# EPD - ENVIRONMENTAL PRODUCT DECLARATION

as per ISO 14025 and EN 15804

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|---|---|
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# TRM - Piling systems
# Tiroler Rohre GmbH


PILING SYSTEMS

# 1 General information

**Product name**
TRM Piling System

**Declaration number**
EPD-TRM-2017-1-ECOINVENT

**Declaration data**
☒ Specific data
☐ Average data

**Declaration based on**

Name of the PCR: Construction products made of cast iron.
PCR-Code: 2.16.8, Version: 1.0 as of 10.6.2017
(PCR tested and approved by the independent expert committee = PKR-Gremium)

The owner of the declaration is liable for the underlying information and evidence;
Bau EPD GmbH is not liable with respect to manufacturer information, life-cycle assessment data and evidences.

**Declared Product / Declared Unit**
1 m ductile piles with the nominal dimensions:

**Table 1: Dimensions**

| Nominal outside diameter [mm] | Nominal wall thickness [mm] |
|---|---|
| 118 | 7.5 |
| 118 | 9.0 |
| 118 | 10.6 |
| 170 | 9.0 |
| 170 | 10.6 |
| 170 | 13.0 |

**Number of datasets in this EPD document: 6**

**Range of validity**
The EPD are representative for ductile piles of the site Hall in Tirol of the company Tiroler Rohre GmbH with the aforementioned nominal dimensions.

**Type of declaration as per EN 15804**
From cradle to grave

**Data base, software, version**
Data base ecoinvent 3.3, system model “Cut-off by classification“,
Software GaBi 7.3

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**The CEN standard EN 15804 serves as the core-PCR.**

**Independent verification of the declaration according to ISO 14025:2010**
☐ internally ☒ externally

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**Note:** EPDs of similar product groups from different programmes might not be comparable.

# 2 Product

## 2.1 General product description

The TRM-Piling-System is a centrifugally ductile pile tube (ductile cast iron) with a spigot end and a plug-in socket that can be joined to form any desired pile length. The spigot end and the plug-in socket are the essential pile elements that enable the safe and easy ductile pile connection. Driven into the ground, the pile tubes form a rigid connection, absorbing centric forces and bending moments.

Generally, pile tubes are produced with a length of 5 m, an outside diameter of 118 mm or 170 mm and a defined wall thickness. Type 118: Nominal outside diameter = 118 mm, nominal wall thickness = 7.5 mm or 9.0 mm or 10.6 mm
Type 170: Nominal outside diameter = 170 mm, nominal wall thickness = 9.0 mm or 10.6 mm or 13.0 mm

## 2.2 Application

The TRM-Pile-System is applied as a full displacement pile system for the erection of buildings or engineering structures (such as bridges, wind-power and photovoltaic plants, sound protection walls, pipelines, masts) and to secure excavation pits, to stabilize slopes, etc.

The TRM-Pile is driven into the ground, thus effectively transmits the forces from the building into the ground. The TRM-Pile can also be filled with concrete or applied with or without grouting. The subject EPD focuses on the insertion of the pipe tubes into the ground without the consideration of any concrete filling or grouting.

## 2.3 Product relevant standards, regulations and guidelines

**Table 2: Product relevant standards**

| Standard | Title |
|---|---|
| OENORM B 2567 | Ductile cast iron piles |
| ETA 07/0169 | TRM-Ductile piling - ductile iron pile tubes |

## 2.4 Technical data

Evidence of the mechanical material properties shall be provided by the test method according to OENORM EN 545:2011, sections 6.3 and 6.4.

**Table 3: General technical data for ductile cast iron piles**

| Name | Value | Unit |
|---|---|---|
| Iron density | 7150 | kg/m³ |
| Tensile strength | ≥ 450 | MPa |
| Proportional limit, 0.2%-yield strength ($R_{p0,2}$) | ≥ 320 | MPa |
| Notch impact energy | ≥ 10 | J |
| Elongation at fracture | ≥ 10 | % |
| Brinell hardness | ≤ 230 | HB |
| Pile tube length | 5000 | mm |
| Pressure resistance | ≥ 900 | MPa |
| Modulus of elasticity E | 170,000[1)] | MPa |

[1)] Reference value for static calculations

**Table 4: Technical data for ductile cast iron piles depending on dimensions**

| Type | Nominal wall thickness [mm] | Longitudinally related mass [kg/m] | Rated value of the normal load capacity $N_{Sd}$ without concrete filling of grouting (no loss of wall thickness) [kN] |
|---|---|---|---|
| 118 | 7.5 | 21.00 | 833 |
| 118 | 9.0 | 24.42 | 986 |
| 118 | 10.6 | 27.96 | 1144 |
| 170 | 9.0 | 37.14 | 1457 |
| 170 | 10.6 | 42.54 | 1699 |
| 170 | 13.0 | 50.42 | 2052 |

## 2.5 Basic/auxiliary materials

**Table 5: Basic materials in mass-%**

| Ingredients: | Mass-% |
|---|---|
| Iron [1)] | ca. 94% |
| Carbon [2)] | ca. 3.5% |
| Silicon [3)] | ca. 2% |
| Ferric by-elements [4)] | ca. 0.5% |

[1)] Scrap iron.
[2)] Foundry coke carbon. The coke in the cupola furnace serves as an energy supplier for the scrap melting on the one hand and the setting of the desired carbon content on the other.
[3)] Silicon is added in the form of SiC-briquettes and/or ferro-silicon.
[4)] Ferric by-elements are found in the steel scrap in different minor quantities (<1%).

