# ON LIFE CYCLE ASSESSMENT OF HIGHER-LEVEL PRODUCT SYSTEMS WITH PRE-DECLARED PRELIMINARY PRODUCTS

# ZUR ÖKOBILANZ HÖHERSTUFIGER PRODUKTSYSTEME MIT BEREITS VORAB DEKLARIERTEN VORPRODUKTEN

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## SUMMARY

Environmental product declarations have a dual role in the system of life cycle assessments. On the one hand, as so-called “product systems”, they represent the final documentation of the respective process analysis. On the other hand, as so-called “subsystems”, they can also form the data basis for the evaluation of complex technical artifacts, such as for entire buildings or extensive infrastructural systems. These aspects are usually seen as entirely separate work steps. The feedback loops that occur in the course of truly holistic considerations and that eliminate this separation are rarely considered. In the present article, this methodological gap is addressed.

## ZUSAMMENFASSUNG

In der Systematik der Ökobilanzen kommt den Umweltproduktdeklarationen gewissermaßen eine Doppelrolle zu. Einerseits stellen sie als sogenannte „Produktsysteme“ die finale Dokumentation der jeweiligen Prozessanalyse dar. Andererseits können sie auch als sogenannte „Subsysteme“ die Datenbasis für die Bewertung komplexer technischer Artefakte bilden, etwa von ganzen Gebäuden oder umfangreichen Infrastruktursystemen. Die genannten Aspekte werden meist als vollkommen separate Arbeitsschritte aufgefasst. Die im Zuge wirklich ganzheitlicher Betrachtungen auftretenden Rückkopplungen, die diese Trennung aufheben, werden selten betrachtet. Der vorliegende Artikel thematisiert diese methodische Lücke.

# 1. INTRODUCTION

Life cycle assessment (LCA) is an essential and already well-established tool for the evaluation of the environmental impact of technical products and services. The basic procedure to be applied can be found in DIN EN ISO 14040 [1]. The central concept introduced in this standard is that of the "product system". Each concrete calculation is based on an object hierarchy, which is made up of objects of the classes "flow", "unit process" and "product system". The objects of the flow class are assigned to two subclasses, namely the elementary flow class and the product flow class. In the simplest case, a product system is used to cover the demand for exactly one required end product. All other product flows occurring within the object structure have the character of intermediate products for which there is only an indirect demand. These are therefore theoretically handled in such a way that they are produced in the required quantities in the course of the modelled production process, but are also completely consumed again. The corresponding analysis of a product system results in quantified elementary flows being assigned to the end product - or more precisely: to the associated fulfilment of demand. This step in the LCA is known as the life cycle inventory (LCI).

The LCI results are subsequently assigned to selected impact categories in a further process step - the life cycle impact assessment (LCIA) - in which they are weighted using characterisation factors determined by specialized scientists in supplementary research. The approach described above presupposes that all intermediate product flows occurring within a product system can be traced back to elementary flows. This is self-evident in a truly holistic approach, as the required materials and energy sources can ultimately only be obtained from the natural environment and no other sink is available for emissions and waste than this natural environment. Due to the complexity of the actual circumstances, however, it is generally not possible to fully calculate the elementary flows. It is rather the case that certain preliminary products flow into product systems for which the required knowledge is not complete or is not available in principle. This raises the question of how to proceed under such circumstances.

# 2. ECOSPHERE AND TECHNOSPHERE

The LCA methodology described in the introductory section is based on the implicit assumption that the world in which people work and trade can be divided into two sufficiently distinct sub-areas. These two areas are referred to as nature and culture, nature and technology or ecosphere and technosphere. The separation line between these two areas of the world is systematically required in order to distinguish between the elementary and product flows described above. The elementary flows are those flows which, in contrast to the product flows, cross the aforementioned separation line in one direction or the other. The question of the existence and selectivity of the separation line, which is thus indispensable for the purposes under consideration, falls within the realm of cultural philosophy and, in particular, the philosophy of technology, where it has been the subject of undiminished controversy in recent times. Authoritative monographs such as those by Hans Poser [2] and Evandro Agazzi [3] provide excellent introductions to this field.

