

## 3.2 Upgradable system opportunities in order to rationalize materials

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### Abstract

Design of more sustainable products is a fundamental priority in our society. New opportunities for facilitating the dissemination of the remanufacturing approach or the Product-Service Systems, or for increasing the lifetime of product (three ways for rationalizing of materials) are proposed by the integration of upgrades, functional enrichments brought to the product. This paper aims to show the need of product upgradability through a concrete study focused on four hypotheses:

- H1- Upgradability concept requires a potential of disposed devices which still works.
- H2- Upgradability concept requires a need for adaptability of product towards user needs.
- H3- Upgradability concept requires a need for adaptability of product versus the competition.
- H4- Upgradability concept is consistent with an accumulation of problems.

The first results show the necessity to consider a new sort of "evolutionary" products for sustainability: Innovations with multiples upgrade cycles.

### Keywords:

Sustainable innovation, Upgrades, PSS, Remanufacturing

## 1 CONTEXT

Our society is increasingly concerned by environmental issues. The accelerating rhythm of products renewal causes accelerated exploitation of materials and energy. Today, with an annual consumption of raw materials of approximately 60 billion tons [1], the world population consumes about 50% more natural resources than 30 years ago [2]. In OECD countries, the domestic waste stream has increased by 40% in volume between 1980 and 1997 [3].

These current patterns of consumption and mass production are no longer compatible with sustainable development, a development that meets the needs of present generations without compromising the ability of future generations to meet their own needs [4]. To remedy this, it is necessary to imagine new paradigms of production / consumption, such as the "post mass production" [5] or the "parsimony" paradigm [6].

### 1.1 Upgrading and Remanufacturing

In order to contribute to the rationalization of the use of materials some recent works focus on the management of different "end of life options" for a product (or parts of a product) [7-10]. There are three main different end-of-life strategies: reuse, remanufacturing and recycling.

Remanufacturing is "the process of restoring discarded products to useful life" [11] or "the process of returning a used product to at least Original Equipment Manufacturer performance specification and giving the resultant product a warranty that is at least equal to that of a newly manufactured equivalent" [12]. In our past research works [13], a more proactive and global approach of designing remanufacturable systems has been defined: the MacPMR methodology of designing remanufacturable systems (which consists of six tasks [14]). In this method, a remanufacturable system is characterised by several cycles of use, several "meetings" between the customer/user and the product improved step by step with the integration of upgrades [15]. An upgrade is

defined as a functional enrichment brought to the product. These upgrades brought to the product, at each change of cycle, increase the attractiveness of a remanufacturable system for the customer. This added attractiveness, brought dynamically and in step with integrated upgrades, is an opportunity for facilitating the dissemination of the remanufacturing approach.

### 1.2 Upgrading and Lifetime of product

More generally, with these upgrades the lifetime of any system can be increased. Why? Because, it becomes possible to manage the two key reasons why users discard products [7]: (a) Physical Life Time (PLT) [lifetime related to reliability] "the time until a product breaks down" and (b) Value LifeTime (VLT) [lifetime related to the obsolescence] "the time until a product is disposed when its performance, functionality or appearance cannot satisfy customer's needs any more, although the product itself might work well." [7]. The concept of "Utility Value" (UV) which reflects the "whole time" when the product has value [16] is similar: it depends both on "physical causes", and "value causes". The integration of upgrades can be made by a distributor/retailer, by a technician at home, by user (in "plug-and-play" way), etc., and not necessarily with remanufacturing operations. Then the reliability problems could be managed with the upgraded modules (when upgraded modules and no reliable modules are the same) or with a specific maintenance agreement. So upgrading is a way to increase the lifetime of any system. And delaying the replacement of a product is a strategy for rationalizing materials.

### 1.3 Upgrading and PSS

Another way for rationalizing materials is the dematerialization principle. Considering multiple cycles with integration of upgrades implies "upgradability services" and these added services could conduct manufacturers to switch offering more services, more precisely "Product-Service Systems" (PSS): "A product-service system is a system of

products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customers' needs and have a lower environmental impact than traditional business models" [17]. Three types of PSS are defined related on the share of services in these new offers [18]: product-oriented PSS, use-oriented PSS and result-oriented PSS. Increasing the rate of the product use by the servicing of the offer represents another strategy for rationalizing materials. But it's hard to propose new service with added value: it's one of the reasons why PSS has difficult to generalize.

