substructure. The cubes are placed 40 cm apart in the direction of the struts and 30 cm apart in the direction across the struts, according to the manufactures installation guide. Compared to the wood terraces the WPC terrace needs the supporting pillars closer together due to the lower stiffness of the WPC material compared to wood. The WPC struts are fixed to the concrete cubes using stainless steel screws – 6 per strut. The decking boards (WPC, 25x150) are placed on top of the substructure and fixed with special fittings and screws (stainless steel) to the substructure struts. 1 screws per board/strut crossing. The distance between each board is 5 mm. The area of the terrace is adjusted slightly to 4.96 x 6.03 m to get an integer number of boards (32) on the width of the terrace.

3.4.2. Materials

Decking

Boards: WPC terrace boards (incl. 10% waste): Dimensions: 25x150 mm. Quantity: 212.3 m. Volume: 0.796 m^3. Weight: 618 kg.
Origen 1: WPC, Produced in Zhejiang Province, China. Transport distances: Production site to Shanghai (truck) – 100 km, Shanghai to Hamburg (ship) – 19960 km, Hamburg to Stockholm (truck) – 1000 km.
Origen 2: WPC, Produced in Sachsen-Anhalt, Germany. Transport distances: Production site to Stockholm (truck) – 1280 km.
Screws: Stainless steel, 3.0x40mm, 672 pieces (21x32), 2.00 g/piece = 1344 g total.
Fittings: Stainless steel special fittings, 693 pieces (21x32 + 21 extra for start row), 8.72 g/piece = 6042 g.

Substructure

Struts (incl. 10% waste): WPC struts. Dimensions: 30x40 mm. Quantity: 114.6 m. Weight: 113 kg (0.99 kg/m).
Origen 1: WPC, Produced in Zhejiang Province, China. Transport distances: Production site to Shanghai (truck) – 100 km, Shanghai to Hamburg (ship) – 19960 km, Hamburg to Stockholm (truck) – 1000 km.
Origen 2: WPC, Produced in Sachsen-Anhalt, Germany. Transport distances: Production site to Stockholm (truck) – 1280 km.
Screws: 3.0x40mm, 273 pieces (21x13), 2.00 g/piece = 546 g total.
Concrete cubes: Dimensions 100x100x70 mm. Weight: 1.55 kg. Quantity: 273. Total weight: 423 kg.

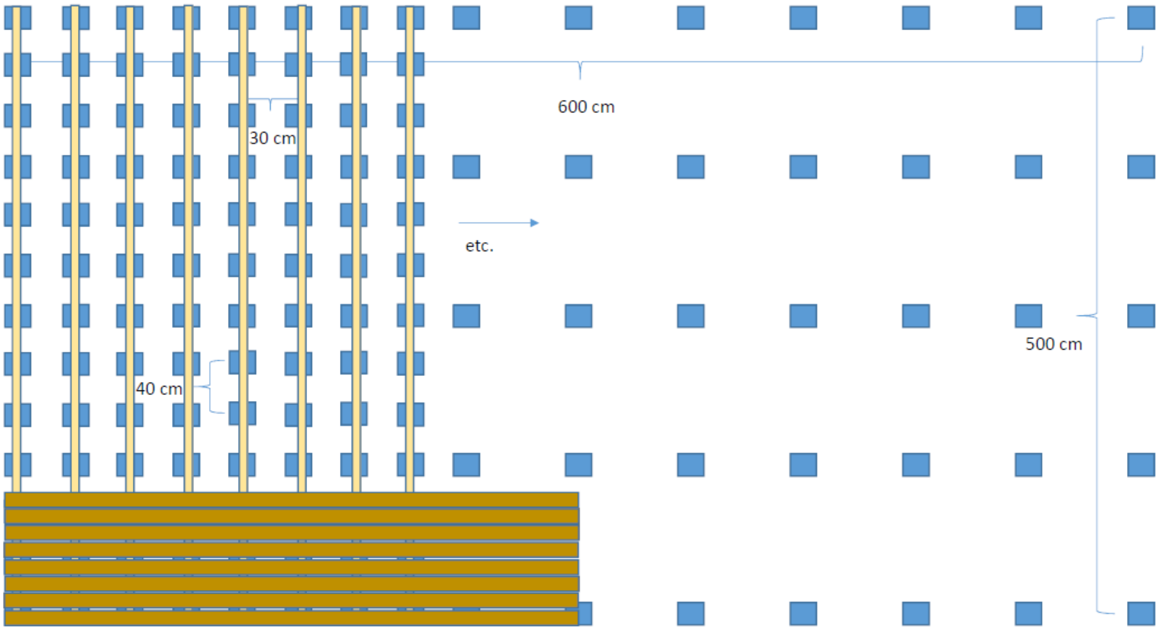

Figure 4. *Schematic drawing of the WPC terrace, showing the substructure and part of the decking. See text for details.*

3.5. Concrete

The lifetime of the terrace is assumed to be 30 years. The LCA data for concrete cradle to gate (A1-A3) comes for an EPD valid for concrete used in an external environment (Svensk Betong 2017). The LCA data for gravels and crushed rock is fund in Gabi databases and is therefore generic data. The concrete is produced in Sweden. The chosen geometry of the concrete blocks was 15x15x6 cm. The assessment includes the foundation (hard core, gravel, coarse and fine sand).