However, the fact that the division of the world into the two areas mentioned is inadequate can be recognized even without the study of basic philosophical texts by the fact that the end point of a flow, which represents the actual end product of a product system, cannot be appropriately located in either of the two areas.

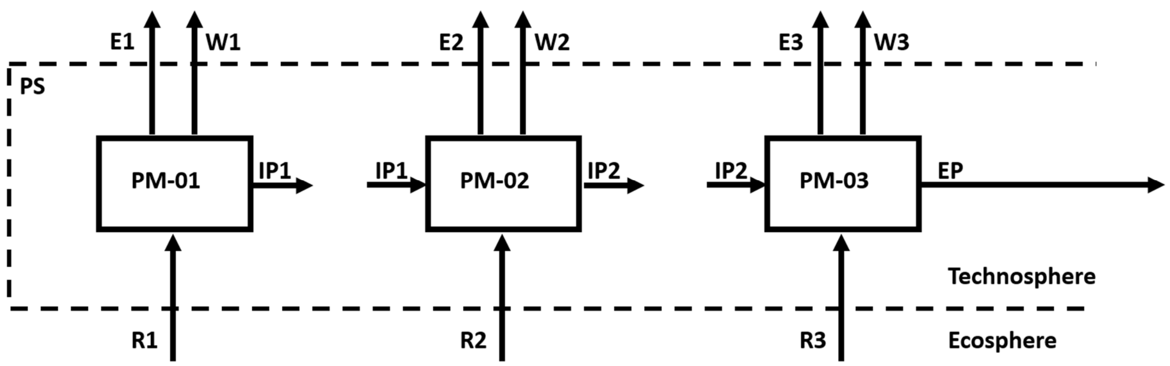


*Fig. 1: Simple Product System*

To illustrate this, a simple schematic product system is shown in Fig. 1. In this diagram, PS denotes the product system as a whole, E1 to E3 symbolize the total emissions caused by each of the three unit processes PM-01 to PM-03. Accordingly, W1 to W3 symbolize the liquid and solid waste generated in this process. The resource consumptions are labelled R1 to R3. IP1 and IP2 are the intermediate products occurring in the model under consideration, the quantities of which are set to zero in the course of the analysis (see above). The dashed separation line is located between the ecosphere on one side and the technosphere on the other. The end product EP serves to fulfil a need. This can be both technical and non-technical in nature. The only thing that can be said with certainty about such a need is that it is something that ultimately results from a need perceived by humans. For further considerations, it initially seems helpful to replace the postulated separation line with a transition zone.

