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A framework to evaluate eco-innovative concepts

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Résumé — Eco-innovation is the development of products, services or processes which bring value to the customers and the company while reducing significantly the environmental impacts. Within the eco-innovation process, the evaluation is crucial. It is defined as the stage where a proportion of concepts are selected for further development. Nevertheless systematic methods for the early evaluation of ideas are scarce, above when it requires to assess the concepts with environmental or social criteria. This paper is focused in the evaluation stage and proposes a framework to qualify and evaluation eco-innovation concepts generated during the eco-ideation stage. This framework is based on a systemic thinking, so the design team must qualify the concept at different levels (users, value chain and society) in order to limit the potential rebound effects, and is linked with the eco-ideation method previously developed in order to allow the maturation of the concepts and the iterative process between the generation and evaluation stage. As this paper is a first step of the research process, the framework is tested on a real case study coming from a French start-up company.

Mots-clés — evaluation, eco-innovation, concept, sustainability

I. INTRODUCTION

Environmental, and more broadly sustainable stakes have been explored and integrated to engineering design methods and practices by scholars and industrial practitioners for nearly three decades. Ceschin and Gaziulusoy [1] reflect upon the evolution of Design for Sustainability methods, from insular product-oriented to large systemic views. They also stress that if the focus was initially techno-centered, it moved to a more human-centered attention, for instance related to the question of sustainable consumption [1].

Close to Sustainable Product Service design or Design for Sustainable Social Innovation, eco-innovation strives to develop products, services or processes which bring value to the customers and the company while reducing significantly the environmental impacts [2]. Eco-innovation is also about integrating sustainability to the development of a business model in cooperation with partners of the value chain, spreading a life cycle thinking throughout all the business operations [3].

In the so-called Fuzzy Front End of Eco-innovation (FFEI) [4], design team generate potentially eco-innovative concepts, in the "eco-ideation" stage. In previous research work, we have seen that although tools for helping environmental evaluation were developed, few of them are centered on early phases of an eco-innovation process. In this paper, we are interested in research question as follows: *"What support to qualify the sustainability of eco-innovative concepts in the FFEI ?"*

In section 2, a synthesis of literature on evaluation of concepts derives from three lenses: environmental, innovation and business management. In section 3, we propose a framework to qualify eco-innovative concepts and help design teams make an upstream qualitative, but yet informed, judgment on concepts that are promising from a sustainability perspective. The framework is applied to the creative outcomes of an eco-ideation workshop based on a real startup company case, dealing with the development of an aquaponics solution of filtration for aquariums. Section 5 discusses on how the framework differentiates from what has already been developed and concludes on perspectives of evolution and testing.

II. A TRIPLE PERSPECTIVE ON THE EVALUATION OF ECO-INNOVATIVE CONCEPTS

According to O'Hare et al. [5] (2014), eco-innovation relies on three main pillars of knowledge that are engineering/innovation; business management and environmental science. We hence structure the literature review on the evaluation of concepts with similar lenses: (1) Evaluation of concepts seen from an environmental or sustainability perspective; (2) Evaluation of sustainability of concepts based on their business models; (3) Evaluation of concepts seen through the innovation lens.

A. *Environmental perspective on the evaluation of concepts*

Life cycle assessment [6] (ISO 14044: 2006) is the recommended method to assess the potential environmental impacts associated with products and services. It is however acknowledged that, in the early phases of development like FFEI, concepts are poorly formalized and encapsulate too few details to achieve this type of quantitative assessment [7]. In order to evaluate eco-innovative concepts based on Green House Gas emissions, the "Pain Gain Tool" proposes to qualitatively map the reduction of environmental impact (namely « Gain ») and the level of implementation difficulty for the company (namely « Pain ») [8]. Lopes-Forniès et al. [9] combine creative and environmental dimensions into four evaluation criteria: Newness, Utility, Feasibility and Environmental Factor. Each criterion is split into four scoring levels. The environmental scoring corresponds to a GWP (Global Warming Potential) difference between the new concept and the reference.

Telenko and Wood [7] reckon that intuitive evaluation of sustainability by designers can be an efficient support to the FFEI, and especially in concept generation. Intuitive evaluation was tested on sustainability and innovativeness perception of 8 environmentally conscious products based on a 5-point Likert scale, and compared to a simplified LCA for each product. The authors conclude that intuitive sustainability metrics and evaluation methods are still needed to "*embrace the complexity, variety and scales of impacts rather than rely on single metrics*".

