Environmental Product Declarations for Steel Pipes

By Hans-Jürgen Kocks and Simon Kroop

In accordance with the Construction Products Directive, environmental product declarations (EPDs) based on material and energy balances are provided for hollow sections, oilfield tubulars, as well as water, oil and gas line pipes. For this purpose, a holistic life cycle assessment (LCA) is compiled, covering all the phases from raw materials production through the manufacture and use of a product right down to its recycling and disposal, as the case may be. The calculations show that the manufacture of the semi-finished products has a significant impact on the balances.

Steel hollow sections and water line pipe are manufactured to standards that are harmonized at a European level and subject to the Construction Products Directive. These products are required to bear the CE mark, which denotes the manufacturer's declaration of conformity with EU requirements [1].

In the case of water line pipes, the pipes used for drinking water deserve special consideration. In contrast to pipes for aqueous media such as industrial water, salt water and brines or waste water, drinking water pipes require a verification of its hygienic suitability for the application in line with the Construction Products Directive. However, this verification is currently regulated at a national level for the EU member states. Therefore, the CE mark cannot be applied to steel pipes for drinking water systems and, strictly speaking, the pipes would not be subject to the Construction Products Directive.

Drinking water pipes are manufactured to DIN 2460 and must be provided with a cement mortar lining [2]. So, the steel pipe according to DIN 2460 is never in contact with the drinking water it transports. Exposed pipe surfaces in the area of welded joints, incisions or saddle fittings are irrelevant for the assessment of hygienic suitability [3]. This means that, on the one hand, the respective national requirements have to be observed for the cement mortar coating. On the other hand, the steel pipe that is not in contact with the drinking water is subject to the Europe-wide harmonized DIN EN 10224 as technical delivery condition. Accordingly, the requirements of the Construction Products Directive are obligatory, at least for the steel pipes used in drinking water systems.

In addition to the mandatory CE mark, the Construction Products Directive recommends that the manufacturer's environmental product declaration (EPD) be used, if available [1] for assessing the sustainability of resource utilization and the impact of construction works on the environment. EPDs contain data on the use of natural resources in the manufacture of a product and the associated emissions into air, water and soil. Other important aspects include product-specific environmental impacts, such as the greenhouse and air acidification potentials. This means EPDs allow products to be compared from an ecological point of view. It is to be expected that the topic of energy efficiency and environmental compatibility will be more strongly weighted in future as a decision criterion when it comes placing orders. By issuing environmental product declarations for its steel hollow sections and water line pipe, Mannesmann Line Pipe GmbH (MLP) is following this emerging market trend. However, meantime this regulation has been transferred to other applications as well, so oil and gas line pipes as well as oilfield tubulars are of course affected. As starting material in pipe production, steel stands out for its unparalleled recyclability. Accordingly, the percentage of recycled material used in pipe production is very high, which works out as a considerable influencing factor in the balances to be created. Environmental product declarations thus document in an impressive manner the ecological benefit of products made from steel.

Background

With its inherent properties and low alloying contents, steel is nearly fully recyclable, without any losses in terms of quantity and quality. In fact, due to these properties, it is the world's most recycled material. The recycling of 20 million tons of steel per year in Germany not only conserves natural resources but also prevents more than 20 million tons of CO_2 emissions during the same period [4]. This, coupled with superb durability and longevity, is what gives steel products their outstanding sustainability. Many steel products offer CO_2 avoidance potentials beyond their life cycle, e. g. in automotive light-weight engineering, or in steel applications in the context of renewable energy utilization [5]. However, the ecological sustainability of products is not based on CO_2 considerations alone (global warming potential), but also comprises factors such as energy and resource efficiency or the impact categories of acidification and eutrophication potential.