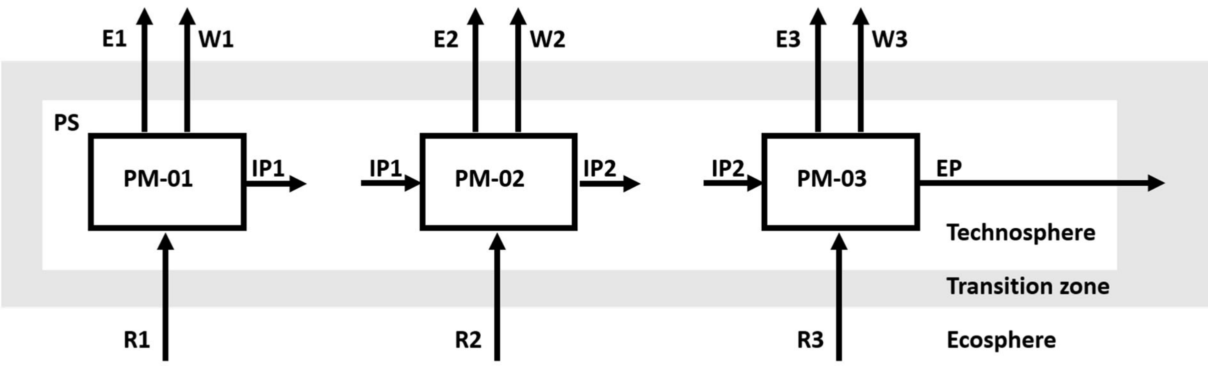


*Fig. 2: Product System with transition zone*

Fig. 2 shows a revised version of the considered product system model. It remains to be clarified which phenomenon and action areas are represented or covered by the transition zone. In any case, it is recognizable that the end point of the arrow, which represents the flow assigned to the end product (EP), is now located neither in the ecosphere nor in the technosphere, but in the newly introduced transition zone.

## 3. THE THREE-PILLAR MODEL OF SUSTAINABILITY

The LCA is a central element in the assessment of environmental impacts, although it is only one element of several assessment tools that can be used in the context of holistic sustainability analyses. Due to the ultimately unfulfillable requirement that such considerations must be carried out holistically, this results in an almost unmanageable number of individual criteria, the relative weightings of which can also not be conclusively determined. A rather pragmatic approach to solving the problem that arises here is the so-called three-pillar model of sustainability. This usually assumes that three areas ("pillars") can be considered independently of each other and should be weighted equally, i.e. the area of ecology, the area of economy and finally the socio-cultural area. Some authors supplement this concept, which is predominantly found in literature of the technical sciences, with further pillars or dimensions, such as the institutional-political dimension (s. [4] p. 85 ff). The necessary weighting process between the dimensions under consideration represents a separate problem area, for the solution of which numerous proposals exist, but which hardly take into account the complexity of the actual situation.

Assuming that the three areas mentioned above can be summarized as one anthroposphere, which encompasses all areas of human influence on the world, the question raised at the end of the last section about the nature of the transition zone introduced there can now be answered. It can only be the area of the non-technical anthroposphere, which is composed mainly of the economy and the socio-cultural sphere. Whether and to what extent a specific product that is required as an intermediate product for a higher-level product system is actually available generally depends on unpredictable economic and political conditions, which can change considerably over time. In particular, feedback effects are to be expected, e.g. based on the fact that the demand for an intermediate product is significantly influenced by the actual fulfilment of demand for the associated end product.

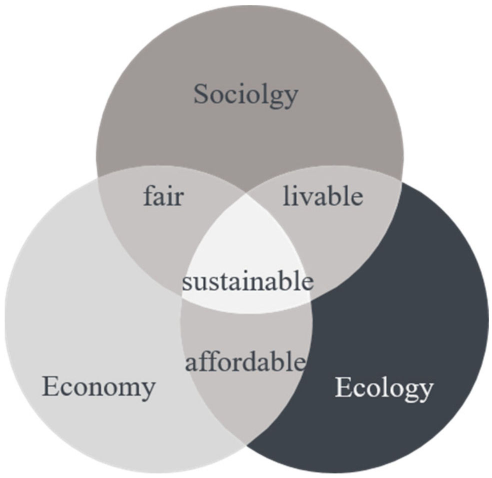


*Fig. 3: Sustainability dimensions as equally sized, overlapping circles*

In addition to the three-pillar model, there are also other approaches to presenting the three dimensions of sustainability. A major criticism of the three-pillar model is that the dimensions presented as independent pillars appear as if there are no interactions between them. To illustrate the interactions between the dimensions, the Venn diagram is now preferred (see Fig. 3). In this model, the three dimensions are represented as three equally sized and overlapping circles. An environment that takes social and ecological aspects into account is worth living in. If social and economic aspects are taken into account, this can be described as fair. Taking ecological and economic aspects into account is sustainable. The common intersection of all three dimensions is referred to as sustainable, i.e. the area in which economic, social and ecological aspects are taken into account.