## 2.6 Production

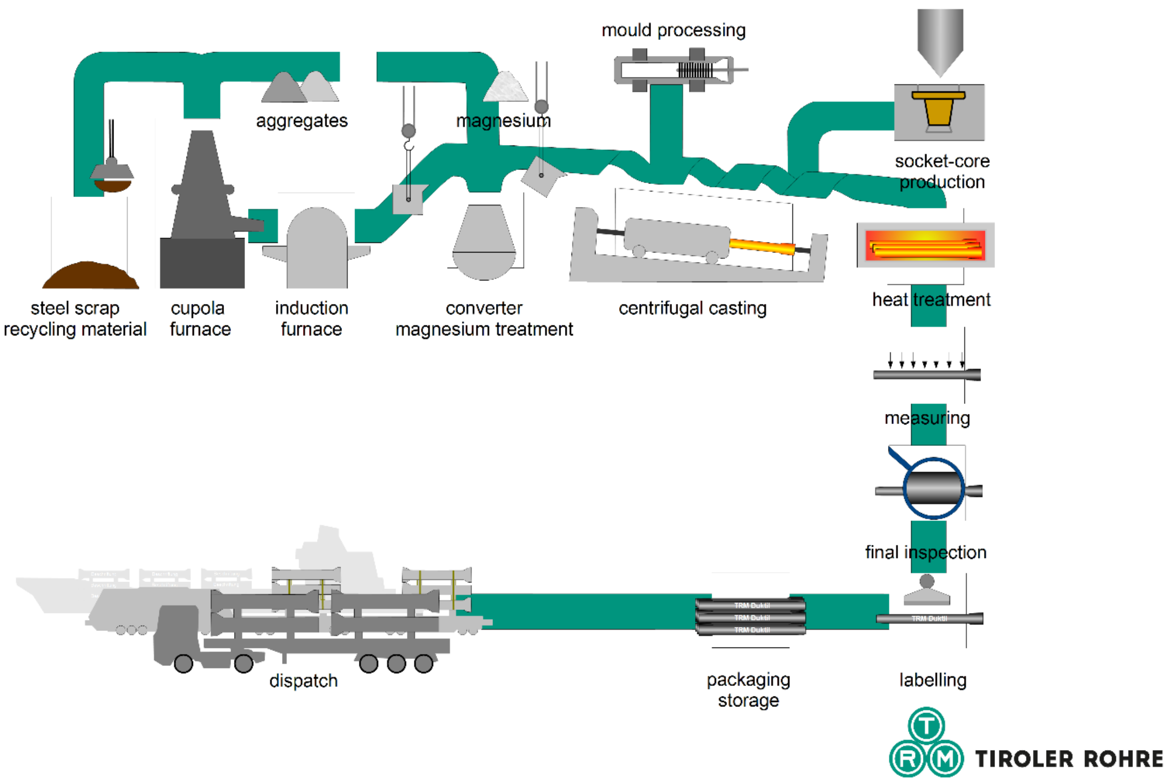


**Figure 1: Flow-chart production process**

With the help of coke as a reaction and reduction agent, steel scrap and recycled material are smelted in the cupola furnace. Silicon carbide is added as an alloying element as well as the aggregates that enhance slagging. The chemical composition of the smelted basic iron is then constantly monitored through spectral analysis. The smelted basic iron is then kept warm in the channel furnace, a storage medium, and treated with magnesium in the Georg Fischer-Converter, in order to reach the appropriate ductility. The liquid iron is then cast in a centrifuge machine with the De Lavaud-procedure. In order to produce a specific type of pile the machine must be equipped with the corresponding mold (metal form that the liquid iron is poured into). The socket core made of quartz sand seals the inlet of the machine and forms the plug-in socket. With the help of an automatic transport system the glowing pile is pulled out of the cast unit and placed in a furnace for heat treatment in order to achieve the desired mechanic characteristics.

In the course of a final pile treatment, the pile is treated if necessary, measured, tagged and bundled. With a fork-lift the corresponding package units are then taken to a storage area.

## 2.7 Packaging

The TRM-Pile is bundled with the help of squared lumber and PET binding tapes for storage and transport.
Both packaging materials can be used for thermal recycling.

## 2.8 Conditions of delivery

The ductile cast iron pipes are bundled with the help of squared lumber and PET binding tapes for storage and transport. The size of the individual bundles depends on the type of pile. In case of the type TRM 118 one bundle consists of 15 piles with a dimension of 5.5 m x 0.62 m x 0.42 m. 8 piles of the type TRM 170 form a bundle of 5.5 m x 0.72 m x 0.37 m. The TRM-ductile pile needs to be transported and stored with special care. All relevant regulations for storage at the place of use and the technical provisions must be fulfilled.

## 2.9 Transport

Within Europe, the ductile piles are transported via truck to their destination and by ship for overseas destinations.

## 2.10 Processing / Installation

Installation and design of the full displacement piles consisting of ductile pile tubes must correspond with Eurocode 3: Design of steel structures (OENORM B 1993), Eurocode 4: Design of composite steel and concrete structures (OENORM B 1994), Eurocode7: Geotechnical design (OENORM B 1997) and OENORM EN 12699: Execution of special geotechnical work – displacement piles. National regulations must be followed as well.

The pile shoe forms the basis for the first pile tube. All additional pile tubes are inserted into the socket of the element previously driven into the ground, and driven into the construction ground to the final depth by displacing the soil. The excess length is then cut so that the construction ground is level with the planum and used as the starting segment for the next pile. After the driving process the pile can be filled with concrete in order to increase its inner load capacity. Pile heads on top of the piles transmit the force from the building to the piles. Optionally, piles can also have a bigger pile shoe, which forms an annular space along the entire pile circumference that can be continuously grouted with mortar during the driving process by means of a pump. The subject EPD focuses on the insertion of the pipe tubes into the ground without the consideration of any concrete filling.

The installation of the pile tubes is performed with a light manoeuvrable excavator with a hydraulic blow hammer.

As the soil is displaced to the side, there is no excavated earth to deal with. Manual work is reduced to simple physical and safe procedures.
All applicable safety precautions for construction sites must be observed

## 2.11 Phase of utilisation

If installed and designed professionally and if the phase of utilization is not disturbed, no modification of material composition of construction products made of ductile cast iron occur.

## 2.12 Reference service life (RSL)

**Table 6: Reference service life (RSL)**

| Name | Value | Unit |
|---|---|---|
| Ductile iron piles | 100 [1)] | Years |

[1)] Pile foundations must have a service life that corresponds with the overall construction. According to "Eurocode – Basis of structural design (OENORM EN 1990)" engineering structures (such as bridges) have a service life of 100 years, that is why ductile cast iron piles are assessed with a corresponding service life.

## 2.13 Re-use and recycling

Reuse and recycling of ductile cast iron is technically feasible but not reasonable under the current ecological and economic conditions. The piles remain in the ground, unless they disturb other construction projects.

## 2.14 Disposal

The piles are disposed of in rare cases. The EAK-waste code number for iron and steel from construction and demolition is 170405.
This EPD, however, is based on the scenario that the piles remain in the ground.

## 2.15 Further information

For further information about the TRM-Pile-System and possible applications see the website http://trm.at.

