



HAL
open science

Learning from the construction of Environmental Performance Indicators in new project development: a case study

Ludivine Dupont, Florence Charue Duboc, Christophe Midler

► To cite this version:

Ludivine Dupont, Florence Charue Duboc, Christophe Midler. Learning from the construction of Environmental Performance Indicators in new project development: a case study. 24th Innovation and Product Development Management Conference (IPDMC), Jun 2024, Dublin, Ireland. hal-04579468

HAL Id: hal-04579468

<https://hal.science/hal-04579468v1>

Submitted on 17 May 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Public Domain

Learning from the construction of Environmental Performance Indicators in new project development: a case study

Ludivine Dupont

i3-CRG, CNRS, Ecole polytechnique, IP Paris
ludivine.dupont@polytechnique.edu

Florence Charue-Duboc

i3-CRG, CNRS, Ecole polytechnique, IP Paris
florence.charue-duboc@polytechnique.edu

Christophe Midler

i3-CRG, CNRS, Ecole polytechnique, IP Paris
christophe.midler@polytechnique.edu

ABSTRACT

In the realm of product innovation, the integration of environmental considerations at the outset of the design process is crucial for ensuring sustainability. This context is framed by the concept of eco-design, emphasizing the significant influence of early design decisions on a product's environmental impact. The roles of designers, project managers, and environmental impact management tools are pivotal in this process. While traditional environmental assessments, such as Life Cycle Assessment, have been popular, their applicability in early design phases and decision-making is limited, leading to the adoption of simplified methods like Environmental Performance Indicators (EPIs).

The primary focus of this paper is to investigate the dynamics among stakeholders involved in the development and implementation of EPIs in new product development. Through an extensive study involving over 50 interviews and 30 meetings with stakeholders, this research provides insights into the roles and interactions of various groups, including experts, project teams, and executive management, in the construction, selection, and adoption of EPIs. This paper contributes to the understanding of stakeholder dynamics in eco-design, particularly in the context of EPI development and selection, enriching the discussion around stakeholder integration as introduced by Heslouin et al., 2017.

KEYWORDS

Eco-design, environmental performance indicators, sustainable innovation

1. INTRODUCTION

In the 50's, researchers pointed out that corporations have responsibilities to society that go beyond their legal and financial responsibilities (Bowen, 1953; McGuire, 1963). Indeed Bowen (1953) highlighted that companies have a great impact on society, and therefore should include it in their decision-making: it is the birth of Corporate and Social Responsibility (CSR). In parallel to the CSR birth, the concept of sustainable development came in 1987 with the Brundtland report, and in 2015 the UN adopted a set of 17 goals for a Sustainable development, and a worldwide action plan "Transforming our World: the 2030 Agenda for Sustainable Development". Sustainability is now adopted by many companies through their mission statement and strategy. Indeed, in 2022 the GRI (Global Reporting Initiative) Support the Goals published that 83% of companies support the SDGs and recognize the value of aligning their reports with the 2030 Agenda. Nevertheless, integrating environmental aspects of sustainability into programs and projects, which are key to implementing an organization's strategy, remains challenging. To effectively evaluate projects in alignment with an organization's objectives, it is crucial to consider the goals and corresponding metrics, and criteria encompassing economic, social, and environmental factors.

The innovation process is intrinsically linked to a product's environmental impact, as the decisions made during the requirement and design phase (product function or performance for example) will profoundly shape sustainability outcomes, making eco-design a crucial approach to embed environmental considerations for the start (Ceschin, 2012; Masui et al., 2003). Indeed, eco-design is a widely spread approach that considers, during the design, the environmental impact of a product throughout its lifecycle.

Several dimensions are pivotal in the implementation of eco-design: the roles of designers (Schäfer and Löwer, 2021), project managers (Kivilä et al., 2017), and environmental impact management tools (Aggeri & Labatut, 2010). While many environmental assessments have been explored since the early 2000s (Buchert et al., 2014; Schäfer & Löwer, 2021), Life Cycle Assessment (LCA), though popular, is not always apt for early design phases (Quernheim et al., 2023) or decision-making (Sabini & Alderman, 2021).

Simplified methods like Environmental Performance Indicators (EPI) have emerged, focusing on operational performance drivers (Azzone et al., 1996; Heslouin et al., 2017; Kaebemick et al., 2003). Early publications selected EPIs based on the product's LCA or expert data (Kaebemick et al., 2003), and newer research advocates for a hybrid stakeholder-inclusive approach (Heslouin et al., 2017; Puig et al., 2014). However, Sabini et al. (2019) in their review of sustainable project management, emphasized a remaining disconnect between academic literature and practical application.

Though few studies analyze in detail the process of environmental indicators development and implementation in new product development, the research tends to overlook the intricate dynamics and interactions between these actors, and how they impact the implementation of EPIs.

What goes through the construction process of an EPI in a company? How is it understood and appropriated by different actors within the organization? What are the dynamics behind it and their impact? How does the construction process can contribute to the increase of environmental performance? Are some of the questions arising.

The author had the opportunity to analyze longitudinally and in real time the process of definition and implementation of EPIs dedicated to the project phases of new product development for more than a year (more than 50 interviews and 30 meetings with all stakeholders).

This paper provides insights into stakeholder dynamics during the development and selection of Environmental Performance Indicators (EPIs). The research differentiates the roles of various stakeholders: experts, project teams, and executive management in EPI construction and selection. Moreover, it stresses that each group emphasizes specific criteria and that the dynamics during the indicators' construction derived into transversal learning and compromising for all the stakeholders, and a better understanding of an uncertain topic.

The observation of EPI selection, the construction of meaning around it, and the expectations of stakeholders regarding this tool, allow us to enrich the discussion around stakeholders' integration in this process as introduced by Heslouin et al., 2017.

Following a description of the literature on project environmental performance tools and their implementations, we present the research questions and the qualitative research approach. This is followed by a description of our main observations during a 1-year field study around the construction of environmental indicators within the R&D department of an industrial company. Then, based on this case study, we analyze the dynamics involved in the implementation of this environmental management tool and its impact on results. Finally, we discuss the significance of this work in terms of the success factors for implementing eco-design practices through such indicators to monitor the environmental performance of products under development.

2. LITERATURE REVIEW

2.1. Eco-design

2.1.1. History of eco-design

Eco-design is a product development approach that considers the environmental impact of a product throughout its entire lifecycle. Eco-design aims to reduce the environmental impact of products throughout their life cycle, right from the design phase. This approach makes it possible to act at source on the quantity of materials, the choice of materials and processes, and even on emissions linked to use and end-of-life.

According to Steux & Aggeri (2019), eco-design principles started in the 90s, structured around a community of experts and engineers and the LCA methodology (Abrassart & Aggeri, 2002). Eco-design was then mainly a matter for environmental experts with extensive technical knowledge of the subject and highly rigorous tools (Dermody & Hanmer-Lloyd, 1995; Korpalski, 1996).

As eco-design matured, the focus expanded beyond mere technical aspects, emphasizing the need to integrate eco-design into the broader strategy and operations of organizations. This shift led to the development of specific environmental management systems, aligning eco-design with organizational objectives and involving various business units in a more holistic approach (Steux & Aggeri, 2019)

These practices affected regulation and conditioned market entry (Abrassart & Aggeri, 2002), and are today a central part of Circular Economy policies, spreading across the world (Daae et al., 2018; Micheaux & Aggeri, 2021).

As highlighted by the authors, four main determinants have been identified: anticipating future regulations, seeking new markets for eco-innovations, especially through brand image enhancement, reducing production costs, and promoting a prosocial logic to gain societal legitimacy (Delmas & Toffel, 2008; Plouffe et al., 2011).

Despite a favorable environment for eco-design, there's a significant gap between the intentions and actual achievements of companies in this field. Eco-design practices are advancing slowly, with only 19% of French companies implementing them, showing little progress since 2010 (ADEME, 2017). Moreover, these initiatives often result in minor eco-innovations that don't significantly change product identities or achieve substantial commercial success (Bey et al., 2013; Delmas & Colgan, 2018).

2.1.2. A key success factor

To effectively implement eco-design principles, designers have a crucial role to play (Schäfer & Löwer, 2021). However, management tools and instruments (Aggeri & Labatut, 2010) are also crucial for quantifying the environmental impact of products and guiding product development and decision-making (Labuschagne & Brent, 2005; Sabini et al., 2019; Schäfer & Löwer, 2021).

Indeed, various management research studies emphasize the role of management tools and instruments in (1) rationalizing management and decision-making, and (2) triggering and guiding collective action (Aggeri & Labatut, 2010; Berry, 1983; Moisdon, 1997).

2.2. **Eco-design tools**

2.2.1. A reliable tool, but not suited to innovation

Multiple environmental assessments have been studied since the early 2000s (Buchert et al., 2014; Schäfer & Löwer, 2021), but life cycle assessment (LCA) has been the most used and studied method since the early 2000s, in line with ISO standards 14040 and 14044 (Iken, 2021). LCA is reputed to be reliable, certifiable and increasingly accurate, but at the same time less suited to the needs of design teams (Iken, 2021; Millet et al., 2007).

This is because LCA methods require a complex inventory (Haun et al., 2022), in which input and output information for the product's entire life cycle ("cradle to grave") must be collected and modeled, implying a large amount of data and a significant workload. Consequently, this method is not suited to the early design phases (Kaebemick et al., 2003; Quernheim et al., 2023) or to decision-making (Bruhn et al., 2023; Buchert et al., 2014; Sabini & Alderman, 2021), two topics unanimously highlighted in the literature on sustainable project management as the critical parts of its integration (Sabini et al., 2019). The upstream phases are where the levers for reducing the environmental footprint have the greatest impact, because before the design is fixed.