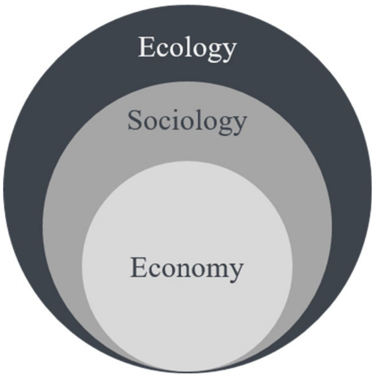


*Fig. 4: Priority model for presenting the sustainability dimensions*

There are also other alternative representations, such as priority models, in which the three dimensions are also assigned a ranking. Ecology, for example, occupies the most important position, with the argument that an "intact" habitat is a prerequisite for humans to be able to interact socially at all, and that it is only through social interaction that they are able to act economically. The three dimensions of sustainability in this priority model are each depicted as circles of different sizes (see Fig. 4). As ecology has the most important position, the circle of this dimension includes the other two circles of sociology and economy.

## 4. ENVIRONMENTAL PRODUCT DECLARATIONS

An environmental product declaration (EPD) summarizes the results of a life cycle assessment for a specific product or an entire product family in a clear and concise form. In the area of building products, DIN EN 15804 [5] is the essential basis for this.

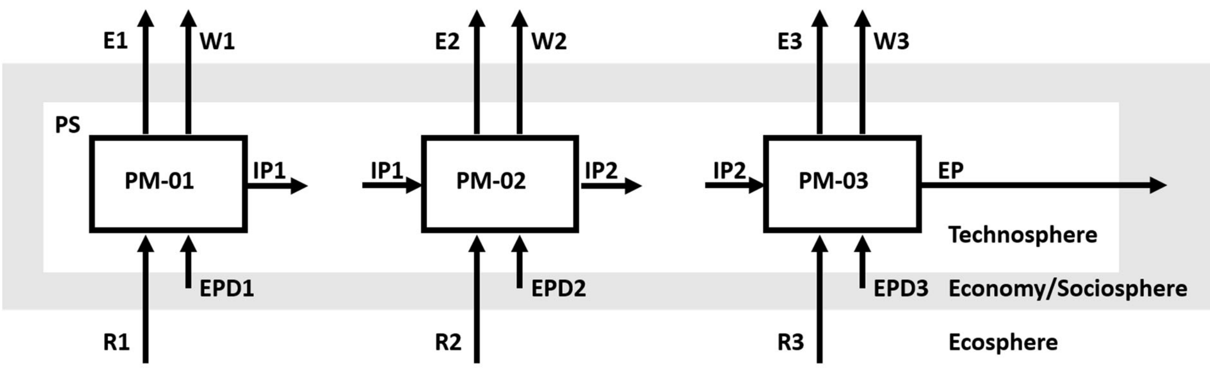


*Fig. 5: Product system with EPD-declared precursors*

Fig. 5 shows a further modification of the product system under consideration. Three flows EPD1 to EPD3 have now been added, which represent preliminary products whose production path cannot be traced back to the elementary flows, as these are things that are available on the market. This origin is symbolised in the diagram by the starting points of the arrows in the transition zone, which is now appropriately labelled as Economy/Sociosphere.

The transition zone and ecosphere shown in Fig. 5 as part of the product system illustration can be transferred to the sustainability dimensions shown in the priority model (see Fig. 4). The economic and sociological dimensions shown in the priority model are comparable with the transition zone in Fig. 5. The ecosphere shown in Fig. 5 represents the ecology dimension in the priority model.

In this context, the unit of comparison required in the course of life cycle assessments should also be considered. A system can have a variety of possible functions. In order to be able to compare different product systems with each other, a functional unit is defined in the LCA methodology. It describes the essential purpose of the system and represents the reference value in a life cycle assessment.

