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The challenges of eco-innovation

From eco-ideation toward sustainable business models

EcoSD Annual Workshop 2015

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Foreword

As president of EcoSD (Ecodesign of Systems for a sustainable Development), I am very proud to present EcoSD, the association which organizes and supports financially this annual workshop and its associated publication since 2013.

EcoSD network is a French association whose main objective is to encourage collaboration between academic and industrial researchers so they may create and spread advanced and multidisciplinary knowledge in the eco-design fields at national and international levels. Several actions are proposed by the EcoSD network with the support from the French Environment and Energy Management Agency (ADEME), from the French Ministry of Higher Education and Research as well as the Ministry of Industry:

- Structuring EcoSD research activities in France to take advantage of the expertise from more than 200 members of this research network,
- Developing knowledge among researchers regarding the field of eco-design, particularly better training of PhD students by organizing relevant training courses over different themes in eco-design,
- Elaborating new methods, new tools and new databases to achieve complex systems design, compatible with the principle of sustainable development,
- Initiating the EcoSD label to acknowledge the quality and inclusion of sustainable development in trainings, research programs, research projects and symposiums,
- Helping interactive collaboration between researchers and industrial partners through the organization of quarterly research seminars in Paris and an annual workshop.

Around 70 researchers from industry, academia and governmental institutions participated in the 2015 workshop on Eco-Innovation and had the opportunity to exchange with experts. The associated publication contains a synthesis of the main contributions presented during this workshop.

I am very grateful to the three coordinators (F. Vallet, F. Cluzel and B. Tyl) for the perfect organization of this workshop held in Paris in March 2015. I also thank all the speakers for the quality of their oral presentation and the fruitful exchanges they permit.

Dominique MILLET

President of EcoSD

Acknowledgements

The coordinators of these proceedings and organizers of the 2015 EcoSD Annual Workshop would like to thank all the people who made this event possible: Dominique Millet, president of EcoSD; Delphine Martin, Michael Saidani, Montserrat Salgado Martinez, Alborz Bekhradi and Yann Leroy from CentraleSupélec; Benoît de Guillebon and Anne-Sophie Moulinier from APESA; Université de Technologie de Compiègne; la Recyclerie; and finally all the speakers who participated to the scientific presentations and debates.

Last but not least, we give a special and warm thank to Jean-Claude Bocquet from CentraleSupélec, researcher but also artist, who performed and provided the cover of this book.

Introduction

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1. Objectives of the annual workshop

The objective of this workshop is to present a scientific approach of eco-innovation concept and to underline how eco-innovation can propose sustainable alternatives to existing production and consumption systems.

To reach this goal, a particular attention has to be paid to the theoretical framework of eco-innovation. Often reduced to its technical dimension, eco-innovation may indeed deal with numerous dimensions (conceptual, institutional, economic, regulatory…), that were clarified during this workshop.

Moreover, to transform a company's activity, and to head toward sustainability requires a deep questioning of its business model, but also of its internal organization. Indeed radical concepts are sometimes killing skills. It seems thus necessary to propose to companies a methodology fostering a mutation of what constitutes its "core business", by identifying adapted partners able to support the launch of the market of these eco-innovations. "Sustainable business model" approaches are emerging in the literature, and it seems promising to investigate how these approaches may enrich eco-innovation methodologies.

Finally, an eco-innovation process rarely emerges in a globalized way, because eco-innovations are fed by resources present on territories. The workshop tackles the territorial approach, but also societal approach of eco-innovation.

2. Presentation of the papers

The event is articulated in 3 parts around 2 keynotes sessions by international researchers, short sessions and discussions with EcoSD researchers, as well as a final round table including industrial and institutional experts.

In Part 1, methodical approaches for eco-innovation are presented. The first keynote paper presents an initiative from UNEP to formalize an eco-innovative approach to be implemented in developing countries. It is proposed to revisit the definition of eco-innovation centred on the notion of business model. The following paper is focused on the generation of eco-innovative concepts, namely eco-ideation. An attempt is made to restructure and unify the eco-innovation literature into 9 creative mechanisms of stimulation in the TRIZ tradition. The last paper in Part 1 proposes a method to eco-innovate in the case of highly complex systems, such as large electrical stations used in the primary aluminium industry. The outcome of the process is a balanced R&D portfolio of future projects to develop.

In Part 2, it is explored how different domains may contribute to eco-innovation by extending its boundaries. After proposing four features to characterize a sustainable business model, the second keynote paper advocates that a co-development of technical artefacts and infrastructures, business models and corporate governance is needed. The following paper extends the traditional 3 dimensions of sustainable development into a 5-dimension sustainable transition method (adding political and territorial issues). The aim is to generate operational and managerial roadmaps to sustainable projects in industry. The last paper elaborates on the concept of upgradability to support new consumption/production patterns. This implies the transformation of the value network over time, and hence a progressive transformation of the business models.

In Part 3, seven participants from industry and institutions are invited to debate on: examples of eco-innovations; levers and difficulties to implement eco-innovation; recommendations to academia regarding eco-innovation research.

3. New opportunities from two years of collaborative projects on eco-innovation

Within the EcoSD network, the organizers of the workshop have completed two projects between 2012 and 2014 concerning eco-innovation processes, methods and tools. This introduction offers a synthesis of the projects. The questions raised indicate some new directions to feed research in eco-innovation for the forthcoming years (see conclusion).

The first project (2012-2013) concerned the perception of eco-innovation by companies. It aimed at defining the features and goals of eco-innovation compared to eco-design in industry. The literature review revealed salient difficulties to establish sharp boundaries between eco-design and eco-innovation. In order to gain a better understanding on an industrial viewpoint, a survey with 12 French industrial organizations with an acknowledged expertise in eco-design was conducted. Results confirm the ambiguity perceived by industrial practitioners. As eco-innovation still is an emerging topic, it does not seem to be supported by any structured process. Nevertheless, products or eco-innovative systems are sometimes created but this eco-innovation seems to be -most often- the result of taking into account economic and environmental constraints.

One communication was made on the topic at the international conference Design 2014 in Dubrovnik (Cluzel et al., 2014).

The second project (2013-2014) made a focus on the particular stage of eco-evaluation and eco-selection of the most promising ideas. In early eco-innovation phases, design teams need to assess the environmental relevance of ideas, making the evaluation stage more critical than in traditional design. In order to understand the emergence of high environmental potential ideas, two methods involving mapping, selection, combination and environmental evaluation of ideas were tested, plus an additional free method. Two different test-cases were considered. Starting with 15 elementary ideas, three groups of mixed academics and industrials were asked to generate 3 to 5 environmentally relevant concepts. Main results show that there is a large inter-group variability in the evaluation of environmental potential of ideas. The format of ideas (text or images) is a factor potentially influencing the results, as mentioned in the next paragraph.

Two communications on the project were presented at the national conference AIP-Priméca 2015 in La Plagne (Tyl et al., 2015) and at the International Conference on Engineering Design ICED 2015 in Milan (Leroy et al., 2015).

After conducting the two projects, the need appeared to confront findings and to open up to other national or European communities. This lead to the opportunity to build a special event (called workshop) on eco-innovation issues, federating international researchers as well as contributors from the EcoSD network. The final program of the workshop is presented hereafter.

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5. Agenda

EcoSD Annual Workshop

The challenges of eco-innovation

From eco-ideation toward to sustainable business models

March 12th, 2015, La Recyclerie (Paris)

PART I: ECO-INNOVATIVE DESIGN OR ECO-DESIGNED INNOVATION?	
Eco-innovation in small to medium sized enterprises - Needs and opportunities for action	**Tim McAloone**, Technical Technical University of Denmark & SIG Eco-design of the Design Society
Proposal of a toolbox to efficiently stimulate eco-ideation	**Benjamin Tyl**, APESA **Flore Vallet**, Université de Technologie de Compiègne
Eco-ideation and eco-selection of R&D projects for complex systems	**François Cluzel**, CentraleSupélec
PART II: TOWARDS SUSTAINABLE BUSINESS MODELS AND TERRITORIES	
Sustainable Business Models for Eco-Design and Innovation – The case of Riversimple	**Florian Lüdeke-Freund**, University of Hamburg
On the use of the 5D-sustainability transition method - A case study	**Romain Allais**, Université de Technologie de Troyes
Upgradable-PSS - Upgrading as core of a new production/consumption mode	**Olivier Pialot**, Université de Toulon **Justine Bisiaux**, Université de Technologie de Compiègne
PART III: INDUSTRIAL AND INSTITUTIONAL VIEWS ON ECO-INNOVATION	
Hélène Bortoli (ADEME) Edouard Carteron (Steelcase) Alexis Dousselain (Mairie de Paris) Laurent Greslin (Z.I. lab) Pierre Tonnelier (PSA Peugeot Citroën) Maxime Trocmé (Vinci)	Chairman: **Bernard Yannou,** CentraleSupélec

Part I

Eco-innovative design or eco-designed innovation?

Eco-innovation in small to medium sized enterprises

Needs and opportunities for action

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This working paper is based largely on the eco-innovation activities ongoing at the Technical University of Denmark (DTU), and within the United Nations Environment Programme, in particular including excerpts from references (Bisgaard & Tuck, 2014; McAloone et al., 2002; O'Hare & McAloone, 2014; O'Hare et al., 2014; Web-reference 2015).

1. Why eco-innovation?

The rapidly increasing diversity and complexity of of environmental sustainability challenges faced by industry points at an urgent need for approaches that can deliver step change improvements in the environmental performance of products. Eco-innovation is an approach that has the potential to meet this need (Fussler & James, 1996; James, 1997). However, despite two decades of on-going research in this area, a relatively low level of maturity is seen in the field, particularly if industry adoption is to be seen as a measure of maturity (McAloone et al., 2002; O'Hare, 2010). An additional concern is that the highly inter-disciplinary nature of eco-innovation means that there is a higher risk of a fragmented research domain resulting, which in turn may lead to poor support for practitioners (Olundh, 2006). The engineering design research community is in a position to contribute to the advancement of the theory and practice of eco-innovation in a number of areas, as the product development process lies at the core of the eco-innovation concept. To capitalise on this potential, it is important to understand the existing body of knowledge and the future research opportunities. This working paper discusses key elements from recent research works on eco-innovation, to provide a review and reflection of on the current status of eco-innovation and to suggest areas where the design community can contribute to developing the maturity this approach (O'Hare & McAloone, 2014). The working paper is a compilation of recent contributions to the UNEP Eco-innovation manual, the DESIGN conference and local research notes and presentations. As a working paper it is not an externally reviewed manuscript.

2. What is eco-innovation?

There exist a number of definitions of eco-innovation, but for the work of the group behind this working paper, two main definitions are dominant. The first definition comes from James, who states:

> "Eco-innovation aims to develop new products and processes which provide customer and business value but significantly decrease environmental impact." (James, 1997)

To supplement this and provide a more operational framework for eco-innovation, the recently produced UNEP Eco-Innovation Manual (the authorship of which was headed by a group including the authors of this working paper) created its own operational approach to eco-innovation, defined as follows:

> "Eco-innovation is the development and application of a business model, shaped by a new business strategy that incorporates sustainability throughout all business operations based on life cycle thinking and in cooperation with partners across the value chain. It entails a coordinated set of modifications or novel solutions to products (goods/services), processes, market approach and organizational structure which leads to a company's enhanced performance and competitiveness." (O'Hare et al., 2014)

A conceptual model of eco-innovation that is based on the UNEP definition is shown in Figure 1 below.

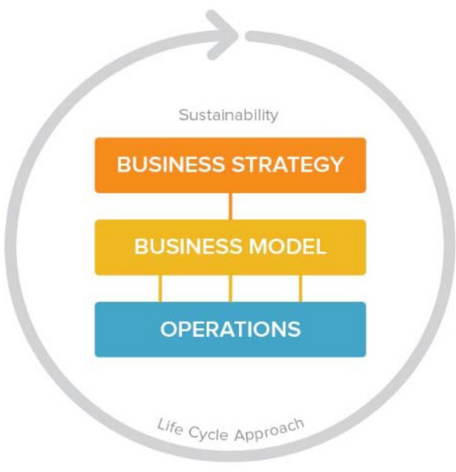

Figure 1: Conceptual model of eco-innovation (O'Hare et al., 2014)

3. Why do companies need to eco-innovate?

In recent decades, there has been a growing recognition amongst manufacturing business leaders that sustainability challenges such as climate change, worker welfare and resource constraints are having a significant impact on the way manufacturing companies do business. These sustainability challenges give rise to drivers for change in the way that companies operate. Sticking with the 'business as usual' approach will leave companies unable to respond to issues such as rising energy costs, disruptions to supply of their raw materials or changes in legislation. Ultimately, companies that do not take action now run a higher risk of failure when these issues inevitably take effect in their industry (O'Hare et al., 2014).

There is therefore an increasing need to find alternative approaches that can help to address sustainability related business drivers, whilst at the same time offering opportunities for growth, cost reduction and competitive advantage. Eco-innovation is an approach that aims to fulfil these multiple requirements by identifying the key sustainability challenges and opportunities and then using these to drive changes throughout the company and its value chain, from the business strategy and business model, through to the operational level (O'Hare et al., 2014).

Figure 2 highlights some of the pressures and drivers for companies to consider eco-innovation, taken from UNEP's publication "Business Case for Eco-Innovation".

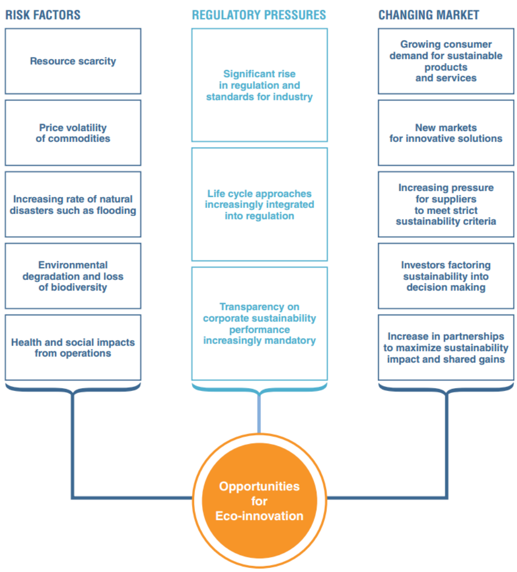

Figure 2: The world changing and its potential impacts on business (Bisgaard & Tuck, 2014)

4. What is the potential of eco-innovation?

There is no doubt from the literature that eco-innovation is seen as being the most promising answer to many of the problems and external pressures (business-led, society-led and nature-driven) that mankind is encountering regarding the achievement of sustainability. In their recent eco-innovation project, UNEP has boldly described everything other than eco-innovation as "tinkering around the edges" of the environmental and sustainability problem, see Figure 3.

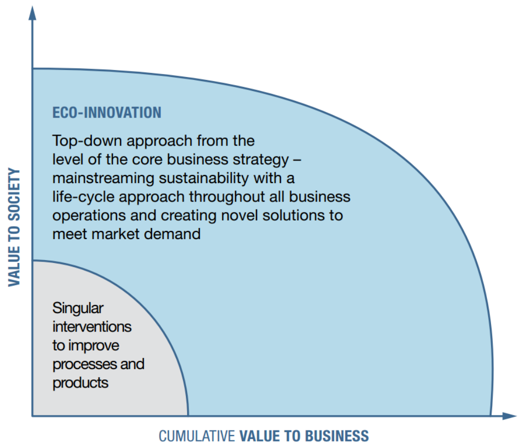

Figure 3: The potential impact of eco-innovation (Bisgaard & Tuck, 2014)

5. What does eco-innovation entail?

In our paper from DESIGN 2014 (O'Hare & McAloone, 2014), we dissected James' definition of eco-innovation (Eco-innovation aims to develop new products and processes which provide customer and business value but significantly decrease environmental impact) in the following manner:

- '…develop new products and processes…' = engineering design
- '…which provide customer and business value…' = strategy and management
- '…but significantly decrease environmental impact' = environmental science

This led us to a conceptual model of eco-innovation, as seen in Figure 4.

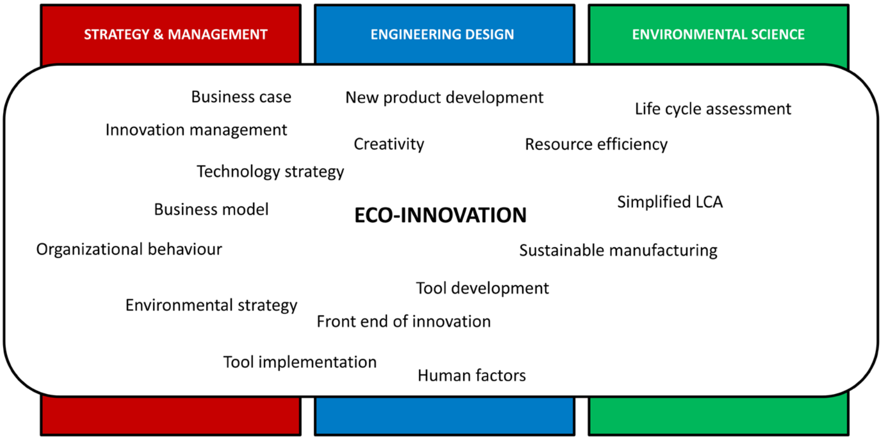

Figure 4: Conceptual model of eco-innovation (O'Hare & McAloone, 2014)

The conceptual model led us, in the DESIGN 2014 paper, to investigate the contents of eco-innovation, by studying the related fields of research and professional activity that would be beneficial to include in a consolidated model of eco-innovation.