We now provide two examples of evaluation methods dealing with a wider issue of sustainable value creation. DRim (Design & Responsible innovation method) aims to support the development of sustainable innovations [10]. The method encourages to develop a critical attitude along three main axes: (1) Reflect upon the needs of people; (2) Measure the direct impacts of innovations; (3) Consider indirect consequences of innovations. A strong emphasis on direct impacts and indirect consequences is also placed in the Sustainability Value Creation approach [11]. It is based on the combination of value creation with sustainable development objectives. Value creation activities cause (1) micro-economic effects at the value chain level; (2) macro-economic effects at the scale of a sector, a region or even a country. Finally, the Eco-i manual [3] introduces several steps of generation and evaluation related to the market, value chain and business model level. The core objective is the business model design. The outcome of the approach is a consolidated set of business model options. An evaluation of the eco-innovation process in itself is also mentioned in the "Review" section.

B. *Business model perspective on the evaluation of concepts*

Obst [12] takes an interest in the characterization of the sustainable performance that can be deployed at the business model level, by means of 15 « Sustainability Performance Indicators » (SPI) positioned on the Business Model Canvas. Hall, Sheperd and Wadud [13] propose an assessment method for electromobility business models. The goal is to qualitatively evaluate the termed "power of the business model", after interviewing main stakeholders to capture their main values.

In the Business case for Eco-innovation [14], it is provided illustrations of financial, social and environmental benefits of eco-innovation for 8 companies worldwide. Each full case is recorded on one page against: business growth since the creation of the activity; business strategy; business model; product innovation (material, usage and quantified impacts reductions); process innovation; organizational structure (distribution, retailing and costs savings). In the sample, half of the companies are located in Europe, one in the USA, two in Latin America and one in Africa.

C. *Innovation and creativity perspective on the evaluation of concepts*

In the creativity and innovation field, scholars have thoroughly investigated methods and criteria to evaluate ideas generated during creativity sessions. The sessions are conducted individually or in group, with or without experts [15]. Ease of implementation and quantity of ideas also characterize the evaluation mode. The evaluation of ideas is often perceived as subjective and irregular [16]. Many criteria were developed to help practitioners evaluate ideas, among which newness and quality of ideas (Shah et al., 2003), feasibility or relevance [18]. In user-centered innovation, Yannou et al. [19] propose four criteria to evaluate the innovative potential of concepts: UNPC standing for pour Usability; Newness; Profitability; Concept.

Relying of the notion of management of immaterial for the evaluation of innovation "*that is being done*", Bertheau, Roche and Dufour [20] advocate for the idea of valuation, as an exploratory and creative exploration of value being created by project teams. As opposed to an external evaluation by the company or clients after launching on the market, the method is explicit, reliable and early. In the method it is however necessary to position the new business model in reference to the initial business model.

D. *Synthesis of the literature review*

In summary of the literature review, we stress several important notions for evaluating the sustainability of concepts being created in an eco-innovation process.

First, evaluation in early stages is indeed a *dynamic approach*, since value is being created in a series of loops between ideation and evaluation, see [20]. Second, the eco-innovation perspective requires a *local view* on the system that is under study, but also a *value chain view*. Third, in the early stages, one has to solve a *qualitative/quantitative dilemma*, meaning that quantitative analysis can hardly be conducted due to a lack of data and details of concepts being elaborated. Qualitative analysis seems more appropriate in this case. Fourth, the existing evaluation approaches clearly either give priority to the value created by the proposition (positive side, against one or several sustainability dimensions), or to the impacts generated (negative side most of the time). Lastly, regarding

sustainability, several authors drew attention to the fact that indirect effects or consequences of the proposition on society have to be taken into consideration. This leads to the proposition of a framework to qualify-or value- eco-innovative concepts as follows.

III. A FRAMEWORK TO QUALIFY ECO-INNOVATIVE CONCEPTS

A. Research method

Our research approach is in three steps. First we capture the description of the concept as well as the driving dimensions of sustainability in an initial proposition of a one-page template (Figure 1)

- The upper zone of the template consists in the user-centric description of the concept, which can be easily filled by designers.
- The middle zone informs about the value created for the key stakeholders and the main potential of reduction of environmental impacts specific to the case-study (for instance water or resource consumption). The environmental zone of the template involves the expertise of an eco-design practitioner.
- The lower zone deals with the evocation of indirect impacts due to the concept on the value chain, on society. It is facilitated by an environmental or a systemic expert.