Aren't the upgrades a new potential to sell "addictive" services? Indeed, the integration of upgrades (functional enrichments brought to the product) could increase the attractiveness of a system for customers, step by step during its life. Therefore « upgradability services » is an opportunity for industrial companies who want to switch to offers with more services, and for the dissemination of PSS.

More generally, upgrading is an opportunity for the diffusion of sustainable innovation rationalizing materials, related to three points-of-view:

- end-of-life management point-of-view (dissemination of remanufacturing)
- extended lifetime point-of-view
- servicialization point-of-view (dissemination of PSS)

In this context, the issue of the need of product upgradability is very important and earns to be treated. That's why after presenting the upgrading opportunities for rationalizing materials in section 1, hypotheses to measure the real need of product upgradability are developed (section 2). This study is based on an important survey completed by a qualitative approach (section 3). The results which show the need of product upgradability are presented in section 4. Conclusions are discussed in section 5.

## 2 ISSUES

In marketing, there is a vast literature on how to sell products, the reasons for purchase, the satisfaction or the segmentation of customers. But very few papers explain the motivations and disincentives influencing the replacement decision.

The motivations influencing the replacement decision can be distributed in three categories [19]: product desired characteristics, situational influences, consumer characteristics. The parameters of product perception can be ordered in two dimensions: hedonic and utilitarian [20]. satisfaction drives fidelity [21]. Finally, three types of disincentives to repair a product are identified: financial cost/ temporal cost / risk [22].

In disincentives influencing the replacement decision, seven criteria for consumer-product attachment are identified: memories, self-identity, utility, life vision, enjoyment, market value, and reliability. Only the criterion "Memories" is positively related to the degree of consumer-product attachment [23]. A psychological cost, defined as the feeling of waste, has been identified [24].

An exploratory study has been done on the household products recently replaced by some people. This study was

based on qualitative (45 persons) and quantitative (90 persons) questionnaires. The goal was to understand better (1) the reasons which motivate product replacement decision, (2) the reasons which curb product replacement decision and (3) the motivations and disincentives to repair. The results are presented in the table below (Figure 1)

. Main Motivations for Product replacement	
The replaced device no longer fulfilled its main function	reason cited spontaneously by 43.2% of respondents; importance in the decision = 5,7 / 7
Willingness of more performance	43,2%; imp. = 5,4 / 7
Willingness of more Options	37,8%; imp. = 5,3 / 7
Willingness of more convenience	35%; imp. = 5 / 7
Because of Visual degradation	18,9%; imp. = 3,7 / 7
. Main brakes for Product replacement	
Price of the new device	64,9%; imp. = 5,1 / 7
Attachment to the old device	18,9%; imp. = 3,3 / 7
. Main Motivations to repair	
Low cost reparation	24,3%
Ecological motivation	16,2%
. Main brakes to repair	
Too expensive/value of device	37,8%
Uncertainty on the quality and the result	21,6%
Repairer hard to find	16,2%

Figure 1: Exploratory study results.

In this study on the recent replacement of a small appliance, two products are more frequent: vacuum cleaner & coffee machine. Even if there are some differences in the results between the different household products, this survey shows the following trends:

- 1. Disincentives for product replacement and motivations and disincentives to repair are mainly related to the price (of the product or the reparation).
- 2. Some devices that still work well are disposed (only 43% have a problem of main function).

From these results, the issue of replacement of products can be focused on the reasons why some devices that still work well are disposed. We make four hypotheses on the causes of product replacement which could also represent potentials in the future for the upgradability of products:

- H1- Upgradability concept requires a potential of disposed devices which still works.

When the device still works:

- H2- Upgradability concept requires a need for adaptability of product towards user needs: it is distinguished changing situation in the user's life (moving, animal adoption ...), weakening performance (declining primary function) and problems including reliability.
- H3- Upgradability concept requires a need for adaptability of product versus the competition.
- H4- Upgradability concept is consistent with an accumulation of problems.

## 3 RESEARCH METHODOLOGY

The original positioning of our article is that we don't want to add another theoretical paper but a concrete study with multi-country (France, Germany, Spain) point-of-views on a specific type of product, the electrical household devices.

To validate the need for upgradable products, two types of study have been conducted:

- a large quantitative survey related to the four hypotheses to quantify the product replacement causes
- a qualitative study (based on focus group) related to the hypothesis 3 to validate the “versatility” of consumers faced with the introduction of innovations.