To prove the ecological benefits of steel pipes, holistic life cycle assessments have been drawn up within the frame-

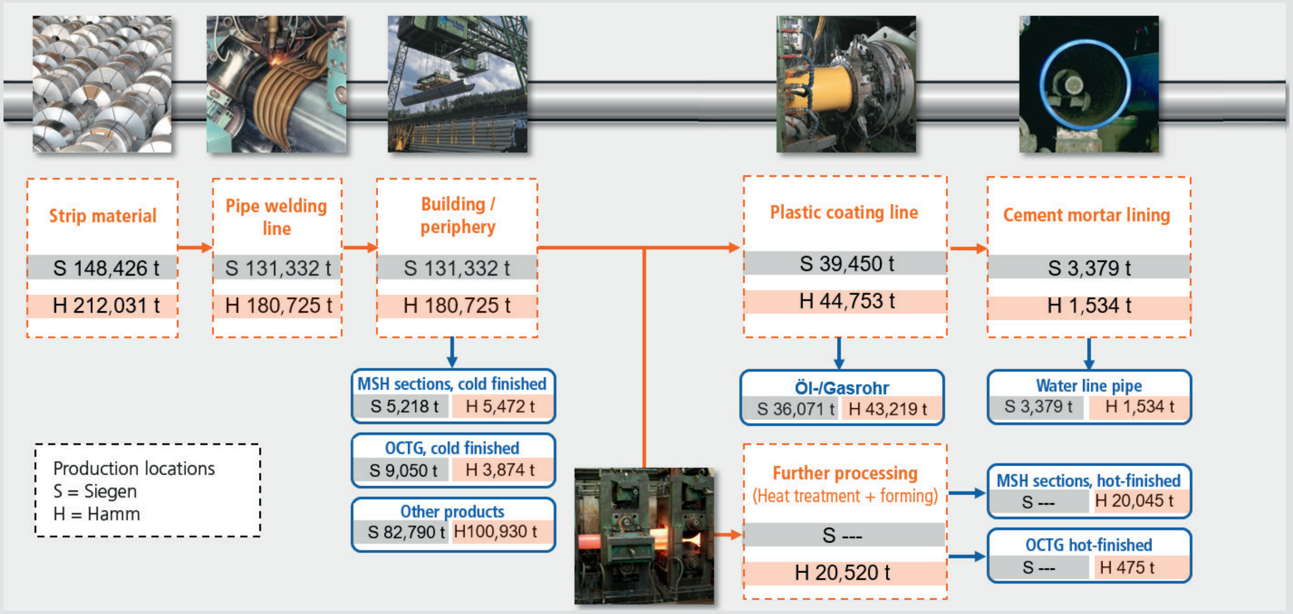

***Figure 1**: Production processes at MLP locations*

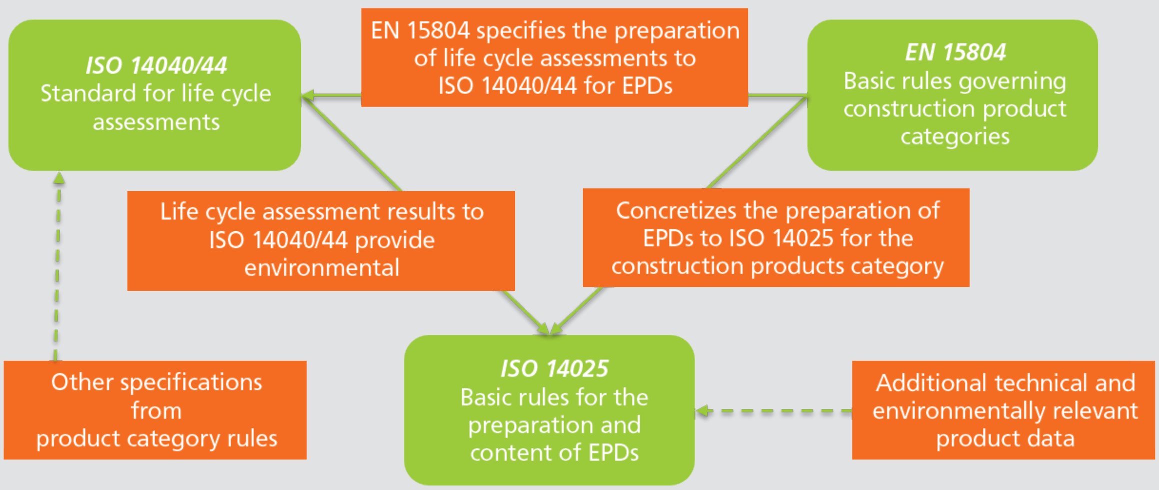

***Figure 2**: Standards governing environmental product declarations*

work of the preparation of environmental product declarations (EPDs) for the following products of Mannesmann Line Pipe GmbH (MLP):

» hot and cold finished hollow sections,
» hot and cold finished oilfield tubulars (OCTG),
» oil and gas line pipe, and
» line pipe for drinking water and waste water.