Second, to demonstrate the value of the template, we consider the existing raw creative outcomes of an eco-ideation workshop, and aggregate the results into a sustainability-valuated concept. The workshop was conducted by the authors with 22 academic researchers in the context of the SIG Sustainable Design (Design Conference 2018). The case-study dealt with an aquaponics filtration system for private aquariums launched by a French startup company (Box 1). The goal of the workshop was to challenge the initial value proposition thanks to an eco-ideation toolkit [21]. Amongst the seven eco-ideation mechanisms (or heuristics) available in the toolkit, four mechanisms were implemented by four groups of participants, namely Innovate through Stakeholders, Sustainable consumption modes, Territorial resources, Biomimicry.

Box 1 : DESCRIPTION OF THE AQUAPONICS CASE-STUDY

	<p>The case study originates from a French startup company proposing natural filters for aquariums. Filters are composed of wood, coconut shell and clay pebbles. The principle is aquaponics filtration, involving an equilibrium between fish, bacteria hosted in the shell and the growing plant. The plant is cleaning the water that flows through the roots thanks to a water pump.</p> <p>The product was developed in an incubator and tested with a pet shop partner in 2017-2018. The filter is compatible with all types of open aquariums (round or straight) ranging from 5L to 30 L. 600 000 aquariums are sold each year in France. The filtration system is suitable for two goldfish (or 10 small fish). The initial value proposition is a change of water once every 6 months (against one change/month), and no use of consumables, i.e. filtering cartridges.</p>
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Source <https://cocoplant.co>

B. Construction of the template

Our proposition is an evaluation template useful for design teams in the practice of eco-innovation (Figure 1 **Erreur ! Source du renvoi introuvable.**). The evaluation of concepts in FFEI is firstly dynamic, and hence relates to the notion of "valuation" [20]. The proposition relies on main contributions from the state of the art, that is to say: (1) A local view on usage and benefits that can be expected by people; (2) The environmental performance, or potential benefit cannot be easily be approached quantitatively, but more likely in a qualitative manner; (3) A system view on eco-innovative concepts is important to hypothesize about their potential direct and indirect effects on value chain and on society. Lastly, we suggest that it is important to link eco-ideation and evaluation phases by tracing the generative method of the ideas in the template.