### 3.1 Questionnaires

The first study is based on a quantitative survey as large as possible on the replacement causes based on 480 questionnaires of 50 items (Figure 2). This survey focuses on two specific products: the vacuum cleaner and the espresso machine, respectively a “drudgery” and “pleasure” device. To consider the context of purchase, this study was conducted in two types of retailers (supermarkets and specialized stores) and in three countries with different consumption habits (France, Germany, and Spain). The questionnaires were administered to people in real situation of product replacement.




	Supermarkets	Vacuum Cleaner	40 questionnaires
		Espresso Machine	40 questionnaires
	Specialized stores	Vacuum Cleaner	40 questionnaires
		Espresso Machine	40 questionnaires
	Supermarkets	Vacuum Cleaner	40 questionnaires
		Espresso Machine	40 questionnaires
	Specialized stores	Vacuum Cleaner	40 questionnaires
		Espresso Machine	40 questionnaires
	Supermarkets	Vacuum Cleaner	40 questionnaires
		Espresso Machine	40 questionnaires
	Specialized stores	Vacuum Cleaner	40 questionnaires
		Espresso Machine	40 questionnaires

Figure 2: The structure of the quantitative study.

The questionnaire is structured as follows:

- Set 1: questions around the replaced product (purchase, use, disposal)
- Set 2: questions about technical problems of the replaced product which push for its replacement
- Set 3: questions about the new features proposed by the market which encourage to purchase a new product
- Set 4: questions about the consumer and his life contributing to the product change

The goal is to distinguish different categories of behavior, by comparing these fields of questions and responses on the four hypotheses.

### 3.2 Focus Groups

This quantitative study was supplemented by a qualitative approach on a vacuum cleaner, based on a series of focus groups to trace the evolution of consumer choice criteria related on their experiences and knowledge of the new products. The goal is to better understand why people change products even if they still work perfectly.

In a first step, the participants imagine a list of innovations they want to integrate in the future product and they individually hierarchize them.

In a second step, 11 specific innovations illustrated by the Figure 3 are presented to the group. Then, each participant hierarchizes the innovations desired again, including the list of innovations imagined by the group and the 11 innovations proposed.

The last step consists in a comparison of the innovations chosen the two times, and their ranking. The “versatility” of consumers about the innovations desired depends on the variance of the results.



Figure 3 : Four innovations among the 11 proposed to the group.

## 4 EXPERIMENT AND RESULTS

### 4.1 Results of the quantitative survey

The analysis of the first results of the survey is presented below. In a first part, a comparison between the studies related to the vacuum cleaner and the espresso machine is proposed. In a second part, the comparison focus on the differences between the results obtained in France and in Germany (the survey in Spain is not completed) for vacuum cleaner, to show the importance of the cultural context.

#### 4.1.1. Comparison between Vacuum Cleaner and Espresso Machine

For the vacuum cleaner and the espresso machine, more of 50% of products are disposed whereas they still work (Figure 4). This result confirms the potential for upgrading identified in the exploratory study: not all products are discarded because they are out of service (hypothesis 1), and so functional improvements could respond to these dissatisfactions in order to extend the lifetime of products.

For the espresso machine, classified more like a “pleasure” product than vacuum cleaner, more products are discarded even if they still work.

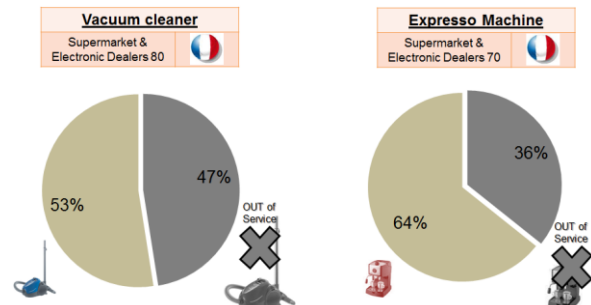


Figure 4: Hypothesis 1 - vacuum cleaner vs. espresso machine.

When the device still works, “the reasons related to adaptability or technical problems of the old device which

push for its replacement” and “the reasons related to new features proposed by the market which encourage purchasing a new product” appear with a certain importance (hypotheses 2 & 3 - Figure 5). Upgrades could satisfy these two types of replacement causes. For the espresso machine, it seems that the reasons related on the benefits’ promises of the new products are the majority. It’s not the case for vacuum cleaner.