Referring to figure 4, in the area of STRATEGY AND MANAGEMENT, the consideration of the business case is paramount. Eco-innovation is reliant on the creation of new business ideas and proposals that are mature in their consideration of cost-benefit, so this area is important to include in such a model. Innovation management is also important, as this covers the consideration of how to nurture an innovation project to completion. Innovation management is necessary to understand, as the innovation process is necessarily quite different from "business as usual" in a company. Technology strategy is also an important focus area, not least as a great deal of potential environmental improvements can be achieved by understanding how to attain systematic technology improvements to the products and equipment that are utilised in providing desired utility to the user. The business model is extremely important to understand and to master, so that all aspects of a new and innovative idea for eco-innovation can be considered, conceptualised and communicated, in terms of the main value proposition and also the necessary inputs and desired outward channels and customers of the new solution. Depending on the level of change through the eco-innovation concept, the company may undergo sincere changes in the way in which it organises itself. The field of organizational behaviour is therefore also interesting and important to consider. Finally, from a strategic perspective, it is clear that environmental strategy is paramount to consider, when working with eco-innovation; without such, any company would not adequately be able to measure its success and improvement.

Referring to figure 4, in the area of ENGINEERING DESIGN, it is clear that new product development (NPD) is a field that can lend a great deal of wisdom and methodology to the act and process of eco-innovation, ensuring that the eco-innovation process is systematic, repeatable and considered. Needless to say, creativity is a virtue that any form of innovation has a need for, whether it be addressed at the main problem itself, or a subcomponent hereof. Creativity can be trained, through techniques and through practice. Tool development is an activity that lies very firmly in the engineering designer's resort, with the large majority of tools and methods for both engineering design and eco-innovation coming from the engineering design community. Tool development is closely related to tool implementation (shared with category STRATEGY & MANAGEMENT), which describes the activity of laying out a methodological approach to eco-innovation, ensuring that the necessary toolbox exists to aid the implementation of ecoinnovation, aided by tools. Front end of innovation describes the early stages of the NPD process, where the creative ideas begin to take form, into concepts of eco-innovation solutions. Finally, human factors are important to consider, both when designing eco-innovative solutions and also when designing the ecoinnovation process itself. Human factors is not traditionally a field that is seen close to the engineering design domain, but recent years have seen an increasing awareness and understanding of the need and merits of considering human factors in design. Referring to figure 4, in the area of ENVIRONMENTAL SCIENCE, it is clear that the act of eco-innovation will require a number of important areas to be considered. Life cycle assessment is a well-established approach to creating an assessment of the environmental footprint of a product, service or system, which helps the designer to set improvement goals for the forthcoming eco-innovation project. The nature of innovation and also the nature of some of the projects that are characterised as eco-innovation projects leads to the need to find faster, more abridged ways of getting an overview of environmental footprints. Therefore simplified LCA is an approach that will lead to a greater usability of LCA approaches earlier on in the ecoinnovation process. Resource efficiency (shared with category ENGINEERING DESIGN) is often seen as the precursor (and sometimes the predecessor) to eco-innovation, and focuses on how to get the most functional unit out of the least effort, materials and/or energy as possible. Although resource efficiency is seen as being an increasingly reductionist approach (especially when compared to e.g. eco-innovation, Cradle2Cradle), the field is vitally important for eco-innovation as it is very rich in tools and methods for environmental improvement. Finally, sustainable manufacturing (shared with category ENGINEERING DESIGN) is an important contributory field to eco-innovation, as there lies a wealth of information, methods, tools and cases, regarding the successful transition of certain manufacturing forms to sustainability.

6. Simply the sum of the parts?

So is eco-innovation merely the sum of the parts described in the previous section? The simple answer to this question is no – however, there are many contributory fields and approaches that are akin to ecoinnovation and that can be collected to create a solid basis for eco-innovation as a methodology and an innovation strategy. In the next and final section of this working paper, we will introduce some of the new elements that we bring to eco-innovation, through our collaboration with UNEP.

7. The UNEP eco-innovation methodology

Through a close collaboration with UNEP on a global eco-innovation project running from 2013-2016, we have created a methodology for eco-innovation. The methodology builds on the many contributory fields to eco-innovation described in the previous section of this paper, plus a bespoke eco-innovation process that has the clear purpose of assisting small to medium sized enterprises in developing economies around the world. The methodology is described in a manual and has six phases: PREPARE, SET STRATEGY, SET BUSINESS MODEL, BUILD ROADMAP, IMPLEMENT, and REVIEW - see Figure 5.

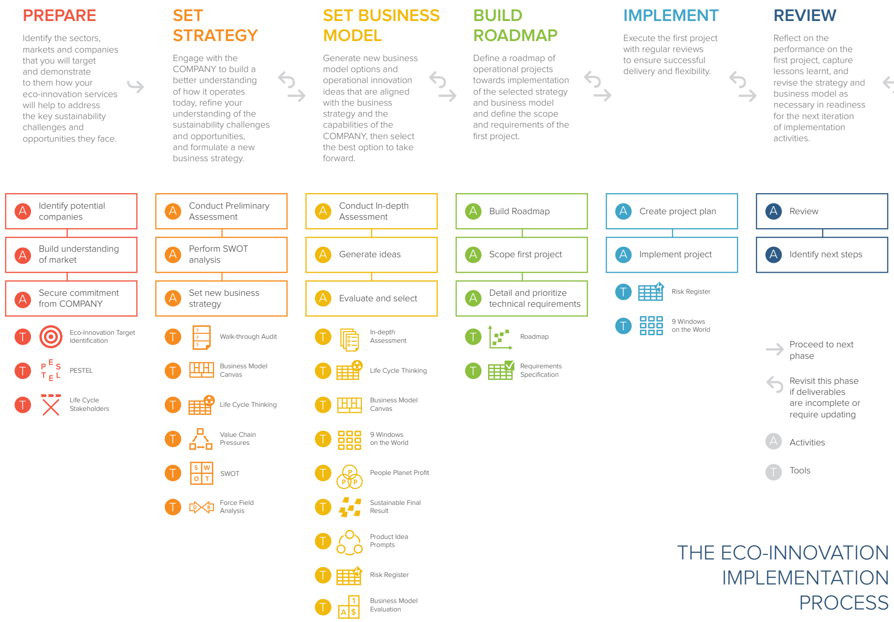

Figure 5: UNEP eco-innovation methodology (O'Hare et al., 2014)

What can the engineering design research community contribute with?

As we have detailed in this working paper, eco-innovation is well underway and there are a number of activities in action already. But as engineers, what is there for us to contribute with? In our paper from DESIGN 2014 (O'Hare & McAloone, 2014), we point at ten opportunities for how the engineering design research community can help with eco-innovation. These ten opportunities are as follows:

- Contribute to a widely accepted typology of approaches to environmental product design;
- Produce a comprehensive and rigorous review of tools to support eco-innovation;
- Give guidance on when and where eco-innovation is relevant;
- Initiate collaborative research at the interfaces of 'strategy & management', 'engineering design'and 'environmental science';
- Carry out studies of eco-innovation implementation;
- Ensure greater reporting of case studies of failures;
- Continue to contribute methodological innovation;
- Bring design thinking to business model innovation;
- Help to understand the role of LCA in supporting eco-innovative product development;
- Develop an interface with policy research and engineering research (O'Hare & McAloone, 2014).

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9. About the author

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Tim McAloone is Professor of Product/Service-Systems at the Technical University of Denmark. He works closely with Danish and international industry, creating new methods and models for a wide range of product development issues, such as product/service-systems, sustainable design and eco-innovation. He has many research activities, including projects such as the Innovation Consortium "PROTEUS", which focuses on the creation of product/service innovation methodologies for the Danish maritime industry, plus the UNEP Eco-Innovation manual. Danish and international industrial companies are Tim's main research object, where most of his work is carried out in the form of empirical studies of product development methodological activities and improvement needs in industry. Tim's international network spreads very broadly, where he has close ties to universities in particularly USA, Brazil, Japan, France, Germany, Sweden and UK. In 2011 Tim was guest professor at Stanford University, USA. He is regularly invited as keynote speaker at international conferences and is also frequently used within Danish industrial seminars and meetings.Tim received his PhD from Cranfield University in 1998, where he studied the integration of eco-design strategies into industry. His first degree is in Mechanical Engineering from Manchester Metropolitan University in 1993.

Proposal of a toolbox to efficiently stimulate eco-ideation

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1. Introduction

The environmental consequences of mass manufacturing and consumption require to completely rethink our way of designing, manufacturing and consuming by implementing, for instance, an eco-innovation strategy. Companies and mostly SMEs have to integrate the different system dimensions (environment, social, technology, stakeholders) from the upstream phase of the eco-innovation process. The purpose of this action is to put on the market products and services with a high environmental and societal ambition.

In eco-innovation, the idea generation phase (or eco-ideation) is essential and has to be carefully supported. It is defined by (Bocken et al., 2011) as the phase during which ideas with great potential for reducing environmental impact are generated. At the end of the session, the group comes up with a set of eco-innovative ideas. The success of eco-ideation depends on the ability of socio-economic partners to open new perspectives. That is to say to look for a new point of view by deconstructing the context of the problem and so to put into perspective alternatives and new situations. The field of business model innovation for sustainability has received noticeable attention from researchers in the past years (Boons and Lüdeke Freund, 2013)(O'Hare et al., 2014). For instance, this led Bocken et al. (2014) to unify bodies of knowledge into 8 sustainable business model archetypes.

Eco-ideation, i.e. the generation of sustainable ideas, has received less attention in the meantime. Nevertheless, idea generation has been tackled recently through four tiny tools in the UNEP eco-innovation manual, supporting the construction of sustainable business models (O'Hare et al., 2014). The statement prior to this research is hence that there is also a need to unify and transfer the many innovative approaches to deliver sustainability into actionable mechanisms to help eco-ideation.

After describing the tools and mechanisms to support eco-ideation, this paper presents a model of an Eco-ideation Stimulation Mechanism (ESM), as well as the construction of a set of ESMs. Through the example of biomimicry, we expose a detailed view of how to use an ESM in eco-innovation. Conclusions and future developments around the ESM concept are then proposed.

2. Eco-ideation : tools and mechanisms

Eco-ideation sessions have firstly been supported by diagrams or radars, such as the LiDS Wheel (Brezet, 1997) or the Eco-Compass (Fussler and James, 1996). A wide literature on eco-ideation methods and tools is based on the TRIZ methodology (Altshuller, 1988), such as its adaptation for eco-innovation by Kobayachi (2006) or Chen and Liu (2003), or the mix with biology patterns (Bogatyrev and Bogatyreva, 2014).

Some works have been developed with a simplified TRIZ approach. Dekoninck et al. (2007) proposed simplified tools based on TRIZ for eco-innovation, using physical and technical contradiction and Ideal Final Results (IFR) statement. More recently, Tyl et al. (2014) proposed a TRIZ-oriented tool, EcoASIT, to generate sustainable ideas.

Lastly, recent developments in eco-innovation tools have been relying on business model innovation as a way to generate sustainable ideas. In this state of mind, the Value Mapping Tool proposes to cover the different values for key stakeholders and to imagine how to convert missed or destroyed values into opportunities (Bocken et al., 2013). In the UNEP eco-innovation manual, four reinterpretations of tools are included to enhance sustainable business model generation, namely: 9 windows on the world, People Profit Diagram, Product Prompts based on LiDS Wheel and Sustainable Final result (O'Hare et al., 2014).

Eco-ideation tools should put into perspective alternatives and new situations (Vidal, 2007). They embed cognitive strategies, or *"ideation mechanisms", "design heuristic", "stimulation mechanisms"* (Yilmaz et al., 2010). These mechanisms help designers to deconstruct the problem and find new ways to solve it. In line with Yilmaz, ideation mechanisms in eco-ideation must provide designers cognitive strategies to create sustainable solutions.

In previous research, a first classification of the ideation mechanisms was developed (Tyl et al., 2014). It relied on the level of the mechanism, according to the following scale:

- a micro level mechanism, i.e. a specific and technical mechanism (for example the innovation principles of TRIZ);
- a macro level mechanism, i.e. a broad and abstract mechanism with no specification to guide the designer, but which encourages a systemic view (for example Eco-Compass or the Sustainable Final result);
- a meso level mechanism, i.e. a compromise between a systemic vision and a technical sharpness (for example EcoASIT).

It was emphasized that an eco-ideation tool with 'meso' ideation mechanisms guarantees effective eco-ideation sessions, especially in terms of rate of idea generation and of variety of the ideas, for several user profiles (Tyl et al., 2014). In this paper it is proposed to use "meso" Eco-ideation Stimulation Mechanisms to support eco-ideation sessions, allowing both to have a systemic vision of the problem, while efficiently stimulating the design team during the whole eco-innovative process. This paper aims to address a critical research question: *"How can we define systemic structure - process- of a meso ideation mechanism adapted to facilitate the exploration of the problem in eco-innovation?"*.

Through the concept of Eco-ideation Stimulation Mechanism (ESM), this paper proposes two main contributions: (1) the development of a first set of ESM to explore the different dimensions of eco-innovation; (2) the development of a model of Eco-ideation Stimulation Mechanism.

3. Proposal of a model: eco-ideation stimulation mechanism (esm)

3.1. Research methodology

The development of the Eco-ideation Stimulation Mechanism (ESM) concept results from both preliminary research on meso ideation mechanisms in eco-innovation (Tyl et al. 2014) and an extensive literature survey carried out by the authors. The survey involved most cited peer-reviewed articles in international journal and papers of conference proceedings, related to the following key words: *eco-innovation, sustainable innovation, sustainable business models*. Through an inductive approach, 9 classes of issues related to eco-innovation emerged. A simple micro-process of innovation was settled for each class of issues. The notion of meso ESM was then elaborated by the normalization of each process. Thanks to several illustrative examples and experimental tests, each ESM was independently tested and updated for more relevance. The entire research method is summarized in Figure 1.

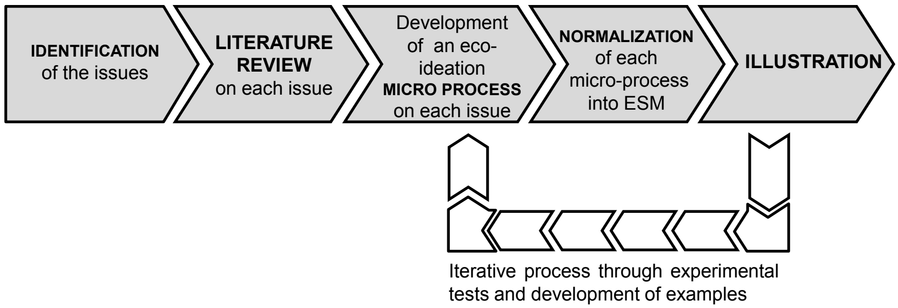

Figure 1: Iterative process of development of ESMs

3.2. Exploration of eco-innovation issues

Through the extensive literature survey, 9 key topics dealing with eco-innovation were identified. Main authors associated with the ESM list appear in Table 1. O'Hare et al. (2014) stated that eco-innovation stands at the intersection of engineering design, business management and environmental sciences. Based on this vision, the 9 ESM were categorized accordingly. The technological viewpoint dominates ESM 7 and 9, while the economic pillar is essential to ESM 1, 6 and 8. ESM 5 and ESM1 are more human centred, with a strong emphasis on social issues.

Table 1: Presentation of the ESM toolbox

ESM		Main area of concern				Reference
		Techno.	*Eco.*	*Env.*	*Society*	
ESM 1	Innovate through stakeholders (ItS)		•		•	[Bocken et al., 2013][Tyl et al., 2015]
ESM 2	Innovate through biomimicry (ItB)	•		•		[Benyus, 1997][Marshall and Loveza, 2009][De Paw et al., 2014]
ESM 3	Innovate through impact transfer and rebound effect management (ItIT)			•		[Hertwich 2005][Figge et al. 2014]
ESM 4	Innovate through short loop thinking (ItSL)		•			[Brissaud 2013][Tyl et al. 2015]
ESM 5	Innovate through eco-behaviour (ItEB)				•	[Lockton et al. 2014]
ESM 6	Innovate through services and functional economy (ItS)		•	•		[Lindahl et al. 2014][Tan et al. 2007]
ESM 7	Innovate through closed loop thinking (IRCL)	•		•		[Pialot et al. 2014][Gehin et al. 2008]
ESM 8	Innovate through sustainable value creation (ItSBM)		•		•	[O'Hare 2010][Bocken et al. 2013]
ESM 9	Innovate through light production (ItP)	•				[Corti et al. 2011][Kothala 2014]

3.3. Features of an ESM

An ESM may be characterized as a meso process that makes a system evolve according to sustainability principles. It is not just a stimulus or ideation component, but a sustainable disruptive intention to help designers characterize an initial state of a system, unstructure it and lastly obtain a new stage of the system. More precisely, the engine of each ESM is structured according to the following process (Figure 7):

- a systematic exploration of the problem components (CKi) of the initial system Si, identified thanks to specific key factors Ki;
- a set of ideation component (IC);
- a set of solutions CKi+1 in order to build a complete scenario or proposition for eco-innovation (concepts Ci+1, Ci'+1, etc.).