Figure 1 shows the steel pipe production systems at the two MLP works in Siegen and Hamm with the production outputs of 2012. As can be seen, the products vary in terms of their processing depth in production and in further processing.

Initially, to prepare the required assessments, it was necessary to collect the data of the material and energy flows for the various products throughout their life cycle. These data then had to be checked for plausibility, and their ecological impact had to be calculated and verified. The latter task was performed externally by the German program holder for environmental product declarations, the Institut Bauen und Umwelt e.V.

The following paragraphs describe the background of EPD preparation for water line pipe, which exhibits the greatest processing depth in production and the most complex material mix.

Relevant standards for life cycle assessment

Various documents are used as a guideline for a meaningful and verified environmental product declaration. The internationally accepted set of standards which are applicable throughout the European Union comprises ISO 14040/44 [6], ISO 14025 [7], and EN 15804 [8]. The connection between these standards is shown in ***Figure 2***.

ISO 14025 is the basic standard governing the compilation, principles and preparation of type III environmental labels and declarations. The objective is the provision of quantitative environmental data for a product, based on a life cycle assessment to DIN EN ISO 14040/44. The standard describes, for example, how a life cycle assessment is to be prepared and also lays down the content of an EPD. For construction product declarations, ISO 14025 is concretized by DIN EN 15804.

According to ISO 14025, the following life cycle phases with subordinate modules define the system boundary of the life cycle assessment in an EPD:

» production phase (modules A1-A3)
» construction phase (modules A4-A5)
» service life phase (modules B1-B7)
» disposal phase (modules C1-C3)
» benefits and loads beyond the system boundary (D)

An obligatory part of environmental product declarations is the declaration of the life cycle assessment results of the production stage with the modules Raw material supply (A1) Transport (A2) and Manufacturing (A3). As a rule, these modules are complemented by Waste processing and Disposal (C3-C4) and Benefits and loads beyond the system boundary (D).

The central element of life cycle assessments to ISO 14040/44 is the analysis of a product's energy and material flows with regard to impact categories through its life cycle. The most prominent example is the environmental category "Global warming potential" with the pertinent reference parameter CO_2 equivalent. Other categories include the acidification, eutrophication and ozone depletion potentials.

Precisely which categories and other indicators are to be used for assessing a product's impact (see ***Table 1***) is, for example, described in EN 15804.

Additional product-specific requirements regarding the preparation of life cycle assessments for EPDs are defined via the product category rules. These are edited by the respective national program holders for EPDs. In Germany, this is the Institut Bauen und Umwelt e.V.

Life cycle assessment software GaBi ts®

GaBi ts® (Ganzheitliche Bilanzierung/holistic balancing) is a globally accepted software developed by the thinkstep AG company for the generation of life cycle assessments (or ecobalances). It has more than 10,000 users worldwide. The related database holds more than 8,400 region-specific datasets, e. g. for raw materials, products or energy sources. These datasets are annually updated [9].

In conjunction with the software environment, these datasets enable the generation of a lifecycle assessment for products and processes in accordance with ISO 14040/44 covering all (cradle-to-grave) or individual (cradle-to-gate or gate-to-gate) life cycle phases. In addition, modelling of the respective product and process systems allows the graphic evaluation of mass and energy balances and of individual categories of the impact assessment.

This means that the software can be used for the preparation of holistic life cycle assessments as well as for the calculation of the CO_2 footprints of companies (ISO 14064) and products (ISO 14067), for environmental product declarations (ISO 14025/EN 15804) and for water footprints (ISO 14046).