# 3 LCA: Calculation rules

## 3.1 Declared unit/ Functional Unit

The functional unit is 1 meter [m] pile. The following table serves the conversion into mass [kg]:

**Table 7: Longitudinally related mass**

| Type | Longitudinally related mass [kg/m] |
|---|---|
| 118 x 7.5 | 21.00 |
| 118 x 9.0 | 24.42 |
| 118 x 10.6 | 27.96 |
| 170 x 9.0 | 37.14 |
| 170 x 10.6 | 42.54 |
| 170 x 13.0 | 50.42 |

## 3.2 System limits

The entire product life cycle is declared. This is an EPD “From cradle to grave“.

| **PRODUCT STAGE** | | | **CONSTRUCTION PROCESS STAGE** | | **USE STAGE** | | | | | | | **END-OF-LIFE STAGE** | | | | **BENEFITS AND LOADS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |
| Raw material supply | Transport | Manufacturing | Transport | Construction/Installation | Use | Maintenance | Repair | Replacement | Reconstruction/Renewal | Operationa energy use | Operational water use | Demolition | Transport | Waste processing | Disposal | Reuse-/Recovery-/Recycling potential |
| x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |

x = included in LCA; MND = Module not declared

A1-A3 Product stage:
The ductile piles are almost exclusively made of the secondary material scrap steel. The system limit was set with the arrival of the scrap iron in the recycling plants. The energy consumption in the recycling plants and the transport to the plant was blamed on this system. The production phase includes the product stages in the plant including the energy supply with the corresponding upstream chains, the production of raw materials, auxiliary materials and packaging; furthermore the transport to the plants, the infrastructure and the disposal of the waste occurring during production.

A4-A5 Construction stage:
Ductile cast iron pile can be designed as unfilled or ungrouted piles or piles with concrete filling and/or grouting. The subject EPD focuses exclusively on the insertion of the pile tubes into the ground without consideration of any concrete filling. Squared lumber and PET binding tapes are thermally recycled.

B1-B7 Use stage:
Generally construction products made of ductile cast iron show no impact on the LCA.

C1- C4 End-of-life stage:

Reuse and recycling of removed ductile cast iron is technically feasible, however, depending on the given situation, the question is whether it is reasonable. If no new building is erected after dismantling the entire construction, the piles remain in the ground, unless they disturb other construction projects, thus preventing additional costs. This EPD is based on the scenario that the piles will not be removed and recycled.

D Benefits and loads:

As the piles will not be recycled, C1-C4 show no benefits. Benefits for thermal disposal of the packaging material under A5 are prohibited according to the "*General guidelines for eco balances and requirements of background reports – PKR-part A*".

## 3.3 Process flowchart during service life

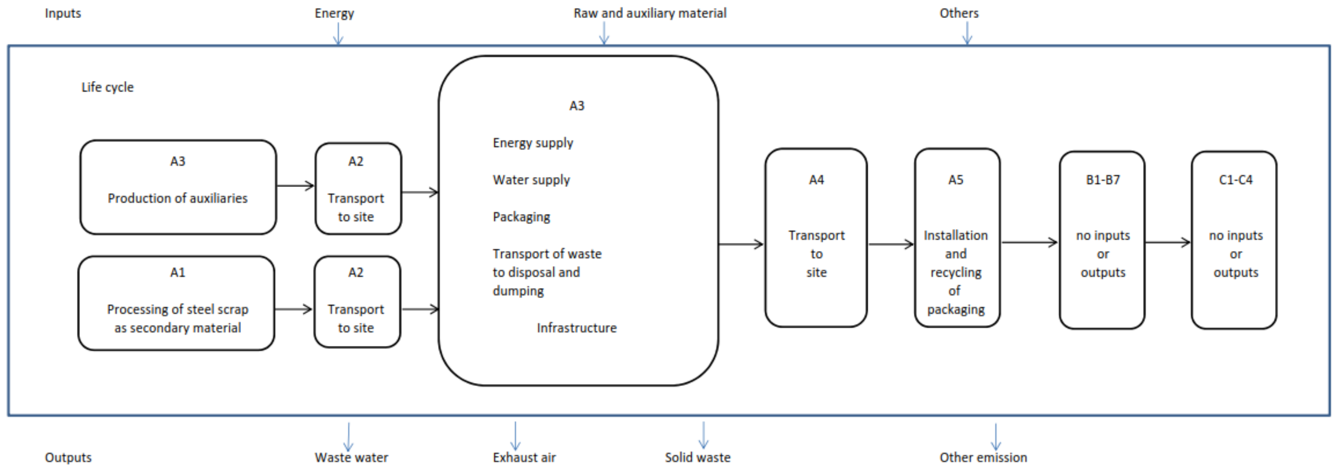


**Figure 2: Process flow chart during service life**

## 3.4 Estimations and assumptions

The ecoinvent databank holds only one data set for silicon carbide, typical for wafer production, having too much environmental impact due to its high SiC content compared to the SiC used for the casting production. It is assumed that an economic allocation reflects reality in a better way.

Cast steel is a special steel with no data set. As the cast is below 1 kg per t of casting the data set for chrome steel is regarded as sufficient.

As the infrastructure have just a minimum environmental impact, the machines were only illustrated with the main components steel and cast.

## 3.5 Cut-off criteria

The producer calculated and submitted the amount of all applied materials, energy needed, the packaging material, the arising waste material and the way of disposal and the necessary infrastructure (buildings and machine parks for the production). The measurement values for emissions according to the casting regulations were specified. The material consumption of moulded steel and the graphite coatings were considered. Auxiliary materials, the material flow of which is less than 1% are insignificant, as well as the in-company transports. It can be assumed that the amount of the insignificant processes is below than 5% of the impact categories.

## 3.6 Background data

Ecoinvent 3.3 with the system model "cut-off by classification" is used as background databank. The software is GaBi 7.3 of the company thinkstep.

## 3.7 Data quality

All essential data such as energy- and raw material consumption, emissions, transport distances and means of transportation and packaging and infrastructure within the system limits is provided by the producer.
The data is up-to-date (annual average over the production year 2015).
The criteria of the Bau EPD GmbH for data collection, generic data and the cut-off of material and energy flows were observed.
The data are plausible
The data is representative for the type 118 and type 170 piles of the company TRM produced in the production year 2015 in the plants Hall in Tirol.

## 3.8 Reporting period

The applied data correspond with the annual average of the production year 2015.

## 3.9 Allocation

The system limits for the applied secondary materials steel and iron scrap was set with the arrival of the scrap iron in the recycling plants. The energy consumption in the recycling plants in module A1 was blamed on this system. The transporte to the plants are included in module A2.

The production of ductile cast piles creates fly-ash, slag, coke dust and district heat as by-products. They make a contribution to the operational income of less than 1% and can thus be neglected according to the "*General guidelines for eco balances and requirements of background reports – PKR-part A"*.

Benefits for thermal disposal of the packaging material under A5 do not apply according to the "*General guidelines for eco balances and requirements of background reports – PKR-part A"*.

Reuse and recycling of the piles is technically feasible but not reasonable under the current ecological and economic conditions, thus there are no benefits in module D.

## 3.10 Comparability

Basically a comparison or an assessment of the EPD-data is only possible if all comparative data sets have been prepared according to EN 15804, if the identical programme specific PKR or possible additional regulations and the same background databank have been applied and all building or product specific features have been considered.

# 4 LCA: Scenarios and further technical information

## 4.1 A1-A3 Product stage

According to OENORM EN 15804 no technical scenario-details are required for A1-A3, as the producer is responsible for the accounting of these modules which must not be changed by the user of the LCA.

