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# InfraGuidER

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# D 14

# Suggestions for a process model for chosen components

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## List of Acronyms

| | |
|---|---|
| AT | Automatic Transformer |
| ATP | Automatic Train Protection system |
| CPM | Competence Centre for Environmental Assessment of Product and Material Systems |
| CWF | Categorical Weighing Factor |
| EMS | Electromagnetic fields |
| ETCS | European Train Control System |
| EPE | Environmental Performance Evaluation |
| EPI | Environmental Performance Indicator |
| EPS | Environmental Priority Strategy |
| ERTMS | European Railway Traffic Management System |
| FSC | Forest Stewardship Council |
| GSM-R | Global System for Mobile Communications – Railway |
| GWP | Global Warming Potential |
| IM | Infrastructure Manager |

# 1. EXECUTIVE SUMMARY

In this report selected railway materials and components and the maintenance routines of rail grinding are presented from the material flow processes' point of view. The processes are modelled with the environmentally relevant inflows and outflows, and environmental performance indicators are identified for each specific material, component and service.

The addressed materials and components are sleepers and electrical and electronic components. The material flows of these groups of materials, and components and the rail grinding services were investigated by experts on those components within InfraGuidER project group. These flows were then, in accordance with the WP3 outline relevance ranked and analysed with an exemplary Environmental Performance Evaluation (EPE) methodology.

The relevance ranking was performed to establish the fact that the actual environmentally relevant materials and substances of the chosen materials, components and service groups were in fact identified, and this ranking is explicitly presented in the dedicated chapter 4.

In chapter 5 the environmental performance of each material, component and service is evaluated on the basis of the environmental performance indicators, by using life cycle assessment methodology and an environmental impact assessment methodology named Environmental Priority Strategy (EPS). The actual choices of data used in these three case studies may be selected differently, but the methodology is general and straightforward. It is based on that well-defined and easy-to-find quantitative data are assigned to the different environmental performance indicators, and the quantitative environmental performance result is automatically calculated by ready-made life cycle assessment process models.

The case studies performed and presented in this report, strongly suggest that the process model presented in figure 1 is considered as a simplified standard process model for railway infrastructure material, components and maintenance activities.

# 2. INTRODUCTION

This report is divided into five parts:

- Infrastructure manager's case studies
- Relevance ranking
- Exemplary Environmental Performance Evaluation
- Simplified standard environmentally relevant process model
- Results and improvement potentials

The first part of the report served as a foundation for the analysis made by the exemplary environmental performance evaluation. The analysis of the components shows their improvement potentials and lists procurement specifications to achieve these improvements.

A key objective of this report is the simplified standard environmentally relevant process model, presented in figure 1 below. This process model shows an overview of the lifecycle of materials, components or services, and should be used as a guide to identify material flows and their potential environmental impact.

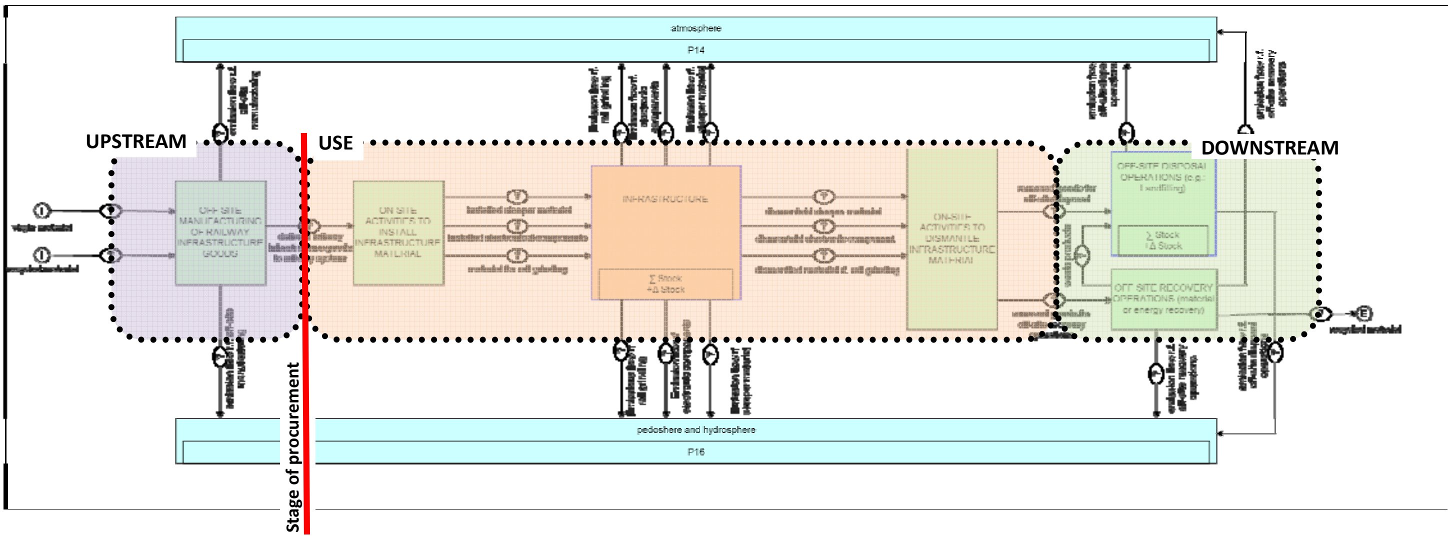



**Figure 1 The simplified standard environmentally relevant process model applied throughout this report, covering the full product or service life cycle, from extraction of natural resources to final waste management.**

## 2.1 OBJECTIVES

The objective of this deliverable is to explain the environmentally relevant processes of railway infrastructure materials, components and services. The processes address the entire railway infrastructure, hence is understood as a standard railway infrastructure process model.

## 2.2 INPUTS FROM OTHER PARTNERS

This report compiles case study input from industry, and combines these industrial case studies with the environmental performance analysis tools, i.e. relevance ranking and environmental performance evaluation. The case studies are done by Network Rail, BBRail, Wiener Linien and the environmental performance analysis tools are done by eco2win.

## 2.3 LINKS TO OTHER DELIVERABLES

This report (D14) combines the analysis of the environmental management systems of railway infrastructure managers described in deliverables D4 (Report on the range of existing environmental management tools, environmental standards, and environmental impact assessment tools) and deliverable D9 (Assessment of initial environmental aspects of railway infrastructure) and the material flow analysis described in deliverable D5 (Flow diagrams for Railway Infrastructure) and D7 (First draft of database (material list)), and combines the viewpoints of these reports into the necessary environmental performance evaluation of railway infrastructure materials, components and services. Figure 1 presents the simplified standard environmentally relevant process model of railway infrastructure material, components and services for the three case studies presented in this report. The process model covers the whole life cycle of material, components and services, from cradle to grave, which means from extraction of natural resources, through the use phase and ends in final waste management or material or energy recycling systems. The process model of the use phase of the material, components and services are well described by the MFA studies and is described in deliverables D5 and D7. The environmental management of the railway infrastructure manager regulates the environmental consequences of the inflow of materials and substances to the use phase by its procurement processes, and it regulates the environmental consequences of the outflow of the materials and substances by its operative environmental management system, its waste management system and by its service procurement routines and regulations.

The environmental performance analysis tools will be further developed in work package 4, and deliverable D19 will include a detailed description of data and functionality of the tools. Deliverable D20 will draft an eco-procurement for railway infrastructure materials and components and will be based on the environmental performance analysis tools.

# 3. INFRASTRUCTURE MANAGER'S CASE STUDIES

This section describes the environmental specifications for two product categories (sleepers, electrical and electronic components) and the maintenance activity of rail grinding.

## 3.1 SLEEPERS

### 3.1.1 Model tender for eco-procurement: Sleeper Materials

Sleepers form a core element of the track system. The material lists developed for InfraGuidER deliverable D7 collected the following data from the partners on sleeper materials:

For the core sleeper material:

- Concrete (ranging from 148-630 tons/km)
- Wood (soft and hard) (ranging from 15-518 tons/km)
- Creosote
- Steel (164 tons/km)

The choice of sleeper material will depend on the technical specifications of the railway line in focus, such as the track radii, line speed, formation, electrification, signalling (track circuits), adjacent track types and line strategy. However, material choice also affects the environmental impacts of the sleeper through its life cycle.

Other sleeper element material

- Steel reinforcement (9-10 tons/km)
- Steel bocks and E-clips (2-4 tons/km)
- Neoprene/rubber (elastic/insulation layer)
- Nylon 66/geotextile

### 3.1.2 Structuring environmental specifications for sleepers – Part 1: Identifying environmental protection areas

Within the InfraGuidER project, the three environmental impact categories climate change, hazardous substances and natural resources have been identified as core environmental protection areas for railway infrastructure material. The following assessment and identification of EPIs are therefore based on these categories.

### 3.1.3 Structuring environmental specifications for sleepers – Part 2: Impacts and Aspects

In a first step the environmental aspects and impacts of sleeper materials have to be considered and understood. In ISO14001, an aspect is an element that interacts with the environment, and an impact is any change to the environment, whether adverse or beneficial wholly or partly resulting from the aspect. The aspects and impacts shall be considered for the whole life of the sleeper materials – upstream manufacturing, in use phase and downstream end of life.

Table 1 provide examples of impacts and aspects for different sleeper materials through the three life stages. The table include both positive (+) and negative (-) impacts.

**Table 1 Impacts and aspects for wooden, concrete and steel sleepers**

| Impact Area | Upstream Aspects | In Use Aspects | Downstream Aspects |
|---|---|---|---|
| **Climate change** | *Wood*<br>– Creosote production - $CO_2$ release<br>*Concrete*<br>– Cement production - $CO_2$ release<br>*All*<br>– Steel production - $CO_2$ release<br>– Direct and indirect fossil fuel use in manufacturing processes - $CO_2$ release<br>– Fossil fuel use in transport - $CO_2$ release | *All*<br>No significant impact | *Wood*<br>+ Potential for waste to energy conversion ($CO_2$ neutral burning of wood)<br>*All*<br>– Fossil fuel use for waste transport and processing - $CO_2$ release |
| **Hazardous substances** | *Wood*<br>– Impregnation of creosote - pollution potential<br>*Concrete and steel*<br>No significant impact | *Wood*<br>– Creosote degradation - pollution potential<br>– Creosote leaching - pollution potential<br>*Concrete and steel*<br>No significant impact | *Wood*<br>– Creosote contaminated sleepers - hazardous waste<br>*Concrete and steel*<br>No significant impact |
| **Natural resources** | *Wood*<br>+ Renewable source of raw material<br>– Non sustainable foresting - reduced biodiversity and land transformation<br>*Concrete and steel*<br>+ Potential for recycled content - reduce resource use<br>– Land use through mining – reduced biodiversity and land transformation - material resource depletion<br>– Water use in production - resource depletion | *Concrete and steel*<br>No significant impact | *Wood*<br>+ Potential for waste to energy conversion – not landfill<br>*All*<br>+ Potential to reuse or recycle - reduce primary resource use<br>– Landfill of waste - land use |

### 3.1.4 **Structuring environmental specifications for sleepers – Part 3: Evaluation**

The key impacts for sleeper materials can after identification be evaluated using assessment tools such as Life Cycle Assessments, Carbon Footprint, Risk Assessment that can be based on results of Material Flow Analysis. For example, a Life Cycle Environmental Assessment undertaken in Sweden concluded that that the wooded creosoted sleeper has a lower life cycle environmental impact on resource use, $CO_2$ emissions, acidification and eutrophication than concrete sleepers, but higher impact for human toxicity and eco toxicity[1]. For the concrete sleeper the manufacturing phase has the largest environmental impact over all lifecycles whereas for creosoted sleepers it is the use phase and leaching of creosote that gives the largest contribution to the environmental impact over all lifecycles.

MFA is a valuable scientific method to analyse the stocks and flows of materials in a bounded system. The method of MFA is described in InfraGuidER deliverable D5 and D13. Different levels of MFA could be undertaken to provide different information on the material flows. For example figure 2 demonstrates how MFA could be used to display the material flows of each sleeper type all over the lifetime (upstream-, use- and downstream process). The data is not available for this case study but the study would include all material flows and stocks that are needed to produce (fuel, water, etc), maintain and dispose a sleeper, as well as corresponding emissions at every life cycle stage.

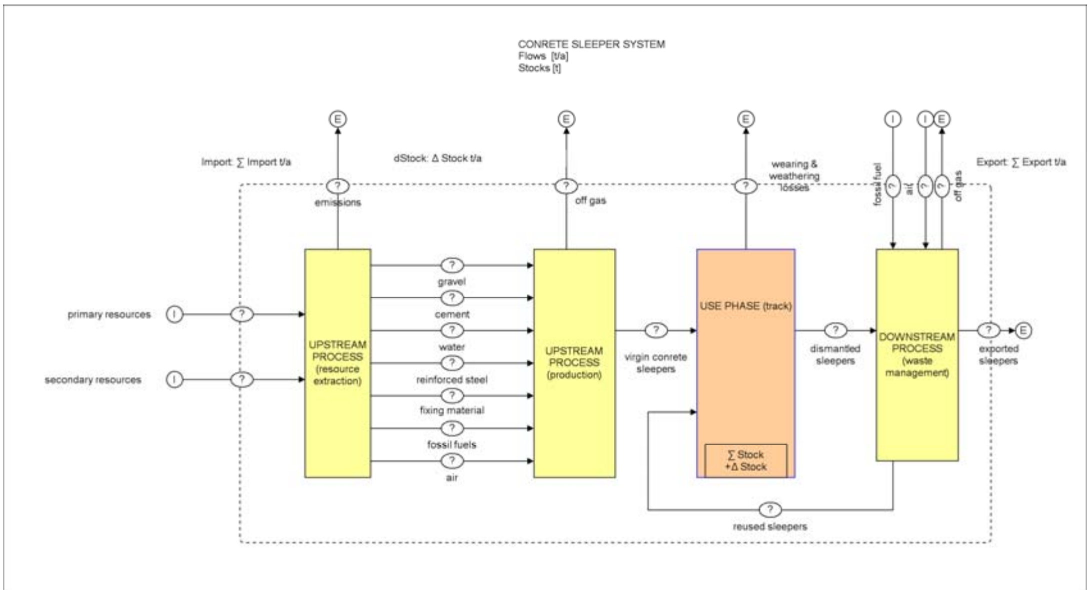



**Figure 2 General MFA model for sleepers**

Figure 2 concentrates on just displaying the material flows over the use phase for wooden sleepers. This model could be extended to display the flows on substance level (e.g. hydrocarbons) to distinguish between easily and slowly volatile hydrocarbons, because these two flows enter different environmental compartments. MFA can therefore be used to analyse the flow of wooden sleepers including the leaching of creosote that has been identified as an impact.