EPD framework for water line pipe

A basic prerequisite of every life cycle assessment is the definition of the associated framework, including the declared unit as reference value, the system boundary, assumptions regarding allocations, information on the data used as well as the period under review and assumptions regarding the selected scenarios. In the following paragraphs, the EPD framework of the MLP product with the greatest processing depth – water line pipe – will be described as an example.

Declared unit

The declared unit is 1 metric ton of water and waste water line pipe with cement mortar lining and plastic coating (see ***Table 2***).

The described line pipe for water and waste water consists of a composite material comprising a steel pipe, plastic and cement mortar. MLP assumes that the proportions of the materials are as follows:

» steel pipe: 69 %
» cement mortar: 28 %
» plastic: 3 %

System boundary

The system boundary in an environmental product declaration consists of the following modules (cf. Chapter 3):

» Production stage (modules A1-A3)
    ▪ Modules A1-A3 comprise the upstream chain of production and supply of raw materials, ancillary materials and energy carriers (A1) as well as their transport to the works (A2) and the manufacture of the products concerned (A3).

Table 1: *Impact categories of an EPD as per EN 15804*

Global warming potential (GWP) Unit: kg CO_2 eq.	**Stratospheric ozone depletion potential (OP)** Unit: kg CFC11 eq.
Acidification potential (AP) Unit: kg SO_2 eq.	**Eutrophication potential (EP)** Unit: kg $(PO_4)^3$ eq.
Photochemical ozone creation potential (POCP) Unit: kg ethene eq.	**Abiotic depletion potential for non-fossil resources (ADPE)** Unit: kg Sb eq.
Abiotic depletion potential for fossil fuels (ADPF) Unit: MJ	

***Table 2**: Data on the declared unit*

Designation	Value	Unit
Declared unit	1	t
Thickness (max. wall thickness)	25.4	mm
Conversion factor to 1 kg	0.001	-

***Table 3**: Relevant life cycle assessment scenarios*

End of life (C3-C4)		
Designation	**Value**	**Unit**
Collection rate	100	%
Loss	1	%
Towards recycling	683	kg
Towards energy recovery	29	kg
Towards landfilling	278	kg

Reuse and recycling potential (D), relevant scenario data		
Designation	**Value**	**Unit**
Recycling rate	100	%

» Disposal stage (modules C3-C4)
- Before composite products such as line pipes for water and waste water can be recycled, they must be separated into their constituent materials (waste processing – C3). Materials without a reuse, recovery or recycling potential are allocated to disposal (C4) e. g. in a landfill or by incineration for energy recovery. All resultant impacts, such as emissions into the air, soil or water are assigned to the disposal stage, while the positive effect of energy recovery is entered in module D.

» Benefits and loads beyond the system boundary (module D)
- Module D is for compiling the benefits (or credits) and loads e. g. regarding the reuse of construction products, recycling of secondary raw materials, and the material or energetic recovery of other products. The benefits in module D follow the assumptions of the life cycle assessment scenarios (Chapter 5.3) and allocations (Chapter 5.4).

Life cycle assessment scenarios

Life cycle assessment scenarios specify the chosen modules within the chosen system boundary. The scenarios of relevance for the water line pipe EPD are listed in ***Table 3***.
The end-of-life scenario in the example shown here is defined by an assumed collection rate of 100 % and losses of 1 % [10]. Of the materials used for the composite pipe, the steel component is assigned to recycling with a recycling rate of 100 %; the plastic materials – PE and PP – are assigned to energy recovery, and the cement mortar to waste disposal. Given the established recycling process and the high-grade recycling potential of steel, the high recycling rate can be considered realistic. Furthermore, the assumptions regarding energy recovery and disposal are very conservative.
Figure 3 shows the model of the life cycle assessment for MLP water line pipe complete with all declared modules and taking into account the system boundaries and the scenarios chosen for the life cycle assessment. The mass view shows all material flows between the modules. Besides the declared unit – i.e. 1 metric ton of water line pipe – the steel scrap (108 kg) used as secondary raw material for pipe production can also be seen.

