Journal of Cleaner Production 112 (2016) 4329–4343

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Eco-ideation and eco-selection of R&D projects portfolio in complex systems industries

François Cluzel [a, *], Bernard Yannou [a], Dominique Millet [b], Yann Leroy [a]

[a] CentraleSupélec, Laboratoire Genie Industriel, Grande Voie des Vignes, 92290 Chatenay-Malabry, France
[b] Université de Toulon, Seatech-Supméca, 83000 Toulon, France

ARTICLE INFO

Article history:
Received 6 June 2013
Received in revised form
1 August 2015
Accepted 1 August 2015
Available online 10 August 2015

Keywords:
Eco-design
Eco-innovation
Complex industrials system
R&D project portfolio
Creativity

ABSTRACT

Eco-innovation methodologies and tools are being applied in companies to an increasing extent. None of them, however, are particularly adapted to complex systems industries, where the eco-design requirements are highly specific. These systems are characterized by large size and mass, and relatively long and uncertain life cycles. The associated organization is also complex as there are multiple highly specialized experts, who rarely collaborate, and much less so on environmental aspects. In this paper, an adapted eco-innovation process based on the eco-design strategy wheel is proposed for use with a working group of internal technical experts. A first phase involves generating a high number of potential eco-innovative R&D projects that are then analyzed and assessed using an appropriate multi-criteria grid. Three structured filters enable an informed selection of the most promising projects that will then make up a balanced R&D project portfolio. The whole process has been successfully applied at Alstom Grid on large electrical stations used in the primary aluminium industry.

1. Introduction

With heightening awareness of the impact of human activities on the environment, environmental concerns have become increasingly important. In companies, this has resulted in a need to respond to new environmental requirements and regulations (Bey et al., 2013). From this perspective, eco-design allows us to consider, manage and improve the environmental performance of products, processes and services (ISO 14006:2011).

However, if this approach is now recognized and well deployed in competitive mass-consumer goods producers (Business to Consumer, B to C), the situation is not so advanced in B to B (Business to Business) industries, in particular for complex industrial systems. They are characterized by a long and uncertain life cycle, involving a high number of subsystems and components or strong interactions with their environment (Cluzel et al., 2012). The technological and regulatory constraints associated with these systems may slow down the ability to innovate, as reliable technologies proven over the long-term are often favoured. Nevertheless, the need for eco-innovation is clearly present, as these systems are linked to substantial environmental impacts.

However, eco-innovation on complex industrial systems is a challenging task. R&D projects in complex systems industries are often driven by technological, not environmental, considerations. These projects need to be identified fairly early in the design process, with little information available. On the other hand, it is generally agreed that environmental-oriented R&D (Research & Development) projects are necessary, but the complexity of the products and organization makes it tricky to introduce an eco-innovation approach. This type of organization is characterized by multiple highly-specialized experts, who rarely communicate together. Furthermore, only a few are trained in eco-design or Life Cycle Assessment (LCA). This is why a simple and effective eco-innovation method is necessary, requiring little preliminary environmental knowledge. This would make the collaboration between multidisciplinary experts possible.

This paper proposes one such intuitive eco-innovation methodology to answer to the following research question: how to generate and select an adapted portfolio of eco-innovative R&D projects for a complex industrial system? From a classical ideation phase, based on the eco-design strategy wheel (Brezet and Van Hemel, 1997), and a simple scoring model taking five dimensions into consideration – including potential environmental benefits - a powerful portfolio of eco-innovative R&D projects is identified via three successive filters using limited resources. The whole eco-

* Corresponding author. Tel.: +33 (0)1 41 13 13 28; fax: +33 (0)1 41 13 12 72.
E-mail address: francois.cluzel@centralesupelec.fr (F. Cluzel).

http://dx.doi.org/10.1016/j.jclepro.2015.08.002
0959-6526/

innovation process is then deployed at Alstom Grid on complex electrical substations.

Section 2 presents a literature review of eco-innovation and R&D project evaluation and selection for complex industrial systems. In Section 3, an adapted methodology is introduced. Section 4 deals with the application of this process at Alstom Grid. Section 5 tests the robustness of the model and discusses the validity of the results. Concluding remarks and perspectives are presented in Section 6.

2. Literature review

2.1. Complex industrial systems

This paper focuses on complex industrial systems whose specificities have yet to be taken into account in eco-design and eco-innovation: these are industrial systems where complexity induces major issues in terms of modelling, prediction or configuration. From the systems engineering domain (Blanchard and Fabrycky, 2011), we define a complex industrial system in the eco-design vein as (Cluzel et al., 2012):

- A large-scale system in terms of sub-systems and components, mass and resource usage;
- A system whose life cycle is unpredictable at the design level in the long-term, in particular with regard to its lifetime, upgrades, maintenance and end-of-life;
- A system whose sub-systems may have different life cycles and different obsolescence times;
- A system which is in close interaction with its environment (e.g. super system, geographic site);
- A system which is supervised by human decisions and management.