3.5.1. Description

The decking layer of the concrete terrace consists of concrete squares 15x15x6 cm. The terrace construction differs substantially to the wood and WPC terraces described above. The terrace is constructed on level soil terrain. The terrace consists of a foundation/substructure and the decking. Establishment of the foundation requires removal of 40 cm of the existing terrain i.e. 12 m^3. The work is assumed to be done by a compact excavator. The foundation consists of three layers of sand/rock mixtures to secure the long term stability of the terrace. At the bottom, a 15 cm layer of hard core. On top of this, a 10 cm layer of gravel, and finally a 3 cm layer of coarse sand on top of which the decking blocks are laid. The blocks are laid with a 3 mm wide open groove between each block. Finally, the space between the blocks is filled with fine sand which is vibrated between the stones. During construction, each layer of material is compacted with a 200 kg plate compactor. The area of the terrace is adjusted slightly to 5.05 x 5.97 m to get an integer number of blocks (33x39) on the width of the terrace.

3.5.2. Materials and equipment

Decking
Concrete terrace blocks. Dimensions: 15x15x6 cm. Quantity: 1287. Weight: 3861 kg.
Fine sand: 400 kg.

Substructure

Hard core: 15 cm layer thickness. Quantity: 4.5 m^3.
Gravel: 10 cm = 3 m^3.
Coarse sand: 3 cm = 0.9 m^3.

Equipment
Compact excavator (fuel: gasoline) for removal of existing terrain.
Plate compactor, 200 kg, for compacting the foundation (fuel: gasoline).

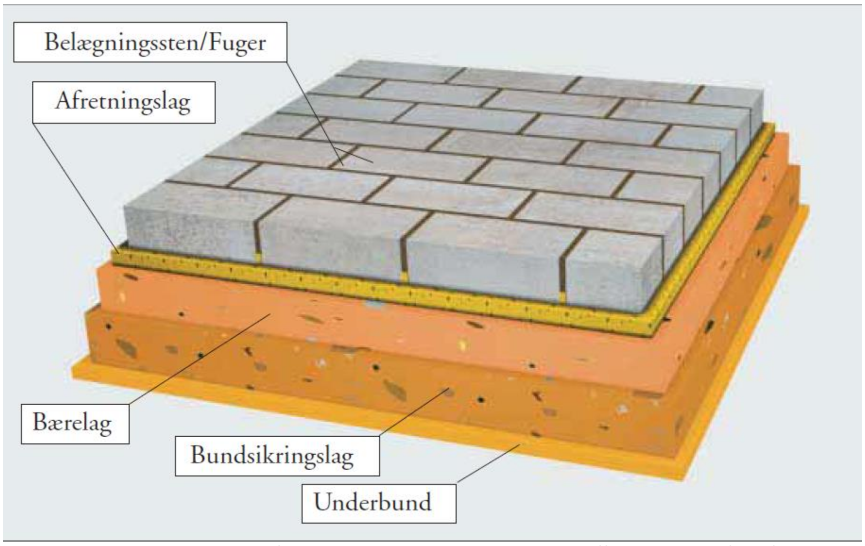

Figure 5. *Schematic drawing of the concrete terrace, showing the different layers of the foundation. Image from Dansk Beton. See text for details.*

4. Impact assessment

4.1. Impact categories

The following impact categories were evaluated:

Parameter	Unit
Global warming potential (GWP)	kg CO_2-eqv
Acidification potential (AP)	kg SO_2-eqv
Eutrophication potential (EP)	kg PO_4^{3-}-eqv
Ozone depletion potential (ODP)	kg CFC11-eqv
Photochemical oxidant creation potential (POCP)	kg C_2H_4-eqv

NTR Class AB is pressure impregnated with fungicides. There are currently no generally accepted methods available for calculating and evaluating toxicity impacts. Therefore, the impact categories human toxicity and ecological toxicity are not evaluated in this study. UseTox is suggested to be used in the EC product environmental footprint (PEF) pilot study, but would likely need to be further developed before accepted in the final PEF system as a mandatory indicator. UseTox do not handle the fact that the availability of metals is reduced over time. If this method is used where metal emissions occurs and combined with the model assumption of integration of impact with an infinity time perspective, the relative importance of metals will be overestimated. Another problem with UseTox is that terrestrial toxicity is not included in the assessment.