## 4.2 A4-A5 Construction process stage

### 4.2.1 Description of the scenario "Transport to the building site (A4)"

Within Europe the ductile pipes are transported via truck to their destination and by ship for overseas destinations. As only tkm can be entered into the ecoinvent-datasets and as parameters such as average fuel consumption, average utilization, etc. are predefined, no table for parameters for the transport description are provided. The dataset "RER: transport, freight, lorry 16-32 metric ton, EURO 4"was applied. This is only true for the transport by ship. The dataset "GLO: transport, freight, sea, transoceanic ship"was applied.

### 4.2.2 Description of the scenario "Installation of the product in the building (A5)"

The piles are driven into the ground with an excavator equipped with a with a hydraulic blow hammer. Depending on the soil condition there might be strong fluctuations, however, based on many years of experience, it is known that an excavator with a performance of 150 kW and a weight of 25 t, consumes 150 l of gasoline on an 8 hour workday. With an average work performance of 300 m piles per day this amounts to a consumption of 0.5l gasoline per pile m. This value is a rough estimation. A finer estimation of the gasoline consumption of the various types of piles is not possible.

**Table 8: Parameter list of the scenario "Installation of the product in the building (A5)"**

| Parameters to describe the installation of the product in the building (A5) | Value | Measurand |
|---|---|---|
| Auxiliary substances for the installation (specified according to substances) | 0 | kg/m<br>l/m |
| Auxiliary substances for the installation (specified according to type) | - | - |
| Water demand | 0 | $m^3$/m<br>l/m |
| Other resources requirement | 0 | kg/m<br>l/m |
| Energy consumption | 0 | kWh/m or MJ/m |
| Other energy carrier: gasoline | 17.8 | MJ/m |
| Material loss on the construction site before waste treatment, caused by the installation of the product (specified according to substances) | 0 | kg/m |
| Output-substances (specified according to substances) due to waste treatment on the construction site, e.g. collection for recycling, for energy recovery or for disposal (specified according to disposal procedure) | 0 | kg/m |
| Direct emission in ambient air (e.g. dust, VOC), soil and water | 0 | kg/m |

## 4.3 B1-B7 Use stage

The Reference Service Life (RSL) is 100 years. During the service life stage the ductile cast iron piles show no material and energy flow relevant for the LCA that means the inputs and outputs equal zero.

## 4.4 C1-C4 End-of-life-stage

Reuse and recycling of ductile iron is technically feasible but not reasonable under the current ecological and economic conditions. The piles remain in the ground, thus cause no further disposal costs. The inputs and outputs equal zero.

## 4.5 D Potential of reuse and recycling

As the piles are not removed, benefits for thermal disposal of the packaging material under A5 are prohibited according to the "*General guidelines for eco balances and requirements of background reports – PKR-part A*" there are no benefits in module D.

# 5 LCA: Results

The following tables show the results of the functional unit per pile meter [m]. A table in the supplement shows the results per kg pile as additional information.

## TRM Pile System Type 118 x 7.5

### Table 9: LCA results: Environmental impacts per pile meter [m] type 118 x 7.5

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg $CO_2$ equiv | 22.3 | 2.63 | 1.78 | 0 | 0 | 26.7 | 0 |
| ODP | kg CFC-11 equiv | 1.10E-06 | 4.81E-07 | 3.11E-07 | 0 | 0 | 1.90E-06 | 0 |
| AP | kg $SO_2$ equiv | 5.57E-02 | 1.45E-02 | 1.31E-02 | 0 | 0 | 8.33E-02 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 3.68E-02 | 3.34E-03 | 3.62E-03 | 0 | 0 | 4.37E-02 | 0 |
| POCP | kg $C_2H_4$ equiv | 6.70E-03 | 1.25E-03 | 1.39E-03 | 0 | 0 | 9.34E-03 | 0 |
| ADPE | kg Sb equiv | 2.21E-05 | 7.36E-06 | 1.17E-06 | 0 | 0 | 3.07E-05 | 0 |
| ADPF | MJ, $H_u$ [2)] | 272 | 39.4 | 25.3 | 0 | 0 | 336 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

### Table 10: LCA results: Resource input per pile meter [m] type 118 x 7.5

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, $H_u$ | 22.1 | 0.551 | 0.267 | 0 | 0 | 22.9 | 0 |
| PERM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, $H_u$ | 22.1 | 0.551 | 0.267 | 0 | 0 | 22.9 | 0 |
| PENRE | MJ, $H_u$ | 291 | 40.2 | 25.7 | 0 | 0 | 357 | 0 |
| PENRM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, $H_u$ | 291 | 40.2 | 25.7 | 0 | 0 | 357 | 0 |
| SM | kg | 20.7 | 0 | 0 | 0 | 0 | 20.7 | 0 |
| RSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA [3)] | INA | INA | INA | INA | INA | INA |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

### Table 11: LCA results: Output-flows and waste categories per pile meter [m] type 118 x 7.5

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | INA |
| NHWD | kg | INA | INA | INA | INA | INA | INA | INA |
| RWD | kg | INA | INA | INA | INA | INA | INA | INA |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | |

[1)] Additional information

[2)] Hu stands for (lower) heating value

[3)] INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

[4)] Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions.

## TRM Pile System Type 118 x 9.0

### Table 12: LCA results: Environmental impacts per pile meter [m] type 118 x 9.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1- C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg $CO_2$ equiv | 25.9 | 3.06 | 1.79 | 0 | 0 | 30.7 | 0 |
| ODP | kg CFC-11 equiv | 1.28E-06 | 5.60E-07 | 3.11E-07 | 0 | 0 | 2.16E-06 | 0 |
| AP | kg $SO_2$ equiv | 6.47E-02 | 1.69E-02 | 1.31E-02 | 0 | 0 | 9.47E-02 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 4.28E-02 | 3.89E-03 | 3.62E-03 | 0 | 0 | 5.03E-02 | 0 |
| POCP | kg $C_2H_4$ equiv | 7.79E-03 | 1.45E-03 | 1.39E-03 | 0 | 0 | 1.06E-02 | 0 |
| ADPE | kg Sb equiv | 2.57E-05 | 8.56E-06 | 1.17E-06 | 0 | 0 | 3.55E-05 | 0 |
| ADPF | MJ, $H_u$ [2)] | 316 | 45.8 | 25.3 | 0 | 0 | 387 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

### Table 13: LCA results: Resource unit per pile meter [m] type 118 x 9.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, $H_u$ | 25.7 | 0.551 | 0.267 | 0 | 0 | 26.5 | 0 |
| PERM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, $H_u$ | 25.7 | 0.551 | 0.267 | 0 | 0 | 26.5 | 0 |
| PENRE | MJ, $H_u$ | 339 | 46.7 | 25.7 | 0 | 0 | 405 | 0 |
| PENRM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, $H_u$ | 339 | 46.7 | 25.7 | 0 | 0 | 405 | 0 |
| SM | kg | 24.1 | 0 | 0 | 0 | 0 | 24.1 | 0 |
| RSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA [3)] | INA | INA | INA | INA | INA | INA |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

### Table 14: LCA result: Output-flows and waste categories per pile meter [m] type 118 x 9.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | INA |
| NHWD | kg | INA | INA | INA | INA | INA | INA | INA |
| RWD | kg | INA | INA | INA | INA | INA | INA | INA |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | |

[1)] Additional information

[2)] Hu stands for (lower) heating value

[3)] INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

[4)] Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions.