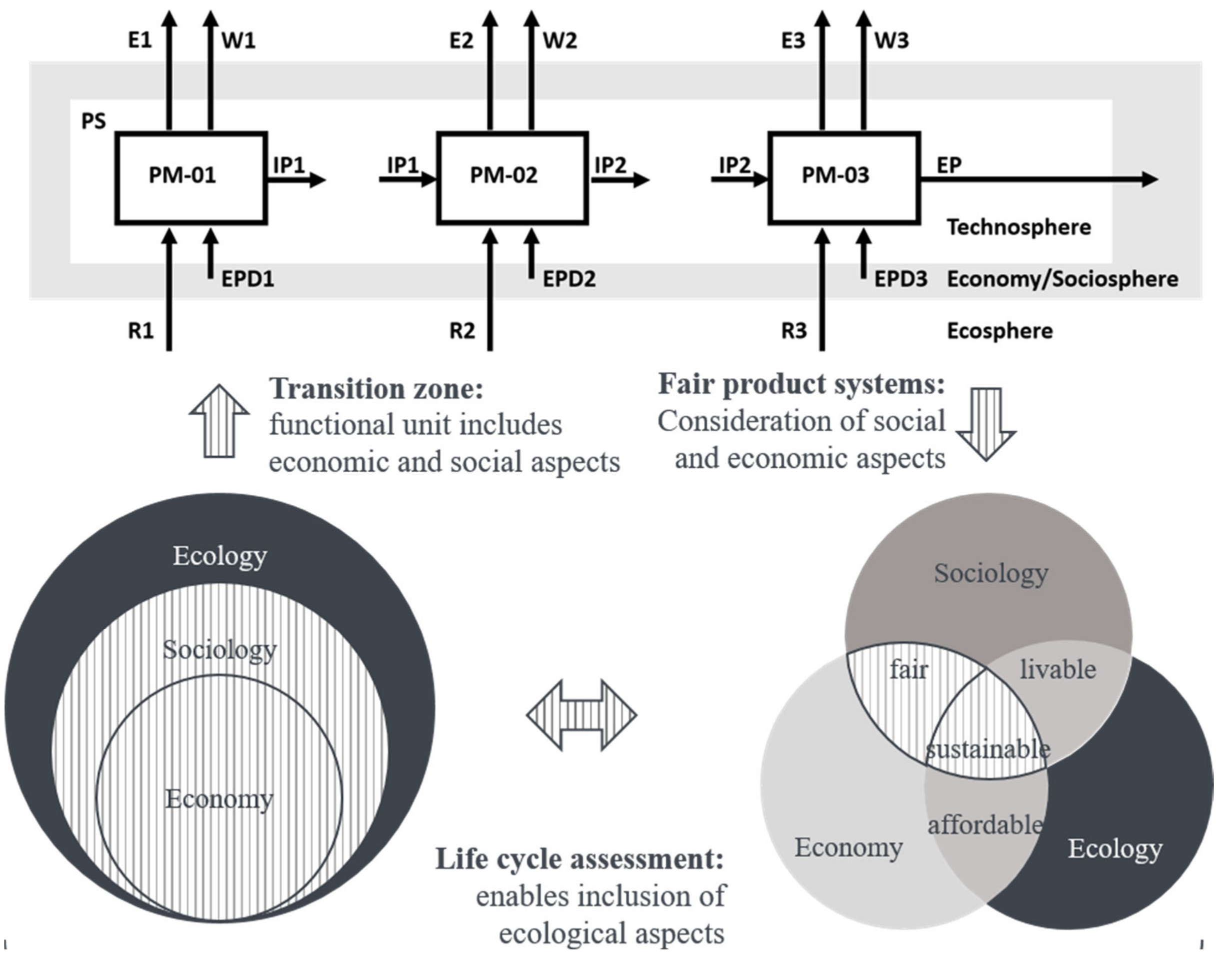


*Fig. 6: Transition zone represents the social and economic dimension of sustainability*

The standard DIN EN 15804 [5] describes basic rules for environmental product declarations for the product category of construction products. The declared unit is used instead of the functional unit in life cycle assessments if these do not cover all life cycle stages. It is also used if no functional unit can be defined, e.g. because the function of a product cannot be clearly described, as the construction product can be used in various ways in the building context. Construction products are used to manufacture components or buildings. The life cycle of a construction product after its manufacture usually takes place as part of components or buildings, and therefore in higher-level product systems. The mass or volume of a construction product is usually defined as the declared unit.