In the EU, chemicals for wood impregnation are regulated through the chemical regulation REACH and the BPR (Biocidal Product Regulation). To have a chemical approved for wood impregnation purposes, it must first be approved and registered in REACH and then approved for wood impregnation purposes through the BPR. Here, the manufacturer must, through calculation of a series of scenarios, prove to the authorities that the human and environmental exposure to impregnation chemicals are below the threshold values defined by the authorities.

All impregnation chemicals used for NTR marked wood are approved through REACH and the BPR.

5. Interpretation

The LCA results are given in table 1 for the examined impact categories. The results for the Global warming potential are analysed in more detail below.

Table 1. *LCA results for the different impact categories.*

Impact category	Unit	NTR Class AB	Siberian larch	Ipé	WPC 50-50 DE	WPC 50-50 CN	Concrete
GWP	kg CO_2-eqv	172	422	265	1296	1867	412
AP	kg SO_2-eqv	0.915	3.489	1.918	2.40	7.09	0.807
EP	kg PO_4^{3-}-eqv	0.390	0.802	0.404	0.420	0.774	0.188
ODP	kg CFC11-eqv	8.84E-06	2.99E-05	4.44E-06	6.52E-06	7.79E-06	4.14E-06
POCP	kg C_2H_4-eqv	0.118	0.316	0.116	0.173	0.587	0.010

Results are presented for the different phases of the life cycle (A-C) according to EN15804 (figure 6). In this assessment, focus is on the global warming potential (GWP). According to figure 6, the different parts of the life cycle can be divided into

- A) Product and construction process stage (covering raw material supply, manufacturing, construction/installation, and all related transport)
- B) Use stage (covering use, maintenance, repair, etc)
- C) end of life stage (covering de-construction, waste processing, disposal, and all related transport).

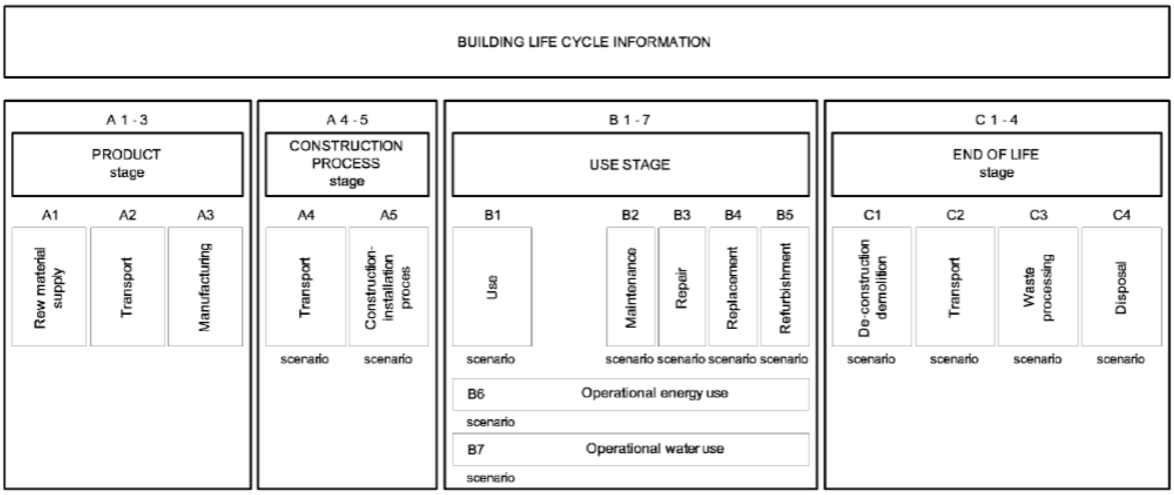

Figure 6. *Life cycle stages according to EN 15804.*

Figure 7 shows the aggregated results for the different terrace scenarios in the form of GWP. Results cover the full 30 m^2 terrace and units are kg CO_2-eqv. The life time of the terraces is 30 years after which the terraces are de-constructed and disposed of. The WPC terrace is represented by two different scenarios: Chinese production site vs. German production site. Both WPC terraces are assumed to consist of 50% wood and 50% virgin HDPE.

Results show that the WPC terraces have by far the largest GWPs. NTR Class AB has the lowest GWP followed by the ipé terrace. The contribution from the larch and the concrete terrace is almost identical. For the WPC terrace, there is a significant difference between the Chinese and the German production scenario. The majority of the difference stems from higher GWP of the Chinese energy mix and transportation form China to Europe.