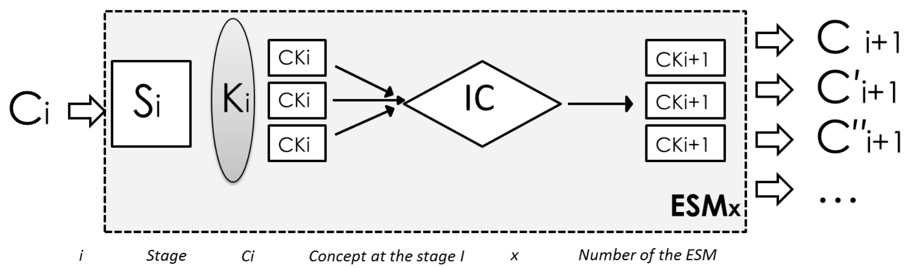

Figure 2: Exploration of a concept by an ESM

4. Illustration of ESM2: innovate through biomimicry

Biomimicry was first described by Benyus (1997), under the assumption that nature develops in essence highly effective and sustainable solutions to nurture living species and systems. Nature is hence considered as a valuable source of inspiration for designers. Although eco-design and biomimicry (or also Cradle to Cradle) focus on merging environmental aspects in the design process, the viewpoints are somehow different. Where eco-design aims at reducing environmental impacts of products throughout their life cycles, biomimicry seeks to "*develop products that benefit their environment*" (De Paw et al., 2014). It is acknowledged that biomimicry appears to be an interesting trigger to find innovative solutions in an eco-innovation process. Conversely, other authors pinpoint that, under certain conditions, biomimicry may also lead to drastically unsustainable systems (Fayemi et al., 2014; Marshall and Lozeva, 2009). There are two ways to refer to nature for a designer (Macnab, 2012): (1) Biomimicry Design Spiral-'Challenge to biology', meaning to identify a design problem first and find inspiration in the natural world; (2) Biomimicry Design Spiral-'Biology to design' meaning to identify natural models first and then look for design applications.

Our objective is to figure out mechanisms which are typical of natural ways of solving problems. The starting point is thus to favor the use of a database of natural examples (http//www.asknature.org) by sticking to the developed taxonomy. We suggest to adopt a problem-based approach and enable the formulation of the design challenge by means of 'functions' (verb and noun). This enables to retrieve relevant sources of inspiration. In order to propose a simple stimulation mechanism, the 8 strategies proposed in the Biomimicry taxonomy of asknature.org are embedded into 4 polarities, which represent the natural processes found in nature: (1) the first polarity is represented by the balance between 'Maintain/Stay X' and ' Modify/Evolve/ Move Y'; (2) the second is represented by the balanced functions 'Generate/create Z while Capture/Absorb/Breakdown W (See Guillian Graves website: http://guilliangraves.com).

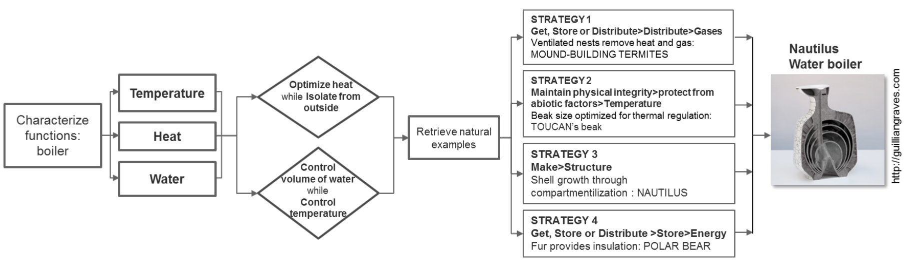

Figure 3: Use of ESM 2 on the Nautilus water boiler

X, Y, Z and W represent key factors which are relevant to the eco-innovation challenge, such as: physical flows (energy, water, liquid, gas, information flows etc). The example of the Nautilus water boiler is detailed to exemplify the approach (Figure 3). The first step consists in the characterization of the main key factors: temperature, heat and water in this case. Then, in line with the Biomimicry taxonomy, two contradictions are expressed: (1) Optimize heat *while* Isolate from the outside; (2) Control volume of water *while* Control temperature. Thanks to an exploration through the browser of Asknature database, four animal strategies related to management of heat, temperature and volume of water were retrieved: mound-building termites keeping a constant temperature in the nest thanks to galleries; toucan's insulated beak from the outside; compartmentilization of nautilus shell; hollow hairs of polar bear for insulation. The creative combination of the four strategies was finally operated in the Nautilus prototype.

5. Conclusion

This article brings a contribution on how to support the eco-ideation stage in order to develop eco-innovative concepts in SMEs. The contribution of this article is twofold. Firstly the notion of ESM is defined as a "meso" mechanism which aims at generating eco-innovative concepts thanks to breaking operators. Secondly, acknowledged approaches to deliver sustainability in design are unified into a toolbox of 9 original ESMs. Lastly, one of the mechanisms, ESM2-Innovate through biomimicry, is justified and exemplified in detail.

This approach is still is at its very early steps of formalization. More work is still needed to challenge the cluster of eco-innovation issues, the number and construction of ESMs. Additional tests with SMEs are also planned to refine the mechanisms. Finally our belief is that the strength of the approach is indeed related to the modularity and relevant combination of ESMs in a global process, depending of the context of application in industry. How ESMs could be chosen and associated should be developed in further work.

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7. About the authors

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Eco-ideation and eco-selection of R&D projects for complex systems

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1. Introduction

Eco-design becomes more and more recognized and well deployed in competitive mass-consumer goods producers (B-to-C). However the situation is not so advanced in B-to-B industries, in particular for complex industrial systems, characterized by a very long and uncertain life cycle, a high number of subsystems and components or strong interactions with their environment. The technological and regulatory constraints associated with these systems may slow down the ability to innovate, as reliable and long-term proven technologies are often favored. Nevertheless the need for eco-innovation is clearly present, however to eco-innovate on complex industrial systems is a hard task. R&D projects in complex systems industries are often driven by technological and not environmental considerations. These project need to be identified really early in the design process, with few information. On the other hand everybody agrees that environmental-oriented R&D projects are necessary, but the product complexity makes the initiation of an eco-innovation approach tricky, and only few R&D decision-makers are trained in eco-design or eco-innovation. That is why a simple and effective eco-innovation method is necessary, with little necessary preliminary environmental knowledge and stimulating the collaboration. Thus we propose in this paper such an intuitive eco-innovation process. It permits to identify at a strategic level and with limited time and resources eco-innovative R&D projects through a multidisciplinary working group.

Section 2 presents a literature study about eco-innovation on the one hand and R&D projects evaluation and selection for complex industrial systems on the other hand. It permits to introduce the adapted eco-ideation process in section 3. Section 4 deals with the application of this process at Alstom Grid. Finally, some concluding remarks and perspectives are presented in section 5.

2. How to eco-innovate in complex systems industries?

2.1. Complex industrial systems in eco-design

This paper focuses on complex industrial and technological systems whose specificities have not really been taken into account in eco-design and eco-innovation. We define a complex industrial system in the sense of eco-design as: a large-scale system in terms of subsystems and components, mass and resource usage; a system whose life cycle is hardly predictable at the design level in the long-term, in particular its lifetime, upgrades, maintenance and end-of-life; a system whose subsystems may have different life cycles and different obsolescence times; a system in close interaction with its environment (super system, geographic site…); and finally system supervised by human decisions and management. Concerning eco-innovation, the main problem of such systems is that the clients' specifications or the regulations and standards largely limit the ability to radically innovate, as only long-term proven technologies are used. Thus the challenge associated to an eco-innovation approach is whether to identify a set of reliable incremental eco-innovative projects, and/or to be able to make possible radical eco-innovations acceptable to the clients. To deploy an adapted eco-innovation approach, a literature review is first performed on eco-innovation and R&D projects portfolio management.

2.2. Eco-innovation

We consider in this paper the eco-innovation definition proposed in (Carrillo-Hermosilla 2010): an eco-innovation is "an innovation that improves environmental performance, in line with the idea that the reduction in environmental impacts (whether intentional or not) is the main distinguishing feature of eco-innovation". This includes in particular radical and incremental innovations. Considering the hierarchical nature of complex industrial systems, as well as the fact that radical changes are often hardly acceptable for clients in complex systems industries, we consider that the eco-innovation framework defined by Carrillo-Hermosilla et al. is well adapted to complex industrial systems.

An eco-innovation approach implies two major activities: the identification of eco-innovative ideas (or eco-ideation), and the evaluation and selection of the most promising ideas. Concerning the eco-ideation process in itself, experts groups are largely used through creativity sessions (Bocken 2011). Researches performed in the last decade have identified some best practices to perform an effective creativity session in eco-innovation. Collado-Ruiz and Ostad-Ahmad-Ghorabi advise to diffuse only 'soft' environmental information to the group because 'hard' environmental information may restrict the creativity (Collado-

Ruiz 2010). Pujari shows that the multidisciplinarity in the working group is an eco-innovation success factor (Pujari 2006).

Finally, eco-ideation processes in companies are often performed as classical creativity sessions supported by an eco-innovation tool. Different eco-innovation tools are well known or regularly used in the literature. The eco-design strategy wheel (also known as the LiDS wheel) (Brezet 1997) is one of them. It is a very simple tool that proposes eco-design guidelines divided in 8 axes on a graphic wheel. 7 axes cover the whole life cycle of the product, whereas the last one aims at identifying new concepts. According to Tyl, its appropriation is really easy. It does not imply specific knowledge and the graphic representation is very clear. It is ideal for a multidisciplinary working group in a company. But as a simple tool, the eco-design strategy wheel may become simplistic, and the pre-defined guidelines hardly allow going further than product-level considerations (Tyl 2011).

However tools like the eco-design strategy wheel do not ensure an effective and multicriteria evaluation and selection step of the most promising ideas. The next section considers general methods in the field of R&D projects portfolio evaluation and selection.

2.3. Evaluation and selection of R&D projects

Once eco-innovation projects have been generated, it is then necessary to identify the best mix of R&D projects to perform. Actually the number of projects selected by a working group may be too high compared to the available resources in the company. This issue deals with the field of R&D projects evaluation and selection and R&D portfolio management. Cooper et al. proposes a classification of the portfolio management techniques (Cooper 1999): financial models, strategic approaches, scoring models and checklists, analytical hierarchy approaches, behavioral approaches and mapping approaches. Cooper et al. shows that a good method should allow to identify the right number of projects, to avoid gridlocks, to highlight high values projects, to ensure a balanced portfolio (for instance long term versus short term), and to be aligned with the company strategy (Cooper 1999). Among all the methods, scoring models and mapping approaches are very popular, mainly because they are easy to use and give good performance results (Cooper 1999):

- Scoring models are simple, direct, effective and flexible (Bitman 2008). They show a good ratio between rigor and time spent on the study. Projects are rated and scored according to several qualitative or quantitative indicators. The weighting of the criteria permits to customize the model for special needs (Cooper 1999). One of the main forces of a scoring model is its ability to be easily implemented in companies. Actually, and contrarily to mathematical or financial models, the use of qualitative scales allows a large diffusion of the tools, for example through an Excel sheet or even a paper questionnaire. However, the success of a scoring approach is clearly linked to the selection of sound variables and indicators (Mikkola 2001). References from the existing literature often propose some categories to consider. However environmental aspects are sometimes mentioned, but never analyzed in depth.

- Mapping approaches: historically the BCG (Boston Consulting Group) and the McKinsey matrices are the most familiar mapping approaches (Mikkola 2001). Highlighting the particular needs for R&D projects selection, Mikkola introduces the R&D Project Portfolio Matrix (Mikkola 2001). Two dimensions are considered: competitive advantage and benefits to client. Nevertheless if the two dimensions do not seem adapted to our needs, we notice that this representation type involving two (or more) dimensions may be powerful. But as for scoring models, eco-innovation aspects, or more generally environmental concerns have not really been considered in the past. One single example is proposed by Millet et al. (Millet 2009). Three dimensions are considered: technico-economic feasibility, functional attractiveness (clients' values), and environmental impacts through an Environmental Improvement Rate (EIR). The latter is represented thanks to bubbles which size is proportional to the EIR value.

2.4. Requirements for an adapted eco-innovation process

Considering the constraints associated to complex industrial systems as well as the previous literature review, an adapted and effective eco-innovation process needs to:

- Consider the different system levels, as incremental innovations are easier at a component or subsystem level, and radical innovations easier at a system level;
- Be very simple, as multidisciplinary knowledge is mandatory to consider all the aspects of such a large scale system, i.e. the process mainly involves non-environmental experts;
- Be performed in a short time and with limited resources, to be easily accepted by the management and the involved experts,
- Be very efficient, to reach the best possible ratio between used resources and results;
- Build a strong basis for future eco-design works, to maximize the success rate of the identified R&D projects;
- Be multicriteria, by considering technical, financial and marketing aspects, to be accepted;

- Provide strong proofs in terms of feasibility and interest for the clients, to be successful on the markets.

Considering these requirements, we propose in the next section an adapted eco-innovation process for complex industrial system, based on a multidisciplinary working group, supported by the eco-design strategy wheel and using a hybrid scoring/mapping model for R&D projects evaluation and selection.

3. Proposition of an adapted methodology

3.1. Prerequisites and general approach

The eco-innovation process for complex industrial systems presented is this paper is part of a larger methodology described in (Cluzel 2012). It is built on several hypotheses. First, the approach is deployed in a company providing complex industrial systems (as defined in section 2.1), but with no specific knowledge in eco-design/eco-innovation. Second, the approach is supported by at least one eco-design expert leading the process, and a first environmental evaluation (Life Cycle Assessment or simplified LCA) of the considered complex technological system has permitted to identify the most impacting elements of the complete system life cycle. Then the main departments of the company need to be represented to ensure a good representativeness of knowledge and skills. Once the working group has been defined, the eco-innovation consists in two main steps: eco-ideation, and eco-innovation R&D projects evaluation and selection, detailed in the next sections.

3.2. Generation of eco-innovative projects

The eco-ideation phase is divided in three sessions, supported by the eco-design strategy wheel:

- Introduction session: as the members of the working group are for most of them not familiar with environmental concerns and eco-design principles, it aims at introducing during a short meeting (1 to 2 hours) the main eco-design concepts, the previous environmental assessments as well as the eco-innovation approach. As stated in (Collado-Ruiz 2010), the diffusion of ‘soft’ environmental information is favored.
- Creativity session, performed as a half-day meeting. A short introduction is first necessary to remind the objectives and the scope of the study and to put the participants in good creativity conditions. Then a divergent creativity phase is launched. During this phase, only environmental considerations

are taken into account (technical, economic or clients' aspects are voluntary omitted). Each of the 8 axes of the eco-design strategy wheel is separately considered during a short workshop (15 to 30 minutes) in a two-step approach:

- A brainwriting phase, where each participant individually generates a maximal number of ideas in accordance with the considered axis using Post-it® papers,
- Followed by a common brainstorming, where all ideas are read and grouped. The participants are encouraged to orally propose new ideas. All the ideas are stuck on pre-defined supports.

The divergent phase is followed by a convergent phase, where all ideas are discussed and sorted out. Technical, economic or clients' aspects are now considered. This phase aims at identifying a first set of promising ideas or ideas groups which are from now called eco-innovative projects.

These projects are synthesized in standardized sheets that include a description of the project, its objectives, its potential environmental benefits, and its technical and economic feasibility. Of course this information is not well known at this step, so only qualitative or estimated data are available. The standardized sheets are then deepened during a few weeks by sharing them out between the working group members according to their own competencies.

- Synthesis session: it consists in a discussion on each eco-innovative project in order to clarify the different design aspects and to ensure that a common vision emerges.

At that point, a first set of promising projects has been identified. But they are generally too numerous to be all considered as R&D projects. Thus the last step concerns the prioritization of the projects.

3.3. 3.3 Prioritization of eco-innovative projects

The objective of this step is to evaluate and select a portfolio of eco-innovative R&D projects. We propose in this paragraph an assessment grid based on three dimensions, assimilated to a simple scoring model without any prioritization of the projects:

- **Potential environmental benefits:** the environmental benefits of the project are compared to the environmental performance of the existing solution thanks to the eight axes of eco-design strategy wheel (Brezet

1997) on a six-level qualitative scale (0 to 5, see Table 1). A final score on 20 points is then calculated (average score on the eight axes).

- **Feasibility** explores both the technical and the economic feasibility thanks to 4 indicators resulting from an expert debate at Alstom Grid: ease of implementation (in terms of time and resources), financial return of investment, technical feasibility (in terms of knowledge), and internal level of control (is the company able to internally manage the entire project or not?). Each indicator is assessed thanks to a six-level qualitative scale (0 to 5) that permits to obtain a final feasibility on 20 points (sum of the four scores).
- **Clients' value:** this dimension assesses the benefits for the clients associated with each project. It uses 4 indicators proposed in (Kondoh 2006): cost reduction, avoidance of risks, improvement of service quality, and improvement of image. As previously each indicator is assessed thanks to a six-level comparative and qualitative scale (0 to 5) that permits to obtain a final clients' value on 20 points (sum of the four scores).

Moreover for each project we have added an expertise indicator that expresses the self-assessment of a user expertise on each project, with four possible levels (from non-expert to expert). The four first dimensions are formalized in an evaluation sheet, and each member of the working group evaluates each eco-innovative project. By weighting each evaluation with the member's level of expertise, we give more value to the assessments performed by an expert rather than by a non-expert. Finally an average score is obtained on the five dimensions and for each project.

We then use a mapping model to draw an overview of the performance of the eco-innovative projects, for example a 'bubble diagram' involving potential environmental benefits, feasibility and clients' value. By defining different quadrants inspired by (Mikkola 2001), we give to the decision-makers the ability to identify a powerful and pertinent set of eco-innovative projects according to their available resources.

Table 1: Qualitative scale used to measure potential environmental benefits on each eco-design strategy wheel axis

Score	Description
0	The project highly deteriorates the environmental performance of the current solution.
1	The project significantly deteriorates the environmental performance of the current solution.
2	The project does not bring any benefit or damage compared to the current solution.
3	The benefits brought by the considered project are weak.
4	The benefits brought by the considered project are significant.
5	The benefits brought by the considered project are very important.

