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IMPLEMENTING SCENARIO TO BETTER ADDRESS THE USE PHASE IN PRODUCT ECODESIGN

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ABSTRACT

Some product categories, like electro-domestics, generate most of their environmental impact during use phase. Yet, the integration of this product life-cycle stage has been a challenge for ecodesign.
Scenario is a formalism that has been used for a long time for integration of the use phase characteristics, in term of actors, actions, and context, into product development process.
This paper presents an adaptation of the scenario formalism that can be used for ecodesign. Our proposal for implementing scenario into the ecodesign process is based on the separation of the use phase into seven “moments” that will cover product lifecycle from installation (ending of the distribution phase) to decommissioning (beginning of end of life phase). The scenario will be used first to evaluate the environmental impacts. Based on this evaluation of the use phase moments, examples of the most efficient ecodesign strategies are presented.
A case study on refrigerator used in Brazil was conducted to illustrate the implementation of scenario for ecodesigning product use phase.

Keywords: eco design, user integration, scenario based design, environmental assessment

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1 INTRODUCTION

Industrial goods are responsible for a substantial part of the environmental impacts of human societies (UN DESA, 1992). Their production, distribution, use and disposal need a lot of resources and generate emissions and waste to all the environmental areas: water, air, soil, that disrupts the equilibrium of ecosystems. Wenzel et al. (2000) evaluate that 80% of the environmental impacts of the product over its lifecycle is determined by decisions made during the design process. Based on this diagnosis, the design phase is the most promising moment of the product life to tackle environmental issues. Such an approach is often called 'ecodesign' and it aims at integrating environmental impacts over product lifecycle during design in order to decrease them (ISO, 2006). Ecodesign requirements are currently being implemented as mandatory for some energy related products entering the EU market, by the Ecodesign Directive (European Commission, 2009).

To order the priority in term of product development, an environmental assessment can be used to identify the significant environmental impact of the product (ISO, 2006). Many product categories generate most of their environmental impacts during use phase due to the consumption of energy or water. Typical illustration of these categories are software based product, like non portable electronic products, or electro-domestics, like refrigerators (Faberi, 2007). Nevertheless, the use phase is poorly integrated in the ecodesign methods and tools (Sauer et al., 2002). Integrating use phase actors, like users or maintenance teams, and, at the same time, environmental issues is still a challenge for designers.

This challenge is due to the necessity to fulfill at the same time the requirements of user centred design and of ecodesign. A first requirement for use phase integration in ecodesign is to be a design support, meaning that the tool or method proposed should be usable for product development. A second one is specific to the use phase and user integration: the tool or method should support the multiple aspects of the use phase: its actors (users, maintenance company…), its contributors (other products that are in contact with the product) and the product. A third one is related to the environmental side of ecodesign: they should support the association of environmental impacts to the multiple aspects of the use phase in order to propose strategies to decrease it. Scenario based design seems to fit the three requirements presented above and it was used for the design of product categories with a high environmental impact in use phase: software (Carroll, 2000) and electro-domestic (Fulton Suri and Marsh, 2000), for example.

This paper aims at verifying that scenario based design is adequate to drive the ecodesign process of products with an impact during use phase. A scenario description for ecodesign is proposed.

In the first section, a literature review is realized to support the statement that a scenario approach fits the three requirements for supporting ecodesign of product use phase. The second part will present the specificity of scenario construction for ecodesign, its implementation for environmental assessment and for improvements of product environmental performances. All of these elements will be illustrated with a case study on the ecodesign of a refrigerator. In the third part, we will discuss the strength and the flaws of this proposal.

2 SCENARIO FOR ECODESIGN: A LITERATURE REVIEW

2.1 Scenario for design

In the design context, a scenario can be defined as a description of typical or significant users' activities (Carroll, 2000) that can be modified to envision future possibilities (Fulton Suri and Marsh, 2000).