[1] Reference used in Banverket but not available during report finalization

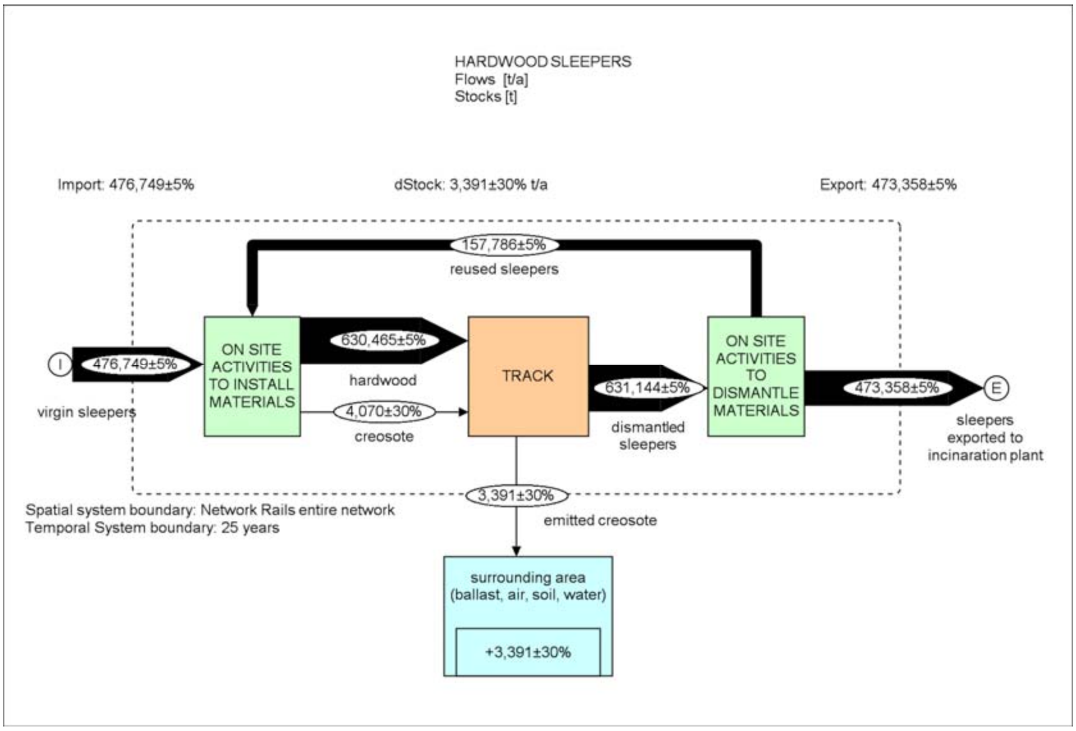



**Figure 3 MFA model for creosote impregnated hardwood sleepers**

### 3.1.5 Structuring environmental specifications for sleepers – Part 4: Weighting of impacts on their relative importance

After the evaluation of impacts, a weighting of the importance of the impacts has to be made based on what the evaluation tools have told us about the different environmental impacts of sleeper materials through the life cycle. Which impacts are important and where are the intervention points where we can affect the size of the impacts through e.g. technical specifications, procurement decisions, in use management processes or disposal management processes?

Requirements then have to be developed based on the weighting. The requirements can be either mandatory or preferable depending on the importance of the related impacts. As an example, Trafikverket in Sweden has developed mandatory requirements for impregnated wooden sleepers that has to be fulfilled in a procurement situation. The requirements concerns e.g. FSC-certification of the wood, what type of creosote oil that is allowed, how storage of creosote oil and impregnated sleepers shall be performed etc.[2]

Having developed an understanding of the aspects, impacts and undertaken an assessment/evaluation of impacts (e.g. through LCA, Risk Assessment) that can be based on MFA results, and decided which requirements are relevant, EPIs can be identified that will enable material procurement choices to be made for sleepers that include the relevant environmental requirements of the products. EPIs are only required for impacts that the procurer wants to control through procurement, not all impacts will therefore be associated with an EPI.

[2] Reference used in Trafikverket but not available during report finalization

This will depend on the significance of the impact determined through the impact assessments, and the policy priorities of the procuring organisation.

The procurement EPIs chosen for this case study are presented in table two below.

**Table 2 Suggested procurement EPIs for sleepers**

| **Wooden sleepers** | **Concrete sleepers** | **Steel sleepers** |
|---|---|---|
| ***Whole life cycle*** | | |
| Design lifetime (years)<br>Sleepers per km (n/km) | Design lifetime (years)<br>Sleepers per km (n/km) | Design lifetime (years)<br>Sleepers per km (n/km) |
| Carbon footprint (kg $CO_2$-eq/sleeper) | Carbon footprint (kg $CO_2$-eq/sleeper) | Carbon footprint (kg $CO_2$-eq/sleeper) |
| ***Upstream*** | | |
| Material content (kg wood, kg impregnating substance (substance), kg steel per sleeper) | Material content (kg concrete, kg steel per sleeper) | Material content (kg steel per sleeper) |
| Environmental controls in impregnating process (y/n) | | |
| Credibly certified timber source (%/unit)<br>Wt.% recycled materials (%/unit)<br>Water footprint (kg/sleeper) | Wt.% recycled materials (%/unit)<br>Water footprint (kg/sleeper)<br>Biodiversity benchmark at production sites (y/n) | Wt.% recycled materials (%/unit)<br>Water footprint (kg/sleeper)<br>Biodiversity benchmark at production sites (y/n) |
| ***Use phase*** | | |
| Creosote leachate rate (kg/lifetime*unit) | | |
| ***Downstream*** | | |
| Recyclability (%/unit) | Recyclability (%/unit) | Recyclability (%/unit) |

These EPIs would then be requested and evaluated as part of the tender.

Note that these are just the EPIs for the procurement intervention point. There are other intervention points during the lifecycle of sleepers that could affect the environmental impacts of sleepers and these would have different EPIs. For example, a waste management intervention point decision for timber sleepers would be to choose the disposal option of waste to energy. The EPI could then be % recovered waste to energy.

During the development of the suggested EPIs for sleepers, the following needs and potentials for improvements have been identified:

- Specification of requirements – mandatory or preferable
- Specification of target values for EPIs
- More detailed specification of relevant environmental controls in impregnation process
- Guidelines for how to assess credibly certified timber sources

- Guidelines for how to implement biodiversity benchmark at production sites

## 3.2 ELECTRICAL COMPONENT

The example provided in this session aims at

- The analysis of what is suggested for the environmental impact and the EPIs of electric and electronic components
- The identification of the differences and the common aspects for the environmental requirements and EPIs of electrical (power) components and the electronic ones (signals).

### 3.2.1 Electrical Equipment in Power Supply systems

The power supply equipment selected for the present environmental analysis is the transformer for high voltage application whose features are briefly described.

The present case study is based upon the high speed lines in Italy, designed as a standard 2 x 25 kV AC electrification system.

Power is taken from the national electricity grid at 132 kV or 150 kV and transformed to the +/- 25 kV AC traction system at substations (132/50 or 150/50 transformers). The transformers are mineral oil insulated with a rated power of 60 MVA (see figure 3).

In each substation there are two transformers installed: one is feeding the line while the other is kept in hot standby as backup (both transformers are alternatively put in service through a switching operation).

**Figure 4 Power transformer 60 MVA at Fissiraga traction substation at high speed Milan – Bologna section (Source: Rete Ferroviaria Italiana)**

Tractions substations are equally spaced along the line by about 50 km. In between substations autotransformer stations are placed at approximately 12,5 km, as shown in the figure below. In these stations, two 25 kV AC autotransformers with a rated power of 15 MVA are installed.

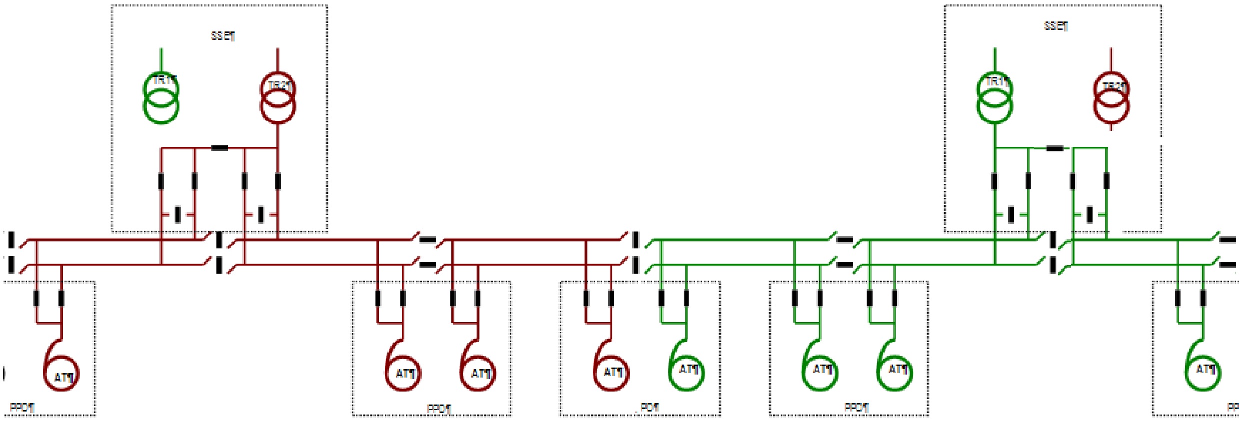


**Figure 5 Feeding configuration for a section between substations - typical**

All these transformers have different sizes and locations but they have, as a common feature, a major amount of the same materials per MVA as well as similar energy consumption and losses patterns.

**For this reason it has been selected as example the power transformer 60 MVA unit, which is among the largest elements of the power supply system and that can be easily located in the railway system.**

## What to manage: Transformer Quantity and Material Resources

The process of the environmental impact analysis for IMs, as suggested in deliverable D4, drives to the evaluation of quantity and content of the component to be managed.

The table shows the average quantity of materials per one km of railway track. The data is collected for the Bothnia Line.

**Table 3 Average quantity of materials per one km of railway track for the Bothnia Line**

| | | | | | | |
|---|---|---|---|---|---|---|
| Transformer | | | | | | |
| AT transformer | 22 units | Copper | 146 tons | 0,698 tons/km | 40 y | 0,0174 tons/(km*year) |
| | | Foundation | 290 tons | 1,389 tons/km | 40 y | 0,0347 tons/(km*year) |
| | | Steel | 186 tons | 0,892 tons/km | 40 y | 0,0223 tons/(km*year) |
| | | Transformer Oil | 68 tons | 0,326 tons/km | 40 y | 0,0082 tons/(km*year) |
| Transformer (placed on poles) Hexaformer, oil cooled, DS2550H 50/22/0,42 (50 kVA) | 75 units | Steel BF/Zn profil | 8 tons | 0,036 tons/km | 40 y | 0,0009 tons/(km*year) |
| | | Steel EAF profil | 12 tons | 0,057 tons/km | 40 y | 0,0014 tons/(km*year) |
| | | Petroleum Oil | 6 tons | 0,029 tons/km | 40 y | 0,0007 tons/(km*year) |
| ion transformer (Type: Schneider Electric.) | 35 units | Concrete | 26 tons | 0,126 tons/km | 40 y | 0,0031 tons/(km*year) |
| | | Copper | 2 tons | 0,010 tons/km | 40 y | 0,0003 tons/(km*year) |
| | | Steel EAF profil | 16 tons | 0,077 tons/km | 40 y | 0,0019 tons/(km*year) |
| Local transformer | 57 units | | | | | |
| | | Aluminium | 14,25 tons | 0,068 tons/km | 40 y | 0,0017 tons/(km*year) |
| | | copper | 3,99 tons | 0,019 tons/km | 40 y | 0,0005 tons/(km*year) |
| | | steel | 57 tons | 0,273 tons/km | 40 y | 0,0068 tons/(km*year) |
| RM6 transformer | 55 units | Copper | 1 tons | 0,005 tons/km | 40 y | 0,0001 tons/(km*year) |
| | | Steel | 19 tons | 0,089 tons/km | 40 y | 0,0022 tons/(km*year) |
| Trafo 11/22 transformer | 3 units | Copper | 5 tons | 0,023 tons/km | 40 y | 0,0006 tons/(km*year) |
| | | Steel | 16 tons | 0,075 tons/km | 40 y | 0,0019 tons/(km*year) |
| | | Transformer Oil | 2 tons | 0,008 tons/km | 40 y | 0,0002 tons/(km*year) |

For the available power supply system data of the new high speed lines built in ITALY is used. The following data sheet displays the quantity of transformers as well as the total rated power available for the new high speed lines in Italy.