3.4 Validation criteria

We consider in this paper the four criteria proposed by Shah et al. (Shah 2003) to validate the approach:

- **Novelty:** two questions are added in the assessment grid: 1) Do you think that this project already exist before the eco-innovation approach in the mind of one or several persons in the company, in a subliminal way? 2) Do you think that this project would have emerged, been formalized and seriously considered by the decision-makers without this process?
- **Variety** considers time horizon (balance between short/middle/long term and prospective projects), project perimeter (balance between component/subsystem/system/super system related projects), and the balance of the nature of the projects (technological, organizational or methodological projects).
- **Quantity** is assessed by the total number of ideas generated during the divergent creativity phase and the total number of eco-innovative projects proposed after the convergent phase. The time spent on the different phases of the eco-innovation process is also considered.
- **Quality** is assessed thanks to the three dimensions: potential environmental benefits, feasibility and clients' value.

These four criteria permit to assess the global performance of the eco-innovation process proposed in this paper. In the next section, we propose a case study performed at Alstom Grid.

4. Case study: application at Alstom Grid

4.1. AC/DC conversion substations for the aluminium industry

Alstom Grid PEM (Power Electronics Massy) designs, assembles and sells substations for the electrolysis of aluminium worldwide. These are large electrical stations designed to convert energy from the high voltage network to energy usable for aluminium electrolysis, which is a particularly environmentally impacting and energy-consuming activity. A substation represents thousands of tons of power electronics components and transformers, costing tens of millions of Euros. These substations are complex industrial systems because the number of subsystems and components is considerable, and the lifetime of a substation is really long, up to 35 or 40 years with high uncertainties. In this context, Alstom Grid PEM wishes to minimize the environmental impacts of its products. A first global Life Cycle Assessment has been performed on an entire substation (Cluzel 2012). This LCA is the basis for the eco-innovation process described in the next parts.

4.2. Eco-innovation process deployment

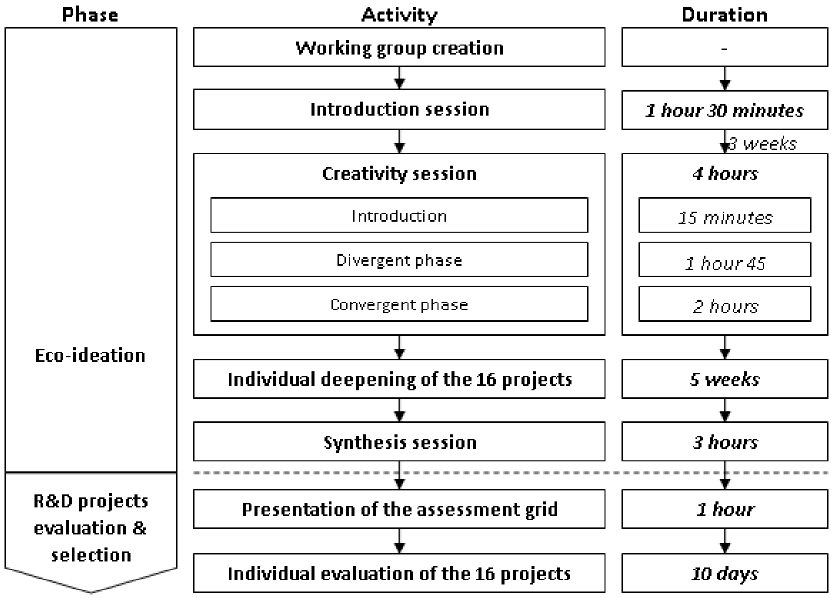

Figure 1: Time line of the eco-innovation process at Alstom Grid PEM

A working group was built with complementary knowledge of a substation, including two persons from the R&D department, one from the Engineering department, one from the Commercial department, two from the R&D department of another Alstom Grid unit providing the transformers, and one academic eco-design expert. The animation was managed by one junior eco-design expert assisted by one eco-design trainee, who were not proposing ideas during the creativity session. So the eco-innovation process involved 9 persons. The whole process lasted about 10 weeks (see Figure 1). After the creativity session, 16 eco-innovative projects were selected and assessed by the working group thanks to the assessment grid presented in section 3.3.

4.3. Results and discussion

4.3.1. Quantity

109 ideas were generated during the creativity sessions. Each axis of the eco-design strategy wheel provided between 10 and 23% of these ideas. Each active member of the working group proposed between 8 and 35 ideas. Relatively to the time spent in the divergent session (1 hour and 45 minutes), it is really satisfactory. After the convergent session, 16 eco-innovative projects were identified.

4.3.2. Variety

The variety of the results obtained is also really satisfactory, as the portfolio including the 16 projects is well balanced on the three criteria (time horizon, project perimeter and project nature). All categories are represented.

4.3.3. Novelty

The answers to the questions evoked in section 3.4 clearly show that a lot of eco-innovative ideas may be present in the company employees' mind but would never emerge without the proposed method. It also shows that new ideas could appear thanks to this method, and that it is a good way to stimulate designer's creativity.

4.3.4. Quality

The quality of the process is assessed thanks to the designer's evaluation of the 16 projects according to three criteria (environmental benefits, feasibility, client's value). The results for the environmental benefits shows that the average score is 10.8 (out of 20), but with a low standard deviation (0.98). It means that the 16 projects propose environmental improvements on some axes of the eco-design strategy wheel, but no generalized environmental improvements. This clearly characterizes incremental eco-innovations. For the feasibility criteria, the average score is 12.2 and the standard deviation is clearly higher (2.70). The projects are well ranged on the scale (from 4.5 to 15.2) showing that the proposed qualitative indicators are sufficient to distinguish the projects. Finally, the results for the client's value criterion show that the average score reaches 10.9 with a standard deviation at 1.34. As for environmental benefits, it is hard to distinguish the 16 projects. But if we consider that only incremental eco-innovations have been identified, it could be explained by the fact that the projects would only bring little benefits for the client's value.

5. Concluding remarks

Starting from the statement that eco-innovation methods are not adapted to complex industrial and technological systems, we have proposed an adapted eco-innovation process. This process includes two main stages: an eco-ideation phase involving a multidisciplinary working group and a creativity session in order to identify powerful eco-innovative projects; and a multicriteria assessment phase performed by the working group, considering environmental, but also technical and economic feasibility, client's value, project perimeter and time horizon. This process has been applied at Alstom Grid on large electrical substations. The results are very satisfactory as we have shown that this method permits to obtain a high number of ideas with limited time and resources. From these ideas a balanced eco-innovative R&D projects portfolio is identified, mainly composed of ideas that would not have emerged without the method, but also of some new ideas.

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Part II

Towards sustainable business models and territories

Sustainable business models for eco-design and innovation

The case of Riversimple

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1. Introduction

The idea that companies and (other kinds of organisation) should strive for "sustainable business models" in order to contribute to a sustainable development of the natural environment, society, and economy is becoming increasingly popular. But it is misleading. A business model *per se* cannot be sustainable. It is a model. And as such it integrates a variety of socially constructed, interrelated, and context-dependent concepts (e.g. value, target groups, resources; cf. (Wirtz et al., 2016)). It is a tool, i.e. a means, and not an end (Doganova & Eyquem-Renault, 2009). Business models, if developed and managed properly, can support sustainable business processes, products, services, and environmentally and socially beneficial forms of consumption. But in all these cases the attribute "sustainable" rather refers to the respective processes, products, etc. Therefore, to be precise, we should speak of "business models *for* sustainable products" and so forth, or, in general, "business models *for* sustainability" or "BMfS" (Schaltegger et al., 2016a; Wells, 2013a). Separating the business model (the means) from the sustainability issue to be solved (the end) is an important first step before we can systematically and effectively think about how business models can support sustainable business.

Following this line of thought, this contribution to the EcoSD Annual Workshop 2015 distinguishes and then brings together two issues: the eco-design question and the business model question. The first asks: *How to create useful artefacts that generate as much utility and joy as possible, using the smallest possible amount of natural resources, including footprints, for the longest possible period of time (Schmidt-Bleek, 2000)?* The second is about a different but related issue: *How to market eco-designs and innovations to unfold their full sustainability potential, in ways that allow users to easily adopt them and that allow eco-entrepreneurs to make a business (Boons & Lüdeke-Freund, 2013)?*

While eco-design, or more broadly speaking eco and sustainability innovation, is a dynamic topic in academic research and business practice, we are only beginning to explore the relationships between eco-design and business models. There is no doubt that moving to the business model level, as a step beyond processes, products and services, is a worthwhile endeavour. It holds the promise of multiplying the positive effects of eco-design through a deliberate focus on how businesses create value under market conditions. Practitioners such as Riversimple founder Hugo Spowers, who is an eco-design and business pioneer in the field of e-cars, increasingly call for this move to the business model level: "Disruptive technology can only work if it comes with a new business model." (Hugo Spowers, in Wysocky, 2014).

This paper offers some general thoughts about BMfS and their relation to eco-design, the barriers that inhibit their emergence and how business model innovation can overcome these barriers. The case of Welsh e-car designer Riversimple is used as an example of eco-design and business model innovation in practice.

2. Approaching Business Models for Sustainability

Based on Chesbrough and Rosenbloom (2002) and Doganova and Eyquem-Renault (2009), we have defined business models as "market devices" that can be used to connect sustainability innovations to markets (Boons & Lüdeke-Freund, 2013). The major idea behind this definition is that innovations such as eco-products or services for poor people hold a particular sustainability potential that will only be realised if the innovation in question is successfully marketed – eco-cars will only help mitigate environmental degradation if they are used by a large number of people, i.e. when the mobility market is transformed by truly sustainable alternatives (Schaltegger et al., 2016b). While eco-designers are concerned about the cars' performance, business model developers are concerned about how to market them. Both tasks are interrelated, but require quite different perspectives and skills.

Business model development and management deal with value propositions for customers, supply chains, market interfaces, and financial models (for a recent overview of traditional business model concepts see Wirtz et al., 2016). Some authors propose sort of guidelines to support business model developers in their search for BMfS. We summarised these guidelines as a set of four "normative requirements", each addressing one of the major areas of a business model (here, we refer to the business model concept by (Osterwalder and Pigneur, 2009)) (Boons & Lüdeke-Freund, 2013):

- The *value proposition* provides measurable ecological and/or social value in concert with economic value.

- The *supply chain* involves suppliers who take responsibility towards their own as well as the focal company's stakeholders.
- The *customer interface* motivates customers to take responsibility for their consumption as well as for the focal company's stakeholders.
- The *financial model* allows a just distribution of costs and benefits among business model stakeholders and includes ecological and social effects.

These requirements are purposely formulated in a generic way. The idea is not to prescribe BMfS, but to improve the likelihood that a business model can be aligned with different kinds of sustainability innovation (this alignment function is discussed in Lüdeke-Freund, 2013). Due to their generic quality, these requirements should be applicable in a wide range of contexts. Major contexts are the introduction of *environmental innovations* (often referring to green technologies such as solar power), *social innovations* (such as inclusion programmes in supply chains), and *economic innovations* (e.g. the introduction of new organisation paradigms). These categories are of course not mutually exclusive since, for example, social innovations can also involve technological innovations, which might change the economics of a business.

Table 1: Major innovation orientations for BMfS (Bocken et al., 2014)

Environmental (incl. technological)	Maximise material and energy efficiency Create value from waste Substitute with renewables and natural processes
Social	Deliver functionality rather than ownership Adopt a stewardship role Encourage sufficiency
Economic (incl. organisational)	Repurpose for society and environment Develop scale-up solutions

These orientations can be further specified (Table 1). "Develop scale-up solutions", for example, refers to business models that deliver ecological or social solutions at a large scale in order to maximise the benefits for the environment and society. Scaling can be achieved through franchising or licensing, for example (e.g. Tesla's technology licensing). "Deliver functionality rather than ownership" is about services that satisfy customer needs, instead of selling physical products they have to own (e.g. Hilti's tool leasing). The assumed effect is a decoupling of benefits for the business and its customers from physical production volumes. As a last example, "maximise material and energy efficiency" is about doing more with less resources, waste, emissions, and pollution (e.g. Dow's closed-loop system "Safechem").

3. Barriers to Business Models for Sustainability

3.1. Barriers to BMfS

While the received literature proposes different frameworks and tools to describe and support BMfS, little attention has been paid to the barriers that inhibit their realisation in practice. Daily experience tells us that most companies do not employ business models that (fully) subscribe to the above proposed normative requirements and innovation orientations. Early on, Wüstenhagen and Boehnke (2008) identified three major barriers to BMfS which are summarised below (for a more recent and fine-grained analysis of barriers see e.g. (Laukkanen & Patala, 2014)).

3.2. Internalisation of external effects

The reduction of negative ecological and social effects expected from sustainability innovations does not necessarily translate into private benefits for the firm and its customers. What is the immediate customer benefit of a solar installation? It reduces CO_2 emissions, but what is the private benefit for users of green power? While conventional technologies often cause ecological and social costs, sustainability innovations are designed to reduce these negative effects. This, in turn, can lead to relatively higher financial costs, if narrowly measured, and, at least in the short term, to competitive disadvantages (think of the early days of renewable energies, or the current situation of most e-mobile manufacturers).

3.3. Capital intensity and long lead times

Developing new technologies, such as fuel cells, requires large investments – and a lot of time. Their financial amortisation usually takes longer than with established technologies and it can even be unpredictable due to insufficient forecasts of cost and revenue profiles. Early adopters have to bear the costs and inconvenience of switching to new technologies, e.g. due to a lack of charging infrastructures for e-mobiles, and its initially higher purchasing and running costs. Both investors and users are important financiers of sustainability innovations, but both might have reasons to wait until others bore the initial costs – a prisoner's dilemma.

3.4. The power of incumbents

Existing companies invested large amounts of money in developing, marketing, and improving their offerings, valuable assets, technologies, and infrastructures.

They often hold strong positions in the market and they are reluctant to change their current businesses before these are fully exploited. Hence, incumbents have a vital interest to inhibit change. While this might call for radical system-level change, e.g. to completely replace conventional energy supplies, incremental change can accumulate until a tipping point is reached. The German energy industry has reached this tipping point after more than thirty years in which renewable energies, smart technologies, and programmes to change the behaviour of energy users were under development or kept in niches.

3.5. Overcoming Barriers with Business Model Innovation

Wüstenhagen and Boehnke (2008) also made general suggestions how to overcome these barriers through value proposition and supply chain design and new financial models. Tools to support according business model innovations are emerging in both academia and business practice (these are not further discussed here; see e.g.(Foxon et al., 2015; Joyce et al., 2015; Upward & Jones, 2016)).

3.6. Value proposition

The value proposition of a BMfS should translate societal benefits at least partly into private benefits for customers, i.e. the societal benefit of an offering must be tangible for the customers who pay for it. Proper value proposition design can help justify the relatively higher costs of green or social offerings. Additional private benefits can be created for example through distinguishing product features. Tesla's e-mobiles are designed to attract high-income customers whose willingness to pay for a premium vehicle is used to finance Tesla's dynamic product and organisation development.

3.7. Supply chain

Wüstenhagen and Boehnke argue that supply chains and networks should combine carefully selected in-house activities, such as R&D, manufacturing, or distribution, with outsourcing of non-core activities with high additional costs and low marginal benefits for the firm. Not doing everything in-house reduces investments and allows focusing on those parts only that must be developed anew. Combining new processes, products, and services with standard parts of third-parties not only reduces R&D costs but also makes sure that the innovation in question is at least in part compatible with existing production and consumption systems.

3.8. Financial model

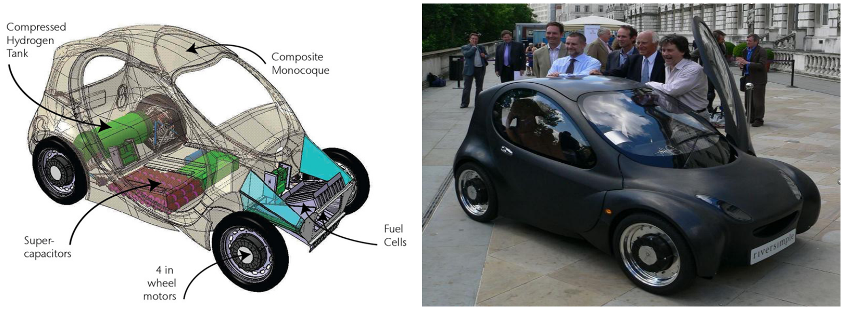
Purpose-driven patient investors and public funding with a long-term horizon are crucial to secure the basic funding for sustainability innovation projects. As argued above, investment needs can be reduced by focusing on particular core activities. Investments can be divided among several investors, e.g. through co-operations with incumbents who co-finance the scale-up and roll-out of a new business model. From a customer perspective, low switching costs and upfront costs are crucial, e.g. through all-in service fees, leasing or contracting models.

4. Riversimple: Designing an Ecosystem for E-Cars

4.1. Riversimple's Eco-Design

Welsh car designer Riversimple (based on information published on http://riversimple.com, as of March 2015) develops a new type of hydrogen-fuelled e-car that tries to circumvent the limitations of the automobile industry's traditional designs and related lock-ins, such as its dependence on the oil industry and large-volume manufacturing models (see Wells, 2013b, for a reflection of sustainability innovation in the automobile industry). Riversimple aims to combine high standards in design and engineering. Only the most recent technologies and materials are used to develop a highly efficient car driven by a hydrogen fuel cell and super capacitators (fast charging energy storages). Strong and lightweight materials are used for the body, mainly carbon fibres, four in-wheel motors move the car, and regenerative braking reduces energy losses (Figures 1a and 1b).

The car's components are aligned with the requirements of low-powered hydrogen fuel cells since Riversimple's eco-design builds on two principles that are inspired, inter alia, by the works of Amory Lovins.



Figures 1a and 1b: Early design studies of Riversimple's "hyrban" prototype (2010)

4.2. Design principle 1: Decoupling energy provision for accelerating and cruising

This principle allows using a small fuel cell, in terms of capacity, for cruising, while fast charging super capacitators provide the energy to accelerate the car. Instead of using a big, heavy, and costly fuel cell for both cruising (low energy demand) and accelerating (high energy demand), separating the energy provision for these two processes allows for a more efficient fuel cell design.

