ArcelorMittal Sheet Piling

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Implementation of environmental criteria in civil engineering (infrastructure)

European countries have set stringent targets on carbon footprint reduction for the next years and decades. National targets change regularly, so that any percentage we could mention may be obsolete in a few months, but overall, it is in the range of 50 % by 2030. There is no doubt that massive investments in the construction industry are required to achieve carbon neutrality by 2050. However, the good news is that simple actions can quickly yield tangible results. Design optimisation is definitely one way to reduce the consumption of natural resources and reduce the environmental footprint of new projects. Optimisation is the never-ending challenge for architects, engineers and construction companies. But the purpose of this brochure is to highlight a complementary strategy: how can public authorities and private investors foster change already today? There are some solutions, so let us illustrate one of them with a product used worldwide in infrastructure: steel sheet piles.

Steel sheet piles are mainly used for **permanent applications** in civil engineering, predominantly for infrastructure and foundations, i.e. construction of quay walls, retaining walls, underground car parks, bridge abutments,... Besides, sheet piles are used for **temporary applications**, such as watertight cofferdams in the water, deep excavation in urban areas, etc. One of the key advantages from a financial and environmental point of view is that they can be driven into the ground and easily recovered after their service life, and either **reused several times before being recycled or directly recycled.**

How can you select the most environmentally friendly solution? You might try a **Life Cycle Assessment (LCA).**

Are LCAs founded on scientific facts? Can you trust them? In principle, yes, but it depends on the way the LCA was carried out and on the relevance and reliability of the data used in the analysis.

+ Life Cycle Assessment (LCA)

Example 1. *An LCA performed by the city of Zurich (Switzerland) in 2014 [1] concluded that, compared to other solutions, steel sheet piles used as temporary retaining walls of urban excavations reduced drastically the carbon footprint of these temporary structures (by a factor of more than three) when the sheet piles were used a couple of times before being recycled.*

Example 2. *ArcelorMittal carried out an LCA comparing the environmental impact of two alternatives for the execution of a quay wall of a cruise ship terminal [2]. The basis of the LCA was a detailed conceptual design of the structures made by a renowned Belgian consulting engineering firm. The LCA considered the same assumptions for the alternatives and was peer-reviewed by a panel of independent experts. Fig. 1 highlights the* **saving of 559 tonnes of CO_2-eq emissions** *by selecting the alternative with the lowest environmental footprint, representing a difference of 44 %.*

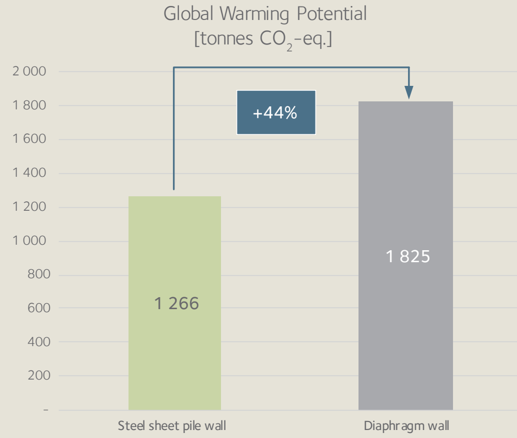

Fig. 1. LCA of the construction of a quay wall – Global Warming Potential of two alternatives [2].

Life Cycle Assessment (LCA) and Environmental Product Declaration (EPD)

For non experts, the difference between an LCA and an EPD is not always evident. In very simple terms, an LCA analyses all the environmental burdens of a product (or service, but this paper focuses on products) during its lifecycle. It encompasses the extraction of all the raw materials and their further processing, the transport, the manufacturing of the product, any additional processing before installation at the jobsite, the use phase, the dismantlement and finally the reuse or recycling of the product. Whereas an EPD is a weighted average of the environmental footprint of a product based on its diverse applications, so to speak, it is the result of several LCAs of a single product. An EPD covers the manufacturing of a product over a specific period of time, usually one year, whereas the LCA considers the lifecycle of the product, which can vary from a very short period of time to many years, depending on the application.