2.2.2. Other tools

To address this problem, two main directions are chosen in the literature: automated LCA integrated into numerical tools (Hassan et al., 2022; Haun et al., 2022), but which does not fully address the problems of early phases where data are not available (Haun et al., 2022) and other simplified assessments such as S-LCA methods (Dewulf & Duflou, 2023; Iken, 2021; Kaebemick et al., 2003; Quernheim et al., 2023; Scrucca et al., 2023) or environmental performance indicators (Azzone et al., 1996; Dewulf & Duflou, 2023; Heslouin et al., 2017; Kaebemick et al., 2003). Indeed, environmental indicators don't have to be based on biophysical results such as the LCA, and they can be separated into 3 categories: biophysical (LCA), economical (eco-taxes, carbon pricing, eco-costs...), or indicator-based (single-score, multi-criteria assessment...) (Masoud et al., 2022).

2.3. Environmental Performance indicators

2.3.1. Definition

Environmental Performance Indicators (EPI) are indicators of environmental performance based on Environmental Performance Drivers (EPD), which are the key drivers of a product's environmental impact (Kaebemick et al., 2003).

The literature differentiates three kinds of EPI, based on the ISO 14031 on Environmental Performance Evaluation (ISO, 1999): i) management performance indicators (information around management performance like employees trained and so on), ii) operational performance indicators (quantity of renewable energy, quantity of raw material used...), and iii) environmental condition indicators (like emission of one specific particle in the air or water).

The focus here will be mainly on operational performance indicators (e.g. power, weight...) and are therefore easier to monitor and improve by company players and to communicate to stakeholders (Heslouin et al., 2017). This approach is the basis of most well-known eco-labels (Dewulf & Duflou, 2023).

2.3.2. Construction methodology history

The process of developing and choosing environmental indicators has grown increasingly intricate due to their multifaceted characteristics. These indicators are tasked with representing a broad spectrum of environmental concerns, illustrating trends across time, forecasting future shifts, and impacting managerial choices (Donnelly et al., 2007). Therefore, it is imperative that the selection of these environmental indicators is underpinned by a thorough and systematic validation procedure.

In early publications, EPIs were defined based on the product's LCA (to find out its environmental footprint and key drivers) and the product and company context (Azzone et al., 1996; Kaebemick et al., 2003). They were then expert driven, as all the eco-design approaches at the time (Steux & Aggeri, 2019).

More recent publications have highlighted the limitations of this expert-based approach and the need to include stakeholders as well in a "hybrid" approach (Heslouin et al., 2017; Puig et al., 2014).

The various frameworks seem to follow the eco-designs literature history. Indeed, Steux and Aggeri (Steux & Aggeri, 2021) structure 3 eco-design frameworks: a techno-centric framework, a customer-oriented framework, and a hybrid framework. They highlight the various players involved, stressing

the cross-functional nature of eco-design integration for the last two frameworks: engineers, designers, marketing, and the importance of top management support for this collective approach.

To deep-dive into the hybrid approach, integrating experts and stakeholders, Puig (2014) identified two main approaches to select indicators: the top-down and the bottom-up. The top-down approach is based on identifying indicators from a literature review (e.g. publications, reports, and standards) and narrowing down to a final set of agreed indicators. The bottom-up approach consists of compiling the final set of indicators from the proposals of sector stakeholders based on their perceptions of issues and significance.

2.3.3. The limitations

As the first studies focused on defining an extensive list of indicators (more than 200 KPIs have been listed), later selection methods have been studied, the right selection of KPIs being a key success factor for eco-design (Issa et al., 2015; Wagner et al., 2016). To implement these indicators in practice and make the most of them, they must, like all KPIs: be in small quantities, have outputs that are understandable and actionable by all users, and be easy to fill in, adapted to designers' constraints.

All the identified EPI publications are oriented towards the identification and selection process of EPI, they are guides, procedures, and “step-by-step” approaches to help identifying useful KPIs for your industry and company and selecting them (Heslouin et al., 2017; Issa et al., 2015; Puig et al., 2014).

Nevertheless, in these publications, the concrete operational design and implementation within a company's processes and culture are not analyzed. Indeed, they focus mainly on the parameters selected in their use cases and give an overview of the method applied, but do not address the dynamics enabling the customization, appropriation and implementation and appropriation of these indicators.

2.4. Indicators appropriation

2.4.1. The nature of management tools

In the early 2000s, the literature on management science took a shift from a “representationalist” approach (organization as an information processor, whose tools model the action faithfully, reflecting a universal truth) to a more “pragmatic” vision (de Vaujany 2006). The organization is then a system of collective actions, and the management tools attempt to interpret its phenomena. This new paradigm changed the focus of management tools research, breaking down the design-use duality (De Vaujany, 2006). Indeed, previously, the instrument was analyzed in terms of its technical performance, the precise design of which was then the most important stage.

Moison (1997), De Vaujany (2006), and Grimand ((Grimand, 2006)) described the use phase (“putting into action” phase) as deeply included in the design, the development process being continuous interactivity between the stakeholders (Moison, 1997), use therefore determines the tool, which does not pre-determine use.

Among the major theoretical approaches to management tools (Aggeri & Labatut, 2010), the situated interaction approach, in which we place ourselves here, emphasizes that management tools should be analyzed based on the relationships they enable, but also from the angle of the knowledge they convey and the learning they enable, and finally from the angle of the meaning they convey through processes of storytelling (Detchessahar & Journé, 2007; Weick, 1995).

In this way, to focus on use, appropriation is at the heart of the discussion, as the movement from the circulating state to the inscribed state of the tool (Chiapello & Gilbert, 2013; Millet et al., 2007). Indeed, it is therefore necessary to analyze management tools not only based on their intrinsic properties but also to investigate the processes of design, use, and appropriation in situations, within the organizations studied.

2.4.2. Appropriating management tools: the end of the design-use dialectic

To analyze the appropriation of management tools, many theoretical frameworks exist (Andrien, 2019). In the context of interaction-situated one theoretical framework is of particular interest to us, that is the "actioning" of the tool, based on valuing the interaction between actors and tools.

Here, appropriation is an interactive process. In effect, the tool is a desire to rationalize a complex environment, and it is these approximate hypotheses that will bind the actors around learning (Andrien, 2019). Design and use are thus integrated into a vast, recursive, and continuous process. After an initial design phase, the tool is appropriated by one or more actors, who shape, distort, and interpret it. It is this cycle of reciprocal prescriptions that allows the management tool to be contextualized and ultimately appropriated. In conclusion, tools are based on knowledge held by prescribers, theoretical knowledge that is tested in contact with operational people, and so they become contextualized and take on concrete meaning for operational people (Aggeri, 2017).

The usual dialectic between design and use is thus overcome. The story surrounding the tool, the narrative that accompanies it, makes it possible to think about its appropriation from the moment it is conceived (Pascal & Thomas, 2006), and to build it continuously according to an iterative social process (Hussenot, 2006).

Appropriation therefore calls on the instrumental dimension of the tool, its technical characteristics, but also on a symbolic dimension, the construction of meanings that accompany user investment (Martin, 2006).

2.4.3. Research question

Finally, we can see here that theoretical frameworks for the appropriation of management tools emphasize the essential role of use in the final design, and the iterative notion of appropriation to give symbolism, significance, and ultimately meaning to the tool (Andrien, 2019) for the tool to drive learnings and transformations (Acquier & Aggeri, 2007) (Riot, 2013).

Use thus serves design, and continuous iterative loops are essential for the creation of meaning and thus the appropriation of the tool. Also, design is highlighted as an important part of appropriation and storytelling, with particular emphasis on the need to integrate user needs for the intrinsic properties of the tool.

Nevertheless, in the literature, the contribution of the preliminary design phase of the management tool, although cited as the first building block for appropriation loops, is not detailed. And, in the case of environmental indicators, and even more so in the literature on Environmental Performance Indicators, the construction phase is seen only in terms of its technical contribution to user needs. So, what are the key aspects of the preliminary design process of an environmental performance management tool? How does this design process initiate the construction of meaning, and thus the appropriation of the tool? Finally, can the preliminary design process have an impact on the company's environmental performance?

In this article, we will argue, based on a one-year field study within a French industrial company, that even before use, the process of preliminary construction of an environmental indicator makes it possible to generate knowledge between stakeholders in a highly uncertain environment, and thus to increase the company's eco-design capabilities. It is also made up of interactive iterations that enable learning based on the artifact under construction, as well as preliminary appropriation by stakeholders and future users.

3. RESEARCH DESIGN: QUALITATIVE ANALYSIS BASED ON 50 INTERVIEWS AND 4 COLLABORATIVE WORK SESSIONS

3.1. Methodological framework: a qualitative research based on a case study

Constructivism suggests knowledge guides action and problem-solving, emphasizing the role of empirical and theoretical data in constructing representations (*Avenier & Schmitt, 2008; Dang, 2011*). It challenges the positivist view by integrating knowledge with action, highlighting the researcher's participatory role in reality's construction (*Dang, 2011*). This methodology appreciates the complexity of human irrationality and cognitive constraints, focusing on the significance of social reality as it unfolds in action. While quantitative research methods are typically aligned with the positivist paradigm, constructivist approaches lean towards qualitative methodologies. The essence of constructivism in the social sciences lies less in eschewing quantitative data and more in prioritizing the interpretation of actions by individuals within specific contexts, leading to what Dumez (*Dumez, 2016*) refers to as "comprehensive research." Unlike approaches that rely on statistically representative samples to deduce generalizable conclusions, comprehensive research delves into a select few cases. This non-representative approach does not aim for broad generalizations but rather explores the potential for developing or refining theoretical frameworks through the detailed examination of unique cases, as Dumez outlines.