**Table 4 Quantity of transformers as well as the total rated power available for the new high speed lines in Italy**

| High Speed Line | Length (KM) | Traction Substations | N° of Power Transformers | Power (MVA) | AT stations | N° of Auto transformers | Power (MVA) | Total rated power (MVA) | Rated power index (MVA/km) |
|---|---|---|---|---|---|---|---|---|---|
| Rome - Naples | 200 | 5 | **10** | **60** | 12 | **26** | **15** | **990** | **4.95** |
| Turin - Milan | 120 | 3 | **6** | **60** | 6 | **16** | **15** | **600** | **5.00** |
| Milan - Bologna | 185 | 4 | **8** | **60** | 9 | **20** | **15** | **780** | **4.21** |
| Bologna - Firenze | 90 | 2 | **4** | **60** | 5 | **9** | **15** | **375** | **4.17** |

The power transformer 60 MVA installation, which material content is described in the next section (see Table 11), includes an underground environmental protection facility in order to control spillage of transformer oil (containment vessels) which has not been considered in the material analysis.
The power transformer 60 MVA installation, which energy consumption during manufacturing and energy losses during use are described in the next section (see Table 12), have not taken into account energy consumption by auxiliary equipment.

The total losses in transformers during use are a percentage of total rated power. Such calculations are based upon an estimated lifetime of 35 years and average load assumed at 30% as shown below.

The following calculation is made for estimating power losses from transformers during use:

$$P_i = 0{,}7 \times P_0 + 0{,}3 \times P_{dc}$$

where:

$P_i$ = power losses for loaded transformer,

$P_0$ = power losses for transformer without load,

$P_{dc}$ = power losses for loaded transformer in direct current.

Total power losses during use for all loaded transformers (n) in the traction system can then estimated by application of the following calculation (the total number of transformers is 2n):

$$P_{Total} = \sum_i^n P_i + nP_0$$

### 3.2.2 **Electronic components in Signalling & Communication systems**

The signalling system selected for the environmental analysis is the ERTMS level 1 and level 2 system whose features are briefly described.

The European Railway Traffic Management System (ERTMS) is a major industrial project developed in the last ten years by six UNIFE members – Alstom Transport, Ansaldo STS, Bombardier Transportation, Invensys Rail Group, Siemens Mobility and Thales – in close cooperation with the European Union, railway stakeholders and the GSM-R industry in

ERTMS has two basic components:

1. ETCS, the European Train Control System, is an in-cab signalling, control and train protection system to replace the existing national (incompatible) safety systems;
2. GSM-R, is an international wireless communications standard for railway applications and communication between the track and the train, based on standard GSM using frequencies specifically reserved for rail applications with certain specific and advanced functions.

ERTMS aims at replacing the different national **train signalling and safety systems** in Europe mainly consisting of the conventional track circuit operating at different frequencies. The deployment of ERTMS enables the creation of a seamless European railway system and increases European railway's competitiveness.

Moreover ERTMS is not standardised in one solution but it can be described as a tool at at three different levels, based on the development of ETCS level 1, level 2 and level 3. In this context only the first two levels are considered as reported in the following figure:

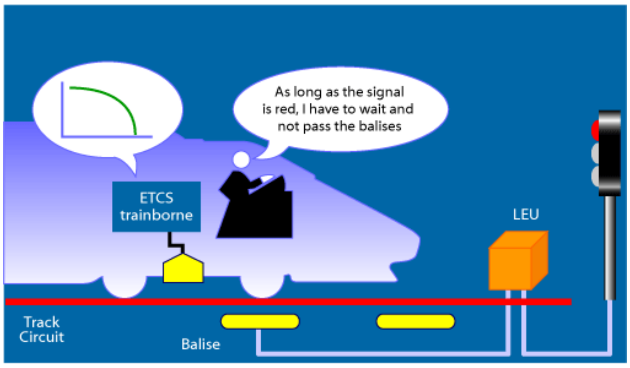



**Figure 6 Principles of ERTMS level 1**

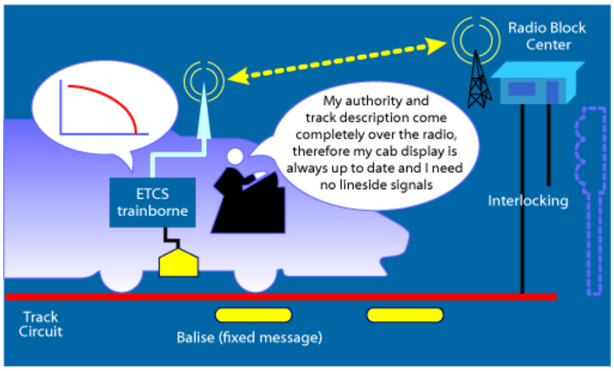



**Figure 7 Principles of ERTMS level 2**

A general list of the electronic components in ERTMS level 1/2 is reported in the following table

**Table 5 ERTMS level 1/2 Components**

| Component | Operation |
|---|---|
| Lineside Encoder Unit LEU | Captures movement authority information from interlocking or signal aspect<br>Selects and sends telegrams to Eurobalise® that contain movement authorities and trackside data. |
| Balise | Energized by power from train antenna<br>Fixed type: Stores infrastructure data as pre-formatted 'telegrams' (position reference, speed limits, line gradient, works on the line, etc.)<br>Switchable type: sends to train movement authorities and trackside the telegrams received by LEU. |
| Track train detection | The detection of vehicles usually occurs through axle counters, or normal track circuits, which provide continuous detection on the position of the vehicle.<br>The **track circuit** is an audio-frequency powered, jointless track circuit. Adjacent track circuits are separated by electrical joints which confine the respective frequencies in the section of track between them. Each joint is formed by a so-called S-shaped cable with cross-section suitable to carry the return electric traction current. Signal injection and reception at joints separating adjacent track circuits takes place by means of an inductive coupIing between the S-shaped joint cable connected to the rails and two insulated "loop" cables, each placed inside one inlet of the "S".<br>**Axle counter** is an electronic device on a railway that detects the passing of a train replacing the more common track circuit. A counting head (or 'detection point') is installed at each end of the section, and as each axle passes the head at the start of the section, a counter increments. A detection point comprises two independent sensors, therefore the device can detect the direction of a train by the order in which the sensors are passed. |
| Signals | Wayside signals are electrical devices erected beside a railway line to pass information relating to the state of the line ahead to train drivers/engineers. at present in ERTMs level 2 are optional and LED based. |
| Radio Block Centre (RBC) | RBC is an interface with local interlockings to obtain track occupation and route set status, and (where supported) to provide instructions to the interlocking such as releasing approach-locking controls, management of movement authorities for all trains within the controlled area, storage, management and transmission of selected trackside data, encryption/decryption of messages exchanged with the trains, communication with any adjacent RBC, with ERTMS Control Center, etc |

| | |
|---|---|
| Interlocking unit | The interlocking is an arrangement of signal apparatus that prevents conflicting movements through an arrangement of tracks such as junctions or crossings. An interlocking is designed so that it is impossible to give clear signals to trains unless the route to be used is proved to be safe<br><br>Computer based interlocking can be either centralised or distributed, in which case the central unit is located in one place and the object controller units that drive the wayside objects can be located at some distance from the central unit. Dual and redundant architecture with hot standby provides high availability. |
| Switch machine | Switch point machine range can be used, depending on what is suitable for the particular market. Conventional or sleeper integrated point machines are used in ERTMs level 2 and they are operated by computer- based interlocking. |

The specific signalling units which belong to the ERTMS level 2 are the ones listed in the database provided in deliverable D7 for the Bothnia Line and reported in the following table:

**Table 6 Specific signalling units which belong to the ERTMS level 2, Botnia Line**

| Power, signalling and telecom systems construction | | | Power, signalling and telecom systems operation | Power, signalling and telecom systems maintenance |
|---|---|---|---|---|
| Power supply system construction | Signalling system construction | Telecom system system construction | | |
| Catenary posts (including all fastening equipment) | Interlocking system | Radio towers with foundations | Operation of electrical equipment | Reinvestment determined by lifetimes of components and constructions |
| Cables | Balises | Computer equipment | | |
| Transformers | Cables | Cables | | |
| UPS-system | UPS-system | UPS-system | | |
| Buildings for electrical equipment | Buildings for electrical equipment | Buildings for electrical equipment | | |
| Construction work | | | | |

All these signalling components have different sizes and location but they have, as a common feature, a major amount of the same materials.

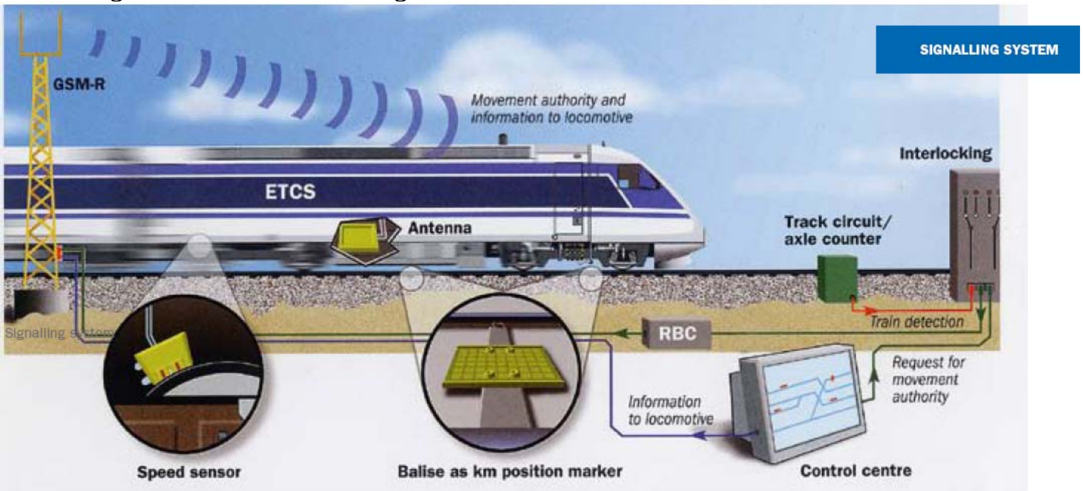
**For this reason it has been selected as example the Interlocking unit, which is the new element of the signalling system and can be centralised or distributed on the trackside.**

## What to manage: Interlocking Quantity and Material Resources

The process of the environmental impact analysis for IMs, as suggested in deliverable D4, drives to the evaluation of quantity and content of the component to be managed.

Concerning the quantity on the wayside some information are collected by the Bothnia Line and by the Ansaldo STS signalling system data of the new high speed lines built in ITALY.

The Bothnia line data are referred to ERTMS level 2 installation as reported in the following figure containing balises, interlocking's**,** track circuits, axle counters and Radio Block Centre's.




## Figure 8 ERTMS level 2 installation

Concerning the quantity of the components on the trackside the draft database in deliverable D7 provides some information referring only to Bothnia Line Sheet (ERTMS level 2) where only the balises, Interlocking Systems, UPS and cable channels are considered.

## Table 7 ERTMS level 2 Botnia Line

| Signaling System and Communication | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UPS batteries, signal | 48 | units | | | | | | | | | |
| | | | Sulphuric acid | 0,13 | tons | 0,001 | tons/km | 10 | y | 0,0001 | tons/(km*year) |
| | | | Glass wool | 0,01 | tons | 0,000 | tons/km | 10 | y | 0,0000 | tons/(km*year) |
| | | | Lead | 0,61 | tons | 0,003 | tons/km | 10 | y | 0,0003 | tons/(km*year) |
| | | | Non woven fabric | 0,00 | tons | 0,000 | tons/km | 10 | y | 0,0000 | tons/(km*year) |
| | | | HDPE + PP | 0,06 | tons | 0,000 | tons/km | 10 | y | 0,0000 | tons/(km*year) |
| Balise (EBI Link 2000 – Eurobalise) | 790 | units | Polymers | 3,7 | tons | 0,018 | tons/km | 30 | y | 0,0006 | tons/(km*year) |
| | | | Brass | 0,1 | tons | 0,001 | tons/km | 30 | y | 0,0000 | tons/(km*year) |
| | | | Copper | 0,05 | tons | 0,000 | tons/km | 30 | y | 0,0000 | tons/(km*year) |
| | | | Rubbers | 0,01 | tons | 0,000 | tons/km | 30 | y | 0,0000 | tons/(km*year) |
| | | | Other material | 0,08 | tons | 0,000 | tons/km | 30 | y | 0,0000 | tons/(km*year) |
| Interlocking System (EBI Lock 950) | 48 | units | Steel | 18 | tons | 0,088 | tons/km | 20 | y | 0,0044 | tons/(km*year) |
| | | | Copper | 2 | tons | 0,010 | tons/km | 20 | y | 0,0005 | tons/(km*year) |
| | | | Polymers | 2 | tons | 0,010 | tons/km | 20 | y | 0,0005 | tons/(km*year) |
| | | | Iron | 1 | tons | 0,006 | tons/km | 20 | y | 0,0003 | tons/(km*year) |
| | | | Aluminium | 0 | tons | 0,001 | tons/km | 20 | y | 0,00005 | tons/(km*year) |
| | | | Other material | 2 | tons | 0,007 | tons/km | 20 | y | 0,0004 | tons/(km*year) |
| Cable channels with lid | | | ? | | | | | | | | |

From Ansaldo STS the following data in terms of components and quantity are available for the ERTMS level 1 and level 2 new high speed lines:

**Table 8 Ansaldo STS components and quantity for the ERTMS level 1 and level 2 new high speed lines:**

| High Speed line | Km | Radio Block Center | Interlocking | LEU | Balise | Track circuit |
|---|---|---|---|---|---|---|
| Rome -Naples | 200 | 3 | **18** | 60 | 1500 | |
| Turin -Milan | 120 | 2 | **14** | 40 | 900 | 180 |

The interlocking unit, as depicted in the following Figure, includes a computer and an on line back up computer and centrally located or distributed object controllers which provide interface to wayside units and are located with the interlocking computers in racks or cabinets holding printed boards, cables, connectors and supply units.

The interlocking system receives routes commands from traffic control centres or local control systems and sends indications and status back.

**EBI Lock 950 Bombardier Interlocking System**

**Figure 9 EBI Lock 950 Bombardier Interlocking System**

The main materials used for the interlocking unit are reported in Table 15 while the kg are referred to the EBI lock 950 provided by Bombardier.

The choice of the material does not depend on the infrastructure conditions but of course the procurement can influence some percentage of them or can drive to specify/use some specific materials.

However, material choice also affects the environmental impacts of the interlocking unit through its life cycle.