Let us refocus on steel sheet piles: their global environmental impact differs slightly from similar structural steels elements, such as beams and merchant bars, mainly due to the higher reuse rate of sheet piles and their vast domain of applications. That is one reason why ArcelorMittal carried out EPDs for sheet piles, for beams and merchant bars, for rails, etc. even when the products are manufactured in the same steel mill and/or rolling mill.

There are two types of steel sheet piles, hot rolled (HRSSP) and cold formed (CFSSP). Both types can be produced from steel from the **primary route** (Blast Furnace / Basic Oxygen Furnace – **BF/BOF** – transformation of iron ore into steel) as well as from the **secondary route** (Electric Arc Furnace – **EAF** – recycling of steel scrap into new steel). The embodied carbon of the production of steel sheet piles with steel from the EAF route, such as the **EcoSheetPile™** range - see [3] - is much lower than sheet piles from the BF/BOF route, for instance ArcelorMittal's CFSSP produced from hot rolled coils - see [4]. The new range **EcoSheetPile™ Plus** [5], which is part of ArcelorMittal's **XCarb®** brand that covers products with a low carbon footprint and ArcelorMittal's transition to carbon neutrality by 2050, uses **100 % of renewable electricity** in the EAF route, thus reducing the embodied carbon by around 30 % compared to the EcoSheetPile range (see Fig. 2 - 370 vs. 520 kg of CO_2-eq/t).

+ Global Warming Potential (GWP)

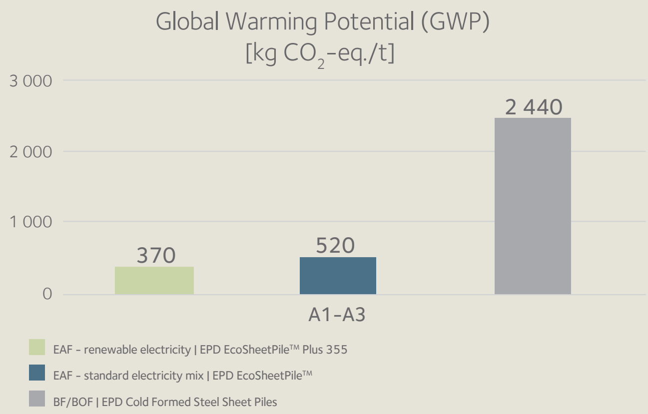

Fig. 2. Comparison of the embodied carbon (Global Warming Potential) of different sheet piles / production routes – Modules A1 - A3. [3], [4], [5].

Environmental criteria - The Dutch showcase

A few European countries started implementing environmental criteria in their public procurement procedures in civil engineering, but the Netherlands are in the forefront. They systematically enforce **environmental criteria in a scheme for public tenders that lead to the most sustainable solution**, based on the *most economically advantageous tender [6]*. Currently public administrations use the **monetization** scheme, which is based on a weighting method applied to multiple environmental indicators either from **national EPDs** or from generic data contained in a national database [7], yielding a single Environmental Cost Indicator (ECI) for each product. The calculated overall ECI comprises the quantities of the materials having a large repercussion on the environmental footprint of the project and is converted into a financial credit (*fictional bonus*, see Fig. 3) that is subtracted from the overall price. Thus, the contract is not necessarily awarded to the contractor with the lowest bid (price). This approach is an **incentive** for contractors and manufacturers to invest in R&D, and to optimise the design and execution in order to reduce the environmental impact of each project. Furthermore, the advantage of this method is that the ECI integrates the effect of multiple environmental indicators and of the total quantities of material supplied, thus preventing a shift from one environmental indicator or product to other ones. It is not limited to the carbon footprint! There is no doubt about it being a good initiative, but the drawback for manufacturers active in several European markets is the need for "national" EPDs.