Therefore, case study research is pivotal for its depth of analysis, particularly in understanding the design processes and stakeholders' interactions. It's recognized for its ability to uncover complex relationships and generate theories, emphasizing the importance of context and detailed examination (*Musca, 2006; Tsoukas, 1989*).

3.2. Data collection

The described project was launched in 2022, supported by two Executive Committee members: the head of R&D and the head of Operations and led by the Innovation manager. This project was integrated into the wider company strategy regarding eco-design transversal integration and its

objectives were to deploy tools and processes for the R&D teams to evaluate the environmental performance of their developing products. Operationally, the project was run by a core team composed of an external consultant, the head of innovation as well as a member of his team from September 2022 to December 2023.

We were included in the daily life of the core team. The core team met every week informally and formally every month. Moreover, additional governance points were set:

- Weekly meetings with the experts (eco-design experts and Hazardous material expert) *call bellow “CSR experts” for more readability*
- Quarterly meeting with the Steering Committee, including the head of innovation as well as the head of global HSE (supervising the eco-design activities) an expert manager from the consulting firm as well as a Partner from the consulting firm.
- Bi-annual meetings with the sponsors (the two Executive Committee members)

These governance meetings including HSE teams (head of HSE and CSR experts) and R&D (top management and teams) highlight the co-construction aspect of this project, deeply integrated from the definition.

We conducted comprehensive qualitative research (Dumez, 2016) based on 50 semi-structured interviews was carried out between September 2022 and December 2023 to understand the dynamics involved in the process of constructing environmental performance indicators for projects, as well as participated in all the meetings of this project.

Initially, interviews were conducted with multiple players, to understand the R&D and HSE (including eco-design) process within the company and the sector (contextual analysis).

Then, two projects appeared as relevant exploration grounds for our question: one known and recognized within the company as the standard-bearer of eco-design and with an available LCA to enable deep impact understanding, the other being a project perfectly opposed to the first (geographically, technologically and in terms of distribution level), thus allowing to be more representative of the company's projects. More than twenty interviews were conducted with operational teams on these two projects, with the aim of understanding not only the project development process, but also the data available at different points in the process. Also, to enrich our selection of indicators, we carried out 2 work sessions with the entire team of each project to challenge the selected indicators with the available data.

Finally, we conducted 4 interviews with the company's HSE management and 2 with the two executive committee's supporting members.

The interviews, which lasted between 60 and 130 minutes, were transcribed in full and analyzed for content.

To complete the qualitative analysis, we carried out a comprehensive review and synthesis of the life-cycle analysis of three of the company's products, to gain a quantitative understanding of the levers impacting environmental performance, as needed to define Environmental Performance Indicators (EPI). The limited number of life cycle analysis available (3) due to the complexity of these calculations, and their limited coverage of the range of products is one of the limitations of this

method which made the team integrate more qualitative analysis for the preliminary design and highlighted the need for a preliminary testing and fine-tuning phase.

3.3. Data analysis

Data from the interviews were thematically coded (Ayache & Dumez, 2011) based on the notes taken during the interviews and work-sessions, enabling iteration between theoretical elements and empirical data emerging directly from the analysis of the material. This coding work was carried out to detect and characterize mechanisms, and processes to highlight beliefs about certain causal relationships and identify recurring patterns.

The coding was carried out in two stages, to analyze the phenomenon appearing during this construction process. The first stage, relating to the opposition and convergence phases observed during the process, provided inputs around the different beliefs, on each dimension of the indicators, but also according to the expertise of the interviewee. This first coding was also analyzed chronologically to highlight the process stage where the events happened.

The second stage of coding enabled us to identify the learning process by analyzing the notes related to the convergence towards a final version of indicators and also the notes during the presentation of the results.

The coding elements of the first phases were also compared with the various versions of the KPI framework archived in the system. The comparison of the multiple versions crossed with the dates and the notes taken during the interviews enabled us to check that the salient elements identified had indeed been integrated.

4. CASE ANALYSIS: MONITORING THE PROCESS OF INDICATORS CONSTRUCTION

As stated above, we integrated the team during the 1-year intervention which was aimed to build the environmental indicators on R&D projects. Therefore, we followed the process of indicator construction and were part of all the discussions around it.

The process can be mapped in *Figure 1* as a 6-step process. The process was non-linear, as we will see further, but the activities were started following this sequence.

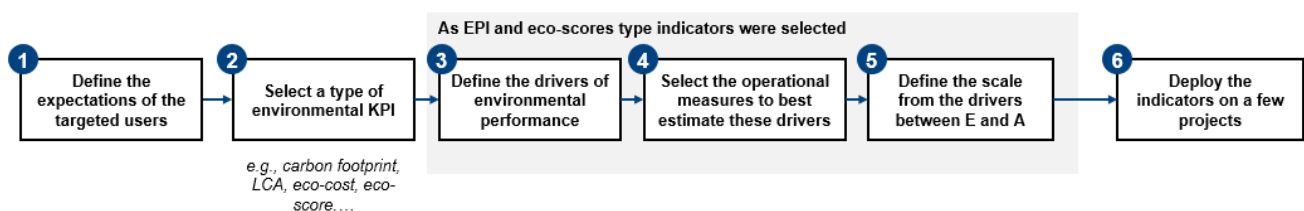


Figure 1: steps of the indicator definition process followed

In the following sections, we will deep-dive on each part of the process, illustrating with examples and interview verbatims our observations.

4.1. Defining the targeted users' expectations

The indicators' team conducted multiple 1:1 interview with the R&D teams to introduce the objectives, listen to their expectations about the indicator, and therefore precise their requirements.

To this we added a 360 view, interviewing all the main R&D, Innovation, and CSR stakeholders of the company. During these interviews, we presented the objective: "build an environmental indicator to apply on the development project in R&D, for teams to be informed and objectify the discussions and decisions towards eco-design". It enabled to identify multiple potential "users" and potential value for them, including the top management, the portfolio manager, and the CSR experts.

4.1.1. Expectations from the R&D team members

The main expectations of the R&D team (targeted users) for this indicator are summarized here, from the verbatim in Table 1:

Knowledge Provision: Given the lengthy product development cycle in the industry (8-10 years), there's a significant need for the R&D teams to understand and mitigate environmental impacts early on to stay ahead of market evolutions.

Actionability: The indicators must be practical for designers and project managers, facilitating impactful actions on targeted projects from the outset.

Early Availability: It's critical to have key performance indicators (KPIs) from the initial phase (Phase 0) to maximize impact reduction, acknowledging challenges in data availability and debates on applicability to new versus existing projects.

Simplicity: The process for data collection and interpretation must be straightforward, considering the existing pressures of cost, quality, and time-to-market constraints.

Involvement of Eco-design Experts: The development and integration of the indicator should be in collaboration with CSR experts, with regular updates and feedback sessions to leverage their insights.

Integration into Eco-design Toolkit: The indicator should complement the existing suite of eco-design tools, such as LCA and eco-design surveys, as emphasized by the CSR leadership during discussions.

#IPDMC2024
Leveraging a plurality of perspectives for impactful innovation
Final Paper

Expectations	Coded verbatims
Bring knowledge	<ul style="list-style-type: none"> • “We would like to have an objectified basis and to be able to compare our projects to it” R&D team member • “We need to know where to prioritize our efforts as we have multiple other constraints” R&D team member
Be actionable	<ul style="list-style-type: none"> • We [R&D] don’t have a saying on the transportation mode or distance” R&D team member • “With carbon footprint we don’t know what lever to activate to reduce” R&D team member
Be available from early stage	<ul style="list-style-type: none"> • “All the directions are possible at phase 0” “it will be very difficult” R&D team members • “We have almost no technical information in phase 0” R&D team members • “Phase 0 is mostly about the concept viability and market attract and not the technical solution” R&D team members • “After phase 0 a lot is already fixed” R&D team member • “Our products are on the market for the next 20 years, this is our main source of negative impact today” R&D team members • “We should not forget the existing implemented base [...] we could replace them or update them” R&D team members
Be simple	<ul style="list-style-type: none"> • “We already have important targets regarding cost control, time-to-market and quality” R&D team member • “During development, mainly for early phases, the teams don’t have a lot of time for additional tasks” Project manager • “It should not take more than 30 minutes” R&D team member • “How long do you need them?” Project manager
Be Built with the eco-design experts	<ul style="list-style-type: none"> • “Have you talked to XXX?” “I guess you are in contact with XXX” “You can ask this question to XXX she/he has all the information” R&D Team members
Be included in the eco-design tools portfolio	<ul style="list-style-type: none"> • “What is the link with this tool?” R&D team members • “We already fill-on a survey last year” “This is easier than [Name of tool]” R&D team members • ” Would it replace [name of tool]?” R&D team members • “It should not replace an existing tool; we need to think of it as a global toolbox” Top management

Table 1: Coded verbatims from the interviews regarding the expectations of the R&D team members

4.1.2. Expectations from the top management and portfolio manager

During management interviews, the core requirements previously identified were largely reiterated. However, additional expectations for the environmental indicator emerged, offering nuances to the R&D team's perspectives as detailed below, with insights drawn from Table 2 verbatims.

Comparability: The results should be usable for assessing the project portfolio to support realistic strategy and decision-making. Therefore, it should be possible to compare the different products of the company. This was also highlighted by the R&D team members but also pointed out as a worry and they started to justify themselves. Whereas from the top management perspective, the comments were frequently in comparison. But they also required fair comparison and therefore categorization of the products.

