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Environmental product declaration (EPD) for the TENSO Sky®- ETFE-System

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Summary. The environmental impacts of construction products have to be known in order to improve these products due to their ecological footprint and, finally, to create ”green” buildings in future only. The Environmental Product Declaration (EPD) supports architects in their selection and comparison of appropriate products to obtain an optimal life cycle assessment (LCA) of the building they intend to design. This contribution describes the example of an EPD for transparent building envelopes or claddings made of three-layer cushions with the TAIYO TENSO Sky® System with the ETFE-film FLUON® NJ from AGC Inc. [1]

1 INTRODUCTION

Nowadays, the Environmental Product Declaration (EPD) is an important tool for the assessment and for the understanding of the impact of products on our environment. This is also valid for all products applied as building components, for example roof- or façade systems consisting of membranes (foils), frames and other parts with minor mass portions.

Used in the architecture since the early 80th of the last century single- and multiple layer structures consisting of transparent, translucent (printed or colored) or opaque ETFE-foils are used for such roof- or façade systems. ETFE stands for the copolymer Ethylene-Tetra-Fluoro-Ethylene, a high grade and durable viscoelastic-plastic material. Because of the relative short time of application ETFE-foil structures can be seen as a quite new type of construction technology. Therefore, just a few EPD’s exist yet related to ETFE-foil structures.

In this article, only one short excerpt from the results will be shown exemplary, to point out the options for the evaluation of the results to find in the EPD and to explain the structure and the purposes of EPD’s in general.

2 PROJECT-SPECIFIC DATA

In general, the life cycle assessment (LCA) for an EPD can be based on average values of a number of projects or on the evaluation of a single representative project. In this case, the second option was chosen.

The EPD [1] for this system is based on a data collection and evaluation of the project “Center Parcs du Bois aux Daims” located in Vienne, France (Figure 1-2) [12]. Build by Taiyo Europe is has been completed in the year 2016. The areal is a large leisure park with the aquatic centre "Aquamundo" in its centre. The transparent envelope covers the Y-shaped aquatic centre with a total roof area of 6,100 m². This area consists of 80 transparent ETFE-foil cushions with serigraphy inflated with dry air provided by two blower units. Ventilation openings are installed at the ridge of each wing of the building. The main participants of the ETFE-cushion lot are listed as follows [12]:

- building owner: Pierre & Vacances Center Parcs, Paris, France
- architect: Art’Ur Architects, Bordeaux, France
- engineer (ETFE): LEICHT France S.A.S, Nantes, France
- execution: TAIYO EUROPE GmbH, Sauerlach, Germany

Figure 1: Center Parcs du Bois aux Daims, Vienne, 2016 – outside view [12]

Figure 2: Center Parcs du Bois aux Daims,Vienne, 2015 – inside view [12]

3 TAIYO TENSO SKY ® SYSTEM WITH AGC INC. FLUON® NJ ETFE-FILM

This System is a transparent or translucent cladding system used for façade and roof applications or for complete building envelopes. It can be used as permanent or temporary structure, e.g., for stadia and grandstands, zoological or botanical gardens and green houses, for infrastructure buildings (airports, train- and bus-stations), for leisure parks as well as for hotels, museums and commercial buildings. This type of construction was built by TAIYO in a wide range of climates in many countries all over the world.

The system consists of a transparent or translucent part made of ETFE-foils and an opaque part made of aluminium, plus secondary elements with minor mass portions, like fasteners, gaskets and seals. The number of ETFE-layers is almost determined by structural and/or building physical requirements (thermal insulation or comfort).

An Environmental Product Declaration (EPD) is a report that provides transparent information regarding to the environmental impact of a product based on its life cycle assessment (LCA). In this context the life cycle means all phases the product's components are passing from the raw materials production to the end of their service life, or simplified "from cradle to cradle". It is a so called type III declaration, based on the codes ISO 14025 [3} and ISO15804 [4].