Both authors have interest in different product type, Fulton Suri and Marsh (2000) for electro-domestic and Carroll (2000) for software, but their conclusions on the benefits of scenario driven design are the same. They agreed on the four following advantages for use scenario implementation in design:

1. It can combine different elements in a same support: user, product and context. The modularity of form makes it easy to include all the elements that are considered of importance for the design case, including who is using the product (the user), where the product is being used (the context) and how it is activated (tasks).
2. It is usable during the whole design process, including in its early stages of design. The scenario can be passed on any form of product model: mock-up, concept lists, prototype, CAD model. So it can be used as soon as the product requirements are defined in product planning

3. Since it can represent multiple views on use, it is an efficient tool for collaboration with users and with other experts. It is also a communication enhancer since it documents all the alternatives of product and users' reactions in a specific environment.
4. It can support decisions making processes by raising awareness on influencing factors of a realistic use of the product (Wolters and Steenbekkers, 2006).

These key elements make the scenario a good candidate for complying with the first requirements, since it has been implemented with success by all authors in product design, and the second requirement, which is to provide multiple views of the product, the use phase and its actors.

2.2 Scenario in environmental science

Another application of scenario is in the collection and the consolidation of information about ideal or potential future representation, especially in environmental/sustainability science (Mizuno et al., 2011). This is what is used for prevision in environmental studies such as prospective for climate change (IPCC, 2007).

A tool that is often used in product environmental assessment, Life Cycle Assessment - LCA, is based on the definition of product potential life cycle, i.e. product possible or probable fate. This future possible life is embedded in the construction of a scenario that is evaluated according to several environmental impacts (Pesonen et al., 2000).

The International Panel on Climate Change proposal is also a good example of scenario usage in environmental forecasting (IPCC, 2007). They evaluate the potential impact of an increase of CO_2 like gases on the global climate of earth as well as the influence of different political remediation measures, formalized in the form of scenarios.

Mizuno et al. (2011) proposed a method to create those forecasting scenarios that can be applied to LCA (ISO, 2006). At first the problems are set, i.e. the product and systems boundaries for LCA. Secondly the relation between elements should be defined in a causal network. Third, the different options of the scenario are described. And fourth, the events that will occur along the scenario are also defined, i.e. the product life cycle phases for LCA.

This use of scenario in the environmental forecasting domain demonstrates that scenario can comply with the third requirement of our proposal: to support the identification of future environmental impacts of the product during the use phase.

2.3 Scenario for ecodesign

Scenarios in ecodesign are used in both dimensions: prospecting the potential impact of decision making as well as describing the use practices to drive design decision.

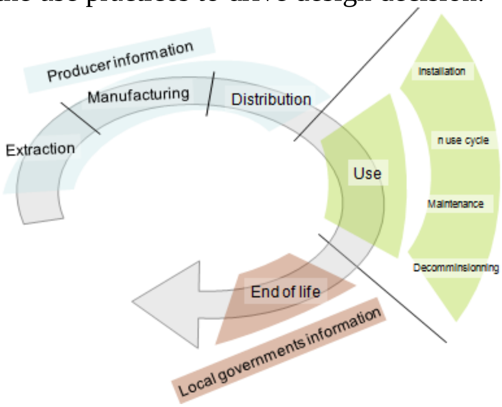

*Figure 1: Product lifecycle, information provider for scenario construction and scope of the use phase (adapted from ISO (2006))_*

In product ecodesign, scenario is often used to evaluate the potential consequences of product design on the future product lifecycle. In this perspective, designers seek information with the actors of each life cycle phase-Figure 1. In order to construct scenario for the extraction, manufacturing and distribution phase, a close relationship with suppliers, integrators or distributors should be maintained. All this relations already exist and the producer has access to it through contracts and agreements along the values chain. For the end of life, the information is centralized by local governments. They

have extensive access to recyclers, waste collection companies trough their delegation of public services contracts and by their political attribution to drive the extended product responsibility policy.
For the use phase, it has been rather difficult to find the appropriate actors and level of detail to be use for design. Sauer et al. (2002) attribute it to the multiplicity of actors and the time frame of the use phase that can be long. Some authors (Wolters and Steenbekkers, 2006; Domingo et al., 2011) already used a detailed scenario of the use phase to represent the entire use phase. For example, Wolters and Steenbekkers (2006) proposal includes in the scenario the combination of the three following elements: product, user and environment of use.
Even though the elements of the use phase are present, the integration of the entire use phase from the end of the distribution to the start of the end of life is not guaranteed.
The specificity of ecodesign regarding the integration of the use phase is that it should integrate the entire use phase not only the punctual moment like installation or maintenance.
The scope of the use for ecodesign is one limiting parameters for the implementation of existing method of scenario of user for design. Even if the scenario implementation in ecodesign fulfilled the 3 requirements especially thanks to the contribution of Wolters and Steenbekkers (2006), the integration of the entire phase is still a weak point.
Our proposal in section 3 is willing to overcome this weakness by separating the use phase in smaller unit that can help covering it entirely.