Target orientation: An indicator shows performance as a measurement of distance-to-target, measuring the distance between current or predicted values of the variable and the reference value. Whereas for top management the target should be a corporate ambition, for the R&D teams the anticipation is more oriented towards technological anticipation.

Transparency: clear understanding is key for the comprehension and adoption by the operational teams. An interesting fact we also observed later, as the teams asked a high number of questions during every presentation, to understand the backbone of the indicator and its result.

Finally, the indicators are **expected to be ambitious**. Indeed, the target was expected to be ambitious to motivate the team to significant progress, the management explicitly showed deception when seeing that with the first scale tested half of the project was in A-score.

Expectations	Coded verbatims
Enable product comparison	<ul style="list-style-type: none"> • “I think it is a great idea, but we should be careful not to compare peers and apples” “the technologies behind the products are very different” • “We don’t select all the parameters, some are from marketing” • “I wonder how this project is doing compared to this other project” • “I am surprised I thought that this project was better than this project” followed by “as we reduced [...]” or even “as it is a recent project”.
Refer to a target	<ul style="list-style-type: none"> • “To anticipate, we must have ambitious reference values” “what is our target?” “What do we want to reach in 10-20 years?” • “What would be technically feasible in the next years?” R&D team member
Be transparent	<ul style="list-style-type: none"> • “Where does it come from?” “I thought that [...], what parameters have you taken?” “How did you normalize [...] and [...]?” “Is the sum weighted? how?” “What is your source for [...]” “Who shared this information?” R&D team members.
Be ambitious	<ul style="list-style-type: none"> • “Under 10% no one moves”

Table 2: Coded verbatims from the interviews regarding the expectations from top management

4.1.3. Other expectations

In the comprehensive interviews, CSR experts emphasized the importance of the environmental indicator **being reliable** and **reflective of market demands**, such as eco-designed packaging or recycled plastics rate. They stressed the indicator's scientific credibility and its ability to capture market-relevant environmental impacts.

A key challenge identified was balancing the R&D teams' preference for simplicity and ease of data collection with the necessity for a reliable indicator that earns trust. This balance was crucial from the indicator's conceptual phase, where CSR experts' involvement and approval were essential for establishing credibility. The choice of operational measures to represent environmental impacts directly influenced the indicator's complexity, necessitating a careful balance between expert-backed reliability and the operational simplicity desired by R&D teams.

Furthermore, CSR experts highlighted the need for the indicator to align with market values, even when these do not directly correlate with the most significant environmental impacts, reflecting their need to streamline answers to clients' demands coming from the marketing.

4.2. Selecting a type of indicators

Several tools have been developed and studied to perform sustainability assessments (Masoud et al., 2022):

1. Biophysical approach considering the flow of resources (e.g. Life Cycle Assessment)
2. Monetary & economical approach (e.g. carbon taxes, eco-costs, prevention costs, Cost-Benefit Analysis)
3. Indicator-based tools (eg multi-criteria Analysis, selection of indicators, calculation of weights, scoring, and aggregation)

These methods were analyzed by the team as they seemed all viable for the environmental assessment of the Innovation and R&D projects.

These approaches were shortlisted and proposed to the targeted users (R&D team) during a workshop where they selected one type by vote (unanimous) among the following ones:

- CO2 calculations, widely used
- Eco-costs, a more complete version of Internal carbon pricing
- Environmental labeling using environmental performance drivers

After the selection we presented the result to the other potential users observed during the 360 (project manager and portfolio managers), to take their feedback and opinion, detailed in the following sections.

4.2.1. CO2

Highlighted for its common use in measuring environmental impact, it faced skepticism for its early design phase applicability and comprehensive impact coverage. Indeed, concerns were voiced that:

- a CO2 result wouldn't help the team to understand the position of their project *"is it good or bad? compared to what?"*
- the CO2 improvement roadmap will need experts support to share the levers
- a CO2 equivalent is difficult to compute in early design phase

Moreover, experts added, *"We need to have a more eco-systemic view, carbon footprint is just one part"*, but adding other categories would complexify the calculation but also limit the understanding for the teams *"Kilograms of antimonies is an expert unit"* R&D team member.

4.2.2. Eco-cost

The eco-cost approach, translating environmental impacts into euros for clear, actionable decision-making, was explored to enhance understanding and applicability across users (Fu et al., 2020; Giang and Phuong, 2022). This method addresses the challenge of justifying eco-design costs, as highlighted in interviews: *"If it increases the costs how do we decide?" "What is the right cost?" "Can we quantify eco-design efforts?"* However, the portfolio manager raised concerns about its complexity and transparency, questioning the basis of conversion factors: *"Who decides these conversion factors? based on what?"*

4.2.3. A mix between Environmental scoring and Environmental Performance indicators

To address understanding and actionability issues with previous indicators, eco-scores, and labels were explored, offering intuitive grading (A, B, C, D, E) and color-coding familiar to all: *"It is something we all know" "really easy to understand" "very user-centric."* R&D teams preferred a scorecard focused on key operational environmental drivers, known as the Planet Score (see Figure 2), for its clarity and direct guidance on improvements: *"It is really clear" "we see what we need to improve."*



Figure 2: The Planet score, an example used during the project for environmental score design selection

Despite concerns about potential leaks and brand image risks—*"eco-score are usually used for external communication... If it leaks because someone interpret it as an external eco-score, it will be a problem"* Marketing team or *"if it is environmental scoring, we should respect multiple norms and regulations linked to environmental communication and environmental scoring"* CSR expert

—the benefits were deemed to outweigh the risks, with strategies for risk mitigation involving confidentiality and change management emphasized.

Ultimately, a project scorecard was developed, rating impactful operational parameters to enhance project team understanding and impact (see Figure 3). This scorecard, designed for internal

comparison, uses a weighted average based on planetary boundaries to facilitate meaningful comparisons.

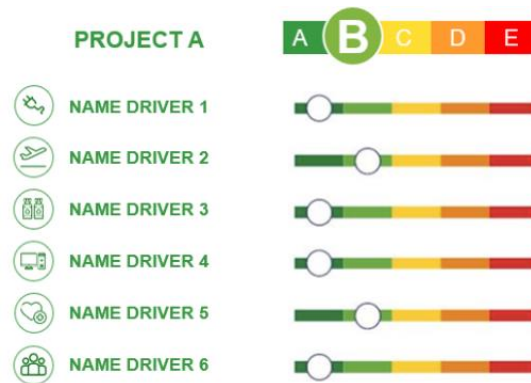


Figure 3: Selected type of indicator and formatting

4.2.4. Methodological implication

The adoption of an Environmental Performance Indicator (EPI) for project scoring necessitated defining environmental drivers, measurement methods, and a grading scale. This process, as outlined in Figure 4 and detailed by Medner and Lapina (2019), involves translating operational measures into KPIs, which are then graded based on predefined criteria to produce an output (A, B, C, D, or E).

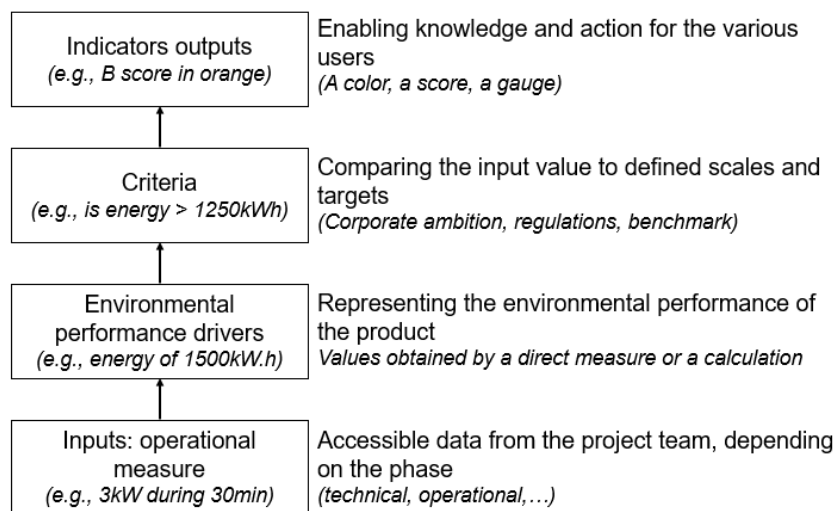


Figure 4: Composition of the indicators and linkage between the indicator's outputs, the scale, the drivers and the operational measures enabling to calculate their values.

To illustrate this process, with an example:

- The R&D team can communicate easily the power and the time for an instrument to run a test: *3kW during 30 minutes*

- With this information, we can calculate the energy needed, which could be a driver of environmental performance: *1500 kWh*
- This energy should be compared to a reference scale, for example *B-grade if the energy is between 1700kWh and 1250kh*
- Resulting in a B-grade

The literature around KPI (Medne and Lapina, 2019) highlight that one can go upstream (from the operational measures to KPI) or downstream (from KPI to the operational measures needed). Here, as we navigate under a high level of uncertainty, not knowing what to measure and where the biggest R&D impacts are (even having preconceived opinions *“The main lever are in purchasing”* *“We should see the water / energy use in manufacturing”*), the team decided to start by investigating on the drivers of the environmental performance.

4.3. Defining and selecting the drivers of the environmental performance

4.3.1. Quantitative analysis

To identify the technical parameters most affecting a product's environmental impact, the team examined available Life Cycle Assessments (LCAs). As noted by Azzone et al. (1996), while LCA is not ideal for early design phase environmental management, it remains the most accurate method to comprehensively understand product impacts across 16 to 18 dimensions, offering an ecosystemic perspective.