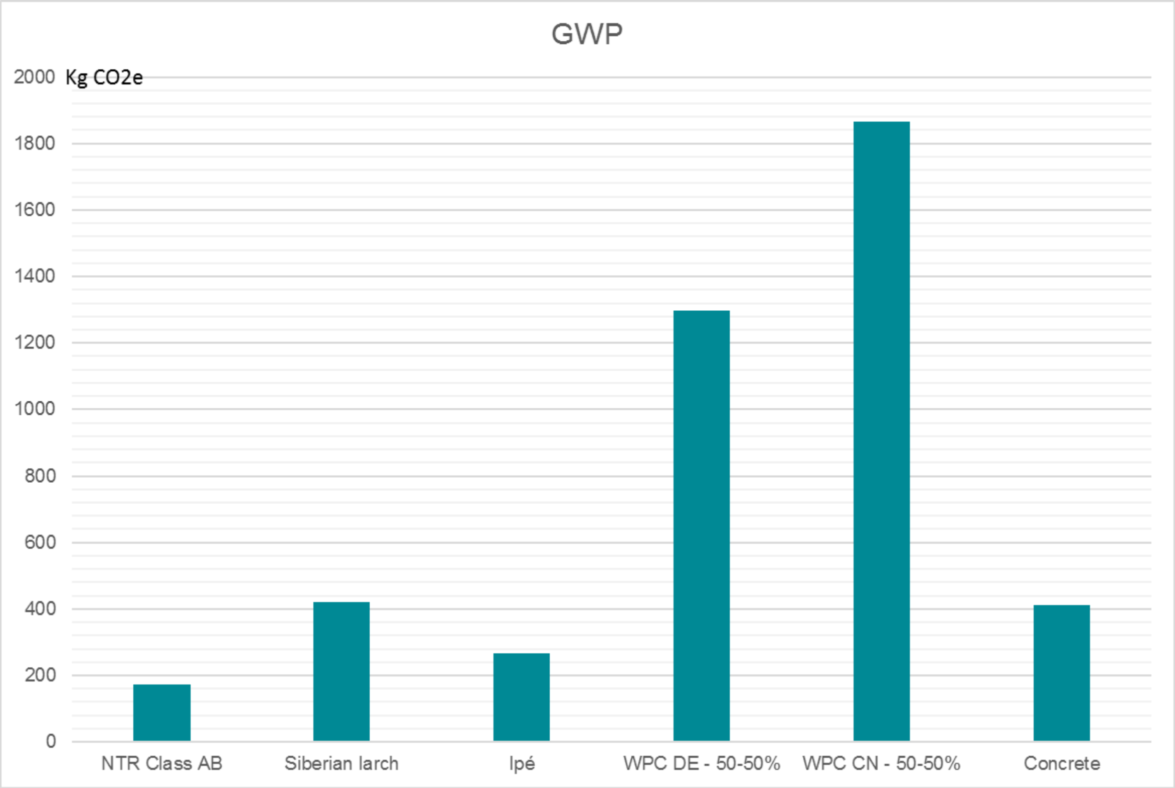

Figure 7. *Global warming potential of the different terrace scenarios over a 30-year lifetime. Full life cycle perspective. WPC DE – 50-50% is WPC produced in Germany with 50% wood, 50% polymer. CN: China. For Siberian larch, the calculation includes changing the decking layer after 15 years, due to the estimated service life of 15 years.*

As in any LCA, the expected lifetime of any individual product has a large influence of the outcome of LCA rankings when comparing products against a required service life. The shorter the expected lifetime of a given product, the more product repairs or replacements you will need over a fixed service life. The challenge is determining the expected service life of a product. This is especially difficult for natural products with a high degree of internal variability, such as wood. For decking, the challenges of predicting the expected life time are complicated further by unknown factors such as, exposure to sun (UV radiation), exposure to water, in which direction is the terrace facing (north, south, etc), use pattern (heavy use, light use), etc.

In this LCA, the expected average life times of the terrace scenarios were assumed to NTR AB 30 years, larch 15 years, ipé 30 years, WPC 30 years, and concrete 30 years. Consequently, the decking layer of the larch decking is changed once during the assumed 30 years use life of the terrace. This explains the relatively high contribution to GWP of the larch terrace compared to the other wood based scenarios.

Figure 8 shows the global warming potential of the different life cycle phases for the different terrace scenarios. The results also show that by far the most significant contribution to GWP comes from the production and construction stage (A). This is true for all the scenarios. The use stage and end of life stage contributes very little to total GWP. The negative values in B and C is accounted for by carbonation of concrete, see appendix 1. The maintenance of the wood terraces by periodic application of water based wood protection product at regular intervals does not contribute significantly to total WPC.