+ Example of a fictional discount based on an Environmental Cost Indicator

For the expansion of a motorway between Schipol and Almere, the government calculated a reference ECI of approximately 14M. In the tendering procedure, they decided to distribute the fictional discount to projects who would present proposals with an ECI lower than 12M. The maximum discount amounted to 10M€ on the full project budget. The fictional discount was distributed linearly between proposals with a minimum ECI of 6M and 12M.

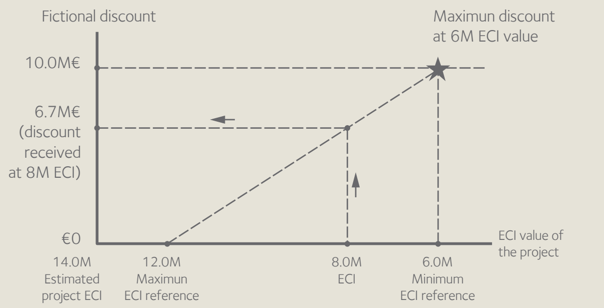

Fig. 3. Example of a fictional discount (credit) allocated to a contractor's bid based on environmental criteria (the ECI) in a Dutch public tender [8].

The Dutch *monetization* method is briefly explained in a **report prepared by the Dutch institute TNO** [8] for ArcelorMittal (report available on request).

Total Life Cycle Cost

As sheet piles can be reused several times and recycled at 100 %, it is important to consider the **Total Life Cycle Cost**, including the burdens or benefits of the End-of-Life phase and beyond (modules C and D of the European standard **EN 15804** [9], which are **dismantling, reusing and recycling** of the building elements. For civil engineering, an LCA is a reasonably fair and transparent method to compare different solutions and suppliers. Although not required by ISO and EN standards, an LCA is more accurate and realistic when it uses specific EPDs from the producers rather than collective EPDs or generic data from databases. Furthermore, since some assumptions made for the elaboration of the EPDs do not apply to a specific project, the LCA practitioner should have enough experience and reliable data from the manufacturer to adapt the results of the EPD to the project specific LCA.

Example: for an underground car park with a service life of 100 years, the probability that the sheet piles will be reused after the service life is quite low, but recycling of the sheet piles is quite probable. Additionally, as the steel is in direct contact with saturated soil, corrosion may have an impact on the quantity of steel that can be recycled. These parameters influence the values of the indicators of Modules C and D and should not be neglected in a project specific LCA.

For steel and other materials, **omitting Modules C and D may lead to an underestimation of the carbon footprint over the lifecycle**. For steel from the EAF route, the value of Module D is often positive and depends basically on the quantity of material available for recycling at the end of life. Based on the methodology proposed by the *Worldsteel Association*, the value of Module D of steel from the BF/BOF route is usually negative and significantly reduces the total life cycle carbon footprint. From Fig. 4, comparing the values of Modules A1-A3 (on the left: 520 vs. 2 440 kg CO_2-eq./t) of the EPDs and the total impact of Modules A1 to D (on the right: 519 vs. 762 kg CO_2-eq./t) leads to the same conclusion, but the difference is attenuated. Note that different EPDs cannot be compared unless all the key assumptions are identical. This is not the case for the three EPDs on the figure: the reuse and recycling rates are quite different, so that Module D is highly influenced by these rates. An adapted version of the EPD shall be considered if you want to compare apples with apples. If this calculation feature is not included in the EPD, you may ask the owner of the EPD to provide the adapted numbers. However, only the values from the EPD have been reviewed and published.

Any additional data supplied by the manufacturer is deduced from the EPD, without any further guarantee, unless it has been calculated with a *certified and reviewed* EPD tool.

Reuse can also considerably reduce the carbon footprint, so that omitting Modules C and D would overestimate the carbon footprint for a specific project (corrosion is negligible for temporary applications) and penalise this solution against other ones (see Fig. 5).