### 3.2.3 Structuring environmental specifications for electrical and electronic equipment – Part 1: Impacts and Aspects

The environmental aspects and impacts of the electrical and electronic equipment under consideration are analysed considering the whole life cycle (upstream manufacturing, in use phase and downstream end of life).

The tables providing examples of impacts and aspects already proposed for different sleeper materials through the three life stages can also be adapted for the transformer and interlocking units.

**Table 9 Impacts and Aspects for Electrical Equipment – Transformer**

| | Life Cycle | | |
|---|---|---|---|
| **Aspects and Impacts** | **Upsteam** | **In Use** | **Down Stream** |
| | **Transformer** | | |
| Climate change | *Negative*<br>High percentage of metals in the transformer unit<br>CO2 released in manufacturing of main parts/ assembly/ transport | *Negative*<br>energy losses<br>energy used for maintenance | *Negative*<br>energy use in decommissioning<br>CO2 released during waste management |
| Hazardous Substances | *Negative*<br>exposure to paint during manufacturing<br>spillage of mineral oil during assembly/ transport | *Negative*<br>spillage of mineral oil during failure or unplanned events | *Negative*<br>hazardous waste management (mineral oil)<br>special treatment of waste of electrical and electronic equipment (WEEE) |
| Resource depletion | *Positive*<br>Potential for recycled content - reduce resource use<br><br>*Negative*<br>Land resources in mining - biodiversity and land take<br>Water use in production - resource depletion | No significant impact | Positive<br>Potential to recycle materials - reduce primary resource use<br><br>*Negative*<br>Landfilling of waste - land take |

**Table 10 Impacts and Aspects for Electronic Equipment - Interlocking unit**

| | Life Cycle | | |
|---|---|---|---|
| **Aspects and Impacts** | **Upsteam** | **In Use** | **Down Stream** |
| | **Interlocking unit** | | |
| Climate change | *Negative*<br>High percentage of metals in the interlocking unit<br>CO2 released in manufacturing/ transport | *Negative*<br>energy for operation<br>energy used for maintenance and installation | *Negative*<br>energy use in waste management - $CO_2$ release |
| Hazardous Substances | *Negative*<br>manufacturing using unknown material<br>contains polymers | No significant impact | *Negative*<br>waste management of polymers and other unknown material (unwanted)<br>special treatment of waste of electrical and electronic equipment (WEEE) |
| Resource depletion | *Positive*<br>Potential for recycled content - reduce resource use<br><br>*Negative*<br>Land resources in mining - biodiversity and land take<br>Water use in production - resource depletion | No significant impact | *Positive*<br>Potential to recycle materials - reduce primary resource use<br><br>*Negative*<br>Landfilling of waste - land take |

### 3.2.4 Structuring environmental specifications for electrical and electronic equipment – Part 2: Tools to be used

To extract the impacts some assessment tool can be used such as Life Cycle Assessments, Carbon Foot printing, Risk Assessment and Material Flow Analyses.

### LCA – transformer

The Life Cycle Environmental Assessment undertaken by ABB Transformers AB according to ISO14021 produced the following results for the Power transformer TrafoStar 63 MVA, based upon an estimated lifetime of 35 years.

The transformer considered in the following brief description of the LCA study made by ABB can be considered valid for similar transformers, provided the range of variations within each impact category does not exceed +- 5%.

The TrafoStar 63 MVA with heat exchanger that has been chosen for the LCA study is a three phase power transformer while traction transformers are single phase with two secondary windings. Such difference in configuration poses also as a difference in material content but the

LCA data from ABB has been taken for quantity reference of a standard 60 MVA transformer in traction substations.

**Table 11 Material use in ABB, 60 MVA transformers in traction substations**

| Material | Manufacturing kg/unit | Manufacturing kg/MVA |
|---|---|---|
| Transformer oil | 20000 | 317 |
| Copper | 18360 | 291 |
| Insulation materials | 1900 | 30 |
| Wood | 1890 | 30 |
| Porcelain | 334 | 5 |
| Electrical steel | 21200 | 337 |
| Construction steel | 14479 | 230 |
| Paint | 277 | 4 |
| Other | 3060 | 49 |
| TOTAL | 81500 | 1293 |

**Table 12 Energy use in ABB, 60 MVA transformers in traction substations**

| Energy net consumption and losses | Manufacturing kWh/unit | Use kWh/unit | Manufacturing kWh/MVA | Use kWh/MVA |
|---|---|---|---|---|
| For transmission and distribution of electric power | 94500 | 47.930.000 | 1500 | 760.794 |
| For traction systems (*) | 94500 | 10.900.000 (**) | 0 | 173.016 (**) |

* Data and calculations for traction systems have been added for the purposes of the present case study. The average load, assumed as 50% in the LCA performed by ABB for transmission and distribution of electric power, is estimated as 30% in the traction systems.

** The calculation of energy losses for a traction transformer during use has taken into consideration the average losses of a standard two transformer substation; one loaded feeding continuously at 30% of rated power and one without load in hot standby for backup.

**Table 13 Waste management from ABB, 60 MVA transformers in traction substations**

| Waste category | kg/MVA |
|---|---|
| **Hazardous waste** | |
| During manufacturing | 10,45 |
| During use | 0,63 |
| At end of life | 317,46 |
| **Regular waste** | |
| During manufacturing | 43775,10 |
| During use | 0,00 |
| End of life total waste | 1214,29 |
| End of life waste to recycling | 22800 |

**Table 14 Climate change effects from ABB, 60 MVA transformer in traction substations**

| Environmental impact categories | Equivalent unit per MVA | Manufacturing | Use | Total life cycle |
|---|---|---|---|---|
| Global Warming Potential (GWP) | kg $CO_2$ equiv. | 4103,58 | 455601,59 | 459705,18 |
| Acidification (AP) | mol H + equiv. | 4278,83 | 81802,27 | 86081,18 |
| Ozone Depletion Potential (ODP) | kg CFC 11 equiv. | 0,00 | 0,00 | 0,00 |
| Photochemical Oxidant Formation (POCP) | kg ethene equiv. | 3,14 | 82,04 | 85,18 |
| Eutrophication (NP) | kg O2 equiv. | 390,53 | 6089,08 | 6479,61 |

**End of life**

- Total waste weight is 76.500 kg/ unit
- The weight of material which poses as hazardous waste at the end of life is 20.000 kg/ unit.

Note:

It is necessary to ask the suppliers to provide further information about

- Recyclability following decommissioning (large metal parts easy to dismantle and recycle, but how about the other materials),
- Energy and resource usage for construction of environmental protection facilities (spillage containment vessels),
- Energy consumed by auxiliary equipment,
- Electromagnetic fields exposure,
- Maintenance resources and energy consumption.

## LCA – Interlocking unit

The Life Cycle Environmental Assessment undertaken by Bombardier according to ISO14021 produced the following results for the EBI Lock 950 - Interlocking System, based upon an estimated lifetime of 20 years.

**Table 15 Material use in Bombardier EBI Lock 950**

| Material | Manufacturing Kg | Use Kg | End of life Kg | Total life cycle Kg |
|---|---|---|---|---|
| Steel | 384 | 0 | -384 | 0 |
| Copper | 43 | 0 | -43 | 0 |
| Polymer | 42 | 0 | -41 | 1 |
| Iron | 24 | 0 | -24 | 0 |
| Aluminium | 4 | 0 | -4 | 0 |
| Other material | 32 | 0 | -11 | 21 |
| TOTAL | 528 | 0 | -507 | 22 |

**Table 16 Primary energy consumption for Bombardier EBI Lock 950**

| Manufacturing kWh | Use kWh | End of life kWh | Total life cycle kWh |
|---|---|---|---|
| 1 | 6132 | 0 | 6133 |

**Table 17 Material recyclability for Bombardier EBI Lock 950**

| Material | Recyclability % |
|---|---|
| Steel | 99 |
| Copper | 100 |
| Polymer | 100 |
| Iron | 100 |
| Aluminium | 100 |
| Other material | 26 |
| TOTAL | 96% |

**Table 18 Climate change effects from Bombardier EBI Lock 950**

| Environmental impact categories | Unit | Manufacturing | Use | End of life | Total life cycle |
|---|---|---|---|---|---|
| Global Warming Potential (GWP) | kg $CO_2$ equiv. | 1405 | 318 | -742 | 981 |
| Ozone Depletion Potential (ODP) | kg CFC 11 equiv. | 0,000004 | 0,00018 4 | -0,000002 | 0,00019 |
| Acidification (AP) | mol H + equiv. | 184 | 74 | -84 | 174 |
| Eutrophication (NP) | kg $O_2$ equiv. | 23 | 5 | -6 | 22 |
| Photochemical Oxidant Formation (POCP) | kg ethene equiv. | 0,18 | 0,15 | -0,07 | 0,26 |

**End of life**

- Total waste weight is 21.12 kg
- The weight of material which needs special treatment at the end of life is 33 kg

Note:

It is necessary to ask the suppliers to provide further information about

- energy use for installation
- energy used for obtaining the requested environmental conditions (temperature and humidity)
- Maintenance resources and energy used

It could be useful to have also MFA for the whole signalling and communication system

### 3.2.5 Structuring environmental specifications for electrical and electronic equipment – Part 3: EPI preliminary definition

Having developed an understanding of the impacts and undertaken an assessment/evaluation of impacts EPIs can be identified that will enable material procurement choices to be made that include the relevant environmental performance of the products.

The procurement EPIs chosen for the present case study are below and are identified considering both the EPIs preliminary identified by InfraGuidER team and the EPIs already included in the UIC 345 leaflet.

**Table 19 List of EPIs for electrical and electronic equipment**

| EPI definition | Description /unit |
|---|---|
| Restricted material | List of legally restricted material/ kg |
| Energy in use | Energy used for operation and operating conditions / kWh or J |
| Unwanted and controlled materials | List of unwanted and controlled materials (SF6, polymers, lead, etc) /kg |
| Hazardous waste | List of unwanted and controlled materials (SF6, polymers, lead, etc) /kg |
| Recyclability | Material recycling rate after use of the product / kg or % |
| Noise emissions | Compliance to specified local and strategic acoustic maps (day and night limits of $L_{Aeq}$) |
| Electromagnetic fields (EMF) | As defined in 2004/40/EC where staff may be present |
| Spillage/ Leakages | Verification that measures to prevent environmental damage due to spilling of oil, leakages, grease, coolant, insulators and other substances have been taken |
| Energy consumption in upstream process | Energy used for raw material extraction, manufacturing, installation / kWh |
| Renewable energy in use | List of renewable energy sources and % of the energy produced for the use / kWh |
| Material resources | List and weight of material used in the product / kg or % |
| Material for protection systems | List and weight of material used for providing the ambient conditions or environmental protection / kg or % |
| Climate change effect | Global warming potential, acidification, etc in the life cycle / equivalent unit of $CO_2$ etc |
| Traced material | Identification of the material for the removal in the downstream process |

## UIC 345 DERIVED EPIS

**Mandatory Indicators**

### UIC-345 Category: Restricted Materials

| Definition of environmental specification | |
|---|---|
| **Legally restricted materials (i.e. PCB)** | |
| **Environmental performance indicator** | |
| **Compliance with legislation (exclusion of legally forbidden materials)** | |
| **Application:** | **All kinds of electrical and electronic equipment** |
| **Type of specification:** | **Mandatory**<br>**Preconditioned by design** |
| **Degree of quantification:** | **Compliance specification** |

**Voluntary indicators**

### UIC-345 Category: Energy in use

| Definition of environmental specification | |
|---|---|
| **Energy consumption and energy losses during use of the equipment** | |
| **Environmental performance indicator** | |
| **Calculated energy net consumption and losses for specific operation pattern (kWh)** | |
| **Application:** | **All kinds of electrical and electronic equipment** |
| **Type of specification:** | **Voluntary**<br>**Preconditioned by design** |
| **Degree of quantification:** | **Performance Specification** |

## UIC-345 Category: Unwanted and controlled materials

| | |
|---|---|
| Definition of environmental specification | |
| **Unwanted or controlled materials (SF6, polymers, lead, etc) which are potentially hazardous to health or the environment** | |
| **Environmental performance indicator** | |
| **Weight ratio % or absolute values (kg) of unwanted and controlled materials** | |
| **Recommended Performance** | |
| **1. Exclusion<br>2. Inventory for LCA and recycling purposes** | |
| **Application:** | **All kinds of electrical and electronic equipment** |
| **Type of specification:** | **Voluntary<br>Preconditioned by design** |
| **Degree of quantification:** | **Performance Specification** |

## UIC-345 Category: Hazardous waste

| | |
|---|---|
| Definition of environmental specification | |
| **Materials which during lifespan or at the end of life need special treatment as hazardous material** | |
| **Environmental performance indicator** | |
| **Weight of the hazardous waste (Kg) according to European waste catalogue** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary<br>Preconditioned by design** |
| Degree of quantification: | **Performance specification** |

## UIC-345 Category: Recyclability

| | |
|---|---|
| Definition of environmental specification | |
| **Recyclability** | |
| Environmental performance indicator | |
| **Defined value for recyclability:<br>- material recycling rate after use and /or<br>- recycling rate after use including energy recovery** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

**Other indicators (not related to key environmental areas)**

### UIC-345 Category: Noise emissions

| Definition of environmental specification | |
|---|---|
| **Noise emissions** | |
| **Mandatory compliance** | |
| **Compliance to specified local and strategic acoustic maps (day and night limits of $L_{Aeq}$)** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Mandatory**<br>**Preconditioned by design** |
| Degree of quantification: | **Compliance specification** |

### UIC-345 Category: Electromagnetic fields (EMF)

| Definition of environmental specification | |
|---|---|
| **EMF exposure in all areas where people may be present** | |
| **Mandatory compliance** | |
| **As defined in 2004/40/EC where staff may be present** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Mandatory**<br>**Preconditioned by design** |
| Degree of quantification: | **Compliance specification** |