## TRM Pile System Type 118 x 10.6

### Table 155: LCA results: Environmental impacts per pile meter [m] type 118 x 10.6

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1- C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg CO2 equiv | 29.6 | 3,50 | 1,79 | 0 | 0 | 34,9 | 0 |
| ODP | kg CFC-11 equiv | 1.47E-06 | 6.41E-07 | 3.11E-07 | 0 | 0 | 2.42E-06 | 0 |
| AP | kg $SO_2$ equiv | 7.41E-02 | 1.93E-02 | 1.31E-02 | 0 | 0 | 1.07E-01 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 4.90E-02 | 4.45E-03 | 3.62E-03 | 0 | 0 | 5.70E-02 | 0 |
| POCP | kg $C_2H_4$ equiv | 8.92E-03 | 1.66E-03 | 1.39E-03 | 0 | 0 | 1.20E-02 | 0 |
| ADPE | kg Sb equiv | 2.95E-05 | 9.81E-06 | 1.17E-06 | 0 | 0 | 4.04E-05 | 0 |
| ADPF | MJ, $H_u$ [2)] | 362 | 52.5 | 25.3 | 0 | 0 | 440 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

### Table 16: LCA results: Resource unit per pile meter [m] type 118 x 10.6

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, Hu | 29.4 | 0.734 | 0.267 | 0 | 0 | 30.2 | 0 |
| PERM | MJ, Hu | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, Hu | 29.4 | 0.734 | 0.267 | 0 | 0 | 30.2 | 0 |
| PENRE | MJ, Hu | 388 | 53.5 | 25.7 | 0 | 0 | 454 | 0 |
| PENRM | MJ, Hu | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, Hu | 388 | 53.5 | 25.7 | 0 | 0 | 454 | 0 |
| SM | kg | 27.6 | 0 | 0 | 0 | 0 | 27.6 | 0 |
| RSF | MJ, Hu | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, Hu | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA [3)] | INA | INA | INA | INA | INA | INA |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

### Table 17: LCA result: Output-flows and waste categories per pile meter [m] type 118 x 10.6

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | INA |
| NHWD | kg | INA | INA | INA | INA | INA | INA | INA |
| RWD | kg | INA | INA | INA | INA | INA | INA | INA |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | |

1) additional information

2) Hu stands for (lower) heating value

3) INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

4) Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions.

## TRM Pile System Type 170 x 9.0

### Table 18: LCA results: Environmental impacts per pile meter [m] type 170 x 9.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1- C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg $CO_2$ equiv | 39.4 | 4.65 | 1.79 | 0 | 0 | 45.8 | 0 |
| ODP | kg CFC-11 equiv | 1.95E-06 | 8.51E-07 | 3.11E-07 | 0 | 0 | 3.11E-06 | 0 |
| AP | kg $SO_2$ equiv | 9.84E-02 | 2.57E-02 | 1.31E-02 | 0 | 0 | 0.137 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 6.51E-02 | 5.92E-03 | 3.62E-03 | 0 | 0 | 7.46E-02 | 0 |
| POCP | kg $C_2H_4$ equiv | 1.19E-02 | 2.21E-03 | 1.39E-03 | 0 | 0 | 1.55E-02 | 0 |
| ADPE | kg Sb equiv | 3.91E-05 | 1.30E-05 | 1.17E-06 | 0 | 0 | 5.33E-05 | 0 |
| ADPF | MJ, $H_u$ [2)] | 481 | 69.7 | 25.3 | 0 | 0 | 576 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

### Table 19: LCA results: Resource unit per pile meter [m] type 170 x 9.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, $H_u$ | 39.1 | 0.975 | 0.267 | 0 | 0 | 40.3 | 0 |
| PERM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, $H_u$ | 39.1 | 0.975 | 0.267 | 0 | 0 | 40.3 | 0 |
| PENRE | MJ, $H_u$ | 515 | 71.1 | 25.7 | 0 | 0 | 612 | 0 |
| PENRM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, $H_u$ | 515 | 71.1 | 25.7 | 0 | 0 | 612 | 0 |
| SM | kg | 36.7 | 0 | 0 | 0 | 0 | 36.7 | 0 |
| RSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA [3)] | INA | INA | INA | INA | INA | INA |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

### Table 20: LCA result: Output-flows and waste categories per pile meter [m] type 170 x 9.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | INA |
| NHWD | kg | INA | INA | INA | INA | INA | INA | INA |
| RWD | kg | INA | INA | INA | INA | INA | INA | INA |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | |

[1)] Additional information

[2)] Hu stands for (lower) heating value

[3)] INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

[4)] Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions

## TRM Pile System Type 170 x 10.6

### Table 21: LCA results: Environmental impacts per pile meter [m] type 170 x 10.6

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1- C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg $CO_2$ equiv | 45.1 | 5,33 | 1,80 | 0 | 0 | 52.2 | 0 |
| ODP | kg CFC-11 equiv | 2.24E-06 | 9.75E-07 | 3.11E-07 | 0 | 0 | 3.52E-06 | 0 |
| AP | kg $SO_2$ equiv | 1.13E-01 | 2.94E-02 | 1.31E-02 | 0 | 0 | 1.55E-01 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 7.45E-02 | 6.78E-03 | 3.62E-03 | 0 | 0 | 8.49E-02 | 0 |
| POCP | kg $C_2H_4$ equiv | 1.36E-02 | 2.53E-03 | 1.39E-03 | 0 | 0 | 1.75E-02 | 0 |
| ADPE | kg Sb equiv | 4.48E-05 | 1.49E-05 | 1.17E-06 | 0 | 0 | 6.09E-05 | 0 |
| ADPF | MJ, $H_u$ [2)] | 550 | 79.8 | 25.3 | 0 | 0 | 656 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