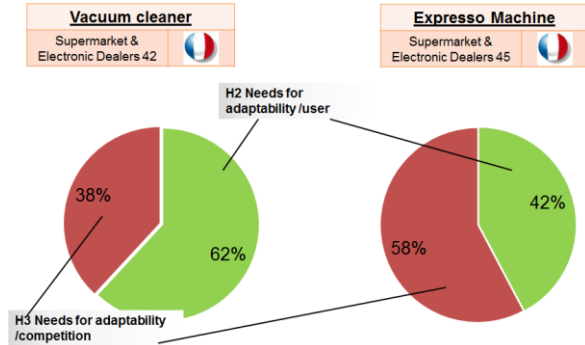


Figure 5: H2 & H3 - vacuum cleaner vs. espresso machine.

Focusing in the reasons related to adaptability or technical problems of the old device which push for its replacement (hypothesis 2), the problems including reliability are more prevalent than two others causes (Figure 6). A weakened performance on the main function represents only 11%. The share of the changing situation in the user's life (moving, animal adoption ...) is more important for vacuum cleaner.

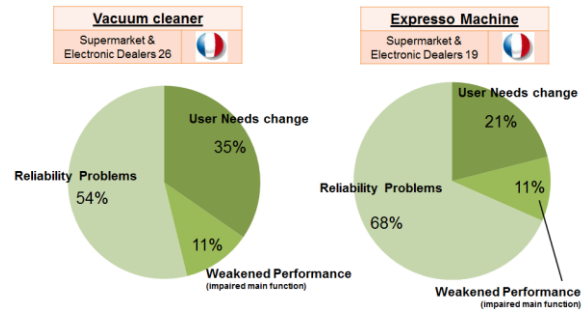


Figure 6: Focus on hypothesis 2 - vacuum cleaner vs. espresso Machine.

The Figure 7 shows the importance of problems accumulation related to: problem of suction (vacuum cleaner)/coffee quality (espresso machine), accessories problems, reliability problems, discomfort of use, handling problems, and maintenance problems. The concept of integrated functional improvements seems a good solution to correct dissatisfactions at the earliest date (hypothesis 4). For the espresso machine, the accumulation of problems is less important: the major cause identified is the quality of the delivered coffee. In fact, it's a product for “pleasure” and requiring few handling actions (it's a “press-button box”). So, the focus is on the quality of the delivered coffee. Consumers have a more hedonic approach. The upgrade concept is interesting for the coffee quality to follow the technological and “coffee fashion” changes, notably if you consider the possibility of different modules or accessories.

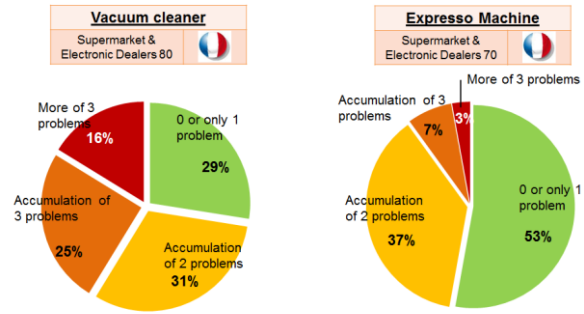


Figure 7: H4 - vacuum cleaner vs. espresso Machine.

4.1.2. Comparison between France and Germany (Vacuum cleaner)

The comparison between the results obtained in France and in Germany (the survey in Spain is not completed) shows a bigger share of disposed devices still working in Germany than in France (hypothesis 1 - Figure 8). The share of the reasons related to new features proposed by the market which encourage purchasing a new product are more important too (hypotheses 2 & 3 - Figure 9). German consumers seem to buy more expensive devices and to be more demanding than French consumers. Maybe that's why they have less problems of reliability (Figure 17) while they verbalize more problems (hypothesis 4 - Figure 11). The importance of the share of a weakened performance on the main function could be explained by the fact that the North European countries have more carpeting (Figure 10). The results are sensibly different but the four hypotheses on the need for product upgradability are validated too.