### UIC-345 Category: Spillage/ Leakages

| Definition of environmental specification | |
|---|---|
| **The manufacturer verifies that measures to prevent environmental damage due to spilling of oil, leakages, grease, coolant, insulators and other substances have been taken** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary**<br>**Preconditioned by design** |
| Degree of quantification: | **Compliance specification** |

## INFRAGUIDER DERIVED EPIs

### INFRAGUIDER CATEGORY: Designed lifetime

| | |
|---|---|
| Definition of environmental specification | |
| **Designed lifetime of the product** | |
| Environmental performance indicator | |
| **Lifetime of the product calculated for the average load in the specific operation pattern (years)** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

### INFRAGUIDER CATEGORY: Energy in upstream process

| | |
|---|---|
| Definition of environmental specification | |
| **Energy used for the upstream process (extraction and production of raw materials, manufacturing of main parts, assembly, transportation and installation of equipment)** | |
| Environmental performance indicator | |
| **Calculated energy consumption for extraction and production of raw materials, manufacturing of main parts, assembly, transportation and installation of the equipment (kWh or J)** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

## INFRAGUIDER CATEGORY: Renewable energy in use

| | |
|---|---|
| Definition of environmental specification | |
| **Type and quantity of renewable energy in use** | |
| Environmental performance indicator | |
| **Electricity mix in the Country/ Region of use** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

## INFRAGUIDER CATEGORY: Material resources

| | |
|---|---|
| Definition of environmental specification | |
| **Declaration of the material used up to 100% of the product** | |
| Environmental performance indicator | |
| **List and quantity of the material content in the product (kg or % of the total weight)** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

## INFRAGUIDER CATEGORY: Material resources for protection systems

| | |
|---|---|
| Definition of environmental specification | |
| **Definition of the protection systems needed (air conditioner, insulating equipment, buildings, spillage containment vessels)** | |
| Environmental performance indicator | |
| **List and weight of the material needed for indoor equipment protection (in ambient conditions) and outdoor equipment protection (i.e. spillage containment vessels)** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

## INFRAGUIDER CATEGORY: Climate change effects

| | |
|---|---|
| Definition of environmental specification | |
| **Definition of the climate change effect of the product** | |
| Environmental performance indicator | |
| **CO2 equivalents released during the whole life cycle.** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

## INFRAGUIDER CATEGORY traced material (leakage)

| | |
|---|---|
| Definition of environmental specification | |
| **Identification of the material for the complete removal in the downstream process** | |
| Environmental performance indicator | |
| **Marked components/materials used** | |
| Application: | **All kinds of electrical and electronic equipment** |
| Type of specification: | **Voluntary** |
| Degree of quantification: | **Performance specification** |

## 3.3 RAIL GRINDING

### 3.3.1 Model tender for eco-procurement: Rail Grinding in metro systems

Definition: Rail grinding is a rail maintenance service operation which results in a better quality of the rail surface. It needs to be done to

- Prevent damage resulting from rolling contact fatigue (headchecks can cause railbreaks),
- Prevent noise emissions resulting from corrugation
- Improve the vehicle ride quality by grinding special profiles (gauge extension, asymmetric, etc.)
- Reduce rail and wheel wear

**Figure 10 Rail Grinding in Vienna's metro system (Source: Wiener Linien)**

### 3.3.2 Structuring environmental specifications for rail grinding – Part 1: EPI method

In a first step the environmental performance indicators (EPIs) for rail grinding as well as the environmental specifications have to be considered.

EPIs (in case they are not known) can be derived within an expert brainstorming session. Certain pre-defined environmental impact categories should be mapped with the work or service to be tendered. From these questions, single EPIs can be derived.

For rail grinding, these EPIs were defined as the following:

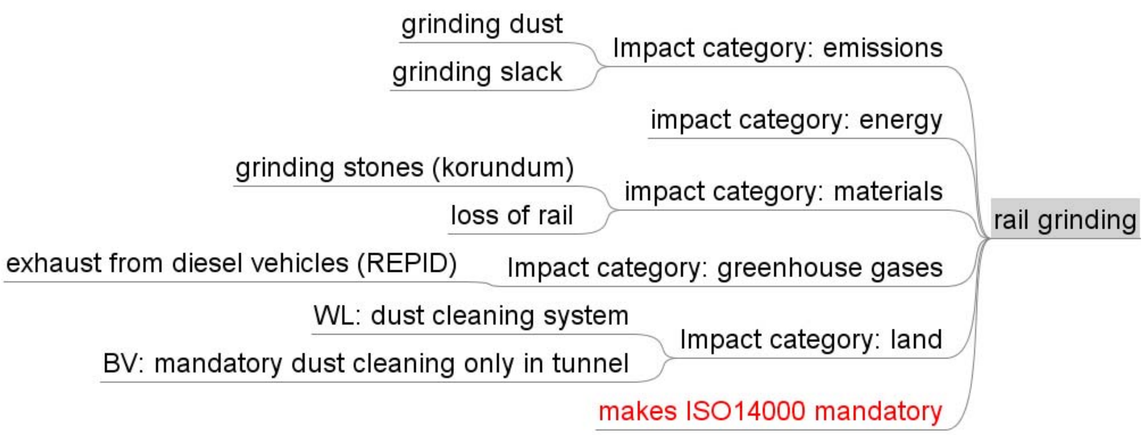



**Figure 11 Environmental aspects for rail grinding**

From these 5 categories, three main emissions could be derived. These are:

- Dust emissions from the grinding procedure
    - Rail
        - steel dust
        - steel sparks
        - steel chips
    - Grinding Stone
        - dust resulting grinding stone
- exhaust from the diesel generator of the vehicle (REPID)
- energy consumption of the diesel engine (carbon footprint)
- water consumption

These can be mapped to the following environmental aspects:

- maximum concentration of particles in grinding exhaust → emissions
- prescribe dust collection system → emissions
- restrict hazardous materials in grinding stones (if any hazardous material is present) → materials
- $CO_2$-emissions / litre of consumed diesel → greenhouse gases
- water consumption / ground meter of track

**Table 20 rail grinding environmental specifications**

| | | Performance mainly dependent on design | | Performance mainly dependent on operation | |
|---|---|---|---|---|---|
| | | Key Area | Specification | Key Area | Specification |
| Taken from UIC 345 for vehicles | Legally madatory specifications | Noise | ▪ Passing-by noise<br>▪ Stationary noise<br>▪ Starting noise | | |
| | | Diesel exhaust Emissions | Diesel exhaust emissions (particles) | | |
| | | Materials | Legally restricted materials for vehicle production | | |
| | | Others | Electromagnetic compatibility | | |
| | Voluntary specifications | Energy | | | |
| | | Materials | | | |
| | | Others | | | |
| InfraGuidER | InfraGuidER specifications | Emissions | | Emissions | ▪ particles in grinding exhaust<br>▪ particles in grinding slag<br>▪ dust collection system |
| | | Energy/Water | | Energy/Water | water consumption / ground metre of track |
| | | Materials | materials in grinding stones | Materials | |
| | | Greenhouse gases | | Greenhouse gases[3] | CO2-emissions / litre of diesel |
| | | Land | | Land | |

### 3.3.3 Structuring environmental specifications for rail grinding – Part 2: Material Flow Analysis (MFA)

The MFA is a valuable scientific method to analyse e.g. industrial processes like rail grinding from a material point of view. The method of MFA is described in InfraGuidER deliverable D5. The MFA results are the basic for evaluation methods like LCA or Risk assessment.

The chapter starts with a system description of the MFA model. Finally, the stock and flow diagrams are displayed.

---

[3] identified via MFA-model (Figure 12)

## System description

a) Goal: The goal of this analysis is to quantify and display the material stocks and flows caused by the maintenance process “rail grinding”.

b) System boundaries: The spatial system boundary is determined by 1 kilometre ground single track. The temporal system boundary is set with 1 year.

c) Processes: A process is defined as the transformation, transport or storage of materials. Table 21 displays the relevant processes to model the material stocks and flows of rail grinding. The first level processes “grinding vehicle” and “track” are further decomposed, in order to be modelled in more detail. The “grinding vehicle” contains the subprocesses “engine”, “water tank”, “grinding unit” and “dust collection system”. The “track” contains the subprocess “rail” and “rail surrounding”. Finally, the “rail surrounding” contains two subprocess (3rd level), namely “suction process” and “evaporation process”.

d) Flows: A material flow is defined as “mass flow rate” [mass per time unit].The processes are linked by flows. Table 22 displays the relevant material flows for processes on 1st level. The flows entering or leaving subprocesses are only displayed at the material balance sheets.

**Table 21 Relevant processes of “rail grinding”.**

| 1st level | 2nd level | 3rd level |
|---|---|---|
| grinding vehicle | engine | |
| | water tank | |
| | grinding unit | |
| | dust collection system | |
| track | rail | |
| | rail surrounding | suction process |
| | | evaporation process |

**Table 22 Relevant material flows of “rail grinding”.**

| Process: grinding vehicle | |
|---|---|
| **Import flows** | **Export flows** |
| fuel | CO2 |
| air | off gas (excl. CO2) |
| virgin grinding stones | dismantled grinding stone (for disposal) |
| water | dismantled dust from collection system) |
| collected grinding dust (steel) | water spray |
| collected grinding dust (stone) | grinding slag & dust (stone wear) |

| Process: track | |
|---|---|
| **Import flows** | **Export flows** |
| water spray | collected grinding dust (steel) |
| grinding slag & dust (stone wear) | collected grinding dust (stone) |
| | evaporated water |

## Material balance of “rail grinding”

This chapter contains material balances of the rail grinding process, displayed by material stock and flow diagrams. The calculations and diagrams were created by free software STAN (download: http://www.iwa.tuwien.ac.at/iwa226_english/stan.html). The “rail grinding” file is available at www.infraguider.eu.

In a general picture (Figure 12) all the inputs and outputs in a rail grinding operations are sketched.

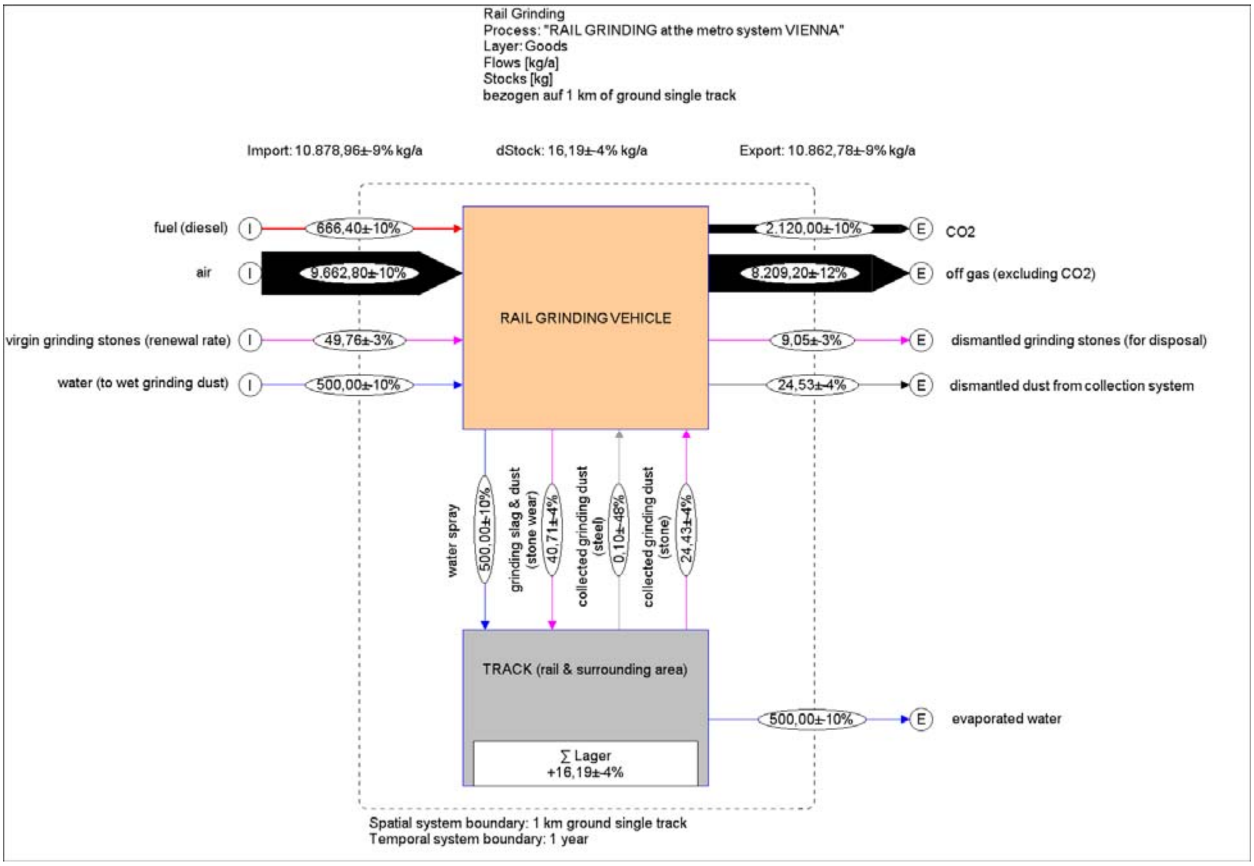



**Figure 12 Overview of the rail grinding procedure within an MFA picture (Software: STAN).**

All the material inputs and outputs for the MFA example are calculated for a year presuming

- *a small metro grinder (machine type: Autech VM 8000-12),*
- *approx. 150 grinding shifts per year,*
- *a shift length of 3,5 h,*
- *a grinding capacity of about 100m per shift and*
- *a medium metal removal of 1 mm at the gauge corner.*

The units are displayed in a box in figure 12. The actual system boundary is one km of metro track (single track). Stocks and flows are displayed in [kg] or [kg/a].

The quantities derived within the MFA cannot be compared to grinding on main line railways, as the main line grinding machines are different in their conception and grinding power. These numbers are derived for grinding on metro and tram systems (urban public transport) with short shift lengths and mostly tunnel areas.