The choice of a solution shall consider several key indicators, the principal one being the construction cost, which in some countries can be as low as 50 % for public works. It is a good practice to carry out a sensitivity analysis on some parameters that have a large influence on the results. It is also vital to realise that conclusions from an LCA cannot simply be transposed to other situations, nor to other locations or countries, without applying adequate adjustment factors.

It has already been mentioned that the values of the various indicators stated on an EPD depend on the assumptions made, but although it might seem odd, the results also depend on the software and database that was used, and consequently, on the version of these tools. Hence, when using or comparing data from EPDs, it is recommended to use EPDs from the same program operator, and if this is not possible, to analyse the influence of the assumptions and calculation methods on the results of the EPDs. To make it fairer and simpler for all the stakeholders, some countries accept only EPDs that have been registered with their national program operator. For instance, in the Netherlands only EPDs registered with the MRPI [10] can be used for an LCA.

Furthermore, a project specific LCA relies on a design. Changes to the design or to the manufacturing of the product can substantially modify the conclusions of an LCA. The design of civil engineering structures is a quite long and dynamic process, with its limitations on reliability on costs and techniques, and can evolve quickly. Hence, an LCA should be performed at every stage of the project, and especially when selecting the contractor. Consequently, it is also vital to monitor during the execution phase and at the end of the project the environmental footprint. In case of failing to achieve its environmental goals the contractor faces a fine that is proportional to the observed deviations.

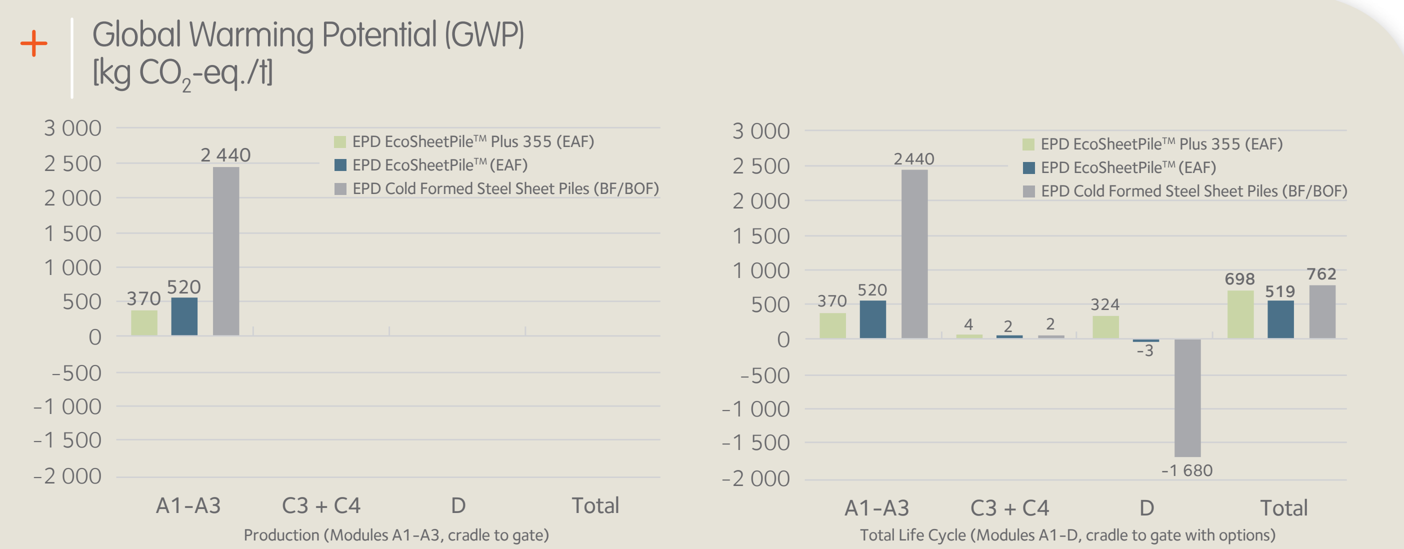

Fig. 4. EPDs - influence of the "End-of-life stage" (Module C) and the "benefits and loads beyond the system boundaries" (Module D) – example.