The goal was to pinpoint the primary environmental drivers of the company's products or those in similar categories or industries, aiding in the initial creation of the environmental KPI by narrowing down key R&D parameters. This involved detailed LCA reviews to grasp the impact drivers thoroughly.

By applying planetary boundaries normalization (Bjorn & Hauschild, 2015) to the LCAs, the analysis identified three main drivers responsible for over 80% of the total weighted environmental impact, streamlining the focus for KPI development.

4.3.2. Qualitative and contextual analysis

To have more relief, the context was analyzed based on internal interviews (CSR experts, marketing and customer service for the customers' needs, legal for the market regulations and strategy for the prospective) and on-line regulatory and competition research.

Moreover, the environmental impact of our field study sector was investigated. Indeed, the main impacts could drive future regulations. Therefore, investigating not only today's regulations but also the sectoral LCA, and its contribution to the planetary boundaries (for example) appeared critical. After this analysis, we decided to add one additional driver, impacting only one of the 16 impact categories but for more than 80% of this category.

Finally, based on the context analysis (e.g. REACH and ROHS regulations on toxic substances), it was decided to add 2 additional drivers, giving a total of 6 environmental drivers.

All the drivers were selected as operational drivers (e.g. electrical consumption, quantity of plastic, ...) for the project team to directly identify domains of improvement.

The steps followed are presented *Figure 5*.

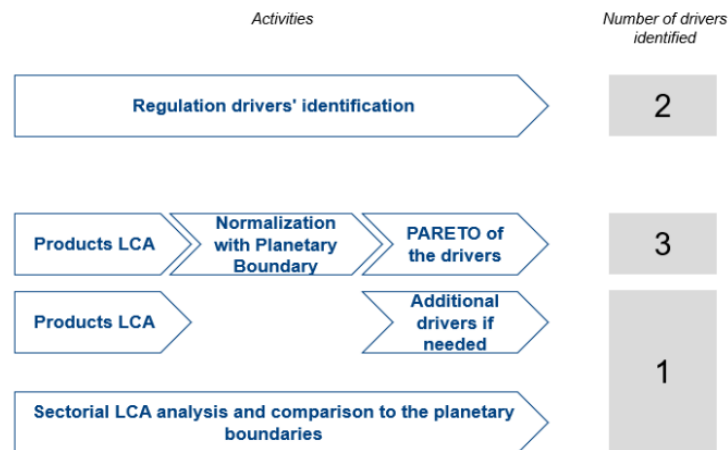


Figure 5: Activities that lead to the drivers' definition and their impact on the number of drivers

4.3.3. Feedbacks and first learnings

The indicator's core team presented the identified environmental drivers to the R&D teams, CSR experts, and later to top management, seeking their feedback.

Initially, R&D team members questioned the selection process but gradually acknowledged the scientific rigor behind it, often expressing surprise at the factors identified as most impactful: *"I am surprise not to see [...]" "Why isn't the [...] in this list" "How did you [...]" "Have you taken into account [...]"*. This led to a noticeable increase in awareness about the key parameters for reducing environmental footprints in product development, sparking proactive discussions on potential improvements: *"Oh then we can use the client's computer and an updatable software" "We don't need it to be always on"*.

CSR experts, while not surprised by the findings, suggested refinements in terminology for clarity, such as renaming 'circularity' to better reflect its measure, and proposed the inclusion of additional drivers to meet market demands: *"Circularity implies that we are measuring here the % of recycled materials, we should call it repairability"* and *"We should include [...] as it is a demand from the market" "Where do we find [...]"* This feedback underscored the importance of precise language and the consideration of market expectations in defining environmental drivers.

4.4. Short-listing the operational measures to compute an indicator/score for each driver

4.4.1. R&D teams work-sessions

After selecting the six key environmental performance drivers for the product range, the challenge was to determine operational measures for scoring each driver, especially during early design phases where data are scarce. To address this, the team collaborated with R&D teams, the primary users of the KPI, through three workshops aimed at brainstorming measurement methods.

Observations from these sessions included:

- Initial difficulties in hypothesizing technical details led to specific queries like *"Is it by patient or by test?"*, *"Do we include IDLE mode?"* or *"How do you include the real use"*.
- Surprises were expressed over the absence of certain expected high-impact parameters, such as secondary packaging.
- Discussions often shifted towards solution-finding rather than focusing on operational inputs for the indicators.
- Adjustments were made to some drivers to reflect aspects directly influenceable by R&D *"The transportation mode partially depends on the manufacture site and client location so on the sales and distribution choices, nevertheless we can impact on [...] to be able to take boat whatever the distance"*

These workshops led to the refinement of the environmental drivers, ensuring they were actionable by R&D and aligned with available operational data. The revised drivers remained within the scope of the initial six but focusing on areas directly impacted by R&D decisions.

4.4.2. The triple positive outcomes

By involving deeply the R&D teams not only in a feedback session but in a work-session to define the operational measure accessible for each driver, we observed three consequences:

- Enhanced understanding of their projects' environmental footprints and actionable levers.
- Shaped the indicators to reflect what is realistically actionable through design decisions.
- Prompted immediate collaborative solution brainstorming.

This approach not only refined the environmental drivers but also fostered a deeper engagement and awareness among R&D teams regarding their role in environmental impact reduction.

4.4.3. CSR experts feedbacks

Heading towards the next step (scale definition), the indicators were presented to the CSR experts, including the drivers but also the operational measures needed. Their feedbacks collected underlined a **need for more precise data** *"The theoretical power is not sufficient, we need to use the measured energy in run"* *"we need to include the client's real usage"*, the **impossibility to have an indicator in phase 0** and the need to include data that not useful for the drivers (meaning that are not in the pareto of the impacts) but that valorize actions already done by their team or optimize their data collection (i.e. data that they need to answer to a client or legal request)

These feedbacks were in contradiction with the R&D teams work-sessions as it opposed simplicity to get the information (R&D team) vs complex but accurate information (CSR experts), and R&D actionable levers vs data useful for the CSR experts.

4.4.4. A final compromise

After some iteration between experts, R&D teams and the indicators' teams, the final version of the indicators was:

- **Based on assumed and clear assumption** (example of the choice to normalize per result or per patient) instead of precise data, validated by both stakeholders during this alignment process
- **With only few and simple inputs** (a sensitivity analysis was presented to the teams)
- **Starting from phase 0** (the teams showed using a use-case that it was possible)

4.5. Scaling toward the ambition

In this section, we use either the word “criteria” or “scale” to designate the graduated scale selected to go from A to E, from. We use the word “target”, “A-grade” or “A-score” to designate the criteria that enables reaching the A score on the scale.

Once the 6 drivers and their operational measures were defined, the next step dedicated was to set the indicators' criteria, meaning the scale to pass from E to A.

This step included the highest number of exchanges and modifications, as it was seen as the most critical. Indeed, for the R&D teams as well as for the expert and the top management, the scale selected on each driver indirectly implies a corporate target. Setting the A-score to be -X% of plastic or electric consumption for example is seen as a message and a corporate decision for the teams.

Therefore, multiple meetings were organized to validate a scale, as it needed an alignment between the top management (*“ambition”, “internal message”*) and the CSR experts (*“need for realistic targets”*).

The steps followed were the following:

- The KPI team did a first rough proposition of targets, to open a discussion based on figures with the next stakeholders
- Then, they included the CSR experts, which challenges the targets using EU targets for A-grade, as well as their expertise around the main physical limitations but also their personal believes based on their expertise *“the European union has a clear target for energy, we should align on it”*
- The modified targets for each driver were then presented to the top-management, who challenged their ambition *“we need to be ambitious” “under -15% nobody acts”*, but also questioned the integration of these targets in their global strategy *“we should have a strategic discussion to see if we target 0g or -80%” “This just be discussed in a global strategic perspective”*
- Other iterations were done this way, between CSR experts and top management, before aligning on the 6 scales.

The output of these discussions was a scale validated by both parties, a governance process defined, but also some strategic discussions organized around some product strategy in the light of these drivers and targets.

This discussion had another positive impact that it required experts and top management to deep dive in the conversation and therefore to align on the drivers, share their knowledge on the topic and compromise towards a collective solution.

As an example, for a same driver:

- the experts push a target using the EU 2030 objectives,
- the top management pushed for an ambitious percentage reduction from their experience to be motivative for the team and ambitious,
- the R&D teams wanted to know what will be technically possible in 2030 based on the developing technologies

Finally, after all these iterations a collective agreement was reached.

4.6. Collecting results and deployment of the EPI

4.6.1. Deployment of the framework

Few months after the launch, the framework was validated for deployment on 7 projects.

These seven projects were defined to cover (in addition to the two first) the range of projects of the Company, but also the range of phases (stage-gate process phases 0 to 3) and technologies.

Project leaders showed enthusiasm for the scorecard, committing to allocate time for their teams to engage with the indicators. Feedback highlighted challenges regarding the inputs and integration of this new tool within existing review processes. The feedback session also sparked discussions on potential new drivers for different project types, like digital projects, for future KPI versions.

A notable outcome during an interview regarding a phase 0 project was the team's proactive reevaluation of their concept for greater sustainability. Despite having general directions for most drivers without specific parameters, realizing the negative impacts of their initial choices prompted immediate reconsideration towards more sustainable alternatives. This early engagement steered the project towards more environmentally friendly decisions.

4.6.2. Results presentation

Finally, the preliminary KPI were computed on the company's past and present projects and the results presented to the Steering committee.