4.3. Design principle 2: Mass decompounding

The principle of mass decompounding opens up a virtuous circle based on using a decreasing amount of components and overall mass, and accordingly decreasing energy use. Fewer components lead to less weight, which leads to less energy consumption and a smaller fuel cell and engine, which in turn reduce the car's weight and so forth.

4.4. Riversimple's Business Model (in the Making)

While Riversimple's design principles address the "eco-design question" the company is also working on the "business model question". Riversimple's eco-design approach is a means to revise traditional automobile design and manufacturing, and thus the root cause of many negative effects on the natural environment and human health. The company's idea for a new business model – which is still under development – is equally radical as it seeks new ways to create multiple forms of value for the company's various stakeholders in an integrated manner. Some business model properties are evocative of Better Place and Tesla Motors (e.g. fee-based revenue model, open source philosophy) while some are unique (e.g. distributed local manufacturing based on replicating small-scale facilities).

4.5. Value proposition

The value proposition describes the benefits a company promises its customers and further stakeholders based on the products and services it offers. Riversimple's value proposition can be sketched as follows:

- Affordable and aesthetic eco-mobility for everyone;
- Car for urban traffic and daily commuting;

- No ownership due to an all-in leasing fee;
- Individual mobility as hassle-free service.

4.6. Supply chain

The supply chain, the backbone of any business infrastructure, shall build on a network of local small-scale manufacturers offering locally produced cars for local use. Another characteristic is the public availability of design details:

- Manufacturing network based on local, small facilities (5,000 cars/year);
- Open source philosophy, design details openly available as CAD files;
- Sale-of-service model along the supply chain;
- Team of engineers, designers, and business developers with professional backgrounds (e.g. Formula 1, Fiat, Porsche Holding).

Riversimple plans to offer its e-cars, for which the company will retain ownership, and related services mainly through local distribution networks:

- Local provision of locally manufactured cars;
- Local refuelling network;
- Riversimple retains car ownership.

4.7. Financial model

The economics of this model still have to be tested, but some general features are already described on Riversimple's website. The model builds on dedicated and specialised financiers and an attractive monthly fee for future customers:

- Investments from patient seed and venture capital providers (Bscope, investment arm of Piech-Nordhoff family, former shareholders in Porsche)
- Monthly all-in leasing fees as major revenue source
- Fees cover the car, fuel, maintenance, and insurance

Figure 2 summarises the most important business model features according to current publications by Riversimple. It must be considered that their model is currently under development and still needs refinement and validation.

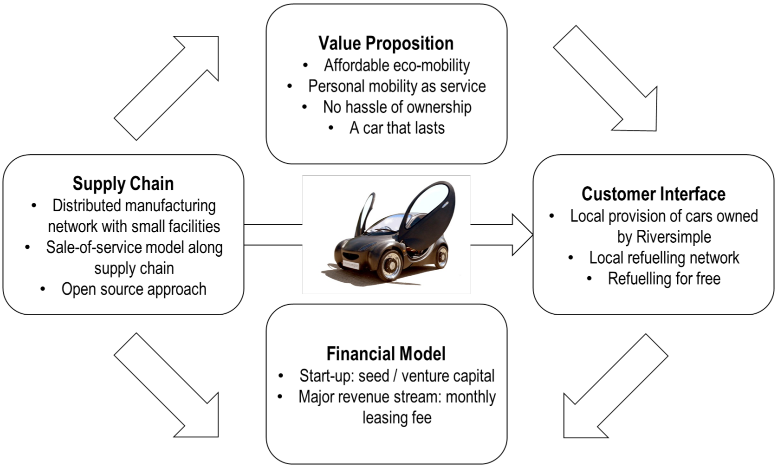


Figure 2: Overview of Riversimple's planned e-car business model

4.8. Conclusion

Riversimple's approach to designing a new kind of hydrogen-fuelled e-car is based on the co-development and co-evolution of a whole ecosystem: the company develops a new technological artefact, the e-car, *and* anticipates the networks that are necessary to produce and use it, although developing these networks goes far beyond car design in a narrow sense. While other car developers mainly focus on their cars, Riversimple works on the parallel establishment of different networks: a local manufacturing system, a refuelling infrastructure, and a stakeholder network as part of the company's governance system. On top of that, a new business model carrying these technological and organisational innovations is under development. Its central theme is to offer an aesthetic form of individual eco-mobility to everyone.

This business model for eco-mobility faces several barriers. How can Hugo Spowers and his team motivate customers to contribute to the reduction of negative environmental and social externalities, i.e. *how to offer eco-mobility and private benefits?* The central idea is to offer eco-mobility as a hassle-free, all-in, fee-based service that might appeal to a broad range of customer segments. How does the company try to overcome the problem of capital intensity and long lead times, i.e. *how to finance R&D over a long period of time?* Riversimple found patient and purpose-driven investors to finance the development of its e-car and its market introduction. The most challenging barrier, however, is the power of incumbents, i.e. *how to overcome the lock-in effects and path dependencies of one century?* One way of dealing with this barrier is to create a network of allies who can contribute or even replicate Riversimple's model in the future without belonging to the original company. Riversimple's transparency, non-exclusivity, open source philosophy, and its dedicated network approach might become the nexus of a future movement of which climax might be a global e-car revolution.

Finally, which innovation orientations are contained in Riversimple's business model draft? Obviously, *maximise material and energy efficiency,* as can be found in the car's light-weight construction, high-efficiency fuel cells and engines. The model is also about *delivering functionality rather than ownership* since Riversimple plans to own the cars while users pay all-in fees. The company's open access and network approach as well as the plan to design locally replicable manufacturing units suggest that the company is aiming to *develop scale-up solutions*. Whether this combination of innovation orientations in Riversimple's business model for eco-mobility will allow for a sustainable business is a question for future research.

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6. About the author

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On the use of the 5D-sustainability transition method

A case study

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1. Introduction

Considering the continuous degradation of the ecosphere, it appears obvious that a system innovation for sustainability must be performed (Gaziulusoy et Al., 2013; Brezet, Van Hemel, 1997). System innovation is defined as a transition from one sociotechnical system to another, with fundamental structural changes regarding the following criteria: strong sustainability, system thinking, radicalism, long-term orientation and mindset change (Gaziulusoy et al., 2013; Gaziulusoy, 2015). Transitions are the result of multi-scale interactions that alters dominant practices, paradigms and structures over time (Loorbach, Wijsman, 2013). The mainstream business case of sustainability (i.e. corporate sustainability) does not question the fundamental paradigm of the capitalist market economy (i.e. mass consumption, growth) which is the source of most of the current socio-ecological problems (Schneider et al., 2010; Buclet, 2011).

In order to overcome these limitations, (Allais et al., 2016) develop a maturity grid to support the transition towards the 5 dimensions of sustainability (i.e. environmental, social, economic, political and territorial). The governance maturity grid is based on the assumption that the systematic adoption of the intangible capital (OCDE, 2006; Fustec et al, 2011) in strategic and operational governance (Nelson et Al., 2001; Delorge et Al., 2014) fosters sustainability integration at a strategic level. Maturity grids are designed to support the transitions from unsustainable to 5D-sustainability compliant companies and from economic-based to intangible-based governance requires decision-support tools. This research on system innovation for sustainability is centered on industrial companies embedded in a territory within the ecosphere. Figure 1 represents the system considered in this study within the 5D-sustainability.

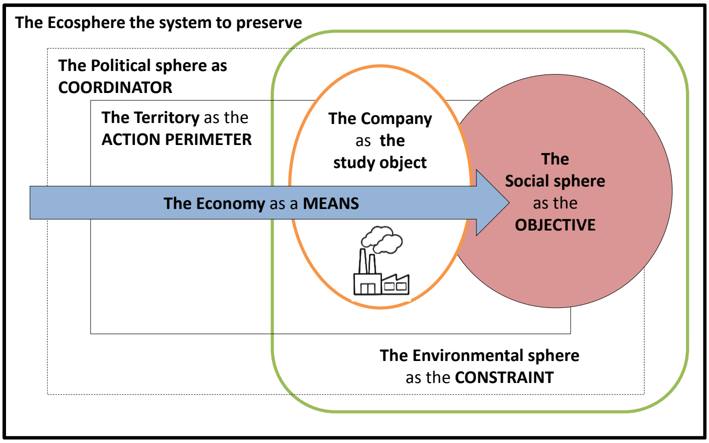

Figure 1: System considered and the 5 dimensions of sustainability (Allais et al., 2016)

Maturity grid is an element of a method for the integration of sustainability at strategic level in industrial companies (Allais et al., 2015). Even if it is dedicated to design improvement, this method is addressed to senior management as it provides decision-support tools for the strategic process. In fact, it extends strategic analysis to the whole value constellation of the company (internal value creation network, territorial dimension and integration of intangibles) (F1); supports the selection of strategic objectives toward 5D-sustainability (F2) and provides tools for the implementation and valorization of this strategy (F3). Maturity grid supports (F1) and (F2). Figure 2 illustrates the architecture of the method for the 5D-sustainability transition.

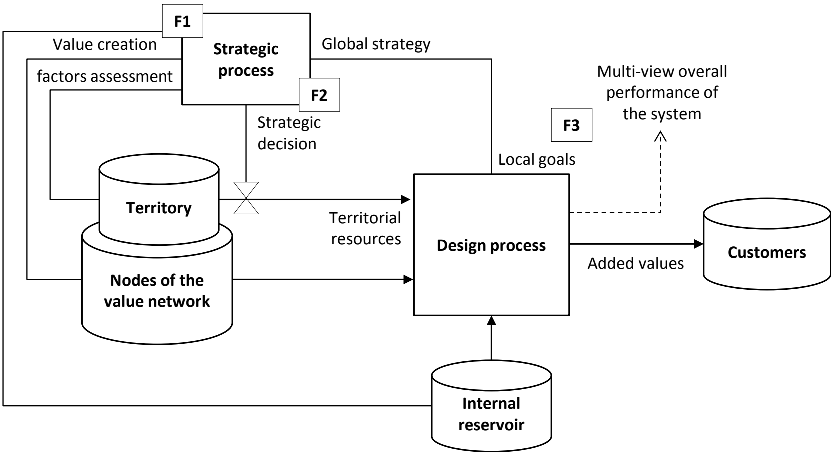

Figure 2: Functional representation of the 5D-sustainability transition method (Allais et al., 2015)

The third function of this method (i.e. implementation and valorization of the strategy) is supported by the Convergence program that proposes a systemic navigation framework to address the lack of sustainability integration at all corporate hierarchical levels (Zhang, Rio, Allais et al., 2013). A multi-level approach was developed from global strategic decisions by top management, through planning and organization by tactical management, to daily engineering and production activities of the operational level. This framework is divided into three distinct modules linked by a set of indicators. These are dedicated to each specific level and aggregated into a global strategic scorecard extended to intangibles (Fig.3).

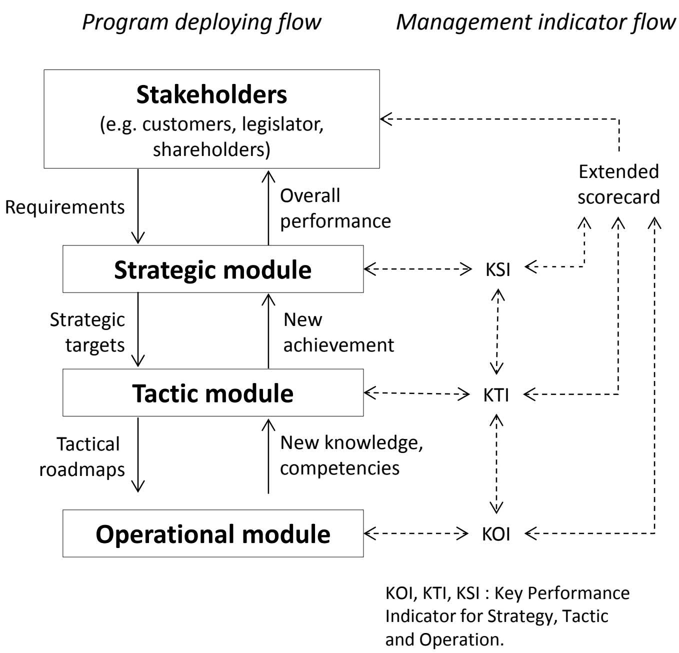

Figure 3: Convergence architecture for sustainability integration into companies (Zhang, Rio, Allais et al., 2013)

The strategic module provides top management with extra-information during the strategic process to support the strategic analysis, the choice and deployment of the company's sustainable objectives. The tactical module supports department managers and experts in formulating an achievable roadmap to respond to strategic and project needs. These trajectories gather a chain of environmental methods and tools to pilot the generation of environmental improvements. The operational module provides a flexible and dynamic framework based on federation of tools, which supports the design process deployment in line with the defined tactic. The aim is to optimize the interactions needed between the product design process and environmental engineering activities (supported by tools, software).

Over the 5 dimensions of sustainability, the Convergence framework supports only environmental strategies deployment through managerial roadmaps to operations. The integration of territorial resources into product development process has been theoretically explored in (Allais et al., 2015).

The aim of this communication is to present a case study performed in the context of the Convergence research program to discuss the 5D-sustainability transition method.

2. The case study

The case study presented here was performed from December 2011 to June 2014 in collaboration with an industrial partner of the Convergence project. Due to confidentiality restrictions, none of the results of the evaluation or strategic decisions are published. The focus is on the implementation of the 5D-transition methodology and on the discussion of the results.

2.1. Objectives and success criteria

The objective of this case study is to test the implementation of the 5D-sustainability transition method regarding one particular aspect: the environment. Success criteria come both from literature on system transition and interviews of internal stakeholders of the company during the first step of the experiment.

- Theoretical requirements come from the system innovation definition (Gaziulusoy et al., 2013; Gaziulusoy, 2015) (i.e. strong sustainability, system thinking, radicalism, long-term orientation, and mindset change).
- Practical requirements from the Convergence research program were to provide a fast and zero cost method (from the company point of view) for strategic/governance assessment and improvement.
- The experiment also has the objective to validate the interoperability between the different modules (i.e. strategic, tactic, operational).

2.2. Step one: F1- extending the internal strategic analysis to all the value creation factors

This first step has the ambition to provide senior manager with extra information on the value constellation of the company within its territories. It concerns the knowledge of the strategic and operational governance, the portfolio of intangible assets of the company and the value constellation extended to the territory. Note that the territorial dimension was not taken into account in this case study.

2.2.1. Mapping the value constellation

December 2011. The complete methodology for mapping the value constellation is detailed in (Zhang et al., 2013); it consists in semi-directed interviews to understand current internal processes (top managers, back office, design, marketing, operation and sellers) and the corporate environmental program. Interviews were centred on an explorative environmental project previously deployed in the company. Researchers seek to understand both standard processes and daily activities and the incidence of environmental constraints on standard activities (i.e. perceived limitations of standard processes to the inclusion of environmental issues and the potential improvements). 28 interviews were conducted with the delegate of each internal function as well as the different hierarchy level agents (including top managers, managers of each section, designer and end operational people of each function).

From these interviews, a complete mapping of the activities of the extended company was created according to this model of representation (Fig. 4). This enables an overall comprehension of the decision and work flows within the company. It also gives information on the standard communication supports that will be used to integrate environmental issues in daily activities.

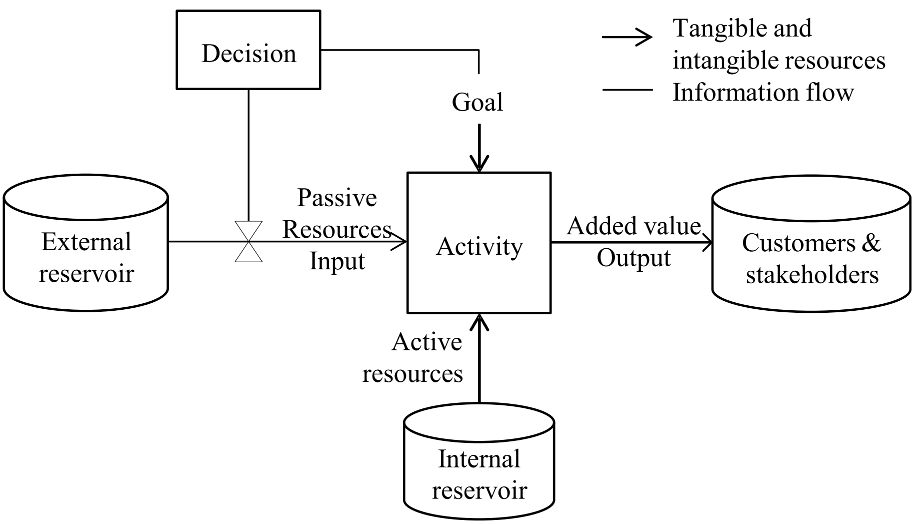

Figure 4: The value constellation mapping model adapted from (Duffy et Al., 2009; De Rosnay, 1975)

September 2012. With the support of expert from the French *Observatoire des immatériels*, a think tank was dedicated to intangible capital and its potential, semi-directed interviews were conducted with the human resources director and the sustainability manager. These interviews aim at understanding the portfolio of intangible assets of the company and highlight the key assets of the company (e.g. differentiators, risks) and their management (i.e. strategic and operational governance of intangible assets).

Three systems of intangible assets were identified during this workshop. These provide competitive advantage to the company and must be managed consequently. As an example, one of the key assets of the company is its human capital as it is creative, anti-conformist, entrepreneur and sharing a common culture. But, due to the employee turnover after a certain age, the transmission of internal knowledges and culture may be threatened. This step helps senior managers formalize and share a common vision of the company's intangible assets portfolio.