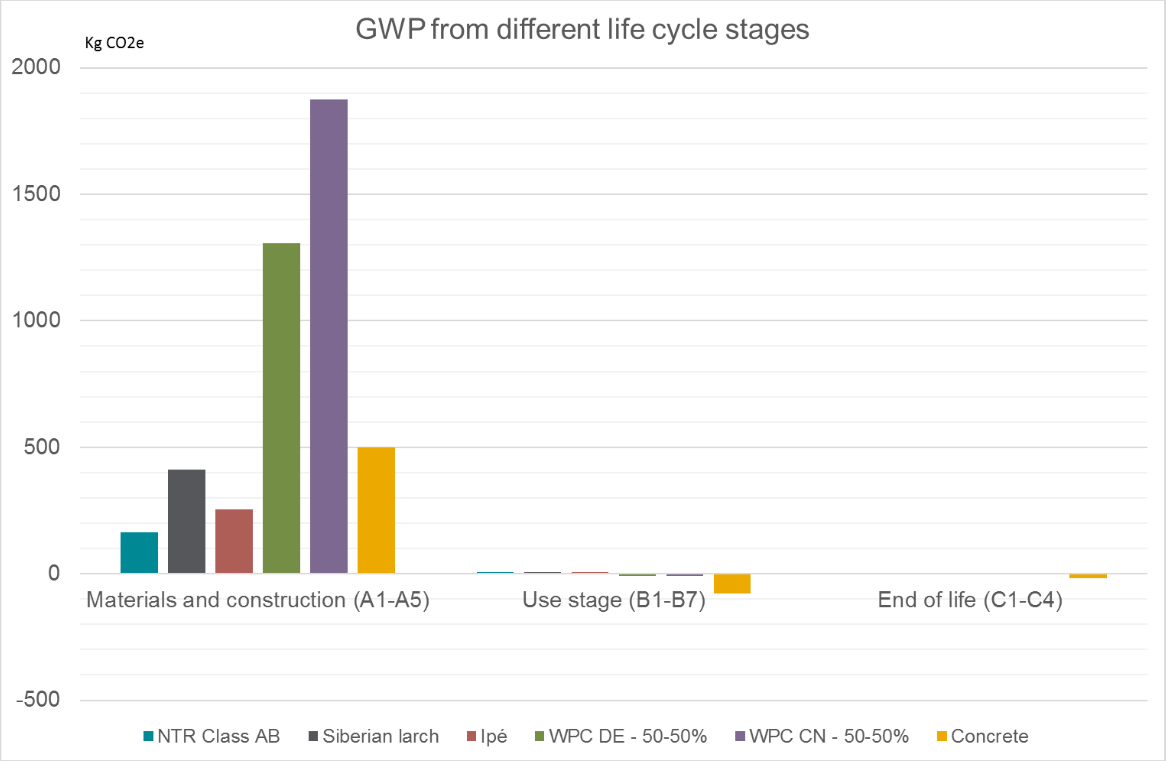

Figure 8. *The global warming potential of the different life cycle phases for the different terrace scenarios.*

Figure 9 shows the results excluding WPC. Figure 10 compares the results for the wood terraces only. In this figure, the contribution from transportation (A2 and A4) is separated to show the effect of transportation on the overall GWP contribution. NTR Class AB is grown and produced in Sweden and therefore contribution to GWP from transportation is relatively low. Ipé is grown and produced in South America, and long transportation to Sweden results in a higher contribution to GWP. Siberian larch is grown in Siberia which means the long transportation to Sweden makes a relatively large contribution to GWP, Furthermore, because the expected life time of the Siberian large terrace (15 years) is lower than the expected life time of both the NTR Class AB and the Ipé terraces (both 30 years), the decking layer of the terrace is assumed to be changed once in the 30-year life time of the terrace, which doubles the contribution from production and transportation.