All members were intrigued by the results: some by the scoring of a product they have in mind, or the relative positioning of a product compared to another, or even the positioning of the new in-development products compared to other former ones already in the market and development 10 years from today. *"I am surprised by [...]" "Why this project is D when [...] is B?" "It is surprising because [...]" "What value have you taken [...]" "We should have another check on the raw inputs"*

It also uncovered multiple questioning related to the scale, ambition and score. *"We should re-do the scale as there is no one in B and C" "We have too many projects in A, we should be more ambitious"*

“*Should we normalize the results by tests and not sample?*” which led to few sensitivity analysis to evaluate the impact of these changes on the final results and another loop of convergence. But this also led to a raised awareness for everyone attending to the meeting, starting to challenge the on-going projects, but also to realize which part of the activity has the most impact.

5. RESULTS AND IMPLICATION

5.1. Indicators deployed on 7 of the company’s projects

During this year, we followed the development and operational implementation of Environmental Performance Indicators for the innovation and product development process. The objective of these indicators was to increase the integration of eco-design in R&D departments in the private sector and therefore reduce the future environmental impact.

The final drivers and indicators developed comply by-design with the requirement of EPIs for eco-design applications as summed-up by Dewulf and Dulfou (*Dewulf & Dulfou, 2023*):

- *Drive or represent a significant environmental aspect of the product*: a Pareto analysis of the LCA of the products was done as well as a context analysis for any other environmental aspect not represented in the LCA
- *Be measurable (unambiguous procedures, availability of data)*: this part was ensured by including the R&D teams and testing on existing projects from the beginning
- *Be influenced by the organization*: by including the designers from the beginning and emphasizing the actionable requirement, was ensured to select only drivers on which the users can have a lever

Moreover, these indicators were deployed on 7 projects after the development phase.

Whereas the existing literature around EPI focuses on their selection, listing 500+ different indicators depending on multiple factors (including the users) and pushing the industrials and academics to “pick” from the lists and “fine-tune” (*Heslouin et al., 2017; Issa et al., 2015; Wagner et al., 2016*), little is known about the interactive and interactive process required to define these indicators in the corporate context, politics, stakeholders and its benefits. This is what we intended to do below.

5.2. A hybrid, dynamic process, involving players with different levels of understanding

5.2.1. Multiple internal stakeholders included in the process

As described in the Section 4, during the process of construction of these environmental indicators, few internal stakeholders were involved in different phases and with various implications: the R&D teams were included by design (4.1, 4.2, and 4.4), to tailor the indicators to their constraints. Then, the CSR experts were included in 4.3 to share the Life Cycle Assessment data and in 4.4 in the form of feedbacks and expertise-sharing sessions. The top management and CSR experts were actively integrated (work-sessions) during the 4.5 to define the reference scale. Moreover, during the 360 interviews done in parallel with the construction process, we identified other potential users of the

indicators: portfolio managers, top management, CSR experts but also marketing. The figure below summarizes the various involvement during the 1 year of the project.

The *Figure 6* highlights that the process was a **hybrid approach**, meaning it mixed bottom-up, top-down and expert-driven approaches.

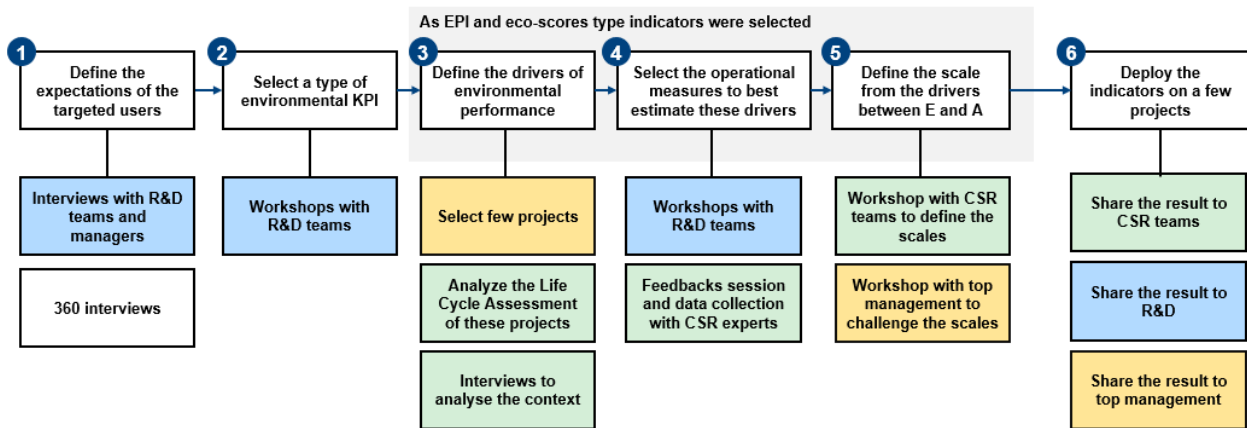


Figure 6: Decomposition of the involvement in the process according to the department (in blue the R&D, in green the CSR and in orange the top management)

This hybrid approach ensured:

- reliability and credibility of the results (expert-driven) *“ok if it has been reviewed by [CSR experts member’s name]” “Have you cross-checked it with [CSR experts member’s name]”* for both R&D teams and top management
- usability, accessibility, adoption, integration in the projects' constraints (bottom-up) *“It is really easy to use” R&D team member*
- usefulness in their integration in the companies’ objectives and reporting (top-down) *“it must be linked to a corporate objective and followed at a higher level than just the project team” R&D team member*

This approach enabled a deep co-construction of the indicators, where all the stakeholders were involved. This was ensured by high support from the top management which brought the credibility of the approach but also the availability of the teams (multiple hours of work-sessions and interviews).

5.2.2. A diversity of understanding and objectives from the different stakeholders

From the beginning of the project, during the 360 interviews, the R&D teams, the CSR experts, and the top management, who were all later deeply integrated in the process, shared very different perspectives around these indicators. Also, during the process detailed in section 4, they all shared feedbacks on the indicators related to very distinct aspects. These expectations and focuses are summarized in the Table 3.

Group	Expectations for environmental indicators	Main focus during the indicators' construction
Top management	To monitor the strategy achievement, to understand better the impact and solutions, to manage the portfolio	Focus on the ambition <i>"we need to be ambitious"</i> and on the adequation to the shared strategy <i>"this will imply to change our [...] strategy"</i>
CSR experts	To guide the R&D decision-making, to monitor the environmental performance and measure achievements	Focus on reliability, robustness, context-sensitivity (based on regulations <i>"today WEEE requires [...]"</i>) and completeness (<i>"Where is the biodiversity?"</i>) <i>"We must use real power not theoretical"</i>)
R&D teams	To inform on multiple scenario's impacts	Focus on usefulness, simplicity and compatibility with other constraints (cost, time-to-market) <i>"Today we already have a lot of constraint in the project"</i> <i>"It is too early"</i> <i>"it is too long and complex to fill"</i>

Table 3: Sum-up of the expectations and focus of the various stakeholders during the process

5.2.3. The influence of their dynamics

Moreover, these interactions (5.2.1) and the various attention points of stakeholders (5.2.2.) required that the process was highly iterative. We were able to witness and follow the successive modifications and their sources and plot them in the figure below.

Each circle represents a new version of the indicators, this figure highlights the "ping-pong" between the three groups for the drivers' definition as well as the target setting. We can highlight that every phase required some iteration and interaction, but the definition of the operational measures needed was the most iterative. Indeed, we observed that as the indicator got more precise, the internal stakeholders became more and more involved when asked (e.g. the CSR experts and R&D teams for the Phase 3 and the CSR experts on the ambition definition phase).

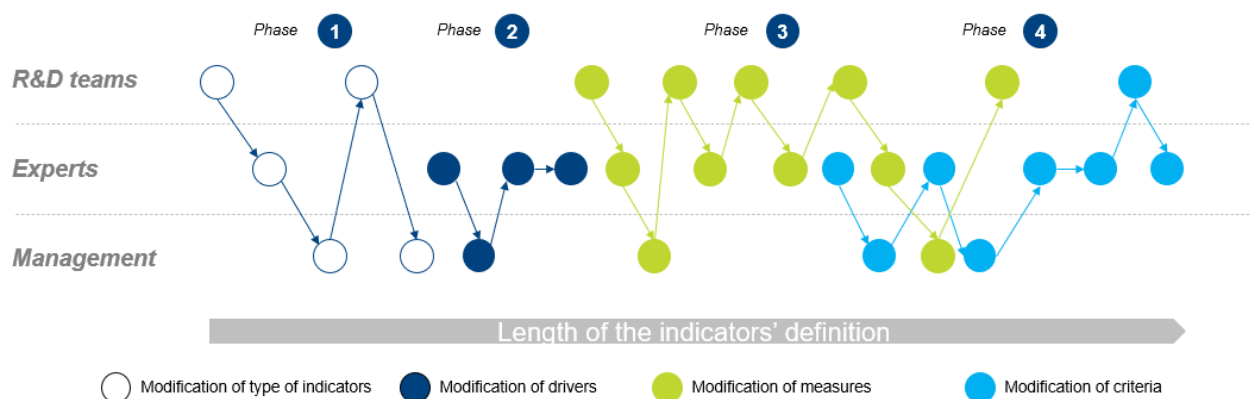


Figure 7: Chronological representation of the modification of indicators by the stakeholders interaction and their source

This iterative and interactive process, due to the co-construction method selected, enabled enlightened debates, internal convergence, and thus adoption, as explained below:

5.3. Adoption requires agreement, convergence and consensus-building

As illustrated in the previous section, numerous iterations happened due to the interaction between the internal stakeholders and the indicators. These interactions required to reach a compromise to build and launch the indicators in phase 5. Below, we listed the various compromises detailed in the Section 4:

- **Convergence on the need:** indicator for economic decision-making versus indicator to guide R&D teams versus external valuation indicator (section 4.1.)
- **Convergence on the type of indicators:** physical values (CO₂, etc.) and economic quantifications versus the eco-score indicator, or the need for an aggregate score to compare indicators (section 4.2.)
- **Convergence on drivers:** the desire to include market demands or indicators enhancing internally efforts already made versus the desire to include only the Pareto of impacts to reduce the number of indicators (section 4.3.)
- **Convergence on operational measures:** the need for simplicity, transparency, and rapidity of indicators involving the making of assumptions versus the need for a complete and reliable indicator, or the difference in perception as to the difficulty of obtaining information by teams (section 4.4.)
- **Convergence on rating scales:** justifying the strategy in place versus being very ambitious versus being justifiable by a normative or local target versus being scientifically realistic and rigorous (section 4.5.)