Following these codes the processing of the EPD can be divided in three phases (Figure 3), in which are involved three parties (in this case): TAIYO EUROPE GmbH / AGC Inc., SPHERA^{TM} and the Institut Bauen und Umwelt (IBU).

The first phase includes the description of the product and the materials used as well as the collection of the information from projects where the system had been used, done by the party mentioned first (EPD owner) needed for the later LCA. The second phase refers to the performance of the LCA using the data collection following the product category rules (PCR's). This phase was conducted by the involved consultant SPHERA^{TM}. The third and final phase includes the verification of the LCA, the certification and publication of the EPD and the registration of the EPD owner.

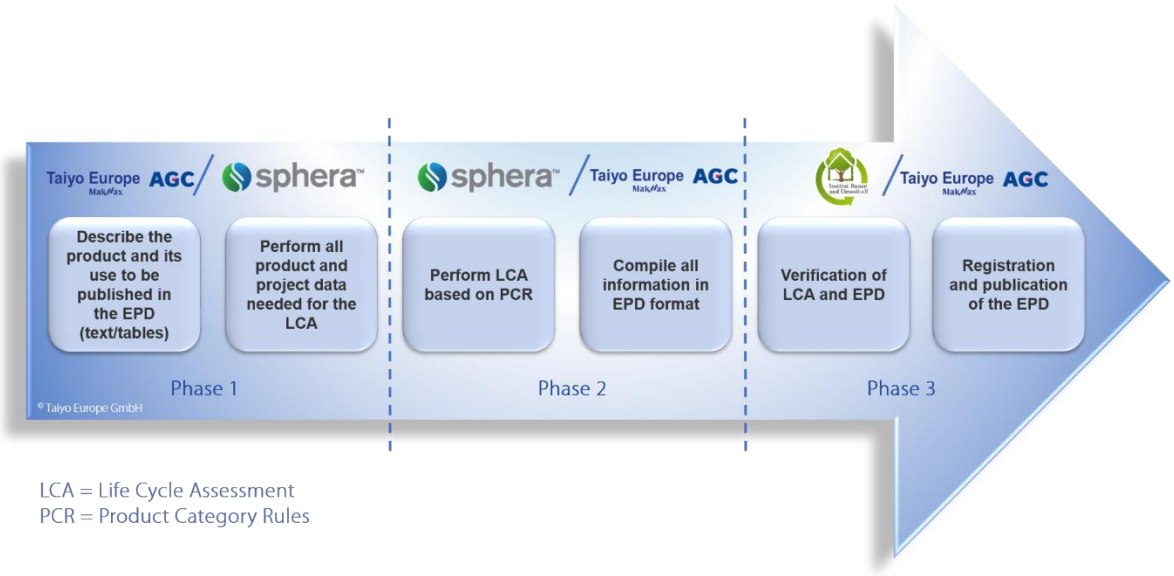

Figure 3: EPD for the TENSO Sky® System – Individual Process Flow Chart [13]

The EPD [1] (Figure 4) refers to one square meter of the TENSO Sky®-System which means less than 4 kg/m² mass per unit area for the three layers made of AGC Inc. FLUON® NJ ETFE-film, the frame made of aluminium and the secondary components in mass proportions underlined in Table 1. Without the other components the ETFE-part has just a weight of approx. 1 kg/m² mass per unit area. The film thickness for this solution is of 250 µm (layer 1 and 3) and 100 µm (layer 2). The EPD was issued in August 2019. It is valid for five years until August 2024. When the declaration expires it can be prolonged - respectively renewed, to be based on the state of the current legal situation, especially due to the second amendment of EN 15804+A2 which has been passed the committees of standardization already (chapter 6).