### Table 22: LCA results: Resource unit per pile meter [m] type 170 x 10.6

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, $H_u$ | 44.7 | 1.12 | 0.267 | 0 | 0 | 46.1 | 0 |
| PERM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, $H_u$ | 44.7 | 1.12 | 0.267 | 0 | 0 | 46.1 | 0 |
| PENRE | MJ, $H_u$ | 590 | 81.4 | 25.7 | 0 | 0 | 697 | 0 |
| PENRM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, $H_u$ | 590 | 81.4 | 25.7 | 0 | 0 | 697 | 0 |
| SM | kg | 42.0 | 0 | 0 | 0 | 0 | 42.0 | 0 |
| RSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA [3)] | INA | INA | INA | INA | INA | INA |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

### Table 23: LCA result: Output-flows and waste categories per pile meter [m] type 170 x 10.6

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | INA |
| NHWD | kg | INA | INA | INA | INA | INA | INA | INA |
| RWD | kg | INA | INA | INA | INA | INA | INA | INA |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | |

[1)] Additional information

[2)] Hu stands for (lower) heating value

[3)] INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

[4)] Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions

## TRM Pile System Type 170 x 13.0

### Table 24: LCA results: Environmental impacts per pile meter [m] type 170 x 13.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1- C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg $CO_2$ equiv | 53.4 | 6.31 | 1.80 | 0 | 0 | 61.6 | 0 |
| ODP | kg CFC-11 equiv | 2.65E-06 | 1.16E-06 | 3.11E-07 | 0 | 0 | 4.12E-06 | 0 |
| AP | kg $SO_2$ equiv | 0.134 | 3.49E-02 | 1.31E-02 | 0 | 0 | 0.182 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 8.83E-02 | 8.03E-03 | 3.62E-03 | 0 | 0 | 1.00E-01 | 0 |
| POCP | kg $C_2H_4$ equiv | 1.61E-02 | 3.00E-03 | 1.39E-03 | 0 | 0 | 2.05E-02 | 0 |
| ADPE | kg Sb equiv | 5.31E-05 | 1.77E-05 | 1.17E-06 | 0 | 0 | 7.20E-05 | 0 |
| ADPF | MJ, $H_u$ [2)] | 652 | 94.6 | 25.3 | 0 | 0 | 772 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

### Table 25: LCA results: Resource unit per pile meter [m] type 170 x 13.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, $H_u$ | 53.0 | 1.32 | 0.267 | 0 | 0 | 54.6 | 0 |
| PERM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, $H_u$ | 53.0 | 1.32 | 0.267 | 0 | 0 | 54.6 | 0 |
| PENRE | MJ, $H_u$ | 700 | 96.5 | 25.7 | 0 | 0 | 822 | 0 |
| PENRM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, $H_u$ | 700 | 96.5 | 25.7 | 0 | 0 | 822 | 0 |
| SM | kg | 49.8 | 0 | 0 | 0 | 0 | 49.8 | 0 |
| RSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA [3)] | INA | INA | INA | INA | INA | INA |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

### Table 26: Output-flows and waste categories per pile meter [m] type 170 x 13.0

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | INA |
| NHWD | kg | INA | INA | INA | INA | INA | INA | INA |
| RWD | kg | INA | INA | INA | INA | INA | INA | INA |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | |

[1)] Additional information

[2)] Hu stands for (lower) heating value

[3)] INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

[4)] Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions

# 6 LCA: Interpretation

It should be noted that the impact assessment results are only relative statements that do not include any statements about “end-points“ of the impact categories, exceeding of thresholds or risks.

As the definition of raw materials (the substances that remain in the product) and auxiliary substances (the substances that do not remain in the product) is not applicable in this case, as a certain percentage of the energy carrier coke remains in the product, and also as e.g. the input material ferrosilicon or silicon carbide and in addition to that the transport share (A2) is relatively low compared to A1 und A3, there is no splitting of A1-A3.

## 6.1 Indicators for an impact assessment

The next two charts show the percentage of the modules A1-A3: Production, A4: Transport to the construction site and A5 Installation in the impact categories considered for the piles with the lowest and the highest longitudinal mass.