Comparison of the environmental footprint of alternatives

A **fair comparison** of several alternatives **can only be achieved if the functional unit is well adapted to the structure**. It can be a simple unit, for instance one meter of finished quay wall, or preferably the complete element to be compared (i.e. 200 meters of finished quay wall). This approach allows the comparison of the finished structure and prevents the shift of an environmental impact form one sub-structure to another one. However, it is not always possible to analyse many combinations of the whole system during the different design phases, mainly because of its complexity. In that case, it might be useful to subdivide the structure in smaller key structural elements and define a functional unit for each sub-structure.

Example: if a retaining wall of an underground car park must be watertight, the comparison of the retaining wall elements must consider the additional sealing systems. Comparing only the elements of the retaining walls would be unfair. An underground car park contains many structural elements, such as the external retaining walls, the slabs and decks, the internal columns, etc. It makes sense to analyse sub-structures separately, such as the retaining walls, except for very small buildings due to the additional time and effort required.

Note also that the structures must be designed for the same use, same level of safety according to the same or equivalent rules and regulations, for the same service life.

The environmental footprint of the transport of sheet piles manufactured in Europe and installed in Europe is relatively low compared to the impact of the production when considering the whole lifecycle of a permanent structure. As a rule of thumb, this contribution is less than 10 % of the total. However, in some specific cases, the impact of transport may not be negligible for steel sheet piles that are reused several times but in different jobsites, nor for sheet piles shipped over very long distances, especially by trucks, or from other continents.

End-of-Life practices

Generally speaking, steel sheet piles are recovered after the temporary use, respectively after the service life. In 2016, for the first EPD, and for the EPD *EcoSheetPiles*, based on customer feedback and a market survey, ArcelorMittal assumed that 25 % are reused, 74 % recycled and 1 % landfilled. This data is representative of the overall production and consumption in Europe. For the EPD *EcoSheetPile Plus*, after a more in-depth analysis, we revised the assumptions to 15 % landfill (loss of steel, sheet piles left in place,...) and 25 % reuse. As a reminder, these values should be adjusted for each project specific LCA: in some projects, no landfill will occur, in others, 100 % will be reused a couple of times, and so on.

Note also that some impacts on the society cannot be expressed through an EPD or an LCA. The quantities of material that need to be delivered to a jobsite have a direct environmental impact calculated in an LCA, but other indirect and non-financial effects should be considered, like traffic and traffic jams in urban areas due to transport of the building elements, noise and vibrations due to the installation, and so on. Unfortunately, the financial impact and the impact on the well-being of people living in the area is difficult to estimate. Consequently, choosing prefabricated light and compact elements, as well as solutions that can be finished faster, are an environmental judicious choice.

The graph in Fig. 5 highlights the results yielded from different assumptions between an EPD (overall impact of the sheet piles production) and project specific LCAs (impact of the sheet piles for a specific project). The examples are based on, respectively adapted from, the EPD *EcoSheetPile™ Plus* for 1 tonne of sheet piles at the manufacturer's gate (excludes transport and installation).

Fig. 5 shows how essential it is to consider the influence of the assumptions made for a specific project, and most importantly Module D. Using the values from the EPD is acceptable at a very preliminary design stage when performing an overall analysis of several solutions, but for the design, a project specific LCA should be performed. Additionally, if one would omit the benefits of reusing sheet piles in temporary structures, it would drastically penalise its first use: *Total per use* of only 122 kg CO_2-eq./t vs a *Total* of 698 kg CO_2-eq./t if only one use. Module D can be positive or negative, depending on the production route and the recycling rate of steel after the service life.