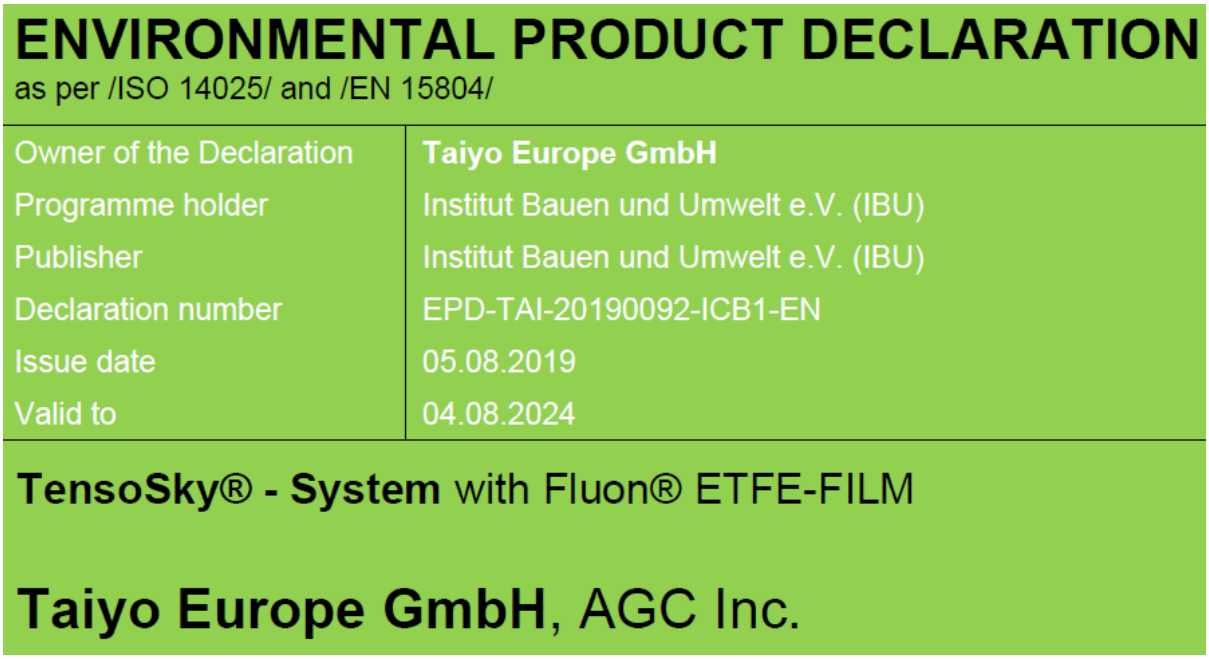

Figure 4: Environmental product declaration (EPD) for the TENSO Sky® -System – Headline [1]

Name (component)	**Value (mass portion)**
Aluminium (frames, air valves)	40%
ETFE-Film (3 layers)	27%
Mild Steel (gutter)	22%
EPDM (gaskets)	5%
Stainless Steel (fasteners)	3%
other plastic materials (seals, coating, spacers)	3%
Total	**100%**

Table 1: Mass portions [1]

4 LIFE CYCLE ASSESSMENT (LCA) AND LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The Life Cycle Assessment (LCA) is defined by ISO 14040 as "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" [5].The LCA for the TENSO Sky ® System has been done by using the software GaBi provided by the EPD expert company SPHERA™. The calculations are done according to the standards ISO 14040 [5] and ISO 140446 [14] considering the Product Category Rules (PCR - Part A and PCR – Part B) [7], [8] and [9] related to the relevant product category (based on the core rules given by EN ISO 21930 [10]. Additional guidance for calculations with the GABI software is provided by SPHERA™ [11]. For the verification of the life cycle assessment (LCA) by the Institut Bauen und Umwelt e.V. (IBU) the numerical results are submitted and supplemented by additional information in form of a background report.