3 USE PHASE INTEGRATION IN ECODESIGN

3.1 Defining specific moments in use

In ecodesign, the entire product lifecycle is considered and the use phase boundary is generally defined by a gate to gate approach. For example for electro-domestics, the gate metaphor is used to represent the user home door. So, to model the use phase, we need to consider all the events that can or will happen during the time the product will spend inside the door of user home.
In order to cover everything that happens from door to door, we tried to define smaller unit of time during use phase. We named these smaller units “moments”. The term moment was chosen over task to add the notion of frequency over the entire use phase. A moment is not only a succession of actions, ie. a task, that happens once but the addition of all the similar tasks over the product use phase.
Weger et al. (2001) define 5 moments over the use phase: buying act, launching operation, use, maintenance and decommissioning. Wolters and Steenbekkers (2006) uses the following moments in its scenario: ready to use, use, cleaning and storing. In software design (Maguire, 2001), they define installation, use tasks, maintenance and training.
We decided not to consider the buying act because it is much more related to marketing research than design.
Based on the literature, we defined the following seven “moments” of the use phase:

- Installation: the moment when the product is placed and set in a specific place. This can occur several times over the product use phase.
- Learning and training: we extended the notion of training to learning. For most products, its execution is learned through self-education and not through formal training. This moment represents the time spent trying to make the product use automatic.
- Usage moments: the moment when the product is integrated in the daily routines of the users. It can be implicated in several different usage moments. A usage moment happens after a moment of learning.
- Maintenance and Cleaning: we grouped these moments because they have a similar function: giving back the initial properties of a product.
- Storage: it represents the moment where the product is not operational for use and waiting to be used again.
- Decommissioning: it represents the moment when the product is considered not usable or not needed anymore to perform a function. It is most of the time followed by the end of life phase but not always.
- Upgrading moment: We decided to add this moment that was not specified in our literature review. It represents the moment when the product gains additional functions or improves the performance of existing ones.

Those seven moments can happen at the same time for a product and not all the products will passed through those types of moments.

3.2 Environmental assessment of use phase moments

In order to perform an environmental assessment of the use phase, environmental inputs and outputs should be defined in terms of life cycle inventories (ISO, 2006) and elementary flows.
Each moment of the product use phase should be detailed according to:

- Environmental inputs (from 1 to m) and outputs (from 1 to p) involved in the moment.
- Intensity of inputs and outputs for a moment
- Frequency and time duration of the moment.

Based on product parameters, inputs and outputs can be defined because they depend on design decisions. The intensity of the inputs and outputs can also be evaluated based on product parameters (Domingo et al., 2011).
The frequency and time duration are dependent on user behavior. Since our proposal depends on the user point of view, the identification of the user influence on environmental impact should be much easier than with a scenario model based mainly on the product design point of view.
In order to define frequency and time, designers should try to specify the usage moments (from 1 to n). Some important parameters to consider for usage moments are: seasonal variation, time of the day, time of user life (graduation, parenthood, retirement, …), and activity (work, holidays).
Figure 2 represents a template for use scenario documentation, with product parameters in the first column and use moments in the first row.

	Installation		Learning and training		Usage moment 1		…	Usage moment i		…	Usage moment n		Maintenance and Cleaning		Upgrade		Storage		Decomissioning	
	Value	Unit	Value	Unit		Unit		Value	Unit		Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit
Frequency over lifetime																				
Time duration of 1 iteration																				
Input 1																				
…																				
Input j																				
…																				
Input m																				
Output 1																				
…																				
Output k																				
…																				
Output p																				

Figure 2: Template to be documented with product parameters and use moments' parameters