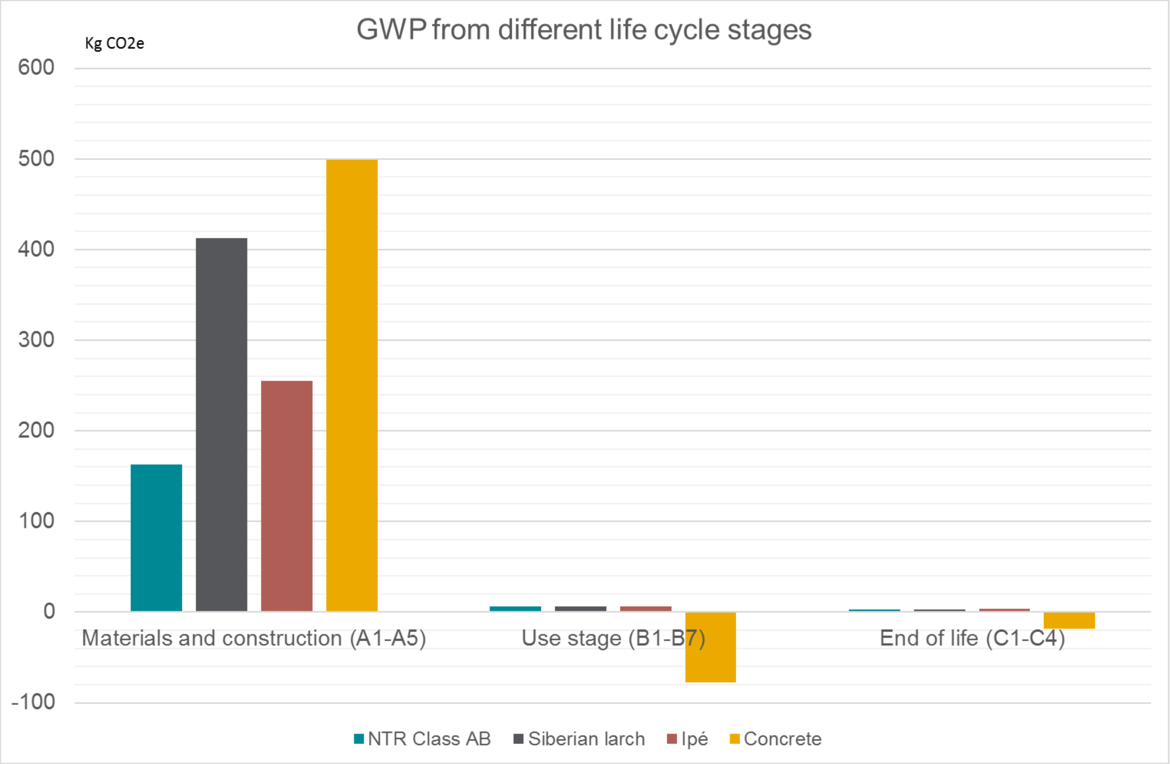

Figure 9. *The global warming potential of the different life cycle phases for the different terrace scenarios – excluding WPC.*

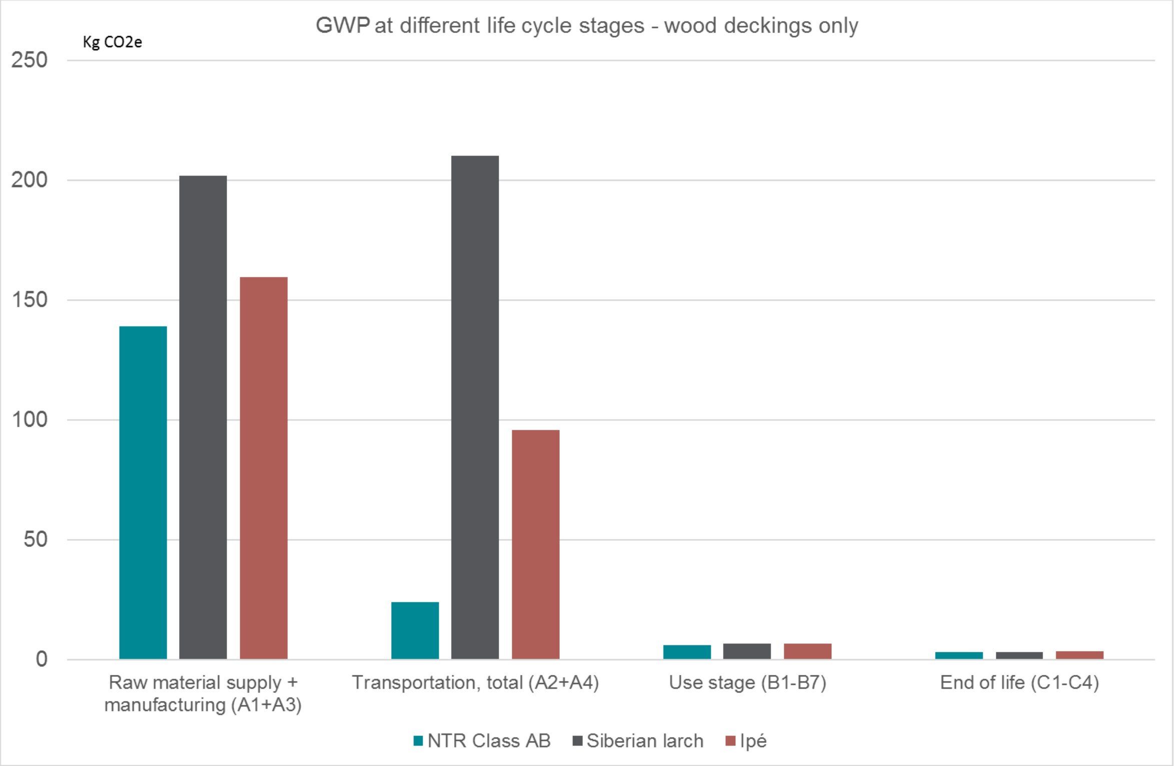

Figure 10. *The global warming potential of the different life cycle phases for the different decking scenarios. Wood deckings only.*

Figure 11 shows the potential savings in GWP from adjusting the input parameters for the WPC terrace. Significant reductions in the GWP can be achieved by 1) moving production from China to Germany, 2) increasing the amount of postconsumer recycled plastic in the polymer part, and 3) increasing the wood/polymer ratio in the final product. However, even if all of these objectives are achieved at the same time, the WPC terrace still comes out with a larger GWP than the alternatives.