In this 1-year process, the indicators represented an objectivation and simplification of the complexity highlighted by M. Berry (1983), with here the complexity being both the environmental footprint evaluation but also the various personal beliefs (*see the diversity of reaction in section 4.3.3. and 4.6.2. when presenting the results, results confronting their personal beliefs and actual knowledge*).

Being on the border of these objectives (data) and subjective (beliefs) topics, the indicator construction process stimulated the confrontation, but in an objectified way, where the object (indicator) acted like a regulator, and thus, also stimulated the consensus process.

Indeed, these various situations, where we needed to put the stakeholders around the table and converge on a solution, enabled us to build the set of indicators, with a global alignment. The final indicators were then the physical representation of the consensus that emerged from this confrontation of different rationalities.

This phenomenon, discussed in the literature by De Vaujany (2005) during the use phase to break the conception/use dialectic ("It is through learning, through conflicts over control, through the

autonomy-control dialectic, that the tool finally takes shape.”) was here observed even from the preliminary conception phase. To go further, we conclude that in a context of high uncertainty and personal beliefs (like scope 3 in sustainability), these iterations need to be carried out at the design stage, before deployment, to ensure effective appropriation of the tool. In the last paragraph, we will emphasize the positive externalities of this process, greater than the tool itself.

5.4. A learning process that goes beyond indicators definition

Finally, two types of learning were observed: learning through confrontation between actors with different views (to reach a consensus) and learning through the search for and application of indicators.

Indeed, in the first case, the stakeholders mentioned above, with very different needs and knowledge of the subject in question, had to negotiate together to find points of convergence. These negotiations made it possible to put forward their points of view but also to hear those of others, and finally to objectify the situation around the indicator as physical support (for example, the CSR experts were able to learn which data are easily accessible by the teams and useful, or the possibility of having a first faithful and useful vision by taking hypotheses).

In the second case, they all gained a better understanding of the factors influencing the environmental performance of their projects, and of the positioning of instruments, particularly the relative positions between instruments in the same range. Initially, this learning generated a great deal of questioning, which was then transformed into discussion and action on the part of the R&D teams.

The process of constructing environmental indicators was, therefore, a source of learning for all the involved stakeholders, and of convergence between them. In this respect, even if the construction of indicators requires time and investment, what is to be preferred to "pick & collect" based on existing lengthy lists in the literature, as the process de-siloed knowledge, revealing to everyone the expectations, constraints, and knowledge of the others, and creating not just a common object, but a common knowledge.

5.5. Next steps of the research

This article aimed to take a comprehensive approach to understanding the process and dynamics behind the process of construction of environmental indicators for R&D innovation and product development in a company. To analyze the dynamics between the stakeholders and with the indicator, we followed the whole process and propose here a stakeholder-oriented description of the followed process.

We highlighted that (i) the process of construction of Environmental Performance Indicators is a hybrid approach highly interactive and iterative (ii) this dynamic is a key success factor in the construction of these indicators, confronting various beliefs and realities towards a consensus (iii) it results in a learning process for all stakeholders involved, even before using operationally the indicators. Thus, going beyond research on appropriation, here the very construction of the tool has created learning that goes beyond the tool and has already moved the lines, like opening EXCO-level

reflections challenging the company's strategic orientation on one of the subjects or the reorientation of a project that was in phase 0 on some of the drivers. Indeed, beyond the management tool, in this context of great uncertainty and a multitude of points of view, the process of designing the EPI was a vector of learning and change.

To go further, some questions were raised during the process around how to use these indicators for decision-making, particularly in the context of complex arbitrage? And mainly, would they be taken seriously compared to the usual triple constraints?

Moreover, there is a need to follow the implementation of these KPI in the long time, to see if they activate the collective action. Indeed, no authors observed and described to use over time of Environmental Performance Indicators. This implies studying the performance (Aggeri, 2017) of these management tools and potential distortions, identifying the transformations or transitions that the use of this framework causes (Disse & Aggeri, 2022). Indeed, approaches by management tools in management sciences highlight the importance of questioning the logic of pure instrumental rationality and analyzing appropriation phenomena (David, 1998; Moisdon, 1997; Aggeri & Labatut, 2010).

Assessment tools being a necessary condition for environmental action, but there is little critical debate about their ability to encourage sustainable development (Pope et al., 2004).

6. BIBLIOGRAPHY

Abrassart, C., & Aggeri, F. (2002). Abrassart C. et Aggeri F. (2002), «La naissance de l'éco-conception. Du cycle de vie au management environnemental produit», in *Responsabilité et Environnement* n° 25, *Annales des Mines*, janvier, p. 14-63. https://www.academia.edu/4844315/Abrassart_C_et_Aggeri_F_2002_La_naissance_de_l%C3%A9co_conception_Du_cycle_de_vie_au_management_environmental_produit_in_Responsabilit%C3%A9_et_Environnement_n_25_Annales_des_Mines_janvier_p_14_63

Aggeri, F., & Labatut, J. (2010). *La gestion au prisme de ses instruments. Une analyse généalogique des approches théoriques fondées sur les instruments de gestion.*

Andrien, L. (2019). *Les outils de gestion et la construction du sens de l'action collective: Étude de cas d'un outil d'évaluation des besoins dans des associations de parents de personnes en situation de handicap intellectuel.* [Phdthesis, Université Paris Saclay (COMUE)]. <https://theses.hal.science/tel-02443257>

Avenier, M.-J., & Schmitt, C. (2008). *Quelles perspectives le paradigme des sciences de l'artificiel offre-t-il a la recherche en entrepreneuriat?* In "Embracing Complexity: Advancing Ecological Understanding in Organization Studies",.

Ayache, M., & Dumez, H. (2011). *Le codage dans la recherche qualitative une nouvelle perspective ?* *Le Libellio d'AEgis*, 7(2-Eté), 33–46.

Azzone, G., Noci, G., Manzini, R., Welford, R., & Young, C. W. (1996). Defining Environmental Performance Indicators: An Integrated Framework. *Business Strategy and the Environment*, 5(2), 69–80. [https://doi.org/10.1002/\(SICI\)1099-0836\(199606\)5:2<69::AID-BSE48>3.0.CO;2-W](https://doi.org/10.1002/(SICI)1099-0836(199606)5:2<69::AID-BSE48>3.0.CO;2-W)

Berry, M. (1983). Une technologie invisible—L’impact des instruments de gestion sur l’évolution des systèmes humains. <https://hal.science/hal-00263141>

Bey, N., Hauschild, M. Z., & McAloone, T. C. (2013). Drivers and barriers for implementation of environmental strategies in manufacturing companies. *CIRP Annals*, 62(1), 43–46. <https://doi.org/10.1016/j.cirp.2013.03.001>

Bruhn, S., Sacchi, R., Cimpan, C., & Birkved, M. (2023). Ten questions concerning prospective LCA for decision support for the built environment. *Building and Environment*, 242, 110535. <https://doi.org/10.1016/j.buildenv.2023.110535>

Buchert, T., Kaluza, A., Halstenberg, F. A., Lindow, K., Hayka, H., & Stark, R. (2014). Enabling Product Development Engineers to Select and Combine Methods for Sustainable Design. *Procedia CIRP*, 15, 413–418. <https://doi.org/10.1016/j.procir.2014.06.025>

Ceschin, F. (2012). The introduction and scaling up of sustainable Product-Service Systems. A new role for strategic design for sustainability. <https://www.politesi.polimi.it/handle/10589/56785>

Chiappello, È., & Gilbert, P. (2013). *Sociologie des outils de gestion. La Découverte.*

Daae, J., Chamberlin, L., & Boks, C. (2018). Dimensions of Behaviour Change in the context of Designing for a Circular Economy. *The Design Journal*, 21(4), 521–541. <https://doi.org/10.1080/14606925.2018.1468003>

Dang, R. J. (2011). L’ intégration des PME au sein des dynamiques territoriales d’innovation: Une approche fondée sur les connaissances. Les cas de deux clusters du Pôle de compétitivité SCS [These de doctorat, Nice]. <https://theses.fr/2011NICE0049>

David, A. (1998). Outils de gestion et dynamique du changement. *Revue française de gestion*, (120), 44-59.

De Vaujany, F. X. (2006). Pour une théorie de l’appropriation des outils de gestion: Vers un dépassement de l’opposition conception-usage. *Management & Avenir*, 9(3), 109–126. <https://doi.org/10.3917/mav.009.0109>

Delmas, M. A., & Colgan, D. (2018). *The Green Bundle: Pairing the Market with the Planet.* Stanford University Press.