Especially when concepting the detailed MFA-model (figure 13), some open environmental issues could be specified (e.g. oxygen input for diesel engine, resulting in CO2-emissions; water emissions).

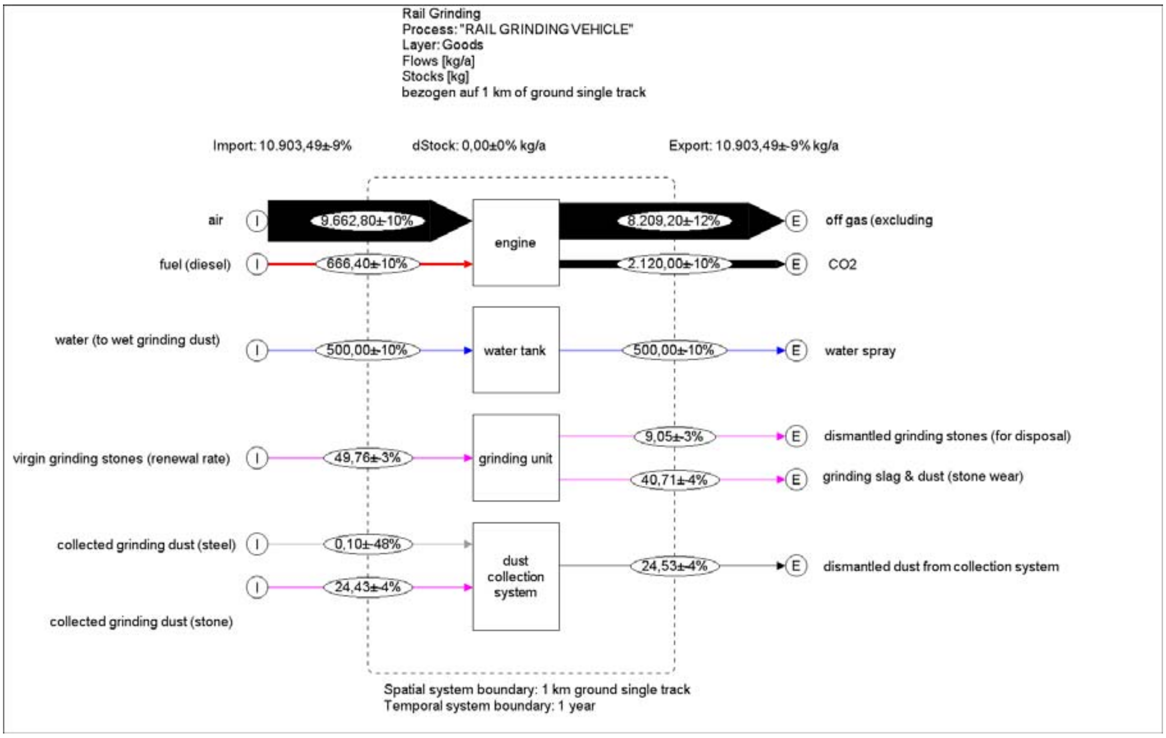



**Figure 13 Detailed MFA model of the rail grinding vehicle and the processes involved (Software: STAN).**

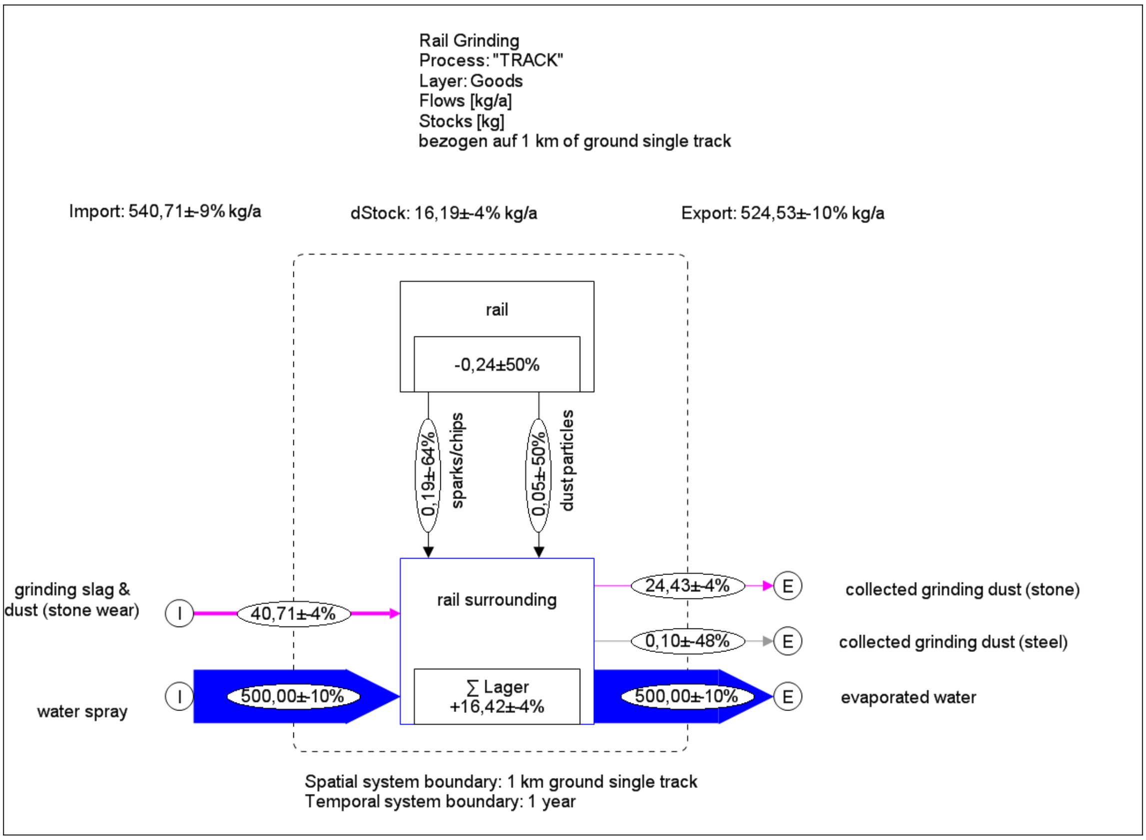



**Figure 14 Detailed MFA model of the track showing the accumulation of grinding dust within the system (Software: STAN).**

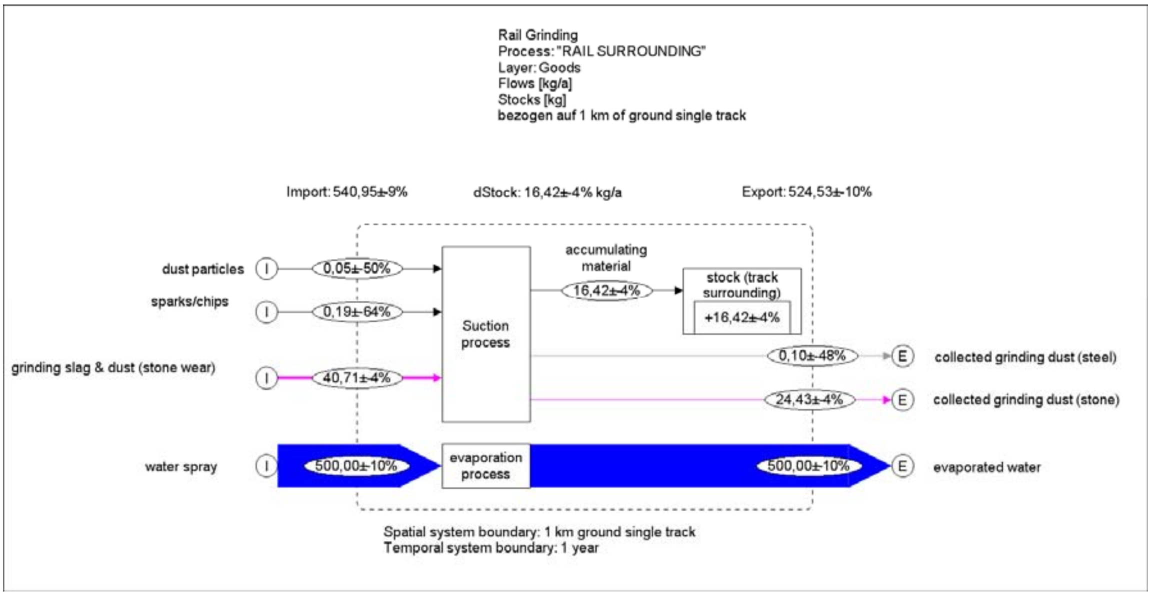



**Figure 15 Detailed MFA model of the track surrounding process (Software: STAN).**

### Conclusions based on MFA results

- CO2 Emissions: About 2 tons of CO2 are emitted per kilometre ground single track and year.
- Dust collection system: The efficiency of the dust collection system is essential in order to fulfil labour legislation and to avoid the accumulation of grinding wear along the track. So, the suction rate and the chemical and physical composition of the wear act an import role to evaluate the human end environmental relevance of this flow. In this case, about 60% of the grinding slug and dust resulting from the grinding stones, and 24% of steel wear are collected by the dust collection system. In other words, about 25 kg are collected and removed. The remaining flows increase the material stock on the rail surrounding with a rate of ~16 kg/year.
- Water: 500 litres of water are used every year, to grind one kilometre ground single track.

## 3.3.4 Setting up (exemplary) environmental specifications for a grinding tender

Analogous to the procedure in the UIC-leaflet 345[I], a detailed description of the single environmental specifications is given.

### UIC-345 Category: Noise

| | |
|---|---|
| Definition of environmental specification | |
| Passing-by noise, stationary noise, starting noise | |
| Environmental performance indicator | |
| specified in EN 14033-2 und EN 14033-3 | |
| Target Value | |
| dB | |
| Long-term goal | |
| Lower noise-emissions of vehicle | |
| Application: | Rail-bound railway maintenance vehicles |
| Type of specification: | Mandatory if defined so by tenderer<br>European Standard<br>Preconditioned by design |
| Degree of quantification: | Target specification |

## UIC-345 Category: Emissions

| | |
|---|---|
| Definition of environmental specification | |
| Diesel exhaust emissions for NOx, CO, HC and PM | |
| Environmental performance indicator | |
| Emissions in g/kWh for standardised load factors (load cycles) | |
| Target Value | |
| Defined by EU directive 97/68/EC amended by EU directive 2004/26/EC and in the equivalent national laws | |
| Long-term goal | |
| Lower greenhouse gases | |
| Application: | Diesel multiple units and locomotives |
| Type of specification: | Mandatory<br>Preconditioned by design |
| Degree of quantification: | Compliance specification |
| Notes: | Compliance specification cannot be used as a criterion for competition within a tender (e.g. points system). Not compliance means exclusion from the tender procedure. |

## UIC-345 Category: Materials

| | |
|---|---|
| Definition of environmental specification | |
| Legally restricted materials for vehicle production | |
| Environmental performance indicator | |
| Compliance with legislation | |
| Target Value | |
| to be decided | |
| Long-term goal | |
| to be decided | |
| Application: | All kinds of rolling stock |
| Type of specification: | Mandatory<br>Preconditioned by design |
| Degree of quantification: | Compliance specification |
| Notes: | Compliance specification cannot be used as a criterion for competition within a tender (e.g. points system). Not compliance means exclusion from the tender procedure. |

## InfraGuidER Category: Emissions

| | |
|---|---|
| Definition of environmental specification | |
| particles in grinding exhaust | |
| Environmental performance indicator | |
| 1. maximum concentration of particles in grinding exhaust | |
| 2. mandatory dust-collection system | |
| Target Value | |
| 1. to be decided | |
| 2. Include system into vehicle | |
| Long-term goal | |
| Lower number of particles in grinding exhaust | |
| Application: | Rail-bound railway grinding vehicles |
| Type of specification: | 1. Mandatory if defined so by tenderer |
| | 2. Mandatory if defined so by tenderer |
| Degree of quantification: | 1. Target specification |
| | 2. Compliance specification |
| Notes: | Compliance specification cannot be used as a criterion for competition within a tender (e.g. points system). Not compliance means exclusion from the tender procedure. |

## InfraGuidER Category: Energy/Water

| | |
|---|---|
| Definition of environmental specification | |
| water consumption | |
| Environmental performance indicator | |
| water consumption / ground metre of track | |
| Target Value | |
| use industrial water instead of drinking water | |
| Long-term goal | |
| Lower water consumption of grinding operation | |
| Application: | Rail-bound railway grinding vehicles |
| Type of specification: | Mandatory if defined so by tenderer |
| Degree of quantification: | Target specification |

## InfraGuidER Category: Materials

| Definition of environmental specification | |
|---|---|
| materials in grinding stones | |
| Environmental performance indicator | |
| Compliance with legislation | |
| Target Value | |
| Materials defined in legislation | |
| Long-term goal | |
| Prevent hazardous substance in grinding dust | |
| Application: | Rail-bound railway grinding vehicles |
| Type of specification: | Mandatory if defined so by tenderer |
| Degree of quantification: | Compliance specification |
| Notes: | Compliance specification cannot be used as a criterion for competition within a tender (e.g. points system). Not compliance means exclusion from the tender procedure. |

## InfraGuidER Category: Greenhouse Gases

| Definition of environmental specification | |
|---|---|
| CO2-emissions / litre of diesel | |
| Environmental performance indicator | |
| Already Defined (Emissions in g/kWh for standardised load factors (load cycles)) | |
| Target Value | |
| EU directive 97/68/EC; EU directive 2004/26/EC and in the equivalent national laws | |
| Long-term goal | |
| Lower greenhouse gases | |
| Application: | |
| Type of specification: | |
| Degree of quantification: | |

# 4. RELEVANCE RANKING

The relevance ranking is done to be able to quantify which flows are the important ones and which are not important from an environmental point of view. This information together with MFA can give valuable guidance about which flows can be controlled with environmental performance indicators.