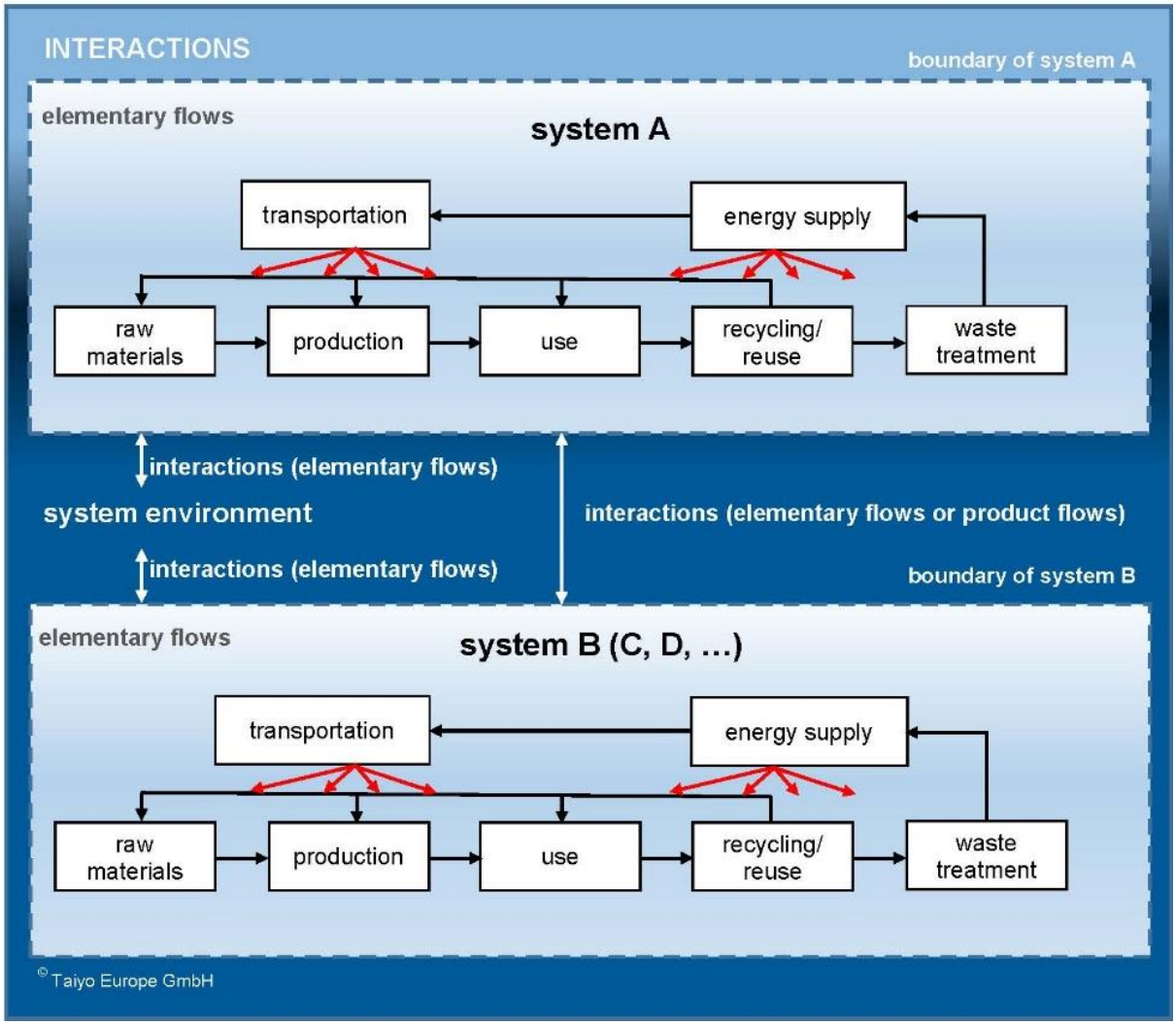

Figure 5: Model of the LCA [12] (following [11])