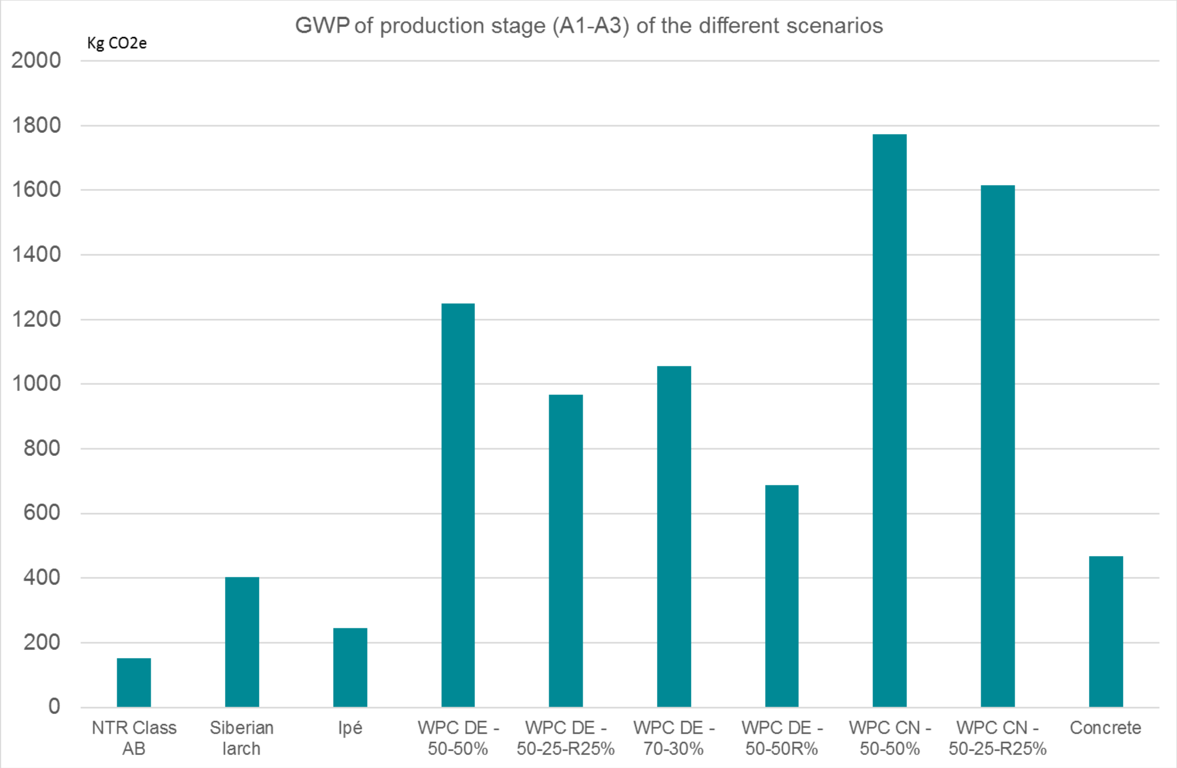

Figure 11. *The global warming potential of the different life cycle phases for the different terrace scenarios. The effect of changing the input parameters of the WPC terrace is shown. DE: Germany, CN: China, R: post-consumer recycled polymers. E.g. WPC DE – 50-25-R25% is WPC produced in Germany with 50% wood, 25% polymer (virgin) and 25% post-consumer recycled polymer.*

To put the results into an everyday context the global warming potential of the different scenarios are compared to the global warming potential of driving an average size gasoline car. An average size car is defined here as a car with a CO_2-emission of 120 g/km. The results are shown in table 1 and figure 12.

Table 1. Terrace GWP compared to the GWP of driving a standard gasoline car.

Terrace	GWP (kg CO_2-eqv)	Comparable to the emissions caused by driving a standard gasoline car[1] (km)
NTR AB	172	1433
Siberian Larch	422	3517
Ipé	265	2208
WPC 50-50 Germany	1296	10800
WPC 50-50 China	1867	15558
Concrete	412	3433

[1]) A standard car is defined as a gasoline car with a CO_2-emission of 120 g/km. Excluding emissions from producing the car.