2.2.2. Company's governance profile

October 2013. It consists in the implementation of the maturity grid that enables a qualitative assessment of the governance regarding inclusion of the 5 dimensions of sustainability and the intangible capital into governance (Allais et al., 2016). The assessment was performed thanks to a multi-choice survey conducted by researchers to the Chief Operating Officer (CEO), a member of the steering committee and the head of product range of the company.

The ambition maturity grid (i.e. integration of sustainability into governance) indicates that, even if the company has a global sustainability policy, it is not directly discussed at the strategic level. In fact, initiatives come mainly from middle management and operations. At a strategic level, environment and social aspects are taken into account as risk factors or factors of economic performance (i.e. conformist and opportunist). The number of stakeholders integrated into corporate governance is limited to the steering committee and shareholders. The means maturity grid (i.e. integration of intangible capital into governance) indicates that there is strategic thinking around the intangibles that provide competitive advantages. Brands and their representatives are considered as a key factor for differentiation and a protection strategy is implemented. Strategic and operational governance are based only on business performance, and intangible risk factors are occasionally discussed and managed at strategic level.

Table 1: Ambition maturity grid, environmental dimension, extracted from (Allais et al., 2016)

Sustainability governance maturity grid	Short description	Consideration of the environment in governance
1- Resistant	The company is in conflict with the laws relating to sustainable development and ignores completely.	The environment is not taken into account. Non-compliance on several points, frequent opposition to new environmental regulations.
2- Conformist*	The company is in compliance with the laws and regulations regarding labor, the environment, health and safety	Compliance with legal requirements related to the environment that is managed as a risk factor case by case (new regulations, market demand ...).
3- Opportunist*	The company identifies opportunities for cost reductions by a selective consideration of sustainability issues	Use of the environment to reduce and control costs (waste reduction, reducing the consumption of non-renewable resources...).
4- Integrated	The company has incorporated some aspects of sustainable development into its business model as competitive advantage	Systematic ecodesign of products and services by combining environmental and economic performance (cost reduction and differentiation).
5- Innovative	The company creates value for all its stakeholders by territorial system innovation in compliance with the environmental limitations of the system's boundaries	The environment is the core business. The entire activities are built to reduce the environmental impacts of the business.

2.3. Step 2: F2- supporting strategic decisions towards sustainable strategy

The governance maturity grid provides both an assessment and an improvement tool. Theoretical development and design is detailed in (Allais et al., 2016).

October 2013. After the qualitative assessment described in 2.1.2, interviewees were invited to select an environmental objective to comfort or improve environmental integration. The alternative objectives were limited to the environmental dimension among the 5 dimensions of sustainability (Table1). Interviewee selected two strategic environmental objectives to validate existing processes (i.e. environmental legislation compliance – level 2) and to consolidate existing environmental products (reduce material intensity of product - level 3).

2.4. Step 3: F3- managing the deployment from strategy to designers

This step aims at supporting the deployment of strategic objectives to operations thanks to the realization of roadmaps at a tactical level. The deployment is supported by a navigation system which provides a holistic, overall and systemic support to companies willing to integrate environmental concerns in their processes (Zhang et al., 2013), see also (Zhang, Zwolinski, 2012; Rio et al., 2013).

Once the environmental strategic objectives (ESOi) selected, they are then detailed (ESOij). There are broken down into environmental tactical objectives (ETOa), translated into roadmaps and specific actions (Act b1). Every strategic, tactical of operational element is linked with indicators that are aggregated into a scorecard extended to intangible (Fig. 5).

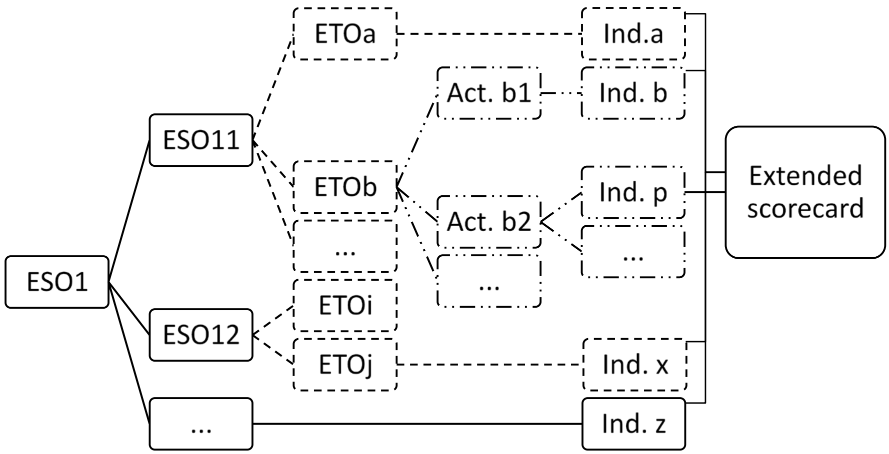

Figure 5: Architecture for the deployment of strategic objectives to tactics and operations.

The roadmaps and associated scorecards were generated by researchers and then proposed to the company for implementation.

3. Discussions & conclusions

The 5D-sustainability transition method was partially implemented in the company. First, only one dimension was explored (the environment) and there was no implementation of the proposed roadmaps. However, the method supports senior managers in extending their strategic analysis thanks to the realization of the governance profile (i.e. integration of 5D-sustainability and intangible capital into governance). A contribution for users was to question their practice regarding strategy and governance. In fact, the first step of the case study initiates discussions on value creation and the means to manage these factors. It enables senior managers to step back and question the sustainability (ambition –necessary?) of the company.

The 5D method also supports senior managers in selecting environmental strategic objectives in accordance to their company's governance profile. In fact, interviewees consider that intangible management is insufficiently implemented at strategic and operational levels even if it is considered as a key factor for both business and sustainability management. The method enables the generation of environmental roadmaps and associated extended scorecards. This validates both the interoperability and the feasibility of the proposition.

Regarding the success criteria for system transition, the 5D-sustainability transition method validates the strong sustainability, the system thinking, the radicalism and the long-term orientation criteria (Allais et al., 2016). However, the mindset change criterion is not validated. It is not possible to draw conclusions on the following criteria (i.e. supporting transition in governance practices or the integration of sustainability principles into governance, adoption of intangible capital) because there were no actions taken after the initial assessment phase and roadmap generation.

The no cost-no time requirements from the company are not validated. In fact, the required resources for the implementation of the method were supported here by public founders.

Even if these implementations considered only environmental strategies, the 5D-sustainability transition method assists decision and generate operational and managerial roadmaps (i.e. top-down approach). The company did not implement these roadmaps so no changes were perceptible in terms of pragmatic results. The main benefit of these experiments was to question leaders' strategic analysis, as they highlighted aspects that had not yet been discussed at a strategic level.

Finally, the mindset change criterion appears as the main difficulty for system transition. Future research work has to consider this aspect by developing strategies to use current mindset models as levers for system change (i.e. what is the profitability?) or develop strategies to modify current mindset in company.

4. Acknowledgement

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6. About the author

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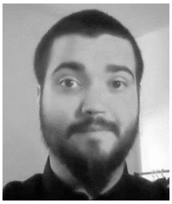

Coming from production engineering and automotive design, Romain Allais has slowly discovered research in eco-design. Through his PhD, he proposes a methodology for sustainability integration into product design process in industrial companies. The adopted strategy is to activate territorial tangible and intangibles resources thanks to organizational innovation. He has collaborated to the white paper « Immatériels, nouvelle gouvernance de l'entreprise » from the French Observatory of Immaterials. Since September 2014, he is involved as a research engineer in a research project on functional economy for small household appliance in the Research Centre for Environmental Studies and Sustainability (CREIDD) in University of Technology of Troyes.

Upgradable-PSS

Upgrading as core of a new production/ consumption mode

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1. Introduction

Our society is increasingly concerned with 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 (SERI Research center, 2009), the world population consumes about 50% more natural resources than 30 years ago (CGDD, 2010). These current patterns of consumption and mass production are no longer compatible with sustainable development (WCED, 1987). To remedy this, it is necessary to imagine new paradigms of production / consumption, such as the "post mass production" (Umeda et al., 2000) or the "parsimony" paradigm (Cucuzzella, 2009). We consider the upgrades, defined as a functional enrichment brought to the product. We can imagine a mode of consumption/production based on a dynamic of multiple Upgrades integrated into sustainable products, in other words, a product whose end of life would be projected over a longer term through optimal modularity. With such products, any technical, functional or visual improvement could be "easily" integrated, and could even depend on the changing needs of each user. The optimization of modules' lifespan would rationalize the use of materials and the most efficient technologies in terms of energy could be put to use at any time.

Section 1 shows the opportunities of upgradability for rationalizing materials' use. Section 2 highlights our proposal for three keystone principles of a new concept of consumption/production based on upgrades with a view to economic growth freed from consumption of resources.

2. Context and opportunity of upgrading

2.1. 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) (Umeda et al., 2007; Rose et al., 2002; Xing et al., 2003; Takeuchi & Saitou, 2006). There are three main different end-of-life strategies: reuse, remanufacturing and recycling. Remanufacturing is "the process of restoring discarded products to useful life" (Lund, 19969) 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" (Ijomah, 2002). In our past research works (Tchertchian & Millet, 2011), a more pro-active and global approach for designing remanufacturable systems has been defined (Tchertchian et al., 2010). In this method, a remanufacturable system is characterized by several cycles of use, several "meetings" between the customer/user and the product improved step by step with the integration of upgrades (Pialot et al., 2012). 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.

2.2. Product's lifetime and upgrading

With these upgrades, the lifetime of any system can be increased because it becomes possible to manage the two key reasons why users discard products (Umeda et al., 2007): (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." (Umeda et al., 2007; Kondoh et al., 2009) The integration of upgrades can be made by a distributor/retailer, by a technician at home, by the user (e.g. "plug-and-play"), etc., and not necessarily as a result of remanufacturing operations. Then the reliability problems could be managed with the upgraded modules (whenever "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 delay in the replacement of a product is a strategy for rationalizing materials.

2.3. 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 to offering more services, more precisely "Product-Service Systems" (PSS) (Mont, 2002). Three types of PSS are defined related on the share of services in these new offers (Maussang, 2008). But it is hard to suggest new services with added value: this is one of the reasons why PSS is difficult to generalize. Are the upgrades a new potential to sell "addictive" services? Integrating upgrades step by step is a service itself. It also offers the possibility of improving products in the short term, for example with new sensors that could be integrated with linked software services or connected to infrastructures involving people. Above all upgradability offers, the possibility of learning more about customers and being able to suit the offers of option/connected module etc. to them; potentially opening up services of accompaniment, personalization and coaching, etc., that would give customers the repeated added value they need to switch to service based offers. Therefore « upgradability services » are an opportunity for industrial companies who want to switch to offers with more services, and for the dissemination of PSS.

Furthermore, upgrading is an opportunity for the diffusion of sustainable innovations which rationalize materials, related to end-of-life management (dissemination of remanufacturing), extended lifetime and servicialization (dissemination of PSS). In the following part, we suggest a new mode of consumption/production based on the concept of "optimized/increased/hybridized upgradability".

3. Towards a reinvented consumption mode based on upgradability

Our results and reflections enable us to define key ideas and characteristics that together are the basis of a new mode of consumption/production exemplified by Upgradable PSS (Upgradable-PSS). These rely on three keystones (Figure 1).

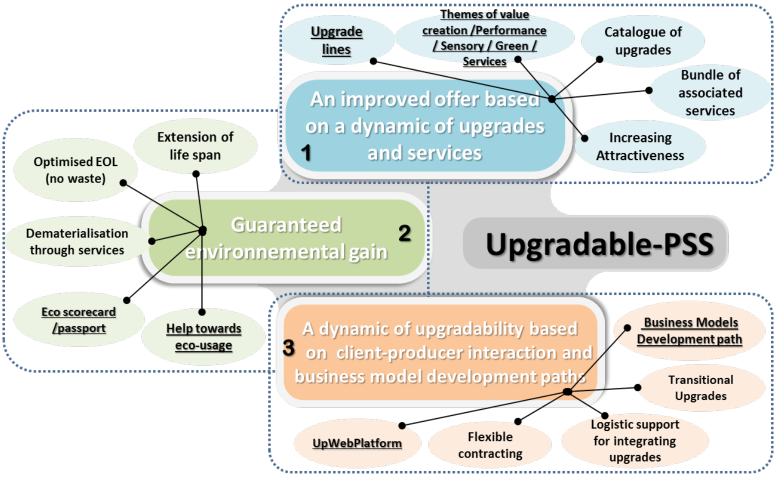

Figure 1: Bases of the Upgradable-PSS mode of consumption/production.

3.1. KEYSTONE 1: An improved offer based on a dynamic of upgrades and services

The first keystone of an Upgradable-PSS relies on the following key ideas:

The **Module upgrade lines** are a succession of upgrades whose integration is programmed over time and which feed the same Themes of VAlue Creation (Figure 2). These upgrade lines enable consumers to anticipate the product's evolution, and allow manufacturers to manage prolonged product lifetime, guarantees, flows of worn module returns or other aspects where value can be created in order to be perceived as innovative. The upgrade lines rely mainly on parametric upgrades that are foreseeable and directly impact the primary performances of the apparatus in question. The idea is to be specific enough about these upgrades to convince clients without giving away plans for innovations to competitors.

The **Themes of VAlue Creation (VaCT)** are the intended target with a view to a future « ideal » system that contributes value. We have identified four types of themes of value creation characteristic of the desired functional evolution for an upgradable system: as well as conventional performance criteria such as "utilitarian" (utility value) and "sensory" (emotional value), we add "environmental" (ethical value), essential when considering a product that is upgraded over the long term, and the "service" value (dematerialised utilitarian value) that improves the system's functionalities.

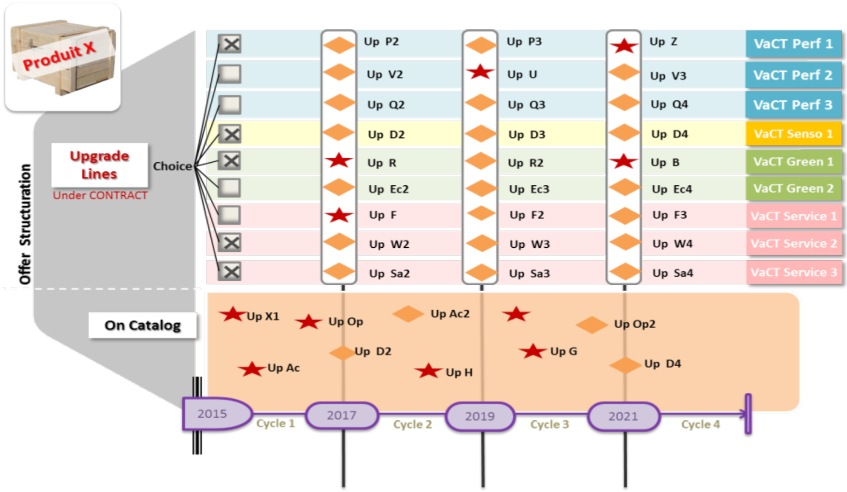

Figure 2: Structure of an Upgradable-PS offer.

To complete the above upgrade lines, a **catalogue of single upgrades** chosen by the client on demand enables consumers to integrate more specific and/or more optional upgrades (especially functional upgrades), and enables manufacturers to offer innovations proactively or reactively over time. The modular structure can be used to fit the product to the consumer, proposing customisation from the start.

An **offer of services** that can be associated to an upgradable product, notably those based on the addition and/or evolution of sensors in the product, opens the possibility to completely new lines of increasing functionalities (that are dematerialised as fitting with the environmental dimension). The themes of value creation related to services can be very new compared to the product's conventional functions. This potential bundle of services, accumulated with the service of upgrades, constitutes a value proposition based on services.

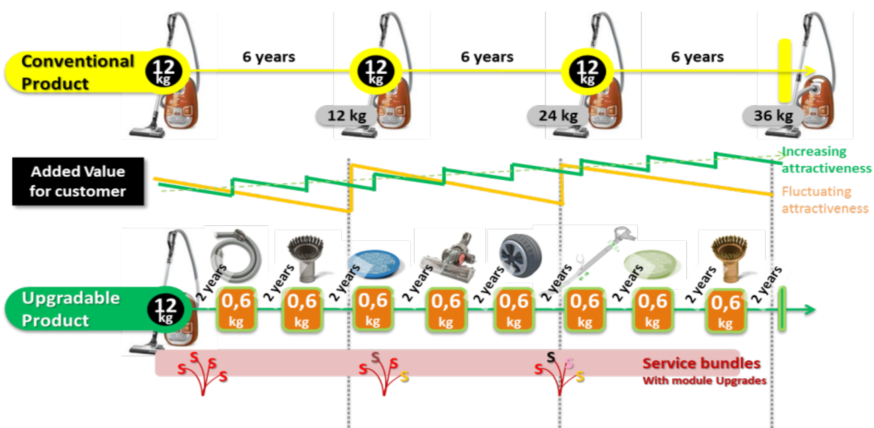

Figure 3: Illustration of the increasing attractiveness of an Upgradable-PSS.

Instead of customers having a product whose attractiveness decreases (from wear and obsolescence), and that they must change to access renewed attractiveness, they obtain a **proposition of lasting value and increasing attractiveness** (Figure 3). It is a system that improves over time with a more robust and reliable product base thanks to successive upgrades and also to access to new services. These attributes are what make upgradable systems increasingly attractive.