In this relevance ranking four main data sources have been used to find the "Characterization factor/risk-phrase". For the environmental impact category's "Climate change" and "Natural resources" most of the data are taken from life cycle inventories, mostly the Swedish CPM database[II] but also from the European Commission Joint Research ELCD database[III]. For the environmental impact category "Hazardous substances" the EPS methodology[IV],[V] and results from the project USEtox[VI] have been used to assign the "Characterization factor/risk-phrase".

**Table 23 Relevance ranking for the three chosen components**

| Environmental impact categories | Substance/material | Category indicators | Characterization factor | Infrastructure material |
|---|---|---|---|---|
| Climate change | Aluminium | GWP | 4,8 kg CO2 equivalents per kg aluminium* | Electronic & electric component |
| Climate change | Cement | GWP | 814g CO2 equivalents per kg cement* | Concrete sleeper |
| Climate change | Composites and resins (set equivalent to plastics) | GWP | 2,05 kg CO2 equivalents per kg composites* | Electronic & electric component |
| Climate change | Construction aggregate | GWP | 1,433g CO2 equivalents per kg aggregate.* | Concrete sleeper |
| Climate change | Copper | GWP | 4,3 kg CO2 equivalents per kg copper* | Electronic & electric component |
| Climate change | Creosote | GWP | All is converted to CO2 (85% carbon in creosote). 3,33 kg CO2 per kg creosote | Wooden sleeper |
| Climate change | Fossil fuel | GWP | 3,3 kg CO2 equivalents per kg fossil fuel | Rail grinding |
| Climate change | Neoprene (set equivalent to | GWP | 2,05 kg CO2 equivalents | Concrete sleeper |

| | | | | |
|---|---|---|---|---|
| | plastics) | | per kg neoprene* | |
| Climate change | Neoprene (set equivalent to plastics) | GWP | 2,05 kg CO2 equivalents per kg neoprene* | Wooden sleeper |
| Climate change | Other metals such as (Lead, mercury, zinc, cadmium, silver gold, tin, nickel) (average values) | GWP | 6,8 kg CO2 equivalents per kg metal* | Electronic & electric component |
| Climate change | Plastics | GWP | 2,05 kg CO2 equivalents per kg plastics* | Electronic & electric component |
| Climate change | SF6 | GWP | 22800 kg CO2 equivalents per kg | Electronic & electric component |
| Climate change | Steel | GWP | 1,3 kg CO2 equivalents per kg steel* | Electronic & electric component |
| Climate change | Steel | GWP | 1,3 kg CO2 equivalents per kg steel* | Rail grinding |
| Climate change | Steel | GWP | 1,3 kg CO2 equivalents per kg steel* | Steel sleeper |
| Climate change | Steel | GWP | 1,3 kg CO2 equivalents per kg steel* | Wooden sleeper |
| Climate change | Steel | GWP | 1,3 kg CO2 equivalents per kg steel* | Concrete sleeper |
| Climate change | Wood | GWP | 122 CO2 equivalents per kg wood* | Wooden sleeper |
| Hazardous substances | Brominated flame retardants (Hexabromocyclod odecane data from USEtox) | Eco tox. | 7,41E+04 CTU** | Electronic & electric component |
| Hazardous substances | Brominated flame retardants (Hexabromocyclod odecane data from USEtox) | Human tox. | Not available** | Electronic & electric component |

| | | | | |
|---|---|---|---|---|
| Hazardous substances | Creosote (anthracene data from USEtox) | Eco tox. | 2,62E+05 CTU** | Wooden sleeper |
| Hazardous substances | Creosote (anthracene data from USEtox) | Human tox. | 1,2E-08 CTU** | Wooden sleeper |
| Hazardous substances | Fossil fuel (toluene data from USEtox) | Eco tox. | 5,59E+01 CTU** | Rail grinding |
| Hazardous substances | Fossil fuel (toluene data from USEtox) | Human tox. | 9,62E-08 CTU** | Rail grinding |
| Hazardous substances | Material in grinding stones | Not known | Not known | Rail grinding |
| Hazardous substances | Neoprene (set equivalent to plastics) | Eco tox. | 1,85E+02 CTU** | Concrete sleeper |
| Hazardous substances | Neoprene (set equivalent to plastics) | Human tox. | 1,21E-06 CTU** | Concrete sleeper |
| Hazardous substances | Neoprene (set equivalent to plastics) | Eco tox. | 1,85E+02 CTU** | Wooden sleeper |
| Hazardous substances | Neoprene (set equivalent to plastics) | Human tox. | 1,21E-06 CTU** | Wooden sleeper |
| Hazardous substances | Particles (PM 10) | PM10 impact on crop | -0,000969 ELU/kg*** | Rail grinding |
| Hazardous substances | Particles (PM 10) | PM10 impact on morbidity | 0,0361 ELU/kg*** | Rail grinding |
| Hazardous substances | Particles (PM 10) | PM10 impact on NEX | -0,01188 ELU/kg*** | Rail grinding |
| Hazardous substances | Particles (PM 10) | PM10 impact on nuisance | 22,8 ELU/kg*** | Rail grinding |
| Hazardous substances | Particles (PM 10) | PM10 impact on severe morbidity | 0,233 ELU/kg*** | Rail grinding |
| Hazardous substances | Particles (PM 10) | PM10 impact on wood | 0.0003964 ELU/kg*** | Rail grinding |
| Hazardous substances | PCB (PCB-155 data from USEtox) | Eco tox. | 1,03E+04 CTU** | Electronic & electric component |
| Hazardous substances | PCB (PCB-155 data from USEtox) | Human tox. | Not available** | Electronic & electric component |

| | | | | |
|---|---|---|---|---|
| Hazardous substances | Plastics (styrene data from USEtox) | Eco tox. | 1,85E+02 CTU** | Electronic & electric component |
| Hazardous substances | Plastics (styrene data from USEtox) | Human tox. | 1,21E-06 CTU** | Electronic & electric component |
| Natural resources | Composites and resins (set equivalent to plastics) | Energy consumption | 37,91 MJ per kg composites* | Electronic & electric component |
| Natural resources | Aluminium | Al reserves | 4,9 kg bauxite clay per kg aluminium* | Electronic & electric component |
| Natural resources | Aluminium | Energy consumption | 63,6 MJ per kg aluminium* | Electronic & electric component |
| Natural resources | Cement | Energy consumption | 2,6 MJ per kg cement* | Concrete sleeper |
| Natural resources | Cement | Limestone reserves | 1,361 kg limestone per kg cement* | Concrete sleeper |
| Natural resources | Composites and resins (set equivalent to plastics) | Fossil fuel use | 1,33 kg crude oil is converted into 1 kg composites* | Electronic & electric component |
| Natural resources | Construction aggregate | Energy consumption | 0,22 MJ per kg aggregate* | Concrete sleeper |
| Natural resources | Construction aggregate | Stone reserves | 1,1 kg rock per kg aggregate* | Concrete sleeper |
| Natural resources | Copper | Cu reserves | 3 kg copper ore (Chalcopyrite) per kg copper | Electronic & electric component |
| Natural resources | Copper | Energy consumption | 47,3 MJ per kg copper* | Electronic & electric component |
| Natural resources | Creosote | Energy consumption | 4,73 MJ per kg creosote | Wooden sleeper |
| Natural resources | Creosote | Fossil fuel use | 1,33 kg crude oil is converted into 1 kg creosote | Wooden sleeper |
| Natural resources | Fossil fuel | Energy consumption | 3,1 MJ per kg fossil fuel | Rail grinding |
| Natural resources | Fossil fuel | Oil reserve | 0,506 ELU/kg*** | Rail grinding |
| Natural resources | Neoprene (set equivalent to plastics) | Energy consumption | 37,91 MJ per kg neoprene* | Concrete sleeper |
| Natural resources | Neoprene (set equivalent to plastics) | Fossil fuel use | 1,33 kg crude oil is converted into 1 kg neoprene | Concrete sleeper |

| | | | | |
|---|---|---|---|---|
| Natural resources | Neoprene (set equivalent to plastics) | Energy consumption | 37,91 MJ per kg neoprene* | Wooden sleeper |
| Natural resources | Neoprene (set equivalent to plastics) | Fossil fuel use | 1,33 kg crude oil is converted into 1 kg neoprene | Wooden sleeper |
| Natural resources | Other metals such as (Lead, mercury, zinc, cadmium, silver gold, tin, nickel) (average values) | Energy consumption | 96,3 MJ per kg aluminium* | Electronic & electric component |
| Natural resources | Other metals such as (Lead, mercury, zinc, cadmium, silver gold, tin, nickel) (average values) | Metal reserves | 21,8 kg metal ore per kg metal* | Electronic & electric component |
| Natural resources | Plastics | Energy consumption | 37,91 MJ per kg plastics* | Electronic & electric component |
| Natural resources | Plastics | Fossil fuel use | 1,33 kg crude oil is converted into 1 kg plastics | Electronic & electric component |
| Natural resources | Steel | Energy consumption | 13,51 MJ per kg steel* | Electronic & electric component |
| Natural resources | Steel | Fe reserves | 2,750 kg Iron ore per kg Steel* | Electronic & electric component |
| Natural resources | Steel | Energy consumption | 13,51 MJ per kg steel* | Rail grinding |
| Natural resources | Steel | Fe reserves | 2,750 kg Iron ore per kg Steel* | Rail grinding |
| Natural resources | Steel | Energy consumption | 13,51 MJ per kg steel* | Steel sleeper |
| Natural resources | Steel | Fe reserves | 2,750 kg Iron ore per kg Steel* | Steel sleeper |
| Natural resources | Steel | Energy consumption | 13,51 MJ per kg steel* | Wooden sleeper |
| Natural resources | Steel | Fe reserves | 2,750 kg Iron ore per kg Steel* | Wooden sleeper |
| Natural resources | Steel | Energy consumption | 13,51 MJ per kg steel* | Concrete sleeper |
| Natural resources | Steel | Fe reserves | 2,750 kg Iron ore per kg Steel* | Concrete sleeper |

| | | | | |
|---|---|---|---|---|
| Natural resources | Water | Resource consumption impact on resource reserves | 0,003 ELU/kg*** | Rail grinding |
| Natural resources | Wood | Energy consumption | 4,73 MJ per kg wood* | Wooden sleeper |
| Natural resources | Wood | Land area used | 7,57 m2*year land used per kg wood* | Wooden sleeper |

* Data taken from Life Cycle Inventory's

** Data taken from the USEtox results

*** Data taken from the EPS methodology

The data in this table was compiled to assess the environmental significance of railway materials and components, as well as the material related service ‘rail grinding’. As understood from the first column, it is based on the three environmental impact categories that have been identified as globally significant for these dimensions of railway infrastructure. The second column lists the major materials and components included in the railway infrastructure, and the third column is an environmental performance indicator for that material in relation to the appropriate impact category. In the fourth column a selected environmental characterization factor is given. This factor quantifies the environmental significance of that specific material. There are different ways to state the environmental significance, depending on where over the life cycle the environmental impact occurs, and depending on how and what the consequence of the impact is. The footnotes *, ** and *** of the table addresses such different data sources and meanings of the characterization factors. Hence, this table is a key for the environmental relevance ranking of different infrastructure material. It is a good help if different environmental impacts and consequences need to be balanced to each other.

# 5. EXEMPLARY ENVIRONMENTAL PERFORMANCE EVALUATION (EPE)

Before procurement can be done, the tenders may be quantitatively evaluated according to the EPIs of the tender. This chapter shows an exemplary quantitative environmental performance evaluation (EPE) that can be used to evaluate the environmental performance of the different tenders.

The environmental performance evaluator described in this chapter (InfraGuidER_EPE.xls, attached with this report) is designed for procurers in the railway industry and is intended to be used for procurement of the material described in the previous chapters. The EPE gives immediate answers and quantified environmental performance data about the tender (dependent on the values identified in the relevance ranking) and it also weights the environmental performance compared to its price.

The EPE contains two weighting factors based on the environmental policy of the organization of the specific railway infrastructure manager. These factors are a “Categorical Weighing Factor” (CWF), which specifies a percentage for which a certain EPI affects the calculated environmental performance value, and “Weighting % ELU versus price” which specifies a policy based value expressed in terms of an ELU[4] price.

In this EPE each product has its own spread sheet. For each product a baseline value is set. This is the value that the tenderer can use to compare with and that can be used to set targets.

As part of the procurement process, a baseline is set. This baseline value represents a benchmark value, which may be the previous product version, best available technology, or any other benchmark.