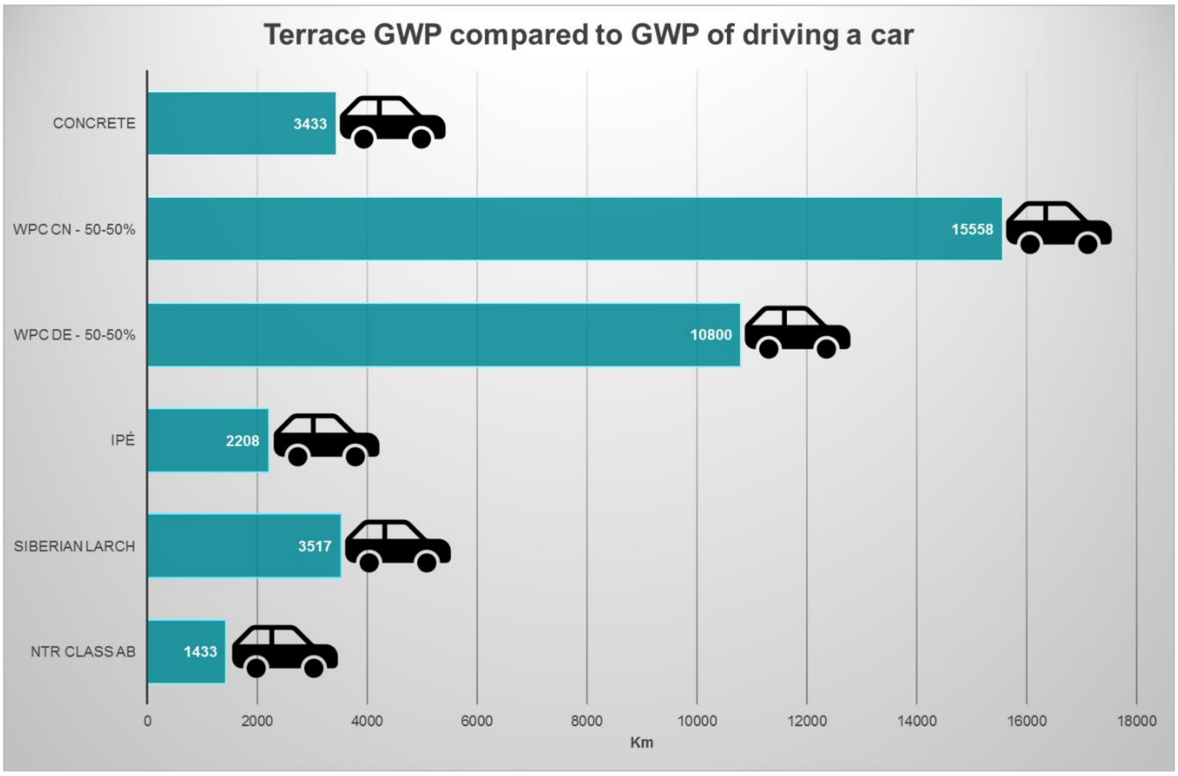

Figure 12. *The GWP (Global Warming Potential) of the different terrace scenarios compared to the GWP of driving an average car with an emission of 120* gCO_2/km.

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Appendix 1 – carbonation of concrete

Carbonation results in the conversion of calcium hydroxide to calcium carbonate under the uptake of CO2 and the release of water, according to the (simplified) equation:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

The rate of carbonation is dependent on a number of factors such as type of cement, humidity, temperature, surface area, availability of CO_2, etc. In this case we have calculated carbonation from the formula (Kjellsen et al. 2005):

$d_C = k*t^{0.5}$

d_C = Carbonation rate
k = carbonation rate factor
t = time

Here, k was set to 1 mm/year.

Depending on the type of concrete, full carbonation corresponds to an uptake of about 67 kg of CO_2 per tonnes of concrete according to Butera et al. (2015).

Rate of carbonation of the concrete blocks is therefore $1.0\ mm*y^{-1} * 30y^{-0.5} = 5.5\ mm$

For the concrete terrace, we have 3861 kg concrete.
Carbonation happens from all six sides. The concrete blocks are 15 x 15 x 6 cm, so after 30 years the volume of the non-carbonized part of the block will be 13.9 x 13.9 x 4.9 mm. This means that 29.9 % of the block has been carbonized in the use phase (30 years). During the next 100 years (backfilling) 10% of the remaining crushed concrete will carbonize when used as backfilling, according to Andersson et. al. (2013).

Then, maximum carbonation is: 3861 kg * 6.7 % = 258.7 kg CO_2.

In the use stage (30 years) carbonation amounts to 29.9%: 258.7 kg * 29.9 % = 77.35 kg
In 100 years end-of-life (backfilling), 10% of the remaining is carbonized: (258.7 – 77.35) * 10 % = 18.14 kg.
Total carbonation: 77.35 + 18.14 = 95.49 kg CO_2.