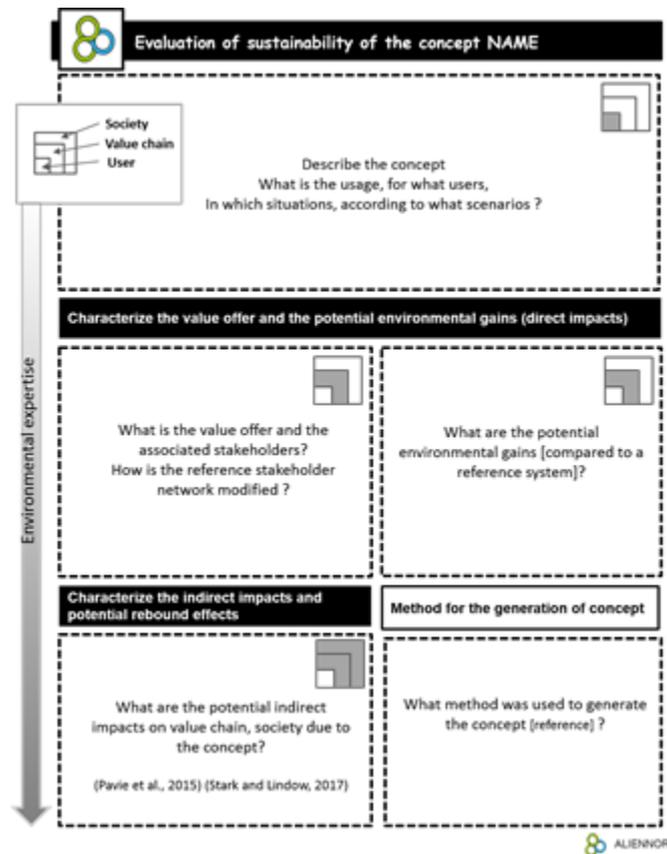


Figure 1 : EVALUATION TEMPLATE OF SUSTAINABILITY FOR ECO-INNOVATIVE CONCEPTS

C. *Implementation : case study on aquaponics filtration*

In this section, one applicative case of the template is provided for the aquaponics filtering system. For the first stage, we evaluate the 'baseline' concept as delivered by the startup in their first iteration. For the second stage, we formalize and evaluate the improvements of the concept generated with the eco-ideation mechanisms during the workshop. The ideas (bottom right) potentially help complementing the four zones of the template (Figure 2). This enables to qualify, at an early stage, the sustainable value of the concept and highlights future maturation steps and raising sustainability issues.

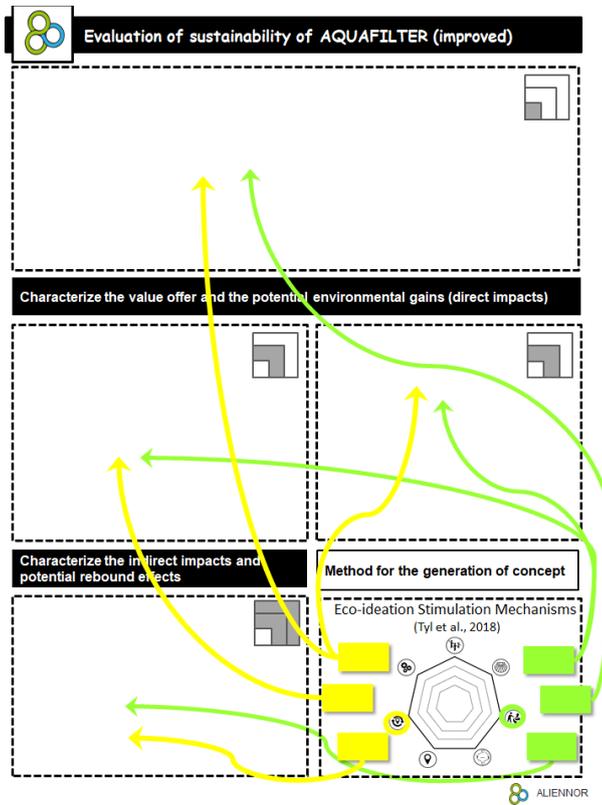


Figure 2 : DYNAMICS FOR EVALUATING THE SUSTAINABILITY OF THE ECO-INNOVATIVE CONCEPT



Figure 3 : EVALUATION OF SUSTAINABILITY OF THE SYSTEM (BASELINE)

We now exemplify the evolution of the concept after the eco-ideation session based on stakeholder thinking. Following [22] [23], the rationale of the ideation mechanism is in three steps: (1) Identify the relevant stakeholders for the system; (2) Describe the values captured, missed or destroyed for the stakeholders; (3) Generate new opportunities by modifying, zooming, removing or adding stakeholders.

The idea generation conducted to two new offers, for B to B customers and schools, and also a major modification of the coconut providing (Table 1). Moving from a whole coconut retailer to a coconut shell provider mitigates the waste of coconut flesh which is detrimental to the proposition, but also implies logistics constraints. Indeed coconuts cannot be grown locally (in Europe), which implies to ship shells from producing countries (i.e. Africa or Asia). This has to be further investigated. These insights are layered in the template to complement the initial startup proposition, (Figure 4, modifications in bold).

Table 1 : NEW VALUE PROPOSITIONS FOR THE SYSTEM

Stakeholders	Offer-Value proposition
Restaurants and fish farms	Provide tank maintenance service for BtoB customers
Schools (teachers, pupils)	Add educational material to teach about circular systems