3.2. KEYSTONE 2: Guaranteed environmental gain

The second keystone of an Upgradable-PSS depends on the following key ideas:

An eco-learning strategy that aims to involve users in the eco-use of products by making eco-usage-feedback to make them aware of the environmental impacts they generate. To go beyond the rationalization of material, it is important to aim for energy efficiency in the use of a device destined for a long lifetime. To involve users in eco-using their devices, they need to be made aware of poor usage, situations where they could be more sparing with energy but also with material in order not counter the intended long lifetime. These situations of poor usage can evolve along with the integration of new upgrades. To help users to graduate towards eco-usage, upgrades provide the opportunity to change strategies over time. This could be eco-usage-feedback via a smartphone for example, but it is possible to envisage systems that would prevent product use if usage instructions were not respected.

An eco-scorecard/passport linked to the upgradable product that aggregates the scores of environmental impacts due to upgrades and their impact on eco-usage, **extension of product lifetime**, **dematerialisation** (by servicization) and **optimization of end-of-life** of worn modules/product structure (the schedule of upgrades, carried out by a support service that collects worn modules at the same time as it implants « improved » modules, facilitates the end-of-life processing of these modules and forms a perennial network of actors in end-of-life channel). This eco-booklet commits both the manufacturer and user towards a common green objective; this is true even in cases of changed ownership or end of contract, the booklet being linked to the product, not to the owner. The booklet is a permanent record of the environmental engagement of Upgradable-PSS.

3.3. KEYSTONE 3: A dynamic of upgradability based on client-producer interaction and the development of new business models

The third keystone of an Upgradable-PSS depends on the following key ideas: The **Up-Web-Platform** facilitates the more frequent consumer-manufacturer interaction due to the dynamic of upgrades. A platform of direct and continuous exchange between producer and client, based on a website, enables stakeholders to gather useful information and interact. The manufacturer can collect and prioritise client dissatisfaction, track changes in client needs, find out more about purchase choice criteria and suggest potential innovations. As well as expressing himself on the above subjects, the customer can access user guides, tips, or configure choices for future upgrades, access "question and answer" workshops with other consumers, swap shops or loans of some upgrades, competitions for designing future upgrades etc. Unlike a conventional product where there is practically no interaction between the client and the producer once the product has been unwrapped, an upgradable system would be regulated by almost continuous interactions that could be increased by connection to « intelligent « systems and sensors making products « connected », or by envisaging a system of rewards encouraging consumers to interact.

Development of business models' path is a succession scenario of several business models in the short, medium and long terms, with a potential coexistence of several of them at a certain date, and using upgradability as a transitional support towards transformation to avoid radical organisational and strategic change (**Figure 15**). The change in value proposition, offer, mode of contract, remuneration and systemised end-of-life as well as the change of used modules and upgradable product structure involve a change in the value chain and the actors in play. This whole business model has to be thought out anew. These changes are deep enough to raise questions about the vision of the company's business in the long term. Upgradability appears as a trigger for a change in modes of consumption towards models that are more service oriented. At the same time, upgrades are an opportunity because they make systems more evolutionary.

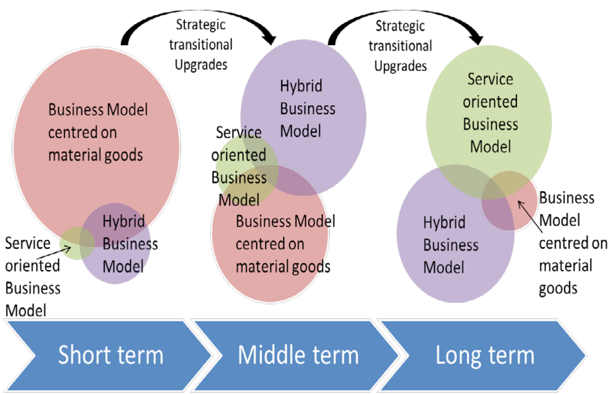

Figure 4: Illustration of a path of business model development using transitional upgrades

Strategic transitional upgrades are integrated "strategically" into the system and seen as transitional supports between two successive business models. For example, integrating sensors to offer services is one way of anticipating a more service oriented offer.

Because of upgrades and the more service oriented offer, the **new models of revenue and contracting** are obviously different. With an upgradable system, there are numerous opportunities to make income. In terms of upgrades, the offer is made up of upgrade lines that are programmed over time and "one-off" upgrades from a catalogue; upgrade lines suggest a contract structure. The servicization of the offer becomes even more significant if one considers "connected" upgrades (based on adding dynamic sensors – processing of service data transmitted). This contributes to a wealth of dematerialized functionalities in the form of services that can be adapted to user needs. Many models of contract/remuneration are possible if one considers the conditions of contracts for modules, sales of "points", lengths of guarantee or even the sale or hiring of the upgradable product itself. For the client, the main thing is to have a "dependence–free relationship" with manufacturer (gradual decreasing pricing of contracts to encourage re-subscription, renewable/extendable guarantee depending on choice of upgrades, resalable or stoppable contracts etc.). For the manufacturer, these new systems involve more stakeholders and several sales opportunities during the product's lifetime, both of which constitute more potential sources of revenue.

The **support services for upgradability** must be set up. These are necessary for the implantation of new upgraded modules and end-of-life processing of used modules. This obviously implies organisational transformations and changes in the value chain. Multiple configurations are possible involving stakeholders from producers to consumers along with distributers. Some users are happy to change their modules themselves while others prefer it to be done by a certified technician. This should not be experienced as a constraint, only as a way of upgrading a product; the manufacturer could leave the choice up to the client; this new and necessary organisation implies new logistics.

4. Conclusion

This paper has consolidated a new mode of consumption/production based on upgradability: Upgradable-PSS. The new systems we have considered are based on multiple upgrade cycles scheduled in the form of upgrade lines chosen by the consumer on themes of utilitarian, sensory, environmental and service oriented value. Upgradable-PSS relies on several principles of rationalization of materials use (prolonging lifetime, adding value to end-of-life material through remanufacturing and/or recycling, dematerialization through adding service-oriented value such as services with "connected objects") and also seeking to encourage users towards eco use of products. Upgradable-PSS thus maximize potential in terms of environmental gain. Moreover, the potential attractiveness of the offer, based on upgrades with added services, seems promising as a trigger to push the client into offers without ownership transfer; this implies changing all or part of the business model centred on a standard market model.

Because a whole new eco-system has to be put in place, we think that is necessary to develop a design methodology specific to Upgradable-PSS (design for upgradecycling). This method would be structured around a backbone of a scenario of upgradability of modules that constitute the upgradable system and the elaboration of new "upgradability" business models (strategies of commercial offering, contracting and upgradability support networks). With a view to helping design teams in their efforts, we are developing micro-tools to ensure a wide spectrum exploration, to calculate some indicators automatically and therefore simulate a great number of possibilities.

5. Acknowledgement

The "Design for upgradecycling" project (IDCyclUM) is an industrial research project (40 months) coordinated by Prof. Millet (LISMMA) financially supported by the French Research Agency (Ref 11-ECOT-001-IDCyclUM-01). The consortium is composed of 7 partners: the laboratories LISMMA, G-SCOP, COSTECH, GAEL, IWF (Germany) and industrial companies ROWENTA and NEOPOST.

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7. About the authors

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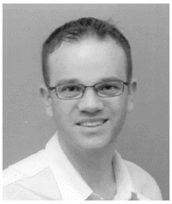

Mechanical Engineer specialized in innovative product design methods (PhD Thesis Industrial Engineering - Laboratory LIPSI-ESTIA and G-SCOP-INPG - «The PST approach as the design process streamlining tool innovative «) Olivier Pialot has worked as a Research Engineer in the team «Ecodesign and Optimization of Systems» of LISMMA (Supmeca-SeaTech) since 2010. Especially, his research focusses on product design and rationalization of the use of materials. Following the MacPMR Project design remanufacturables systems, he built with Pr Millet, works and co-manages the ANR Research Project IDCyclUM (2012-2015) involving 5 laboratories and 2 manufacturers on sustainable innovations with multiple upgrade cycles.

Justine Bisiaux

Affiliated to the COSTECH CRI laboratory (Knowledge, Organization and Technical Systems), Justine Bisiaux is a PhD student in sustainable Innovation at the Université de Technologie de Compiègne. The research work consists in characterizing business models compatible with the diffusion of sustainable innovations and building a methology to define these new business models for companies. She is also involved in the IDCyclUM project (Innovation Durables à Cycles d'Upgrades Multiples / Multiple Upgrades Cycles for Sustainable Innovations). It aims to apply the sustainable innovation in companies by working on the diffusion of evolutionary systems combining servicial business model and modular and upgradable products.

Part III

Industrial and institutional views on eco-innovation

Industrial and institutional views on eco-innovation

Synthesis of the round table

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1. Introduction

This chapter synthetizes the round table chaired during the last part of the workshop by Pr. Bernard YANNOU with six industrial and institutional participants, whose short biography is provided below. The objective of the round table was to confront the research work presented in the previous parts of the workshop with the reality of companies and territories. Several questions were answered by the participants during one hour. The main messages are synthetized in the next sections.

First each participant was asked to present one typical example related to eco-innovation in his/her organization. Then the second part of the roundtable consisted in questions from the audience and from the chairman, before concluding on some key take away messages to academic researchers.

2. Participants to the round table

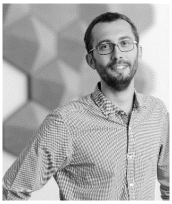
Chairman: Bernard Yannou (CentraleSupélec)

Bernard Yannou is a Professor in Design Engineering and director of the Industrial Engineering research department (Laboratoire Genie Industriel) of CentraleSupelec, France, where he also manages the Design and Ecodesign Engineering Research Group. His area of expertise is design automation, design methodologies, product development, innovation engineering, ecodesign, artificial intelligence in design, design processes and organisation modeling. Bernard Yannou has conducted research for a number of industrial companies. He holds the chair of "Sustainable construction and innovation" of Bouygues Construction. He has supervised 23 PhD theses, authored or co-authored more than 60 international peer-reviewed journal papers, and coordinated 8 books on product design and innovation. He is member of the Advisory Board of the Design Society, member of the ASME, Associate Editor of the Journal of Mechanical Design, Design Science Journal, and International Journal of Design Creativity and Innovation.

Hélène Bortoli (ADEME)

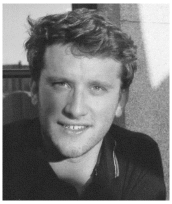
Being an engineer in chemistry and urban planning, Hélène Bortoli-Puig has a 20 year experience in engineering, project planning in urban engineering, consultancy on international projects and environmental communication. Since she joined the French environmental agency ADEME (Agence de l'Environnement et de la Maitrise de l'Energie), she has been coordinating projects on environmental assessment and eco-design in the Product and Matter Efficiency department of the Circular Economy and Waste office.

Edouard Carteron (Steelcase)



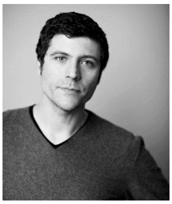
Edouard Carteron joined the sustainability department of Steelcase in 2011 and has been an expert in design for environment for 4 years. After his Master of Science in mechanical and design engineering and Master's degree in Eco-design and Environmental Management (ENSAM), he had a first experience as an environmental engineer in the French wood and furniture Institute (FCBA). In addition to working on industrial Life Cycle Assessment studies and supporting the product development teams on the sustainability topics and on eco-design, he was also involved on the new developments about Water Footprint, helping Steelcase to position itself relative to this issue in the furniture industry.

Alexis Dousselain (Mairie de Paris)



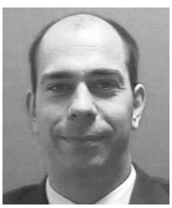
Alexis Dousselain works at the Innovation Office of the Attractiveness and Employment Department of the City of Paris (Mairie de Paris). He is in charge of life sciences and green industries sectors (research, industries, SMEs). His area of expertise concerns incubators, funding, competitive clusters and experimentation. He has also managed the promotion of companies from this sector during the COP21 (2015 United Nations Climate Change Conference).

Laurent Greslin (Z.I. lab)



Laurent Greslin is an industrial designer who started his career by experiencing the work with various forms of matter. After graduating in cabinet making, he discovers forging and fire crafts. In 2002, he obtains a Master's degree in art and design (ESAD Reims), and learns glass blowing. Between 2003 and 2010, he manages the industrial design for the SEB group in the DELO LINDO consultancy. He creates his own design studio in 2010, called Z.I.lab., with the ambition to question and articulate his practice, from arts and craft to high-technology industry. Deeply concerned with issues on our production patterns, he proposes a designer's vision relating crafting excellence and mass production, eco-design and integration of relationship between stakeholders.

Pierre Tonnelier (PSA Peugeot Citroën)



Dr. Pierre TONNELIER is responsible of the Eco Design and Life Cycle Assessment team in the Environmental department of PSA PEUGEOT CITROEN since 5 years and has worked during 7 years on vehicle projects as an expert in recycling and vehicle end of life. He worked on many studies on eco-design and and is member of the French network EcoSD.

Maxime Trocmé (Vinci)

Maxime Trocmé is the Environment and Scientific manager of VINCI group, in charge of environmental topics in the Corporate Social Responsibility approach. He is the coordinator of research and innovation works on eco-design projects, through the management of an eco-design Chair.

3. Typical examples of eco-innovation in the participants' company or institution

To introduce the round table, participants were asked to mention one typical example of eco-innovation in their company or institution (product, product line, initiative…). What were the incentives, the difficulties, and the constraints inside or outside the organization to develop it? A synthesis of each contribution is proposed in the next sections.

3.1. How does ADEME support eco-innovation?

Hélène Bortoli introduced a very simple example of an SME supported by the French environmental agency ADEME to develop an eco-innovative offer. This company, called MobilWood, is a shop fitter, producing chairs, tables, shelves… This company faced two major problems: Economic slowing down, Important waste of raw materials.

ADEME assisted MobilWood to develop an eco-innovative offer to reach more profitable markets. A Life Cycle Assessment of existing products showed the major environmental impacts, related to transportation, varnish and glue. The specifications for the new offer were thus to work on disassembly, to exclude the use of toxic substances and reduce the amount of wastes. Innovation emerged from the design of a new fixing system without glue and varnish, and without toxic substances. The business model was totally redesigned as this offer is now sold as a service and not as a product.

This example shows that even with limited resources, SMEs may eco-innovate. Eco-innovation emerged here from environmental constraints and economic difficulties of the company. The main barriers to implement this approach was to gain the adhesion of employees as it induced radical changes inside the company. Another difficulty to overcome this new business model based on product-service system has been to gain a higher understanding of clients' needs.

3.2. An eco-innovative ottoman for Steelcase

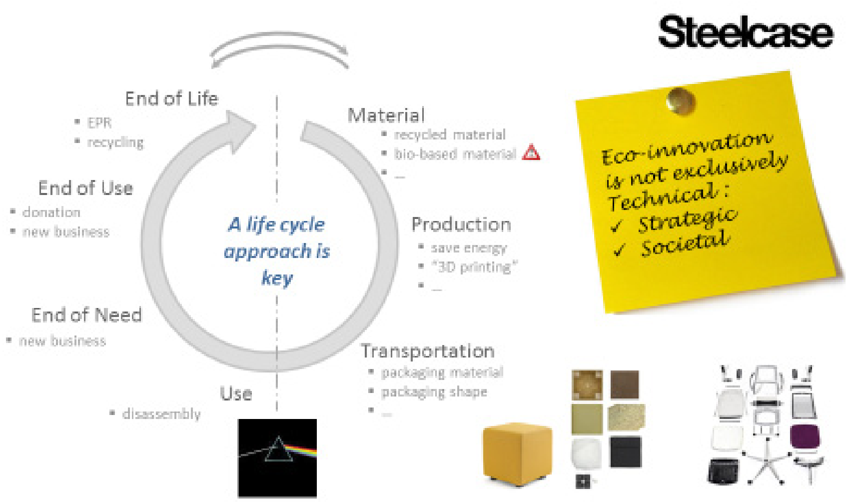
Steelcase is a leading company for office furniture and working space design. Eco-innovation is structured at Steelcase in three main axes:

- Life cycle thinking to avoid environmental impacts at each stage
- Particular focus on the use and end-of-life phases
- Particular focus on materials and their recyclability

Steelcase has also developed a take-back service at the end-of-life of products, which is now well known by customers and brings economic benefits.

Edouard Carteron chose to present the particular example of an eco-innovative ottoman for "in-between" spaces in offices. This product was redesigned from a previous generation with four targets: better quality, better style design, better sustainability and cost. During the design process, the focus was made on the end-of-life and materials. A recycled foam is used, whereas glue is not used anymore. Moreover new technics for upholstery with plastic profile and Velcro gave the opportunity to decrease drastically the number of staples (a stake for disassembly at the end of life for products as sofa). Thus the challenge was achieved.

In definitive, eco-innovation at Steelcase is seen more like a step by step approach than a radical disruption in the particular context of office furniture.

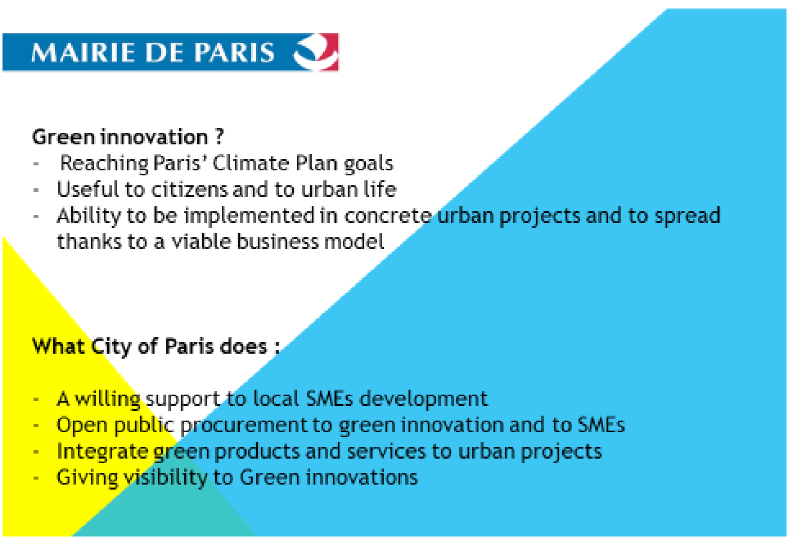


3.3. Fostering eco-innovation in Parisian incubators

Alexis Dousselain works within the ecosystem of Parisian incubators (i.e. incubators developed and supported by the city of Paris) dedicated to green business and green innovation. Since Anne Hidalgo has been elected mayor of Paris, his role is to support SMEs development, but also to implement those green innovations in the space and the life of the city. An innovation network has also been created. It is noticed a growing awareness of the necessity to change current procurement process to foster public actors purchasing eco-innovation solutions for public spaces or in the context of public markets of Paris city.