+ Influence of the assumptions on the EPD / LCA results

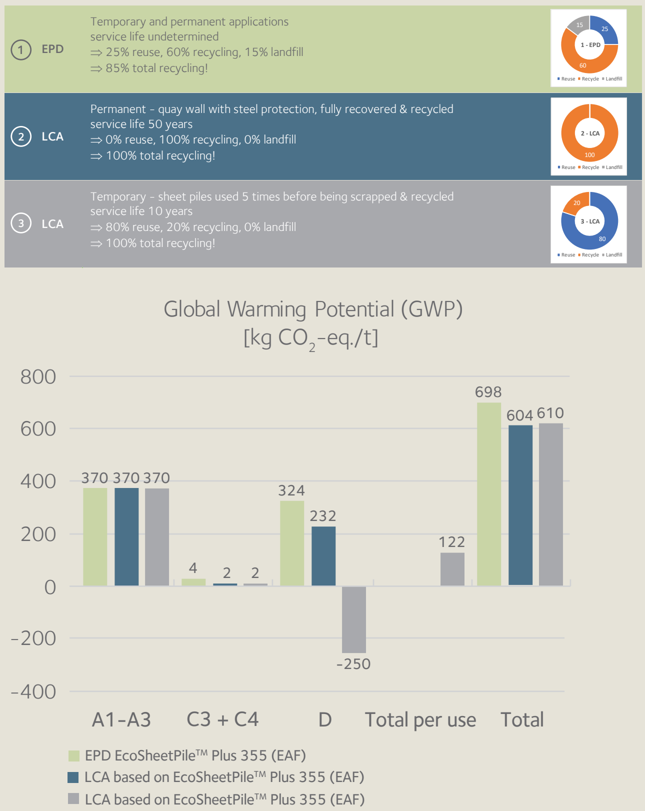

Fig. 5. Influence of the assumptions on the EPD / LCA results – example based on the EPD EcoSheetPile™ Plus.

Besides, the landfill has a negative impact on Module D. If no losses are anticipated on a project, changing the assumption on the landfill rate to 0 % reduces the overall GWP from 698 to 604 kg CO_2-eq / t, a 15 % diminution! Conversely, increasing the landfill of an LCA above 15 % yields a GWP above the value stated in the EPD.

Finally, in some cases a lack of reliable data and information about a specific item may force the LCA expert to omit some phases of the LCA. This is acceptable as long as its impact is low compared to the overall result.

Example: the installation of steel sheet piles will depend heavily on the equipment used by the contractor, but also on the effective soil conditions. In early stages, such as during the preliminary design, this data is not available, or assumptions would be too gross, so that based on previous experience, this impact may be disregarded at that stage. However, at tender stage, the contractor should evaluate this impact based on his offer.

Pitfalls

Several tenders in the past encompassed environmental criteria, but some unfortunately may have had a negative outcome on the choice of the most environmentally-friendly solution. Below are some examples:

- *Transport of the product is the sole environmental criteria*. As seen previously, for steel sheet piles manufactured in Europe and installed in Europe, transport has only a low contribution compared to the production, especially for products from the BOF route. Transport from the manufacturer's gate to the jobsite should definitely be considered, but as an addition to the production and other elements that may not be neglected.
- *Transport is only considered from the intermediate stockist or storage yard to the jobsite*. Again, transport has a low contribution, but the whole supply chain should be considered, from the manufacturer to a subcontractor / stockist, and from there to the jobsite.
- *Finishing / special piles*. Every sheet pile project has some special sheet piles and specific finishing requirements, such as junction piles, coated piles, welded piles, sealing systems, etc. Although their contribution can in some cases be neglected, they should be part of the system analysed in the LCA, especially when it comes to large surfaces of coatings, hot dip galvanization,.... In case cathodic protection replaces a coating system, it should be part of the sub-system *retaining walls* to potentially avoid the shift of an environmental impact to a different sub-system when comparing alternatives.
- *Cuts from stock material*. Some projects require a fast supply of material, and this service can be provided through a smart stock management of used and new material, either at the mill or at a local storage yard. Usually cutting sheet piles from standard *stock lengths to project lengths* has a financial and environmental impact. In general, when the cut-out portions are short, they have no commercial value and will be directly recycled, so that a project specific LCA should consider this loss of material. Hence, the analysis of the environmental impact should be made at the project's gate and include all the losses between the manufacturer's gate and the end-user. Although stock material is essential, for instance for small temporary structures, deliveries from stock material versus project-driven mill material (supply of the optimum length) should be compared on a fair basis.
- *Reused sheet piles and second-hand sheet piles are assigned no environmental footprint (0 kg of CO_2-eq emissions)*: this is a delicate topic. It seems logical that one should only assign the environmental burden once to an element, so that re-using would have no environmental impact.
  However, the methodology used currently can take into account the reuse of elements, and consequently, the more you reuse an element, the lesser impact per use it will have. It is obvious that overall (at the end of life), the environmental impact is the same (excluding transport and losses due to damages), but the impact of each use phase is reduced. The difficulty consists in making the most adequate assumption right from the beginning, so that the environmental footprint can be distributed evenly over the whole lifecycle. See next chapter for our recommendation on this topic.
- *Comparison of the carbon footprint of the production of crude steel (intermediate product such as beam blanks,...)*. Crude steel is an intermediate product that will be processed further in a rolling mill, either in the same mill or in a different location. For EAF steel, the impact of the rolling process (hot rolling, productivity of the rolling process,...) can be as high as the production of crude steel. The sole indicator that should be used is the environmental impact of the finished product that is stated in the EPDs or in a generic renowned database. If additional processing is performed before delivery at the jobsite but is not included in the EPD (i.e. welding, coating, cutting, ...), it should be added in the LCA calculation.

Recommendations on reuse and second-hand sheet piles

In case new sheet piles are reused several times on the same project and recycled afterwards, then the analysis is straightforward: just use the total quantity of new material purchased for the project. However, in most cases, the sheet piles will return to a storage yard, will be cleaned and / or repaired (damaged portions or piles will be scrapped), and later reused on a different project. Based on feedback from customers, around 25 % of the sheets produced are reused several times. Hence **for temporary applications, the LCA practitioner can assume that steel sheet piles pertaining to the "rental business" will be used 5 times with some small losses during the total life cycle** due to damages during installation.

This approach reduces the environmental impact for each use phase to around 1/5 of the overall impact. Note that generally speaking, the lifecycle of a used pile is quite short (rentals can be as short as a few weeks to two or three years) and rarely above five years.

This rationale is different for *"second-hand"* sheet piles, which are integrated in a permanent wall after a first use (as temporary sheet piles). Hence, assuming a single reuse seems reasonable (sheets will be used twice before being recycled).

Conclusions

To avoid wrong assumptions or to avoid missing some key processes, EPDs should be worked out by environmental experts that are also specialized in the industry and applications for which the EPD is elaborated. Collective EPDs or generic data from public databases are a nice tool to compare alternatives at a feasibility stage or design stage for instance. But when it comes to the comparison of alternatives at the tender stage, a specific EPD from the manufacturer of the product that will be installed is the most appropriate and should be required.

For each project, a specific LCA based on data from product specific EPDs adapted to the project specific assumptions should be performed at every design and execution stage. Environmental criteria should in any case be integrated into the design and purchasing procedures, for instance by using the **"monetization"** method implemented in the Netherlands. A product that has a major impact on the LCA result, but which is not covered by a specific EPD, should be penalised, for instance by using a weighting factor on its environmental indicators relative to a specific EPD from a product produced with the same process, or relative to the best-in-class product. Any additional impact due to transport, finishing works, corrosion,... should be taken into account in an impartial manner. A fair comparison of several solutions can only be achieved by choosing a clear functional unit and by analysing the total life cycle of the structure, including the end-of-life scenario as well as reuse and recycling of the elements.

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ArcelorMittal Commercial RPS S.à r.l. | Sheet Piling | 66, rue de Luxembourg | L-4221 Esch-sur-Alzette | Luxembourg
T (+352) 5313 3105 | sheetpiling@arcelormittal.com | sheetpiling.arcelormittal.com