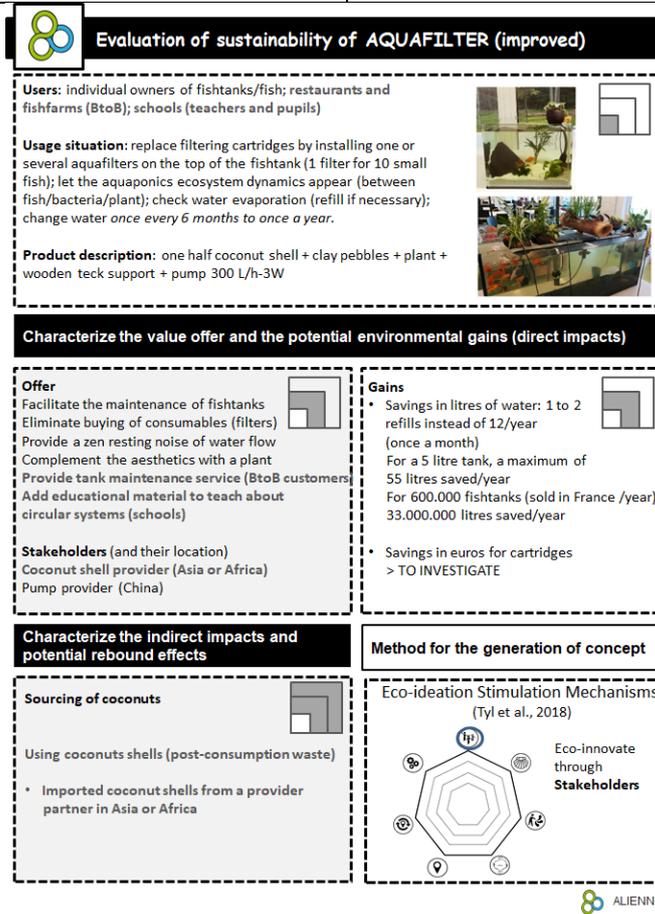


Figure 4 : UPDATED SYSTEM CONCEPT AFTER ECO-IDEATION SESSION

IV. CONCLUSION AND PERSPECTIVES

During the front-end of eco-innovation (FEEI) process, the evaluation stage of concept is crucial and still under-estimated. The design team must deal with various concepts, with different level of details and imagine how to give robustness to these concepts. Our objective was to link an eco-ideation toolkit developed in Tyl et al. [21] to an evaluation tool in a dynamic and practical way. Therefore, our initial research question was “What support to qualify the sustainability of eco-innovative concepts in the FFEI ?” In this paper, we presented a framework to support the design team in the formalization, as well as in the evaluation of eco-ideation concepts. This formalization is built on two main principles, rarely integrated in the evaluation stage of FEEI:

(1) *the systemic approach.*

Eco-innovation requires to develop a global approach of a concept in order to imagine the different potential rebound effects (and not only the transfer of environmental impacts). To do so, we propose to assess a concept at three main levels: the user, i.e. a description of the different users, the scenario of uses, etc.; the value chain, i.e. the different stakeholders involved in the concept

across the whole value chain, and how the concept changes the initial stakeholder network; and the society, i.e. the impact of the product on the value chain and the society. Through these 4 boxes, this framework allows the design team to describe in an synthetic way the concept and its consequences on the global system.

(2) *the dynamics of the process.*

The objective of an evaluation stage is to support the design team in the maturation of ideas. Therefore, the eco-ideation stage and evaluation stage must be linked in a dynamic way. We propose in our framework a specific box to assess the concept according to eco-ideation toolkit previously developed. Moreover, each mechanism of the eco-ideation toolkit is linked to the different boxes of the evaluation framework, so the design team is able to come back to the eco-ideation stage if necessary.

Nevertheless, the first step of this research raises some questions for the future.

A current limit is the validation of the framework and the associated template. The next step is to validate the proposition with a group of eco-innovation experts and with industrial partners (notably with the CEO of the startup company).

The first question deals with the level of synthesis of each concept, and of aggregation of ideas. The eco-ideation process results in various promising ideas, but generally poorly detailed. The path from the generation of ideas to the evaluation stage was not explored and need to be better studied in order to support the design team to not forget any relevant ideas during the formalization and the evaluation of aggregated concepts.

Another question is the integration of the stakeholder notion. In our framework, we propose a first characterization of the stakeholder network. But previous studies show that this notion is crucial in eco-innovation [23] [24]. Therefore, future work will test our evaluation framework in radical eco-innovation processes when the stakeholder network is widely modified, in order to improve the stakeholder characterization. To finish, in line with previous studies [25], perspectives include a focus on the dynamics between the eco-ideation and evaluation stage. We developed in this paper a first proposal to link these two stages but the dynamics and the iteration still have to be improved.

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