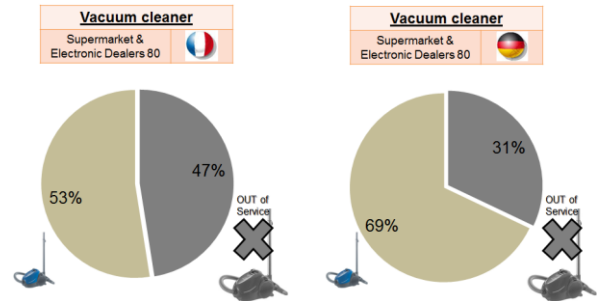


Figure 8: H1 – France vs. Germany.

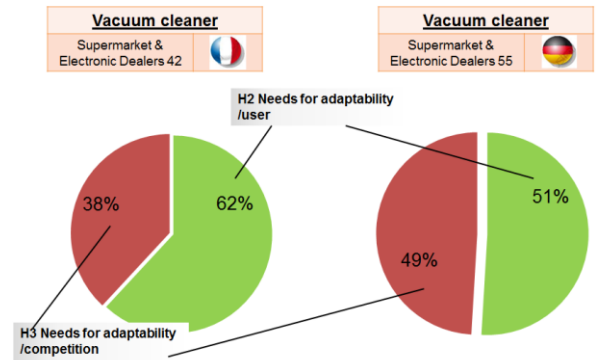


Figure 9: H2 & H3 – France vs. Germany.



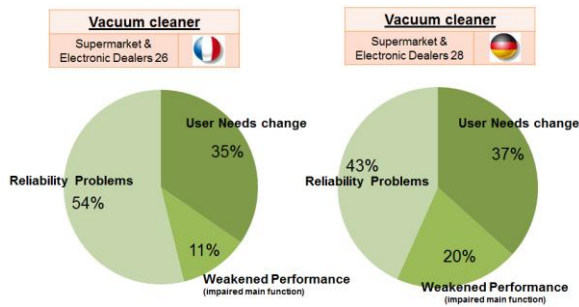


Figure 10: Focus on H2 - France vs. Germany.

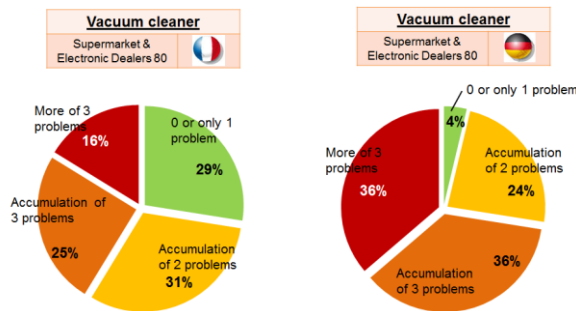


Figure 11: H4 - France vs. Germany.

4.2 Results of the Focus Groups

To complete the survey results, particularly on the Hypothesis 3, two focus groups on a vacuum cleaner have been organized to trace the evolution of consumer choice criteria related on their experiences and knowledge of the products. For confidential reasons, results are presented in term of “anonymous innovations”.

From the first focus group (six persons), the results (Figure 12) show a strong variance between the two parts of the experiment. Only six innovations verbalized by the group are formulated twice (marked in yellow and green color) and only two at the same ranking level (marked in green color). The second part of this table shows that 11/18 innovations desired come from the 11 innovations proposed (see Figure 3).

From the second focus group (five persons), the results (Figure 13) show only two innovations formulated twice and none at the same ranking level. 12/15 innovations in the second part come from the 11 innovations proposed.

	hierarchy of evolutions verbalized by the group	hierarchy of evolutions after the presentation of innovations proposed
person 1	1 innovation n°4	1 innovation n°1
	2 innovation n°1	2 innovation proposed n°3
	3 innovation n°2	3 innovation proposed n°4
person 2	1 innovation n°6	1 innovation proposed n°2
	2 innovation n°5	2 innovation proposed n°5
	3 innovation n°3	3 innovation n°3
person 3	1 innovation n°3	1 innovation n°1
	2 innovation n°4	2 innovation proposed n°6
	3 innovation n°1	3 innovation proposed n°2
person 4	1 innovation n°3	1 innovation proposed n°1
	2 innovation n°7	2 innovation proposed n°7
	3 innovation n°8	3 innovation n°3
person 5	1 innovation n°5	1 innovation n°1
	2 innovation n°3	2 innovation n°3
	3 innovation n°1	3 innovation proposed n°1
person 6	1 innovation n°2	1 innovation proposed n°8
	2 innovation n°3	2 innovation proposed n°2
	3 innovation n°9	3 innovation n°1