This first step of defining the scenario moments and the parameters that influence the environmental impact of these moments is the basis for data collection on users information.
The second step is to collect data on product related parameters (from design information) and user related ones. For the second category, a wide range of data collection methods is available: web questionnaires, interviews, video recording of tasks analysis, marketing data… The selection of a method depends on the resources and time allocated on each project.
The third step is to allocate a value to each parameter in the template of figure 2. For each moment of the scenario, defined in terms of intensity of environmental input and output, frequency and time duration, an environmental assessment can be done. It can be a simple input/output evaluation or a complete life cycle assessment on the use phase (ISO, 2006) according to a specific set of indicators.
In this new framework for environmental assessment, a decision made during a specific moment that influences other ones will be allocated to this specific moment. For example, decisions made during installation, like product location that will influence thermal efficiency, will be allocated to the installation moment.

With an environmental assessment of the use phase scenario, we can define strategies for ecodesign depending on the most impacting moments, and find the respective contributions of product and user parameters on the environmental impact of the product.

3.3 Ecodesign strategies depending on moments characteristics

Ecodesign literature for the use phase is not specific to a moment (Tang and Bhamra, 2008; Luttropp and Lagerstedt, 2006). Nevertheless, these strategies do not have a similar efficiency when applied to the different moments.

With the characterization of the moments in term of environmental impact, we can identify when the decision that generates the impact was made and developed strategy that are more effective for this moment.

For example, if one of the most impacting moment is the installation phase, an informative strategy can be effective because the user is making it decision consciously. Such a strategy is called eco-feedback in (Tang and Bhamra, 2008). By providing feedback on the environmental impact of a specific action, the user will modify it behavior to a more environmentally friendly one. Nevertheless, this strategy is effective if the user is responsive for information. And this happens only during moments like installation or learning and training.

For usage moments, implementing intelligent systems, which regulate their operating conditions depending on ambient values, are of high interest. It seems less effective to influence the learning phase since the aim of this solution is to modify product behavior without user realizing the modification.

For the decommissioning moment, expand product life is effective. Yet, the implication of other moments in the realization of such an event is important. Cleaning and Maintenance, as well as Upgrade are of importance to prevent for part wear and for anticipating user future needs.

In addition to the previous example, thinking in terms of moments helps considering strategies outside the ecodesign area. Energy management acknowledges that installation parameters are unlikely to be modified if user is not dissatisfied by the actual parameters (US EPA, 2008). Implementing the most environmentally effective settings directly on the product is an important strategy to consider for decreasing the environmental impact of installation.

Since instruction manuals are a weak source of learning and training on product, (ISO, 2011) proposes to design auto-descriptive systems. If the auto-description is extended to environmental information, we can expect to enhance knowledge and skills on environmental issues, and thereby decrease the impact of learning and training moment along with the usage moments.

The identification of the most impacting moments can help to identify relevant general strategies and associated technical solution. It can also provide a mapping of most impacting parameters and moments in order to find directly an ecodesign solution by prioritizing the most impacting parameters of the product, of user behaviors or of the combination of both to perform a moment.

3.4 Case Study

We tested our proposal on the ecodesign of a refrigerator use phase, which is one of the significant environmental aspects of the product (Faberi, 2007). The data collection on the use phase took place in a city of the south state of Brazil, Parana.

The first step to perform is to identify all the moments that can occur during the use phase, along with detailing the usage moments, from the users and designers points of view. The product parameter here will be related to the energy consumption depending on user parameters over the different moments.

The usage moments have been detailed according to the following parameters and events:

- Product parameters: Indoor temperature, Outdoor temperature, Short door opening, Long door opening, Food transfer, Defrost, Unplugged;
- Usage moments depending on user: Breakfast, Lunch, Dinner, Snacking;
- Usage moments not depending on user: Summer, Winter.

The others moments identified are: maintenance and storage.

The following moments will not be considered: Upgrade and Installation and Learning.

The second step is to evaluate user parameters. Ten refrigerator users have been interviewed. The interview was face to face and semi-directive. It lasts from 20 to 30 minutes and was perform in a academics infrastructure (a classroom at the Federal University of Technology of Parana). Their selection has been made to represent the socio-economic profiles of the Brazilian region Parana, based on the data from the 2010 census. The interviewer grid was constructed in order to identify the value of product parameters associated to every moment of the use phase of the refrigerator. For example, every time an user mention a door opening, the interviewer asked if it was a short door opening (less than 5 to 10 seconds) or a long door opening. A more precise response was initially expected but no one was able to assess the time spent with the door open. All the data have been transformed in order to fit into the scenario grid. In order to depersonalize the data, 3 profiles were defined (which does not represent a particular user): an average profile, a minimum profile and a maximum profile. The following template – Figure 3 – was defined according to: the list of moments and the product parameters related to product environmental impact over the refrigerator use phase.