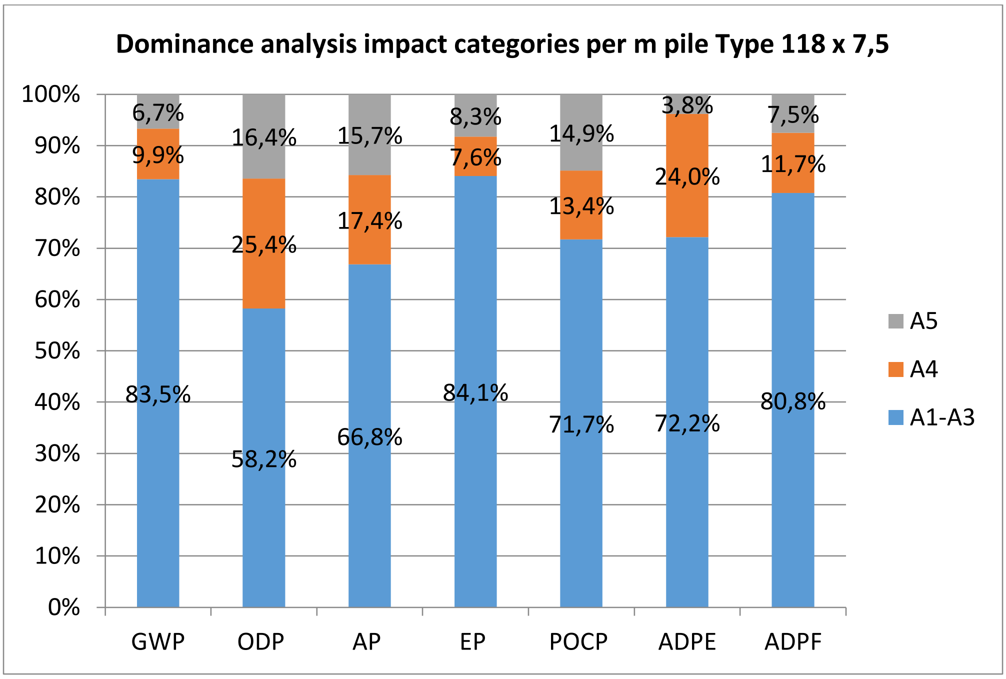


**Figure 3: Dominance analysis of the impact categories for a pile the lowest longitudinal mass (21.00 kg/m)**

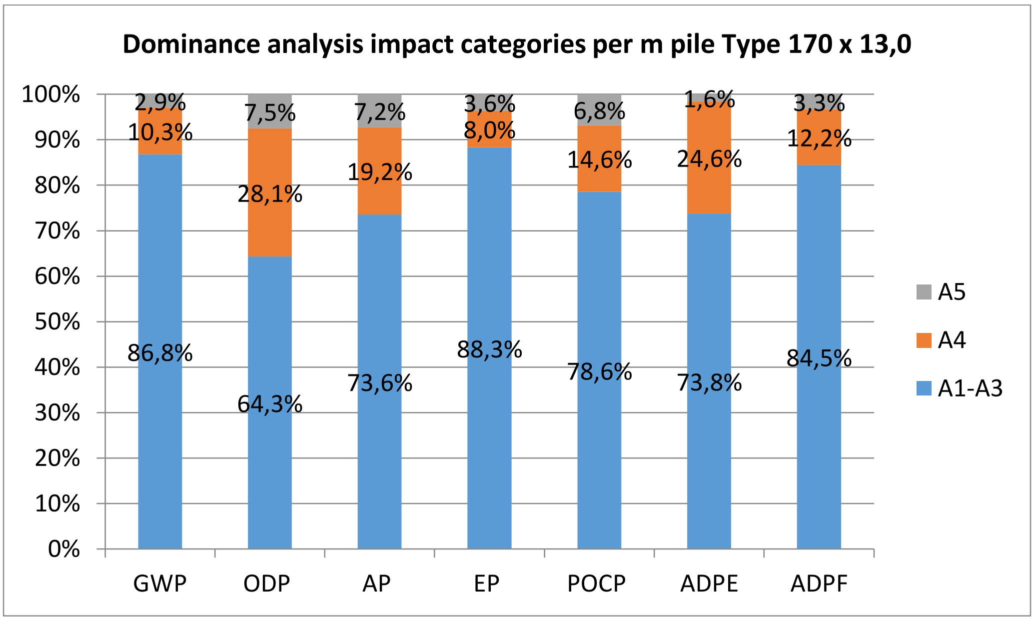


**Figure 4: Dominance analysis of the impact categories for a pile the highest longitudinal mass (50.42 kg/m)**

The difference between the two charts arises basically from the fact that the energy consumption for driving the piles onto the ground may differ due to the soil properties. Thus, only a rough average fuel consumption of the excavator can be estimated. This always identical average value provides different contributions for the individual impact categories depending on the longitudinal mass of the piles.

The production of the piles is the main contribution to all impact categories. As expected, the contribution for the transports is elementary for the ozone-depleting potential, the resource consumption and the acidification is slightly higher than the other indicators. The contribution of the gasoline driven excavator, used for the installation, is relatively high with reference to the indicators ozone-depleting potential, acidification and the photo chemical ozone creation potential.

## 6.2 Indicators of the Material balance sheet

### 6.2.1 Primary energy consumption non-renewable and renewable

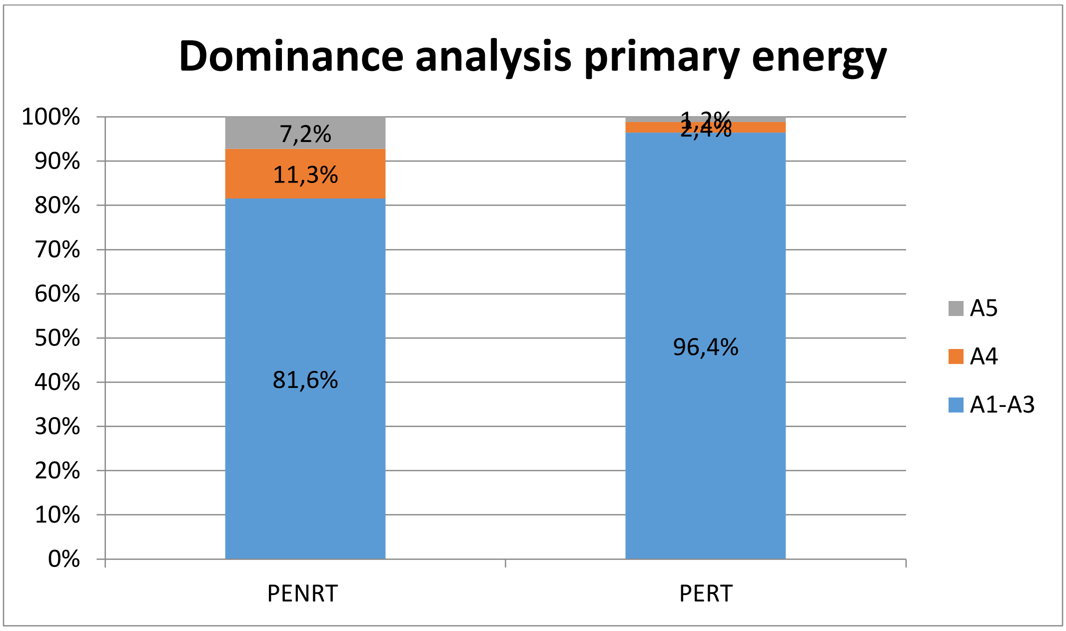


**Figure 5: Dominance analysis of the primary energy for the pile with the lowest longitudinal mass (21.00 kg/m)**

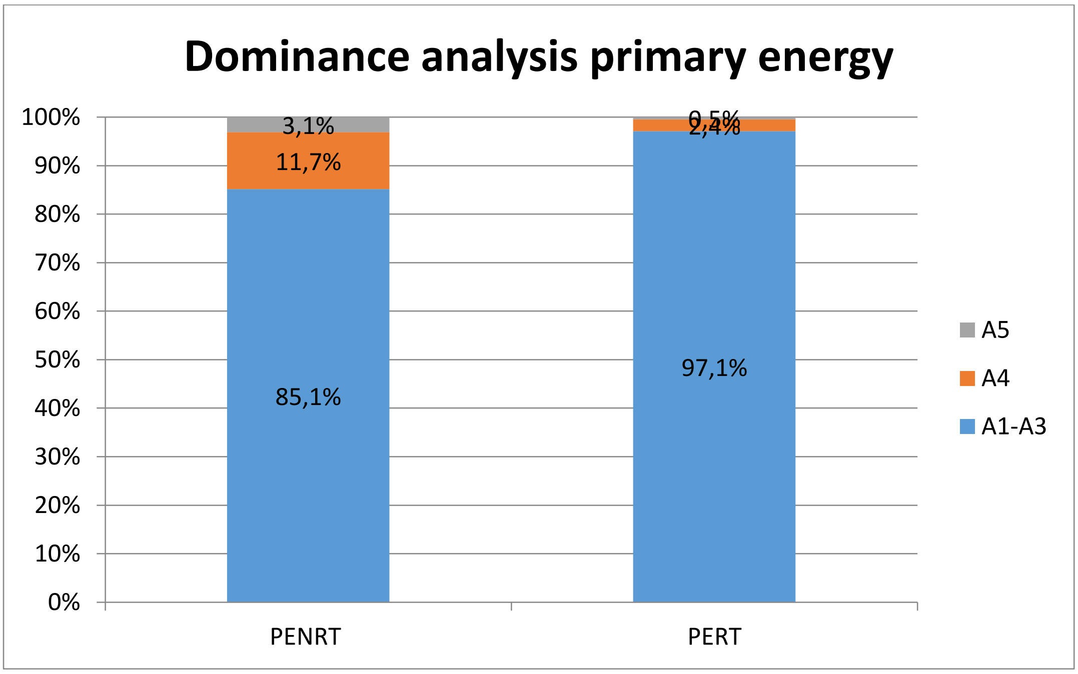


**Figure 6: Dominance analysis of the primary energy for the pile with the highest longitudinal mass (50.42 kg/m)**

This shows the same picture as with reference to the impact indicators. The difference between the two charts, however, is based on the stable numerical value of the energy consumption during installation. The production of the piles requires more energy.