Allocations

Processes with multi-dimensional product systems allocate specific amounts from their material, energy and emission flows to primary and by-products under production and to recyclable residues. A good example of this is the blast furnace process, which produces pig iron as its primary product and calorific process gases as by-products.

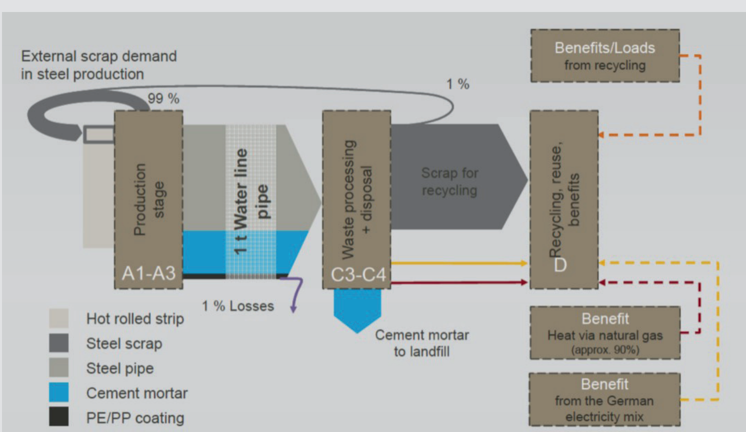

***Figure 3**: GaBi ts® LCA model with all relevant modules for the creation of an EPD for MLP water line pipe*

***Table 4**: Results of the life cycle assessment "Environmental impact" by modules for 1 metric ton of water line pipe, absolute [11]*

LIFE CYCLE ASSESSMENT RESULTS: 1 metric ton of steel line pipe for water and waste water with cement-mortar lining and plastic coating					
Parameter	**Unit**	**A1-A3**	**C3**	**C4**	**D**
Global warming potential	kg CO_2 eq.	1.85E+3	0.00E+0	9.49E+1	-1.23E+3
Stratospheric ozone depletion potential	kg CFC11 eq.	1.92E-8	0.00E+0	7.15E-11	3.53E-9
Soil and water acidification potential	kg SO_2 eq.	6.12E+0	0.00E+0	3.22E-2	-4.55E+0
Eutrophication potential	kg $(PO_4)^3$ eq.	5.40E-1	0.00E+0	4.75E-3	-3.63E-1
Photochemical ozone creation potential	kg ethene eq.	8.78E-1	0.00E+0	3.28E-3	-6.63E-1
Abiotic depletion potential for non-fossil resources	kg Sb eq.	3.54E-4	0.00E+0	2.16E-6	8.22E-5
Abiotic depletion potential for fossil fuels	MJ	2.17E+4	0.00E+0	6.76E+1	-1.18E+4

» Allocations in production
- In accordance with the dataset documentation and as required by the processes with multi-dimensional product systems, the use of the hot strip dataset "Steel hot rolled coil /EN15804 A1-A3/" from the GaBi ts® database leads to allocations of mass, market value, and energy to module 1 (Raw material supply).
- In addition to these allocations, the use of steel scrap for cooling purposes in the production of pig iron must be considered for the hot rolled strip. In the dataset, the cooling scrap quantity is considered free from loads. As Figure 3 shows, 108 kg of steel scrap goes into the production of the hot rolled strip needed for the manufacture of 1 metric ton of water line pipe. Of this, 107 kg can be covered via scrap quantities arising in the manufacture of steel pipe. In the holistic life cycle assessment, the remaining amount is considered via the recyclable amount of steel at the end of the steel pipe's life. Any further amount, termed net scrap quantity, is entered into module D.

» Benefits from recycling
- Module D evaluates the benefits from the recyclable net scrap volume (see Figure 3: approx. 683 kg), based on the Worldsteel [11] approach of "the theoretically 100 % primary blast furnace route". This involves the allocation of the recyclate to the electric route with the electric-arc furnace as the central process. The resultant product with pertinent loads is credited with the product of the blast furnace route.