	Usage winter		Usage Summer		Breakfast		Lunch		Dinner		Checking fridge content		Shopping		Snacking		Storing		Maintenance	
	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit
Frequency over lifetime																				
Time duration of 1 iteration	6	months	6	months														day		
Indoor temperature		°C		°C																
Outdoor temperature		°C		°C																
Long door opening						unit		unit		unit		unit		unit		unit				
Short door opening						unit		unit		unit		unit		unit		unit				
Food transfer						kg		kg		kg		kg		kg		kg				
Defrost																	1		1	
Unplugged																	1			
Spare part 1: Sealing																				unit
Spare part 2: Light bulb																				unit

Figure 3: Template to be documented with the data from the 3 profiles defining in rows the environmental inputs and outputs and in columns the use phase moments.

After defining a functional unit to be able to compare and balance the data from the interview (especially for infrequent moments like maintenance), i.e. “Preserving the food in the refrigerator of a household over a year”. An environmental assessment of the use phase was performed according to the environmental single score indicator eco-indicator 99.
The Figure 4 shows the differences between the three profiles, according to environmental impact, in the product view:

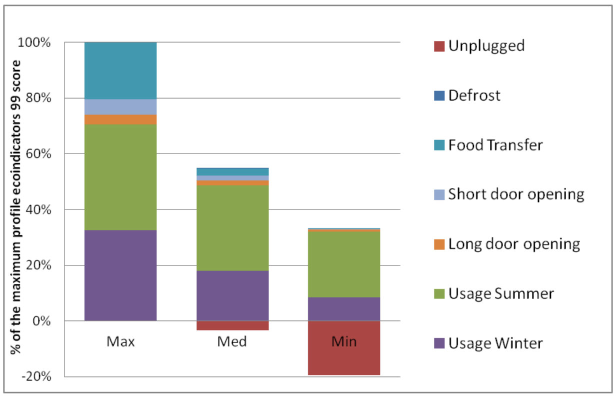

Figure 4: Comparison of the environmental impact (eco-indicator 99) of the three user profiles according to product parameters

The Figure 4 shows that even though there is a significant difference in magnitude between the profiles, the most important contributors to the environmental impact are the refrigerating functions during summer and winter. Another interesting fact from this assessment is that food transfer is highly significant for the maximum profile.

The difference between winter and summer usage profiles can be explained by the difference between the indoor and outdoor temperatures. It is due to an outdoor temperature in winter varying from 0°C in the minimum profile (for houses in the countryside and in altitude) and 24°C for the maximum profile (for apartment in the city with a small heating system). Although in the minimum case, the outdoor temperature is more stable during the year, and the indoor temperature is lower.
The Figure 5 represents the difference of contributors to environmental impact in designer and user views for the maximum user profile. The designers view is characterized with product parameters (like food transfer) and the user view is characterized with moments (like shopping).

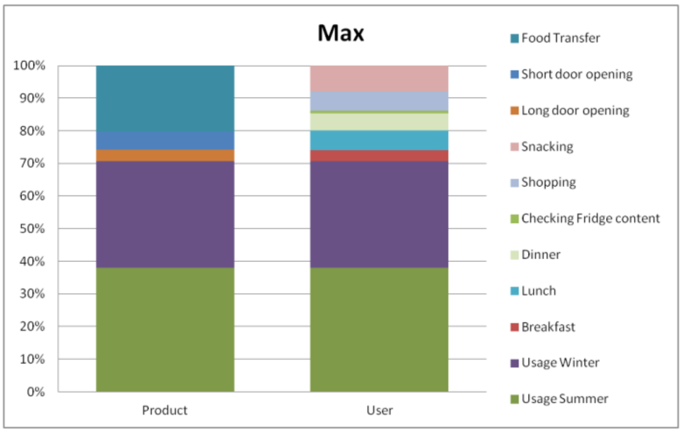

Figure 5: Maximum profile environmental impact (eco-indicator 99) defined by product and user parameters

The Figure 5 shows that designers and users share a partial view on the product environmental impact (first contributors are usage summer and usage winter). Nevertheless, for user, the third most impacting moment is snacking: it is very frequent (more than twice a day) and requires food transfer of a high volume (especially transfers of liquids like soda and water).