The comparative unit of buildings over the entire life cycle is usually much more complex than the declared unit of a construction product. The main function of a residential building is to provide living space for a certain number of people over a longer period of time. The reference unit therefore generally also includes social aspects (see also Fig. 6). The end product of higher-level product systems is therefore assigned to the transition zone economy/sociology.

At the level of these higher-level product systems, more uncertainties are to be expected (e.g. the user behavior of the building's occupants), for which assumptions generally have to be made. Uncertainties should be comprehensively recorded. One possibility is to record such uncertain values using intervals. Interval-based life cycle assessment can then be used for the calculation (see also [8]).

## 5. IMPLEMENTATION WITHIN MULTIVALCA

The option of taking into account preliminary products for which no information is available regarding the relevant unit processes in the associated upstream subsystems, but for which environmental product declarations or comparable documentation of previous calculations are available, has been implemented in the latest versions of the MultiVaLCA accounting software [6].

Fig. 7 shows the input dialogue for entering product declarations. As provided throughout MultiVaLCA, it is also possible here to enter the values to be recorded in the form of intervals. This option can be used, for example, to approximately take into account mutual influences on demand (see above). It is also possible to combine the declarations of several functionally equivalent products into one declaration group. The corresponding input dialogue is shown in Fig. 8. Some basic aspects of this procedure have already been reported on in an earlier article [7].