Alexis Dousselain evoked the example of an SME, hosted in one Parisian incubator and producing natural grass. They developed a very innovative and resistant turf for stadiums, but it was also revealed particularly adapted for public spaces because of its really low water consumption. This turf was experimented in Parisian spaces. However some problems were encountered to include this kind of products in public procurement, as it contains non-organic elements whereas only natural floor can be bought. This case illustrated the reflection that needs to be initiated about public market rules to foster eco-innovations. The city of Paris is aware of the importance to provide eco-innovation insights on public purchases, however it is a hard task, because it is not possible to directly buy innovations from incubators.

In the future, the focus should be made to use more the innovative partners around the city, in particular start-ups and SMEs. The smart and sustainable city plan proposed by Anne Hidalgo goes in this direction by transforming Paris into a living lab to massively experiments products and services useful for cities.



3.4. An eco-innovative chair by an industrial designer

Laurent Greslin is an independent industrial designer, founder of Z.I. Lab company. Z.I. Lab asks the question of production modes with a focus on territories. How to mutualize the forces existing on a territory, to allow the emergence of a "global and multi-technical plant"? When asking this question at the scale of a territory, eco-design and eco-innovation spontaneously emerge because transports distances are lowered. By extending this reflection, Z.I. Lab aims at working on project from the analysis of a life cycle. As an industrial designer, the most significant life cycle phase for Laurent Greslin is the use phase: how to extend life duration of products.

The chair proposed by Z.I. Lab is issued from these positioning. All elements are detachable to be changed or dismantled, only mechanical connections are used. Certified wood is used for the base and wood machining is very simple. The shell is made of agricultural wastes (fibers of flax, nettle and plantain), developed in partnership with the technical center for wood, namely FCBA. The industrial process used to aggregate these vegetal wastes requires only 5% of resin (instead of 10 to 15% for regular composites). It is possible to adjust the color by changing the proportion of each fiber type. The cover is in thermos-molded felt that can be easily changed. All these elements are nestable that allows household use but also use in communities. The chair received two distinctions: the first prize of VIA (*Valorisation de l'Innovation dans l'Ameublement*), and a design label *"Observeur du design"*.

However the market is quite small for such a product, because manufacturing is not that easy and producers are not aware of this type of approach. But a self-production should be feasible. Advances should be obtained in the coming months.

3.5. How eco-innovation is structured at PSA Peugeot Citroën?

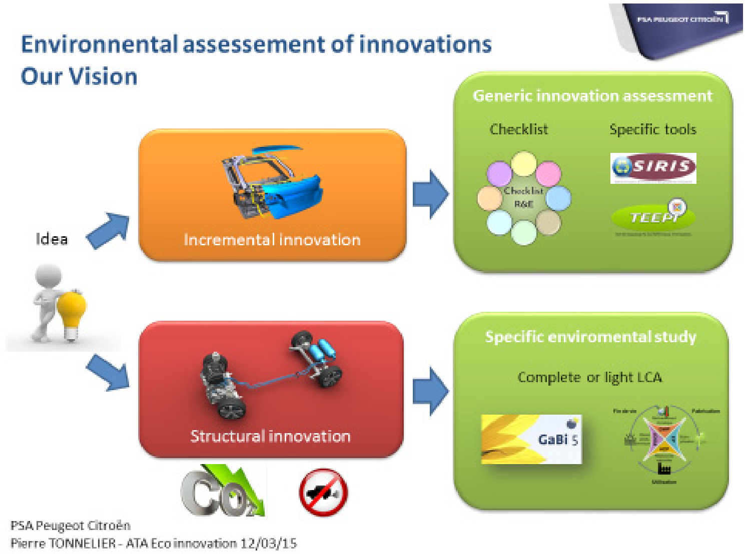
PSA Peugeot Citroën specifically works to include environmental aspects during the innovation process. The objective is to introduce methodologies to perform environmental assessments of innovations. Two types of innovations are considered: incremental innovations, that mainly concern small components of the vehicle, and structural innovations, that may have major impacts. Different approaches are used to include environmental considerations.

For incremental innovations, some specific tools are used, like:

- Checklists on substances (including future regulations);
- Tools focused on recyclability;
- Simplified Life-Cycle Assessment (LCA) in some cases.

Most of these incremental innovations are not eco-innovations as such, because they are not driven by environmental issues.

On the contrary, structural innovations are driven by environmental considerations from regulations (NOx or PM emissions from Euro 6 regulation for example, or CO2 emissions). Of course, all automotive constructors work on these aspects, however PSA Peugeot Citroën goes beyond the regulatory scope with a voluntary eco-innovation approach based on complete LCAs performed for each structural innovation. Performing these LCAs is a hard task because of the lack of information in the upstream phases of the innovation process, but it brings a real added value to propose more environmentally-friendly cars.



3.6. Eco-innovating in the construction sector at Vinci

Vinci is a global leading company in the sectors of concession and construction. It is a contracting company involved in all life cycle stages of buildings and infrastructures by financing, designing, building or operating them. There is no unique business model. So the challenge for Vinci is to create innovative tools fitting this organization of entrepreneur community and regarding environmental performance and eco-innovation.

That is why Vinci has launched in 2007 a scientific chair in eco-design with ParisTech academic cluster. MINES ParisTech considers building energy performance, whereas Ecole des Ponts ParisTech considers sustainable mobility and AgroParisTech biodiversity. Scientific results are available to all stakeholders (principle of corporate sponsorship). Open-source approaches are used to foster the dissemination of these results, because most of the time Vinci does not design the projects, but interact with architects or engineering companies.

Eco-innovative projects have been performed through this chair, for instance in the building energy performance domain. *Oxygène* project is a typical example and concerns the guarantee of the energy performance of a building, which highlights the importance of the design choices all along the life cycle. Generally, Vinci does not use the buildings they have constructed, so there is a clear need to measure the energy performance in a scientific and shared way. Lots of investors now want to be part of green building projects; this type of approach is also a guarantee for the finance sector. 50 major construction projects have already been carried out with *Oxygène*, representing 300 to 400 million euros of investment. It is implemented thank to a software designed by MINES ParisTech, with about 300 architects of engineering companies using it.

4. Are eco-innovation and economic profitability compatible?

Once all the participants have proposed elements characterizing their involvement in eco-innovation, a general discussion was engaged through several questions. This discussion is synthetized in the next paragraphs under the topic: are eco-innovation and economic profitability compatible?

For Edouard Carteron (Steelcase), the company involved in an eco-innovation approach must be deeply motivated. A study from *Pôle Eco-conception* has shown that eco-design can bring profitability. At Steelcase, it is really difficult to quantify the benefits. Actually in B to B business like office furniture, all customers are interested by green products. However sustainable considerations are only one aspect in tenders, all along with costs, quality, delivery… It is thus really hard to know if the sustainable considerations proposed by Steelcase help winning the tender or not. About 80% of tenders now have sustainability concerns in this sector.

In the construction sector, only one main criterion is considered as predominant to the others: cost. So this is quite impossible to sell a more expensive building because it is eco-designed. The challenge is thus to give more environmental value for the same cost.

For Alexis Dousselain (Mairie de Paris), the question of economic profitability of eco-innovations is crucial. That is why the city of Paris has launched a global concertation about circular economy (*"Etats généraux de l'économie circulaire du Grand Paris"*) to associate private and public partners in order to develop circular economy, create economic activity and jobs, develop companies while saving public funds in a win/win situation. The objective is to prove that a smart and sustainable city is profitable for everyone.

As a synthesis of these first testimonies, it seems that if one is able to prove that there is an improvement of the sustainable performance along an increase in services, probably the projects in eco-innovation and circular economy would flourish.

As a continuation of economic profitability, the chairman raised the question of the importance of internet of things and big data analysis to solve this lack of proofs. For Alexis Dousselain (Mairie de Paris), it is clearly a way to solve many problems concerning environmental issues associated with innovative services and products. It is a very strategic area on which the city of Paris is working to develop innovative ways to get, manage and exploit these new data sources.

Another point raised by the audience to promote eco-innovation approaches deals with the connection between major companies and SMEs. Is there a role to play for big companies to be "mentors" in eco-innovation for small organizations? For Pierre Tonnelier (PSA Peugeot Citroën), large companies like PSA Peugeot Citroën have the ability to put some human resources on these subjects, and also to develop or adapt methods and tools to their organization. At its level, PSA Peugeot Citroën is also trying to push relevant information or knowledge to its whole value chain, including small partners, to involve them in eco-innovation approaches. However as these partners often design very small components on the scale of a car, it may be absurd because the environmental impact is not directly linked to their products.

Finally, a last question asked by the audience concerned the capacity of eco-innovation to reduce costs. Often what is asked by customers is cost reduction and not environmental improvement, while eco-design is a lever to foster innovation. Has some participant experienced eco-innovation as a lever for cost reduction? For Maxime Trocmé (Vinci), such approaches have been experienced on materials and conduct to remove a lot of concrete, leading also to cost reduction. Working on eco-innovations is in that sense a way to design low energy consumption buildings at the same price.

5. Conclusion: final industrial and institutional messages to take away for academic researchers

Finally, at the end of the session, the chairman asked the participants to deliver a message to the academic researchers developing models in eco-innovation.

For Edouard Carteron (Steelcase), a lot of methods and tools have already been developed and experienced, however many companies are still not involved in eco-design and eco-innovation. Academia should work on this gap. On the other hand start-ups are often more committed than major companies. A second lead is to promote collaboration between researchers and large companies.

Alexis Dousselain (Mairie de Paris) underlines that Paris is and wishes to remain a major research center in Europe, and thus needs to develop tools to support researchers in the development of projects, companies and partnerships. Moreover there is a lack of indicators to characterize what a sustainable city is, how to design and manage it. Researchers are welcome to contribute on these subjects.

For Laurent Greslin (Z.I. lab), who is also teaching in an industrial design school, tools that are able to support an industrial design project with an understanding of environmental impacts and impact transfers are still missing, and should be developed.

Pierre Tonnelier (PSA Peugeot Citroën) asks researchers to continue their work in eco-innovation and to create more knowledge on how environmental concerns may be incorporated in the global value chain of companies. In other words, how to make environment a classical aspect of design, a theme amongst others?

Finally, Maxime Trocmé (Vinci), who used to be an academic researcher and is managing a scientific chair in eco-design, experimenting prototypes is crucial. Researchers should put more emphasis on experimenting, testing and validating their proposals, as companies like Vinci are ready to collaborate on these topics.

As a general conclusion, eco-innovation appears to be a noteworthy academic and field issue with already several notable successes.

Conclusion

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The ambition of the workshop was to cover different aspects of the eco-innovation process, from the generation of ideas to the development of sustainable business models, but also to identify new opportunities for the engineering design research community to help the development and implementation of eco-innovation in industries.

Therefore, as an introduction, Tim McAloone identified ten opportunities for eco-innovation: (1) a widely accepted typology of approaches to environmental product design; (2) a comprehensive and rigorous review of tools to support eco-innovation; (3) a guidance on when and where eco-innovation is relevant; (4) collaborative researches at the interfaces; (5) studies of eco-innovation implementation; (6) a greater reporting of case studies of failures; (7) methodological innovation; (8) bringing design thinking to business model innovation; (9) understanding the role of LCA in supporting eco-innovative product development; (10) development of an interface with policy research.

From this workshop, several contributions corresponding to these opportunities have been proposed. A first contribution of this workshop was to provide a great variety of eco-innovation examples, acting on different systemic scales. Indeed, the different presentations exposed eco-innovation examples at a product level (see for example the eco-innovative boiler presented by Tyl and Vallet, or the upgradable vacuum cleaner by Pialot and Bisiaux), at a more complex system (see for example the case study of an hydrogen-fuelled e-car presented by Lüdeke-Freund or the case of substations for the aluminum electrolysis studied by Cluzel), and to finish at a territorial level, through the case study of Allais.

A second important contribution of the workshop was to identify the central role of business model to implement sustainable solutions. According to Florian Lüdeke-Freund, the business model level is crucial to market eco-innovation to unfold their full sustainability potential. More specifically, he presented the four main elements of a business model: the value proposition, the supply chain, the customer interface, and the financial model. The new challenge for design teams is to be involved in the design of such business models in order to really co-create successful eco-innovative concepts.

As an illustration, Olivier Pialot and Justine Bisiaux presented the concept of upgradable product and the necessary change of business model to support it. Indeed, even if the upgradable product approach is a promising approach in terms of sustainability, it can't be successful without a business model more focused on services. Besides, companies need to build new business models in a trajectory using upgradable systems.

A third important contribution was to identify the need to implement innovation through tools and methodologies to support radical eco-innovative processes. The workshop focused on the eco-ideation stage, when the design team comes to generate eco-innovative ideas. One proposition was defended by Benjamin Tyl and Flore Vallet. Instead of developing again new eco-innovation tools, they presented appropriate stimulation mechanisms to be implemented into the eco-innovation process to help the design team to generate relevant ideas with a high potential of sustainability. The ambition is stimulate the design team in a systematic way across all the dimensions of eco-innovation: biomimicry, Product Service System, short loop, etc.

In line with these works, François Cluzel presented how an eco-innovation tool is really used in industry, in the case of highly complex systems. This research consisted in developing eco-ideation and eco-selection sessions into a major company in order to propose a portfolio of balanced R&D projects in a long term perspective.

The last contribution of this workshop was to underline the collaborative and multi-disciplinary aspects of eco-innovation. Romain Allais exposed its 5D-sustainability transition method to integrate, on top of environmental, economic and social dimensions: the territory as a new perimeter and the political sphere as a coordinator of actions. This presentation shows the crucial role to open the boundary of eco-innovation to take into account the intangible capital of a territory, in order to achieve sustainability.

Future research directions on eco-innovation

This workshop was the final step of a two-year research program dealing with eco-innovation, within the French eco-design research network EcoSD.

From this two year research program, a set a three main research directions are proposed:

- The first direction concerned the eco-ideation stage. Even if a lot of eco-ideation tools exist, none of them are used in industry. They are judged too complicated or not adapted. Research must focus on developing easy-to-use tools based on all the dimensions of eco-innovation, but also on identifying the right eco-ideation tool in a given context. In parallel, a specific research should identify the adapted format of ideas, to preserve/transfer information during the eco-innovation process and to help evaluation of ideas with a comparable level of detail for all ideas.
- The second direction is to make environmental assessment of ideas simpler and more efficient. This research program clearly identifies the need to go further in the assessment of environmental evaluation methods and tools. Various questions remain open: What is the adapted format of ideas? How to co-create environmental/sustainability criteria in project teams? How to adapt the method/tool to the context/product?
- The last direction is to reduce the gap between academia and industry. It is obvious that with more efficient and improved methods and tools, the transfer of knowledge from academia to industry should be facilitated. But, as underlined during the workshop, this is necessary but not sufficient. It is also essential to stronger integrate business model aspects into eco-innovation processes in order to market advantages of eco-innovation and give competitiveness to companies.


ROUND TABLE: INDUSTRIAL AND INSTITUTIONAL VIEWS ON ECO INNOVATION
IS AN ECO-INNOVATION COMPATIBLE WITH ECONOMIC PROFITABILITY?
IF YES, SHOULD WE BE MORE SYSTEMATIC TO DEPLOY INCENTIVES, ORGANIZATION AND METHOD TO ECO-INNOVATE IN YOUR ORGANIZATION?
THE CHALLENGES OF ECO-INNOVATION
ECOSD RESEARCH WORKSHOP 2015
THURSDAY 12TH MARCH
LA RECYCLERIE, PARIS, FRANCE

EcoSD network is a French association whose main objective is to encourage collaboration between academic and industrial researchers so they may create and spread advanced and multidisciplinary knowledge in the eco-design fields at national and international levels. Several actions are proposed by the EcoSD network with the support from the French Environment and Energy Management Agency (ADEME), from the French Ministry of Higher Education and Research as well as the Ministry of Industry:

- Structuring EcoSD research activities in France to take advantage of the expertise from more than 200 members of this research network,
- Developing knowledge among researchers regarding the field of eco-design, particularly better training of PhD students by organizing relevant training courses over different themes in eco-design,
- Elaborating new methods, new tools and new databases to achieve complex systems design, compatible with the principle of sustainable development,
- Initiating the EcoSD label to acknowledge the quality and inclusion of sustainable development in trainings, research programs, research projects and symposiums,
- Helping interactive collaboration between researchers and industrial partners through the organization of quarterly research seminars in Paris and an annual workshop.

The objective of the EcoSD annual workshop 2015 was to present a scientific approach of eco-innovation concept and to underline how eco-innovation can propose sustainable alternatives to existing production and consumption systems.

This event was articulated around keynote sessions by international researchers, short sessions and discussions with EcoSD researchers, as well as a round table including industrial and institutional experts.

Around 70 participants from industry, academia and governmental institutions participated in the workshop and had the opportunity to exchange with experts.

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