» Benefit from thermal utilization of calorific waste materials
- As set out in Chapter 5.2, calorific wastes from the disposal phase (plastic materials PE and PP) are allocated to thermal utilization for energy recovery. The

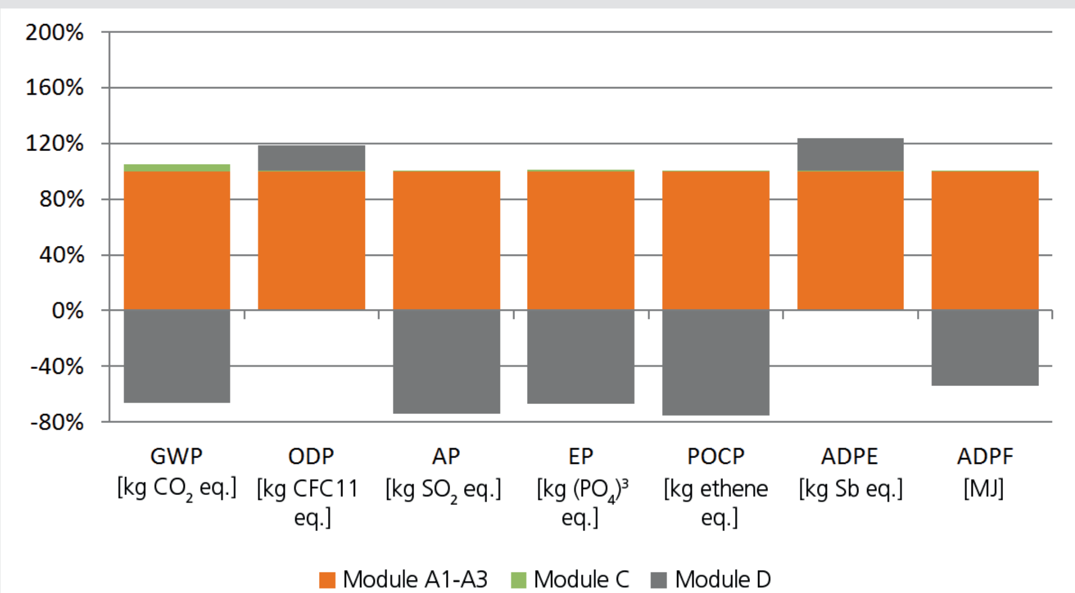

***Figure 4**: Environmental impact across all declared modules (A1-A3 = 100 %, C3-C4, D)*

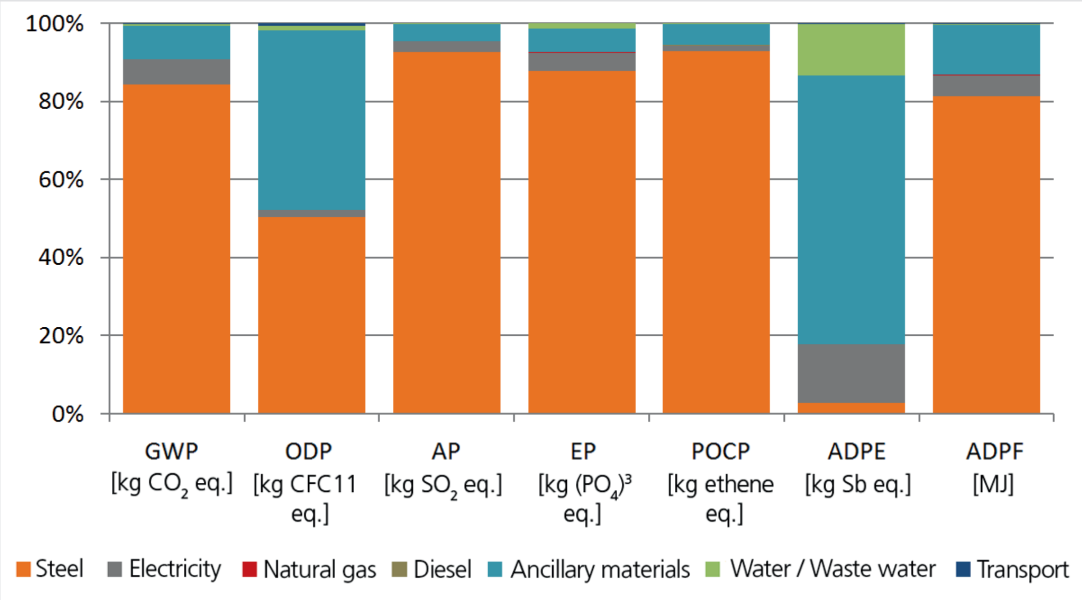

Figure 5*: Shares of individual material and energy categories in the environmental impact of the manufacturing phase*

generated thermal and electrical energy is credited to module D with the datasets of the German electricity mix and steam generation from natural gas.