The elementary flows of a system considered by its life cycle assessment (LCA) are defined in the relevant product category rules (PCR – Part B) [8]. Interactions with the system environment and with other systems should be covered too. Also these interactions could be relevant for the eco-balance and the environmental footprint of the product of course. The LCA is, therefore, as good as the elementary flows, the product flows also with the system environment and with other products are defined. Some interactions with the environment or with other products are worthy to be improved. However, what could have an impact on the LCA-results and what may influence the eco-balance and the environmental footprint of a product has to be evaluated and defined step by step and well structured. It's a lot of work and, of course, and this work is a permanent subjected of technological developments and changes:

Example 1: Transparent ETFE-foil structures usually gain a significant amount of sun light and save, therefore, energy for the reduced necessity of artificial lighting.

Example 2: Multilayer ETFE-foil systems (cushions) can be used as a transparent shelter for photovoltaic modules or for solar collectors. Such elements gain energy to be considered in the ecological balances of the interacting systems.

Example 3: The relative big span width between the beams or trusses of the buildings primary structure, ETFE-foil structures enable, save not only self-weigh of the roof or façade itself. It saves also masses along the whole load path to the ground. Trusses, columns and foundations, for example, can be designed slimmer and, therefore, more ecological and economical.

With the mentioned examples in mind, it can be stated that the current version of the product category rules (PCR – Part B) for the ETFE-foil structure [8] should be improved due to the systems interactions and also due to an accurate definition of the LCA boundary. The goal to compare products assigned to the same PCR – part B is achieved not before all significant impacts are considered and not before the boundary of the LCR is defined well.

Currently the LCA of one ETFE-system may include the air supply system for air inflated structures, the other one maybe not. The same question could be asked on the next level of detailing, due to the consideration of the energy consumption of the dehumidifier, usually integrated in the air blower units by standard. Is this device an optional feature that must not be considered or should it be seen as state of the art that is mandatory to be considered in the LCA? The approach to cover not only all relevant (significant) impacts, but also to consider interactions with the system environment and with other systems is called Life-Cycle Impact assessment (LCIA).

Compared to the LCA the Life Cycle Impact Assessment (LCIA) covers also relevant impacts resulting from interactions with the environment (ores and crude oil, water, land use etc.) as well as emissions into air, water and soil (carbon dioxide, nitrogen oxides etc.). It enables also the consideration of system's interaction with other systems of the building. For ETFE-systems like the one presented here, the LCIA would mean a significant improvement compared to the approach of the LCA applied. It would allow not only the comparison with other products assigned to the same PCR – Part B - Requirements on the EPD for ETFE construction element [8] but also an improved ecological comparison with other systems made of glass, polycarbonate or acrylic glass etc.

5 THE ENVIRONMENTAL IMPACT CATEGORIES OF THE LCA

The life cycle assessment (LCA) contains a huge number of values that show the effects of each material-related system component in all phases of the life cycle related to the applicable product category rules (PCR Part B [8]). The (LCA) considers 27 single impacts summarized in 3 categories:

- **environment impact**: GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophication potential; POCP = Formation potential of tropospheric ozone photochemical oxidants; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources
- **resource use and output flows**: PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net freshwater
- **waste categories:** HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EEE = Exported electrical energy; ETE = Exported thermal energy

These impacts are applied for the assessment in the different stages of the systems life cycle. Each stage comprises of different modules (Figure 6):

- **product stage:** raw material supply (A1); transport (A2); manufacturing (A3)
- **construction process stage:** transport from the gate to the site (A4); assembly (A5)
- **use state:** use (B1); maintenance ((B2); repair (B3), replacement (B4); refurbishment (B5); operational energy use (B6); operational water use (B7)
- **end of life stage:** De-construction demolition (C1); transport (C2); waste processing (C3); disposal (C4)
- **benefits and loads beyond the system boundaries:** reuse, recovery, recycling potential (D)

The modules B3-B5 are marked with “module not relevant” (MNR), because repair, replacement and refurbishment haven’t been done in case of the reference project the LCA is based on. These three modules are not predictable in general, because they are relevant within the systems service life in exceptional cases only.