64% of the share of primary energy is due to the Austrian energy mix; 55% is due to the direct usage in the pile production and about 9% is due to the energy requires for scrub treatment in Austria.

#### 6.2.2 Use of fresh water resources

The background data of ecoinvent 3.3 do not allow a full calculation of the use of fresh water resources.

#### 6.2.3 Waste

Software GaBi 7.3 does not create any waste for ecoinvent 3.3.

## 7 Literature

OENORM EN ISO 14025: 2010 07 01 Environmental labels and declarations – Type III Environmental declarations – Principals and Procedures

OENORM EN ISO 14040: 2009 11 01 Environmental management – Life cycle assessment – Principles and framework

OENORM EN ISO 14044: 2006 10 01 Environmental management – Life cycle assessment – Requirements and guidelines

OENORM EN 15804: 2014 04 15 Sustainability of construction works – Environmental product declaration – Core rules fort he product category of construction products

General guidelines for eco balances and requirements of background reports – PKR-part A, edition 11. April, 2016, Bau EPD GmbH

Requirements for EPD for iron construction products – PKR-part B, edition 2017, Bau EPD GmbH

Eurocode 3 Design of steel constructions (OENORM B 1993)

Eurocode 4 Design of composite steel and concrete structures (OENORM B 1994)

Eurocode7 Geotechnical design (OENORM B 1997)

## 8 Directory and Glossary

### 8.1 List of Figures

## 8.2 List of tables



## 8.3 Abbreviations

| | |
|---|---|
| EPD | Environmental product declaration |
| PKR | Product category regulations |
| LCA | Life cycle assessment |
| RSL | Reference service life |
| GWP | Global warming potential |
| ODP | Depletion potential of the stratospheric ozone layer |
| AP | Acidification potential of soil and water |
| EP | Eutrophication potential |
| POCP | Formation potential of tropospheric ozone |
| ADP | Abiotic depletion potential |

# 9 Supplement – Results per kilogramme pile

### TRM Piling System

**Table 27: LCA results: Environmental impacts per kilogram [kg] pile**

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1- C4[1)] | D |
|---|---|---|---|---|---|---|---|---|
| GWP | kg $CO_2$ equiv | 1.06 | 0.125 | 5.28E-02 | 0 | 0 | 1.24 | 0 |
| ODP | kg CFC-11 equiv | 5.26E-08 | 2.29E-08 | 9.17E-09 | 0 | 0 | 8.47E-08 | 0 |
| AP | kg $SO_2$ equiv | 2.65E-03 | 6.91E-04 | 3.86E-04 | 0 | 0 | 3.73E-03 | 0 |
| EP | kg $PO_4^{3-}$ equiv | 1.75E-03 | 2.65E-03 | 6.91E-04 | 0 | 0 | 5.09E-03 | 0 |
| POCP | kg $C_2H_4$ equiv | 3.19E-04 | 5.95E-05 | 4.10E-05 | 0 | 0 | 4.20E-04 | 0 |
| ADPE | kg Sb equiv | 1.05E-06 | 3.51E-07 | 3.46E-08 | 0 | 0 | 1.44E-06 | 0 |
| ADPF | MJ, $H_u$[2)] | 12.9 | 1.88 | 0.746 | 0 | 0 | 15.6 | 0 |
| Legend | | GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophcation potential; POCP = Formation potential of tropospheric ozone; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources | | | | | | |

**Table 28: LCA results: Resource input per kilogram [kg] pile**

| Parameter | Unit | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|
| PERE | MJ, $H_u$ | 1.05 | 0.0262 | 0.00788 | 0 | 0 | 1.08 | 0 |
| PERM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERT | MJ, $H_u$ | 1.05 | 0.0262 | 0.00788 | 0 | 0 | 1.08 | 0 |
| PENRE | MJ, $H_u$ | 13.5 | 1.91 | 0.758 | 0 | 0 | 16.1 | 0 |
| PENRM | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PENRT | MJ, $H_u$ | 13.5 | 1.91 | 0.758 | 0 | 0 | 16.1 | 0 |
| SM | kg | 0.988 | 0 | 0 | 0 | 0 | 0.988 | 0 |
| RSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NRSF | MJ, $H_u$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FW | $m^3$ | INA[3)] | INA | INA | 0 | 0 | INA | 0 |
| Legend | | PERE = Renewable primary energy as energy carrier; PERM = Renewable primary energy resources as material utilization; PERT = Total Renewable primary energy; PENRE = Non-Renewable primary energy as energy carrier; PENRM = Non- Renewable primary energy as material utilization; PENRT = Total Non-Renewable primary energy; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Non- renewable secondary fuels; FW = Use of fresh water | | | | | | |

**Table 29: LCA results: Output-flows and waste categories per kilogram [kg] pile**

| Parameter | Unit | A1 | A2 | A3 | A1-A3 | A4 | A5 | B1-B7 | C1-C4 | A1-C4 | D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HWD | kg | INA | INA | INA | INA | INA | INA | 0 | 0 | INA | 0 |
| NHWD | kg | INA | INA | INA | INA | INA | INA | 0 | 0 | INA | 0 |
| RWD | kg | INA | INA | INA | INA | INA | INA | 0 | 0 | INA | 0 |
| CRU | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MFR | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 [4)] | 0 [4)] | 0 [4)] |
| MER | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEE | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EET | MJ | 0 | 0 | 0,993 | 0,993 | 0 | 0 | 0 | 0 | 0,993 | 0 |
| Legend | | HWD = Hazardous waste disposed; NHWD = Non- hazardous waste disposed; RWD = radioactive waste disposed; CRU =Components for re-use; MFR = Material for Recycling; MER = Material for energy recovery; EEE = Exported Energy electric; EET = Exported Energy thermal | | | | | | | | | |

[1)] additional information

[2)] Hu stands for (lower) heating value

[3)] INA: Indicator Not Assessed: the software GaBi 7.3 shows no waste for the databank ecoinvent 3.3 and the ecoinvent-datasets allow no complete registration of the water flows.

[4)] Reuse and recycling of piles is technically feasible but not reasonable under the current ecological and economic conditions

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