Data and period under review

Both the modelling procedure and the results of the related life cycle assessment are based on the primary production data and energy/media consumptions of the two MLP works in Siegen and Hamm. The period under review was fiscal 2012, which was checked and found to be representative in terms of plant utilization and production mix.

The primary data have been complemented by secondary data for base materials from the GaBi ts® database (DB Version 6.115, SP 29) [9].

Results of the life cycle assessment

For the purposes of an EPD, the results of a life cycle assessment are subdivided into the three categories "Environmental impact", "Resource use", and "Output flows" and assigned to the respective modules. The subdivision of the results according to modules makes it possible to dispense with certain other modules and thus adapt the valid system boundary of the EPD to potential preferences.

As an extract from the EPD for 1 metric ton of water line pipe, ***Table 4*** lists by modules the associated environmental impacts in absolute values.

In addition, ***Figure 4*** shows the impact of the declared modules in relation to the production stage (A1-A3 = 100 %). As can be seen, only in the global warming potential (GWP) category does waste disposal (C4) account for a share of 5 % of the emissions in the production phase; in all the other categories, its share lies well below 1 %.

The relative share for module D is obtained by aggregation of the loads and benefits (or credits) emerging from the life cycle assessment scenario chosen. The high collection rates lead to high benefits for steel products in the end-of-life phase. Only the categories ODP (ozone depletion potential) and ADPE (abiotic depletion potential for non-fossil resources) are assigned additional loads due to recycling. These are attributable to the increased electricity consumed by the electric-arc furnace process.

To evaluate the impact of so-called life cycle inventory groups, such as steel, electricity and natural gas in the manufacturing phase, their relative proportions are shown in ***Figure 5***. The dominance of the upstream steel production (inventory group "Steel") in nearly all environmental impacts can be clearly seen. Apart from the impact categories "Abiotic depletion potential for non-fossil resources (ADPE)" and the "Stratospheric ozone depletion potential (ODP)", the proportion of the life cycle inventory group "Steel" is over 80 %.

In both categories (ADPE and ODP), the ancillary materials (cement, epoxy glue and PE/PP) also play an important role with about 70 % and 45 %, respectively.

Electricity generation (approx. 15 %) and treatment/provision of cooling and process water (approx. 10 %) are only relevant in category ADPE.

Interpretation and conclusion

With the preparation of environmental product declarations (EPDs) according to ISO 14025 and EN 15804, customers of Mannesmann Line Pipe GmbH now have quantitative, externally verified product data at their disposal [12]. In addition, the transparency of these data allows various construction products and materials to be compared with each other.

The results based on the GaBi ts® model of the life cycle

assessment show for the example „water line pipe“ that the production of the required steel accounts for more than 80 % of the emissions in most of the environmental categories in the manufacturing phase. The remaining share is subdivided among the production of ancillary materials, i.e. cement, plastic materials PE/PP, and epoxy glue. Direct electricity consumption during pipe production is of minor importance in the context of the life cycle assessment.
For the reduction of environmental impacts, material efficiency assumes a central role. Measures for reducing the use of steel strip hold a greater potential in this respect than the reduction of ancillary materials. Depending on the intended application, steel pipe offers the possibility of a reduction in wall thickness and thus savings in material through the use of high-strength starting materials. Here, economic as well as ecological savings potentials can be realized.
Despite the longevity and high-grade recyclability of steel pipe, its ecological sustainability must always be assessed in the context of the intended application (buildings, infrastructural structures, etc.) and combined or compared with other construction products and materials. The new environmental product declarations provide the appropriate basis for these considerations on the part of the customer.

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