DESCRIPTION OF THE SYSTEM BOUNDARY (X = INCLUDED IN LCA; MND = MODULE NOT DECLARED)															
PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	MNR	MNR	MNR	X	X	X	X	X	X	X

Figure 6: Life cycle Assessment - modules A1 … D [1]; MNR = module not relevant

6 CHANGES BY EN 15804: 2012+A2: 2019

Meanwhile the EPD and the related standards (EN 15804, respectively DIN EN 15804:2012-04 [4] (with further revisions e.g. in 2014) have been adopted and applied in many countries around the world. This standard rules the sustainability of construction works, focusing on the Environmental Product Declaration (EPD) and on the core rules for the product categories of construction products.

In July 2019 a major amendment (EN 15804 +A2) was approved which will change the system of the EPD significantly. If the application for an EPD is intended the second amendment A2 is mandatory to be applied as of July 2022. The impact of this amendment are far-reaching, as the following substantive changes show (exemplary):

- Biogenic carbon emissions and storage handling are fully revamped.
- 19 environmental impact categories and 17 other reporting categories are now to be evaluated.
- The consideration of the modules C (dismantling, reuse and disposal) and D (credits and debits outside the system boundaries) are mandatory. These two modules were previously (DIN EN 15804 + A1) just optional.
- In the so-called impact assessment, that is, the bundling of the various emissions and resource consumption into a few key values, revised factors and, in some cases, new models are prescribed.
- …

The described changes mean that the results of an EPD according to the old and to the new standard cannot be compared with one another. It also means that the product category rules (PCR) have to be revised.

7 CONCLUSION

With regard to climatic changes and increasing environmental problems (referring to energy, emissions and waste), the assessment of products with regard to their sustainability is inevitably gaining in importance. This also and especially applies to building products. In this regard, the Environmental Product Declaration (EPD) offers an important tool for evaluating and comparing building products (building systems) with regard to their life cycle assessment (LCA) over their entire service life - also in order to improve the systems energetically.

So far there are only very few EPDs for ETFE film systems available. In addition, the present Product Category Rules (PCR - Part B) for these building systems [8] currently still leave some leeway with regard to the influences to be taken into account on the ecological balance. Examples of this have been given above. Interactions with other systems of the building (supporting structure, foundations, lighting, energy generation by means of photovoltaics and solar thermal energy, etc.) as well as interactions with the environment are currently not yet clearly recorded and still to be specified more precisely. This is necessary in order to ultimately be able to compare systems of the same construction type with one another but also with optional systems (here: glass, polycarbonate, acrylic glass etc.). In this regard, the cooperation and exchange of the construction experts involved (system providers and associations, e.g. TensiNet, AMA e.V.) on the one hand and the specialists for the specification of evaluation criteria and influencing parameters (e.g. IBU) on the other hand, is desirable.

The EPD developed by TAIYO EUROPE GmbH together with the film manufacturer AGC Inc. for the TENSOSky® system with the ETFE film FLUON® NJ is a step in the right direction. The present article has shown only a very small part of the document and its meaning. The EPD has been published and can be downloaded from the website of the certifier, the Institut Bauen und Umwelt e.V. (IBU) (https://ibu-epd.com/en/published-epds/)

The document makes the system's ecological balance more transparent. It should enable architects and building owners to design buildings or to invest in buildings that are sustainable. Finally, the architect can use the fact sheets derived from the EPD to apply for an environmental certificate from a regionally acting and recognized certifier (LEED® [2], BREEAM®, DGNB®) and thus have the sustainability of his/her building certified and documented. But please: Ultimately, our drive should not be the certificate, but the desire and the need to continuously improve our living space and our environmental conditions. We hope that many will follow suit.

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