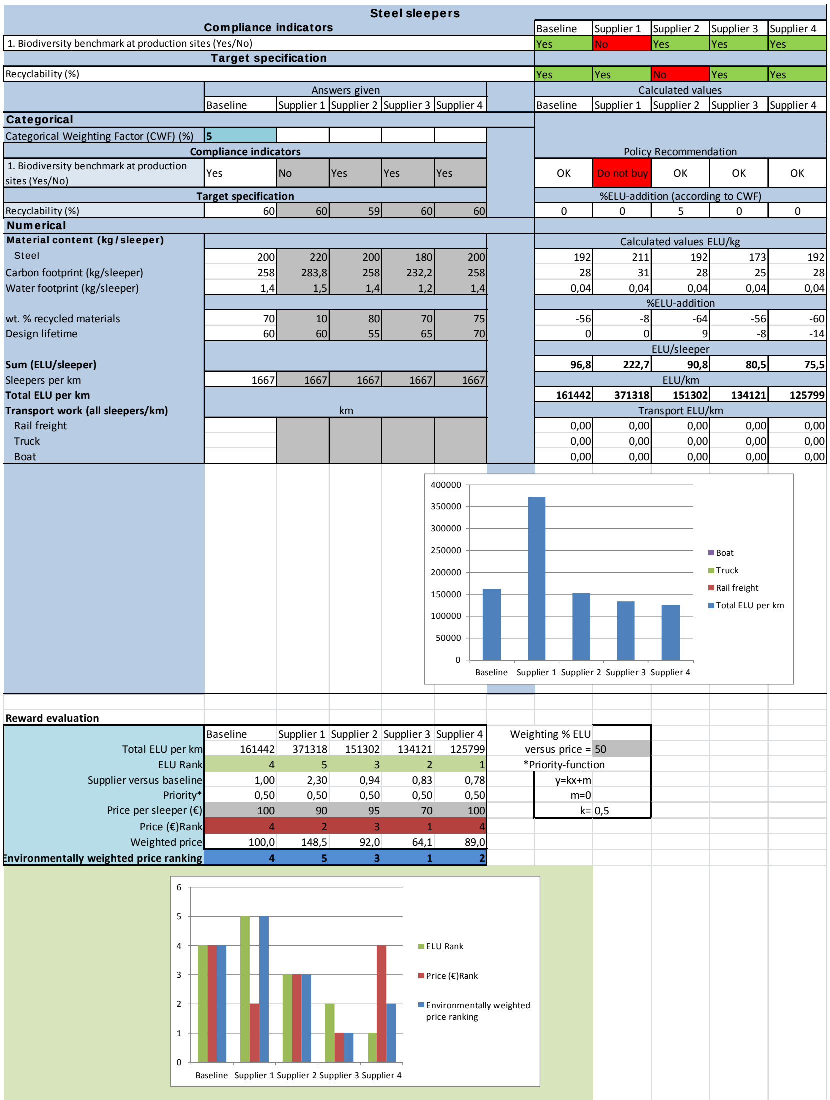
In the spread sheet the cells to enter data into are coloured grey. Each row of the grey cells are associated with different EPIs and they differ between the different products. When the data in these cells are entered, the spreadsheet will perform the calculation and rank the products according to their environmental performance, price and their environmentally weighted price.

The detailed facts on how the EPE works, including supporting material and literature references are presented in deliverable D19, which is planned for month 23 of the InfraGuidER project.

Below are Screenshots of the EPEs for the different materials presented above. The figures in these examples are not in any way meant to be viewed as real; they are only there to show how

[4] ELU, (Environmental Load Unit), which is a damage cost evaluation, describing a societal cost for an environmental damage. [A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system Characteristics, Bengt Steen, 1999]

the EPE works and how it can be used.



**Steel sleepers**

| Compliance indicators | Baseline | Supplier 1 | Supplier 2 | Supplier 3 | Supplier 4 |
|---|---|---|---|---|---|
| 1. Biodiversity benchmark at production sites (Yes/No) | Yes | No | Yes | Yes | Yes |
| **Target specification** | | | | | |
| Recyclability (%) | Yes | Yes | No | Yes | Yes |

| | Answers given | | | | | Calculated values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | Supplier 1 | Supplier 2 | Supplier 3 | Supplier 4 | Baseline | Supplier 1 | Supplier 2 | Supplier 3 | Supplier 4 |
| **Categorical** | | | | | | | | | | |
| Categorical Weighting Factor (CWF) (%) | 5 | | | | | | | | | |
| **Compliance indicators** | | | | | | Policy Recommendation | | | | |
| 1. Biodiversity benchmark at production sites (Yes/No) | Yes | No | Yes | Yes | Yes | OK | Do not buy | OK | OK | OK |
| **Target specification** | | | | | | %ELU-addition (according to CWF) | | | | |
| Recyclability (%) | 60 | 60 | 59 | 60 | 60 | 0 | 0 | 5 | 0 | 0 |
| **Numerical** | | | | | | | | | | |
| **Material content (kg/sleeper)** | | | | | | Calculated values ELU/kg | | | | |
| Steel | 200 | 220 | 200 | 180 | 200 | 192 | 211 | 192 | 173 | 192 |
| Carbon footprint (kg/sleeper) | 258 | 283,8 | 258 | 232,2 | 258 | 28 | 31 | 28 | 25 | 28 |
| Water footprint (kg/sleeper) | 1,4 | 1,5 | 1,4 | 1,2 | 1,4 | 0,04 | 0,04 | 0,04 | 0,04 | 0,04 |
| | | | | | | %ELU-addition | | | | |
| wt. % recycled materials | 70 | 10 | 80 | 70 | 75 | -56 | -8 | -64 | -56 | -60 |
| Design lifetime | 60 | 60 | 55 | 65 | 70 | 0 | 0 | 9 | -8 | -14 |
| | | | | | | ELU/sleeper | | | | |
| **Sum (ELU/sleeper)** | | | | | | **96,8** | **222,7** | **90,8** | **80,5** | **75,5** |
| Sleepers per km | 1667 | 1667 | 1667 | 1667 | 1667 | ELU/km | | | | |
| **Total ELU per km** | | | | | | **161442** | **371318** | **151302** | **134121** | **125799** |
| **Transport work (all sleepers/km)** | km | | | | | Transport ELU/km | | | | |
| Rail freight | | | | | | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Truck | | | | | | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Boat | | | | | | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |



**Reward evaluation**

| | Baseline | Supplier 1 | Supplier 2 | Supplier 3 | Supplier 4 |
|---|---|---|---|---|---|
| Total ELU per km | 161442 | 371318 | 151302 | 134121 | 125799 |
| ELU Rank | 4 | 5 | 3 | 2 | 1 |
| Supplier versus baseline | 1,00 | 2,30 | 0,94 | 0,83 | 0,78 |
| Priority* | 0,50 | 0,50 | 0,50 | 0,50 | 0,50 |
| Price per sleeper (€) | 100 | 90 | 95 | 70 | 100 |
| Price (€)Rank | 4 | 2 | 3 | 1 | 4 |
| Weighted price | 100,0 | 148,5 | 92,0 | 64,1 | 89,0 |
| **Environmentally weighted price ranking** | **4** | **5** | **3** | **1** | **2** |

| | |
|---|---|
| Weighting % ELU versus price = | 50 |
| *Priority-function | |
| y=kx+m | |
| m=0 | |
| k= | 0,5 |



**Figure 16 Screen shot of the EPE for steel sleepers**

As implemented in the excel tool (InfraGuidER_EPE.xls) attached with this report, the environmental performance of each material, component and service is evaluated on the basis of the environmental performance indicators. Figure 15 is a screen shot of one sheet of that tool, showing how the environmental performance evaluation of steel sleepers. The performance is calculated using life cycle assessment methodology and an environmental impact assessment methodology named Environmental Priority Strategy (EPS). The actual choices of data that these calculations are based on in these three case studies may be selected differently in a more detailed performance evaluation within a specific organisation. The methodology used here, however, is general and straightforward and based on ISO 14040 and a well-documented impact assessment methodology (EPS). The calculation is initiated by the user entering well-defined and easy-to-find quantitative data, for each of the different environmental performance indicators. The resulting quantitative environmental performance evaluation is then automatically calculated by the ready-made life cycle assessment process models (see figure 1).

# 6. SIMPLIFIED STANDARD ENVIRONMENTALLY RELEVANT PROCESS MODEL

The simplified standard environmentally relevant process model can be divided into three main phases, upstream, use and downstream. The phases have different environmentally relevant processes related to them.

**Upstream**

The environmental relevant processes in this phase are mainly coupled to resource use, both for energy- and material-extraction. Due to the fact that large amounts of resources and energy are consumed during this phase there could be a substantial release of greenhouse gases. Using recycled material lowers the primary resource need. Procurement can affect the resource use by having demands on the supplier's resource efficiency.

**Use**

The environmental relevant processes in this stage are dictated by the products properties and how the product is managed. These two parameters will affect how much of the product that is leached of and how hazardous the leachate will be. The physical properties of the products are set during the procurement stage and cannot be changed during use. The management of the products can be controlled and changed during to use phase.

**Downstream**

The most environmentally relevant process in this phase is recycling, if hazardous substances are phased out at the recycling process. If recycling is done the amount of waste produced is lowered and the resources outtake for production of new materials is lowered. Procurement is indirectly important in this phase, because during procurement demands for designed for recyclability can be made which enables a higher percentage of the product to be recycled. Other environmentally relevant processes are waste management processes, e.g. waste to landfill and energy recovery.

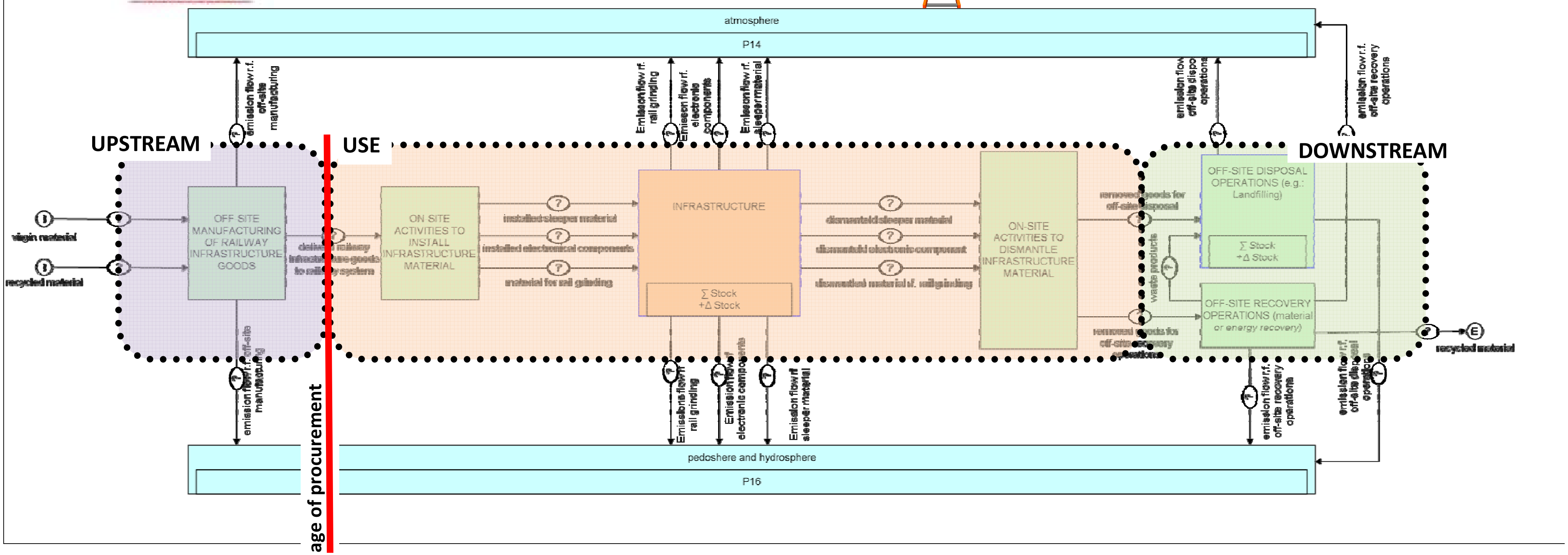



**Figure 17 Simplified standard environmentally relevant process model**

Figure 17 displays a simplified standard view of the process model of the full life cycle of railway infrastructure materials, components and services. The focal point of figure 17 is the procurement of new materials, components and services. By controlling the procurement one also more or less controls the material flows upstream, all the way to resource extraction, and downstream through the use phase and all the way down to waste management and recycling into new raw material. Hence the procurement decisions have the power to impact the environmental performance of the entire life cycle of railway infrastructure materials, components and services.

# 7. RESULTS AND IMPROVEMENT POTENTIALS

## 7.1 RESULTS

The case studies and the EPE show that it is possible, feasible and effective to assign environmental specifications to a product and to evaluate the environmental performance of tenders. It allows for environmental decision support for materials, components and services.

**The case studies performed and presented in this report, strongly suggest that the process model presented in figure 1 is considered as the simplified standard process model for railway infrastructure material, components and services.**

## 7.2 IMPROVEMENT POTENTIALS

The case studies presented in this report have all been done in separate, had they been harmonized during the study they could have been more linked together, with a stronger harmonization of the result. This will be done in D20. The results of D20 may be used to improve harmonization between similar studies in the future.

To be as useful as possible in everyday practice, the list of indicators needs to be dynamic so that EPIs can be added, subtracted or changed if needed. Such a dynamic list can be developed when there is a described methodology on how to develop the list. It should improve the possibility to produce such dynamic lists for future studies.

The exemplary EPEs developed so far are each shown in separate excel spread sheets. In deliverable D19 the models and the structure will be described so that custom corporate information systems can be built. When there is a stronger consensus on which indicators to assess, and which materials to analyse these spread sheet tools will be much more relevant and simple to use, and may be seamlessly integrated into railway infrastructure managers' decision making.

To make the above described procurement process work better in practice, a better evaluation of how the procurement decision is coupled to the environmental goals and the environmental policy for railway infrastructure managers is necessary. This is one of the key results of InfraGuidER and is suggested for further research and studies.

Since railway infrastructure consists to a substantial proportion of rails, the environmental performance of rail production contributes to the environmental performance of railway infrastructure to a large extent. The environmental performance of rail production largely relates to energy consumption and the related $CO_2$ emissions. There are different steel production technologies and different qualities of steel production plants as well as different environmental performances of different energy production systems. Hence, one possibility to control the environmental performance of railway infrastructure is to have information about the actual environmental performance of rail production, considering the overall production system including extraction of raw material, steel production, transport and energy production. A research project could be performed by for example UIC, IISI (International Iron and Steel Institute) and JRC (European commission Joint Research Centre) to develop models that describe rail production.

[I] UIC-Code 345: Environmental specifications for new rolling stock, 1st edition (2006)

[II]CPM, LCA database, http://www.cpm.chalmers.se/CPMDatabase/Start.asp , 2010-06-22

[III] European Commission Joint Research ELCD database, http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm , 2010-06-22

[IV] A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system Characteristics, Bengt Steen, 1999, http://msl1.mit.edu/esd123_2001/pdfs/EPS2000.PDF

[V] A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, Bengt Steen, 1999, http://msl1.mit.edu/esd123_2001/pdfs/EPS1999_5.pdf

[VI] USEtox, environmental model for characterization of human and ecotoxic impacts in Life Cycle Impact Assessment, http://www.usetox.org/ , 2010-06-22