Concerning eco-innovation, the main problem of such systems is that the customers' specifications or the regulations and standards severely limit the ability to radically innovate, as only long-term proven technologies are used. Thus, the challenge associated with an eco-innovation approach is how to identify a set of reliable incremental eco-innovative projects, and/or to be able to make radical eco-innovations possible which are acceptable to customers.

2.2. Eco-innovation

Eco-innovation is an emerging field, for which there are numerous definitions and tools in the literature.

2.2.1. Definition

Eco-innovation has been associated with numerous definitions in recent years. Carrillo-Hermosilla et al. (2010) list, for example, 16 different definitions, before proposing the following: 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 specifically includes innovations where the reduction in environmental impacts is a side-effect, and not the main or initial goal. More importantly, it also includes radical and incremental innovations.

For other authors, an eco-innovation is necessarily radical. This is highlighted by Tyl (2011), and also clearly expressed by Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010). But Pujari (2006) also shows that few eco-innovations are really radical with regards to mass-consumer goods. In some other definitions, an eco-innovative product is significantly less environmentally harmful than the existing ones, but O'Hare (2010) highlights the fact that "*different companies may have different opinions as to what constitutes a 'significant' improvement in environmental performance*".

Given the hierarchical nature of complex industrial systems, as well as the fact that radical changes are rarely acceptable for customers in complex system industries, the eco-innovation framework defined by Carrillo-Hermosilla et al. is well adapted to complex industrial systems: "*Eco-innovations, particularly when they are radical and require techno-institutional system-level changes, are difficult to achieve because the prevailing system may act as a barrier to the creation and diffusion of a new system*" (Carrillo-Hermosilla et al., 2010).

2.2.2. Eco-ideation tools

An eco-innovation approach indicates two major activities: eco-ideation, defined as the generation of ideas that reduce environmental impacts throughout the product life cycle of products (Bocken et al., 2011), and the evaluation and selection of the most promising ideas (Jones et al., 2001). This paragraph studies eco-ideation and the associated methods and tools. Section 2.3 deals with the evaluation and selection of R&D projects, a field as will be seen below that it extends beyond eco-innovation. Indeed Byggeth and Hochschorner (2006) state for example that eco-design and eco-innovation tools usually lack strategic planning considerations.

Regarding the eco-ideation process itself, expert groups are widely used through creativity sessions (Bocken et al., 2011). Pujari (2006) shows that multidisciplinarity in the working group is a key factor for success in eco-innovation. Finally, eco-ideation processes in companies are often performed as classical creativity sessions supported by an eco-innovation tool. Different eco-ideation tools are well known or regularly referred to in the literature, such as the eco-design strategy wheel (Brezet and Van Hemel, 1997; van Hemel and Cramer, 2002), also known as the LiDS (Life cycle Design Strategy) wheel, Eco-compass (Fussler and James, 1997), Product Ideas Tree (Jones et al., 2001), BEC (Business-Environment-Customer) synergy diagram (O'Hare et al., 2007), or TRIZ-based tools (TRIZ is the Russian acronym for Theory of Inventive Problem Solving). Baumann et al. (2002) and Bovea and Pérez-Belis (2012) classify eco-design and eco-innovation tools.

The eco-design strategy wheel is a simple tool that proposes eco-design guidelines divided into eight axes on a graphic wheel. Seven axes cover the life cycle of the product, whereas the last one aims at identifying new concepts. According to Tyl (2011), it is extremely simple to implement and to use, as it does not require 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 restrict usage to product-level considerations. The wheel is shown in Fig. 1 with the axis labels.

Eco-compass is another simple graphical tool. It is composed of five axes that are less linear than the axes of the eco-design strategy wheel, because they incorporate life-cycle-oriented and impact-oriented considerations. But like the eco-design strategy wheel, it is often considered as an eco-design or strategic-oriented tool, limited to a product-level approach (Tyl, 2011).

The BEC synergy diagram is a tool that proposes a positioning of ideas according to considerations of business, environment or customer aspects (O'Hare et al., 2007). This tool is also really simple to use; however it is considered too simple according to the value chain of complex industrial systems, as it is more complex than a simple "supplier–client" relationship (these are for instance several stakeholders that may be called "clients").

Product Ideas Tree (PIT) aims to structure eco-innovation creativity sessions using mind-mapping techniques. It is thus more oriented towards idea structure than ideation. The use of such a