Delmas, M. A., & Toffel, M. W. (2008). Organizational responses to environmental demands: Opening the black box. *Strategic Management Journal*, 29(10), 1027–1055. <https://doi.org/10.1002/smj.701>

Dermody, J., & Hanmer-Lloyd, S. (1995). Developing Environmental Responsible New Products: The Challenge for the 1990s. “Product Development: Meeting the Challenge of the Design-

Marketing Interface. John Wiley & Sons Ltd.
<https://scholar.google.com/scholar?cluster=12329159078974052068&hl=en&oi=scholar>

Detchessahar, M., & Journé, B. (2007). Une approche narrative des outils de gestion. *Revue française de gestion*, 174(5), 77–92. <https://doi.org/10.3166/rfg.174.77-92>

Dewulf, W., & Duflou, J. (2023). Simplifying LCA Using Indicator Approaches—A Framework.

Disse, E., & Aggeri, F. (2022, November). Les sols comme communs à gérer. La comptabilité écologique comme levier de transformation des pratiques agricoles. *RIODD*. <https://hal.science/hal-03978260>

Dumez, H. (2016). *Méthodologie de la recherche qualitative: Les questions clés de la démarche ...* - Hervé Dumez—Google Livres.
https://books.google.fr/books?hl=fr&lr=&id=hfm1DwAAQBAJ&oi=fnd&pg=PT2&dq=M%C3%A9thodologie+de+la+recherche+qualitative:+Les+questions+cl%C3%A9s+de+la+d%C3%A9marche+compr%C3%A9hensive&ots=PB0B7jMsJZ&sig=5I2HAdHXsa-9lbt1JnUiZLuTQOo&redir_esc=y#v=onepage&q=M%C3%A9thodologie%20de%20la%20recherche%20qualitative%3A%20Les%20questions%20cl%C3%A9s%20de%20la%20d%C3%A9marche%20compr%C3%A9hensive&f=false

Grimand, A. (2006). L'appropriation des outils de gestion. Vers de nouvelles perspectives théoriques? (2006), Presses Universitaires de Saint-Etienne, 258 p.

Hassan, S. R., Megahed, N. A., Abo Eleinen, O. M., & Hassan, A. M. (2022). Toward a national life cycle assessment tool: Generative design for early decision support. *Energy and Buildings*, 267, 112144. <https://doi.org/10.1016/j.enbuild.2022.112144>

Haun, P., Müller, P., & Traverso, M. (2022). Improving automated Life Cycle Assessment with Life Cycle Inventory model constructs. *Journal of Cleaner Production*, 370, 133452. <https://doi.org/10.1016/j.jclepro.2022.133452>

Heslouin, C., Perrot-Bernardet, V., Cornier, A., & Perry, N. (2017). A User Oriented Framework to Support Environmental Performance Indicators Selection. *Procedia CIRP*, 61, 709–714. <https://doi.org/10.1016/j.procir.2016.11.211>

Hussenot, A. (2006). Appropriation collective d'une solution TIC de Gestion: Un processus social itératif. Post-Print, Article hal-00267354. <https://ideas.repec.org/p/hal/journal/hal-00267354.html>

Iken, N. (2021). Transition soutenable à l'échelle de l'entreprise: Approche de la performance par les outils de gestion.

Issa, I. I., Pigosso, D. C. A., McAloone, T. C., & Rozenfeld, H. (2015). Leading product-related environmental performance indicators: A selection guide and database. *Journal of Cleaner Production*, 108, 321–330. <https://doi.org/10.1016/j.jclepro.2015.06.088>

Kaebemick, H., Sun, M., & Kara, S. (2003). Simplified Lifecycle Assessment for the Early Design Stages of Industrial Products. *CIRP Annals*, 52(1), 25–28. [https://doi.org/10.1016/S0007-8506\(07\)60522-8](https://doi.org/10.1016/S0007-8506(07)60522-8)

- Kivilä, J., Martinsuo, M., & Vuorinen, L. (2017). Sustainable project management through project control in infrastructure projects. *International Journal of Project Management*, 35(6), 1167–1183. <https://doi.org/10.1016/j.ijproman.2017.02.009>
- Korpalski, T. (1996). The role of the “product steward” in advancing design for environment in Hewlett-Packard’s Computer Products Organization. *Proceedings of the 1996 IEEE International Symposium on Electronics and the Environment. ISEE-1996*, 37–41. <https://doi.org/10.1109/ISEE.1996.500393>
- Labuschagne, C., & Brent, A. C. (2005). Sustainable Project Life Cycle Management: The need to integrate life cycles in the manufacturing sector. *International Journal of Project Management*, 23(2), 159–168. <https://doi.org/10.1016/j.ijproman.2004.06.003>
- Martin, D. P. (2006). Appropriation des outils de gestion et dynamique de l’action collective: Propos d’étape. (p. 29). Presses Universitaires de St Etienne. <https://shs.hal.science/halshs-00257918>
- Masoud, A., Belotti, M., Alfarra, A., & Sorlini, S. (2022). Multi-Criteria Analysis for Evaluating Constructed Wetland as a Sustainable Sanitation Technology, Jordan Case Study. *Sustainability*, 14, 14867. <https://doi.org/10.3390/su142214867>
- Masui, K., Sakao, T., Kobayashi, M., & Inaba, A. (2003). Applying Quality Function Deployment to environmentally conscious design. *International Journal of Quality & Reliability Management*, 20(1), 90–106. <https://doi.org/10.1108/02656710310453836>
- Micheaux, H., & Aggeri, F. (2021). Eco-modulation as a driver for eco-design: A dynamic view of the French collective EPR scheme. *Journal of Cleaner Production*, 289, 125714. <https://doi.org/10.1016/j.jclepro.2020.125714>
- Millet, D., Bistagnino, L., Lanzavecchia, C., Camous, R., & Poldma, T. (2007). Does the potential of the use of LCA match the design team needs? *Journal of Cleaner Production*, 15(4), 335–346. <https://doi.org/10.1016/j.jclepro.2005.07.016>
- Moison, J.-C. (1997). Jean-Claude Moison (sous la direction de): Du mode d’existence des outils de gestion. Les instruments de gestion à l’épreuve de l’organisation. *Politiques et Management Public*, 15(4), 177–178.
- Musca, G. (2006). Une stratégie de recherche processuelle: L’étude longitudinale de cas enchâssés. *M@n@gement*, 9(3), 153–176. <https://doi.org/10.3917/mana.093.0153>
- Pascal, A., & Thomas, C. (2006). Appropriation des TIC: Vers une méthodologie de conception orientée usage. *Post-Print*, Article halshs-00374976. <https://ideas.repec.org/p/hal/journal/halshs-00374976.html>
- Plouffe, S., Lanoie, P., Berneman, C., & Vernier, M.-F. (2011). Economic benefits tied to ecodesign. *Journal of Cleaner Production*, 19(6), 573–579. <https://doi.org/10.1016/j.jclepro.2010.12.003>
- Pope, J., Annandale, D., & Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. *Environmental Impact Assessment Review*, 24(6), 595–616.

Puig, M., Wooldridge, C., & Darbra, R. M. (2014). Identification and selection of Environmental Performance Indicators for sustainable port development. *Marine Pollution Bulletin*, 81(1), 124–130. <https://doi.org/10.1016/j.marpolbul.2014.02.006>

Quernheim, N., Winter, S., Arnemann, L., Wolff, S., Anderl, R., & Schleich, B. (2023). Method Set for an adaptable Sustainability Assessment along the Product Life Cycle. *Procedia CIRP*, 116, 498–503. <https://doi.org/10.1016/j.procir.2023.02.084>

Riot, J. (2013). *Le management de l'environnement à travers ses instruments: De la diffusion d'outils à la construction de dynamiques d'action collective pour l'innovation environnementale* [These de doctorat, Paris, ENMP]. <https://theses.fr/2013ENMP0085>

Sabini, L., & Alderman, N. (2021). The Paradoxical Profession: Project Management and the Contradictory Nature of Sustainable Project Objectives. *Project Management Journal*, 52(4), 379–393. <https://doi.org/10.1177/87569728211007660>

Sabini, L., Muzio, D., & Alderman, N. (2019). 25 years of 'sustainable projects'. What we know and what the literature says. *International Journal of Project Management*, 37(6), 820–838. <https://doi.org/10.1016/j.ijproman.2019.05.002>

Schäfer, M., & Löwer, M. (2021). Ecodesign—A Review of Reviews. *Sustainability*, 13(1), Article 1. <https://doi.org/10.3390/su13010315>

Scrucca, F., Barberio, G., Cutaia, L., & Rinaldi, C. (2023). A simplified methodology for estimating the Carbon Footprint of heat generation by forest woodchips as a support tool for sustainability assessment in decision-making. *Cleaner Environmental Systems*, 9, 100126. <https://doi.org/10.1016/j.cesys.2023.100126>

Steux, C., & Aggeri, F. (2019, September). *Vers une autre conceptualisation de l'éco-conception: Une analyse critique des problématisations et des pratiques des entreprises*. 14e Congrès Du RIODD. <https://hal.science/hal-02324267>

Steux, C., & Aggeri, F. (2021). *De l'éco-conception à l'éco-innovation: Cadres et transformations des pratiques des entreprises*.

Tsoukas, H. (1989). The Validity of Idiographic Research Explanations | *Academy of Management Review*. <https://journals.aom.org/doi/abs/10.5465/amr.1989.4308386>

Wagner, E., Benecke, S., Winzer, J., Nissen, N. F., & Lang, K.-D. (2016). Evaluation of Indicators Supporting the Sustainable Design of Electronic Systems. *Procedia CIRP*, 40, 469–474. <https://doi.org/10.1016/j.procir.2016.01.100>

Weick, K. E. (1995). *Karl E. Weick (1995), Sensemaking in Organizations*, Sage, Thousand Oaks, Californie. *Sociologie du travail*, 38(2), 225–232. <https://doi.org/10.3406/sotra.1996.2274>