Figure 12: Results of the focus group 1.

	hierarchy of evolutions verbalized by the group	hierarchy of evolutions after the presentation of innovations proposed
person 1	1 innovation n°6	1 innovation proposed n°9
	2 innovation n°5	2 innovation proposed n°3
	3 innovation n°1	3 innovation proposed n°1
person 2	1 innovation n°6	1 innovation proposed n°3
	2 innovation n°10	2 innovation proposed n°10
	3 innovation n°5	3 innovation n°10
person 3	1 innovation n°5	1 innovation n°10
	2 innovation n°10	2 innovation proposed n°8
	3 innovation n°1	3 innovation proposed n°1
person 4	1 innovation n°11	1 innovation n°2
	2 innovation n°1	2 innovation proposed n°1
	3 innovation n°12	3 innovation proposed n°6
person 5	1 innovation n°5	1 innovation proposed n°10
	2 innovation n°6	2 innovation proposed n°9
	3 innovation n°12	3 innovation proposed n°3

Figure 13: Results of the focus group 2.

These results show the “versatility” of consumer choice criteria related on their experiences and knowledge of the potential innovations. For certain persons, these new features proposed by the market are sufficient to encourage them purchasing a new product. This population is included in the share entitled “need for adaptability of product /competition” (hypothesis 3).

5 CONCLUSIONS

In this paper, the necessity to consider innovations with multiples upgrade cycles for rationalizing of materials is showed.

The first results of the survey related to the replacement of the vacuum cleaner and the espresso machine show that more of 50% of products are disposed whereas they still work (hypothesis 1 validated). In this park of discarded devices which still works, the replacement reasons concern both the “adaptability or technical problems of the old device which push for its replacement” (hypothesis 2 validated) and the “new features proposed by the market which encourage purchasing a new product” (hypothesis 3 validated). This survey also shows the importance of problems accumulation and/or the variety of these problems (hypothesis 4 validated). The need of product upgradability is validated.

More precisely, for the espresso machine, classified as “pleasurable product” (vacuum cleaner is more identified “house work”), and in the cultural context of Germany, the share of product replacement due to the “new features proposed by the market which encourage purchasing a new product” are more important. The results of two focus groups confirm the “versatility” of consumers in front of the potential innovations proposed to them, which can be sufficient to encourage purchasing a new product. These last results show different determinants (type of product, cultural and competition context, consumer) to define the upgrade integration strategy of an upgradable system. Some issue arise: How many upgrades must be integrated? What types of upgrades? What upgrade integration rhythm?

Faced with the changes in competitors and the evolving needs of customers, the product is currently designed as a too static artefact. We claim the necessity of a new sort of “evolutionary” products able to adapt themselves gradually to the evolving requirements of users by upgrades integration while improving radically the environmental performance on all life cycles (see Figure 14): compared to a conventional product which is changed every six years, an upgradable product with functional enrichment brought more regularly allows an important material consumption reduction. With the

possibility to upgrade the product, the lifetime of the product may be longer, and new possibilities to provide more services that provide value to the customer and money to the company appear.

Faced with these new issues (rhythm of upgrade integration, business model changes, improvement of environmental impact on several cycles ...), this paper shows the necessity to develop a new design methodology (Design for upgradecycling).

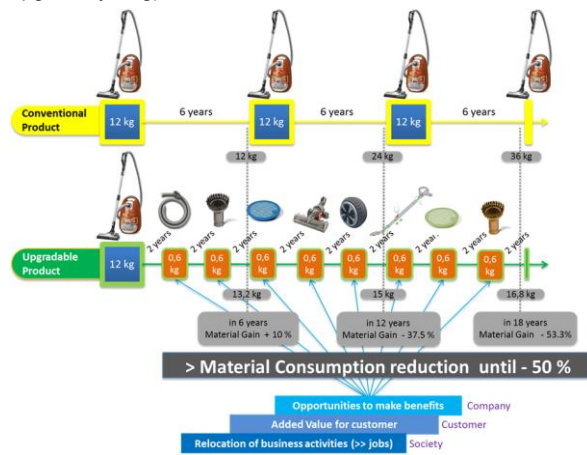


Figure 14: Sustainable innovation with upgrade cycles.

## 6 ACKNOWLEDGMENTS

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