Based on these graphics, 3 ecodesign principles can be identified for the refrigerator redesign.
The environmental impact of the food transfer is highly dependent on user interaction with the fridge. An informative strategy, that can be implemented in the learning phase, could be adequate : for example with a sticker, near the door handle of the fridge, remembering the user to think about what he exactly needs to pick out, and about the transfer of hot or warm content into the fridge. A focusing on snacking can be of interest in the case of maximum profile.
For the main environmental contributors (summer and winter usage), an initial setting on the most adequate indoor temperature (6°C to 8°C) at the moment of installation can be effective. Most of the users will not modify it.
If important changes are expected for indoor temperature, especially in Parana where few heating and cooling systems are installed, a more efficient compressor to both middle temperature (like 25°C) and cooled one (10°C) can be environmentally beneficial.

4 DISCUSSION

Scenario implementation in design activities is already used, especially for information technologies, innovative product and extreme environment exposure product. This formalism of future user interactions is a way to check the robustness of product design to fit use.
In the case of ecodesign, picturing the future of the product is one of the main challenges. Use scenario is a formalism that suits design activities but also environmental assessment. If environmental expert identifies key moments and key parameters of the use phase, a scenario evaluation can make a powerful support for identifying contributors to environmental impact, in terms of user and product parameters. The three requirements for ecodesign of use phase are fulfilled with the adjustments made on moments' identification.
The sub-division into moments makes it easier to think about the entire use phase and not only on the first instants of the product use (installation and learning). The creation of habits during usage is very important for ecodesign, because after these moments, active design interventions are less effective.

By precisely defining when each different moment starts, and what kind of intervention can be made, a wider range of strategies can be implemented on product.
This formalization applied on the use of fridge in Brazil also supports design activities by highlighting that, in most cases, the environmental impact is dominated by the context parameters (summer and winter usage) and not by users actions (door opening and food transfers).
Tang and Bhamra (2012) had some similar conclusions for the use of refrigerator in the United Kingdom-UK. But in their context, one of the key moments of the use phase is the preparation of lunch bags, a moment that was not revealed in the Brazilian context.
This conclusion can lead designers to the development of more effective technology that will be adapted according to moment environmental characterization (developing a drawer for lunch bag preparation for the UK or a more effective compressor for high difference temperature between indoor and outdoor for Brazil).
Regarding the data collection method for scenario creation, the main pitfalls are the quantity and the quality of data. By using interviews in the case of the refrigerator, we had a fair amount of data, but some moments of the use phase were not vivid enough to be identified through this method. A complementary method for data collection in this case can be the task evaluation through video recording with the new product interface. By coupling the task evaluation with interviews, we would be able to have an overview of all the moments of the use phase.
As any user based formalization, use scenario quality largely depends on the chosen users' data. With poor quality data, design decision can be made in the wrong direction. The environmental assessment adding uncertainties due to internal weakness (Reap et al., 2008), poor quality scenario evaluation can point out moments that are not that important in reality.
To sum up, using scenario in ecodesign will have the same flaws as in traditional design. An additional source of weakness is the extension of the conclusion for the current product use to the use in five, ten or twenty years. In the case of the refrigerator, habits and practices are quite established, so there are few reasons to change the scenario parameters. Nevertheless for more innovative products, an additional effort of prospection should be made to be able to have robust data on the last moments of the product use (like decommissioning).
Only with a robust evaluation of the environmental assessment of the use moments, we will be able to develop adequate ecodesign strategies for the use phase.
Even though use phase is a significant contributor to environmental impact of the electric and electronic product, to be compliant to the ecodesign philosophy, an evaluation of potential impact transfers should be performed. An improvement of the use phase environmental impact should not be done if it increases the impact of other life cycle phases. Applying scenario for use phase improvements should always been balance with it consequences, if any, on other lifecycle phases.

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