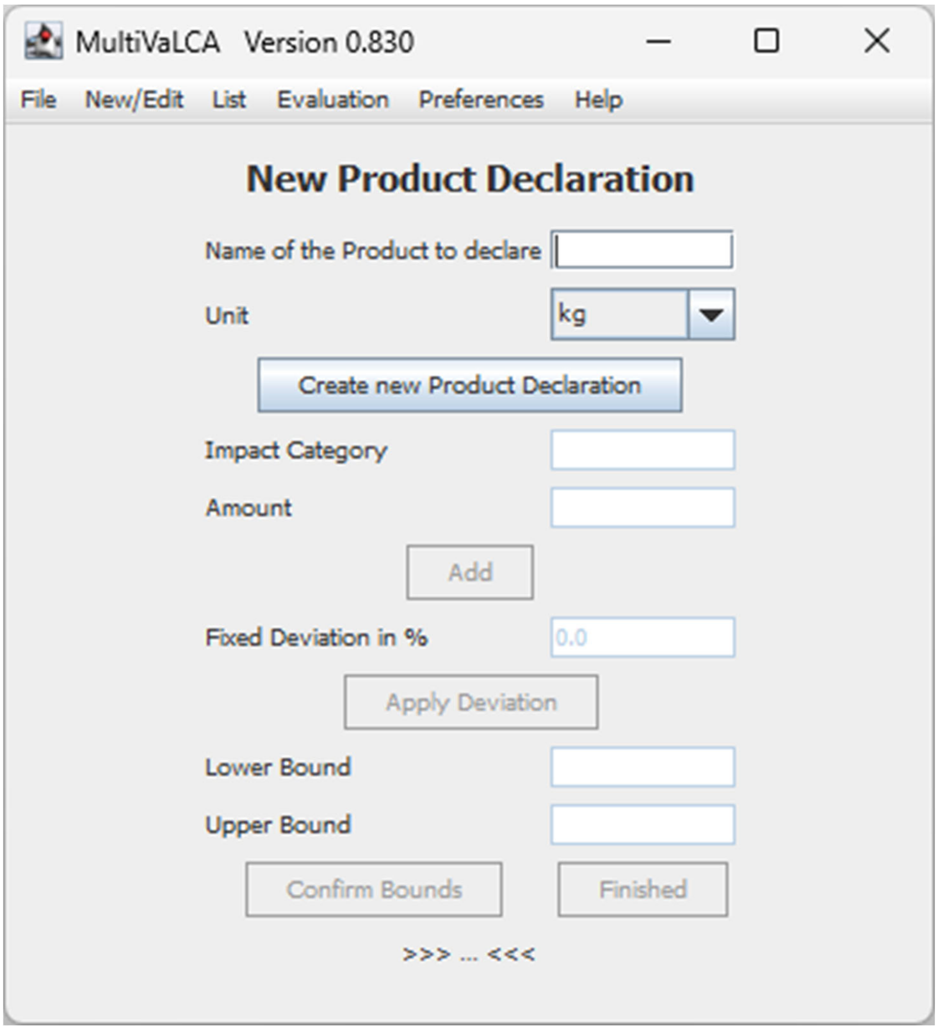


*Fig. 7: MultiVaLCA input dialog for EPDs*

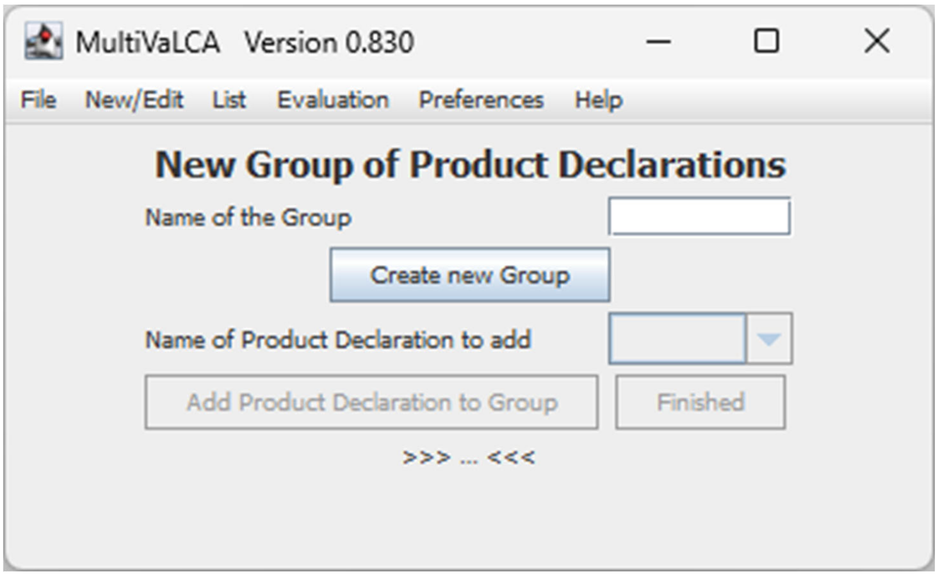


*Fig. 8: MultiVaLCA input dialog for EPD-Groups*

The designations of the recorded product declarations can be used as input flows in the latest versions of the software in question when creating unit processes. In the LCI, these do not have to be explicitly labelled as primary products. With the procedure described here, it should be borne in mind that the impact assessment method on which the EPD of the recorded upstream product is based is generally not the same as that for the product system analysed as a whole. Proper consideration of this difficulty inevitably leads to a further widening of the result intervals.

# 6. CONCLUSION AND OUTLOOK

The usual approach, in which the three pillars of sustainability are regarded as independent fields that can be analysed in completely separate calculations, reaches its plausibility limits in connection with higher-level product systems. In this context, interval arithmetic analyses can make a valuable contribution to avoiding inappropriate interpretations of LCA results.

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