South American Journal of Management
Special Edition 2016

Sustainable Innovations-Design Approach & Improvements

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Abstract

Sustainable business & innovations are need of future generations. This paper aims at filling a gap, the gap between the high-level vision of sustainability and innovator's and designer's everyday work in creating new technical artifacts, services, and businesses. The concepts of sustainability are reviewed in the light of established product development processes, as well as with regard to a number of current proposals for integrating sustainability in innovation processes. The paper describes a framework for the front end of innovation. This framework is capable of reconciling the different notions of sustainability; simplified: "profit, people, and planet". A case study of a sustainable innovation is presented.

Keywords: *Sustainability, Innovations, New sustainable innovations & approach, Design changes.*

1. Sustainability

Sustainability, like 'future', is being used inflationary; often as a mere buzzword by politicians and corporate managers. The designation 'sustainable business' e.g. may mean a business with a positive social bottom line or simply a business that is expected to deliver a positive cash flow over a prolonged time, dependent on the speaker. Moreover, when talking about innovations, a sustaining innovation is one that does not require the acquisition of new competencies or changes to the current business model (Christensen 2009) but lives entirely within the conditions previously established.

According to McGrail (2011) "desirable futures are increasingly seen as sustainable futures". To pick out just a few important historic milestones, the concept of sustainability -its dystopian genealogy -reaches far back. E.g. to Rachel Carson's (1962) book "Silent Spring" that helped starting the environmentalist movement to which the term sustainability is still closely linked. Another widely regarded milestone was Meadows' et al. (1972) report "On the limits to growth" to the Club of Rome. But it was not before the Brundlandt Commission in 1987, that a positive definition of sustainability was established. The term of "Sustainable Development", defined as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development 1987) became known to a larger audience by that time. Given that the use of a technical artefact is largely dependent on human intention and societal context and only partially determined by the design (de Vries, 2005:14-25), it is this social understanding of sustainability that poses a serious challenge to designers and engineers. This challenge is how to embody "sustainability" in a product, create the functionality wanted without the side-effects unwanted.

Hayward (2005:282-283) links the concept of sustainability to the (individual's) ability for post conventional foresight: "Environmentalism itself may be the expression of a nascent social form of post conventional foresight. ... Environmentalism's catch cry, 'sustainability', is strikingly abstract and rarely is it made explicit exactly 'what' is to be sustained. ... Social foresight would have to chart pathways of action through multiple assessments of consequence as it is unlikely that a consequence 'free' pathway of action can be found."

In broad outlines, the approaches towards sustainability on the design side fall into three overlapping groups. The first is (eco-) efficiency, doing the same as before with less impact on the environment (this is the current sustainability mainstream: numerous corporate and political energy / water / materials etc effectiveness campaigns bear witness to this fact). The second group is (eco-) effectiveness with closed circulation of all technical and natural materials modeled after nature's ecosystems (e.g. McDonough & Braungart, 2002 or Pauly, 2011). The third group of approaches fits under the headline sufficiency: Doing and having less (especially material wealth and economic growth) but enough for a decent living and a focus on non-material human needs. It appears that the advocates of sustainability are separated by a common language

With regard to technology the available descriptions (e.g. Vergragt, 2006; Schumacher, 2010; Raskin et al. 2002) of sustainable (appropriate, etc.) technologies in a wider sense are normative and, from an engineer's standpoint, too abstract. They do not present enough guidance for designing such technologies easily and within the established standard engineering processes. The next section will underpin this by reviewing the process perspective of corporate technology generation.

2. Design processes in engineering

In this paper, the reference process described in VDI 2222 is chosen as an exemplar of a linearly proceeding and also widely established product development process (PDP). It is the PDP generally accepted in German industry and taught widely in universities. The successive steps (phases) towards a "product" according to VDI 2222 are[1]:

1. Product planning and clarification of the task;
2. Conceptual design;
3. Embodiment design;
4. Detail design.

Another very common approach is the Stage-GateTM process (Cooper, 2003), emphasising so called gates: Decision meetings in which the product development projects are reviewed and a go/hold/kill/recycle decision is made. An overview of more process models is given by Andreassen (2005).

All of the approaches mentioned share the taylorist separation of planning and execution. Planning precedes design and design precedes manufacturing. The high cost involved in commissioning factory equipment provides a strong economic justification for this separation. In a business enterprise, this separation is mirrored too in departmental boundaries between e.g. sales/product management/ marketing on one and R&D / Manufacturing on the other hand with people trained in different academic disciplines and socialised in different departmental subcultures. While the first functions task is to specify a product, the latter design and realize it "in time, in budget, in spec".

The most important documents in any PDP are the specifications. In the planning phase, the expected demand for the product in the markets targeted is described and restrictions for the design determined. The functional specification is being written in the early conceptual design phase. At this stage, the functional specification gives a solution-independent description of the technical (!) function and expected performance of the artefact (in most cases a product) to be designed. The functional specification answers the question "What is to be designed?". The later conceptual design phase then focuses on creating alternative technological options for realizing these functions and selecting these according to mainly economic criteria. Engineering design proper takes the functional specification and creates a technological artefact with the specified functions by splitting up the overall function into partial functions, finding technical solutions for each of these partial functions, and synthesizing the whole system out of these partial solutions. This concrete technological artefact is then described in the technical specification. It answers the question: "How is it designed?" After conceptual design is finished the concept of the product is frozen. Only detail at the technical and part-level is being added from now on. Changes to the product's principle and features are made rarely,

[1] *Planen, Konzipieren, Entwerfen, Ausarbeiten -translation according to Pahl & Beitz: 1993*

given the high cost involved in propagating any change through all affected partial functions and their concrete principles and technical instances. It is therefore clear that with regard to economic and pragmatic criteria engineering and manufacturing businesses need an ex ante approach to consider all relevant aspects of sustainability upfront. It is desirable to have sustainability considerations integrated into the PDP as early as possible. Ex post regulation or procedures directed at technologies after their creation and introduction to the market (like technology assessment) is desired least as any ex post approach may trigger changes to a finished product that come at a very high cost for the manufacturer.

Furthermore, the more radical the innovations planned are, the less they can be anticipated from outside the corporation, and the less they are accessible to ex post approaches. Given that many of today's companies consider themselves being in a global innovation-race with their competitors, the probability for radical innovations is increasing, therefore the options available for ex-post approaches and societal (often nation-state level) oversight over innovation are decreasing further. Moreover, plans for new products, their technical and other details are most commonly strictly confidential because new products regularly aim at maintaining or increasing a firm’s competitive edge. They are therefore inaccessible to outsiders. All of the aforementioned facts suggest that the best place for reconciling of the sustainability’s and anticipation of intended and unintended side effects is the product planning and design process of the enterprise.

3. Proposals for sustainability-aware innovation processes

Proposals made to the end of integrating sustainability criteria in innovation processes (Krämer, 2011; Fichter, Paech & Pfriem (Hg.), 2005; Pfriem, Antes, Fichter et al. (Hg.). 2006.) suggest measures that can be understood as ‘structural deepening’ (cf. Arthur, 2009:131-144) of the currently established innovation processes by adding new tools to the phases and adjusting selection criteria at the gates to create the new/added functionality required on top of the established innovation processes. But, according to Paech (2005:259-292), these changes to details of an established innovation process will have only minor impact, unless the corporate value system and the culture changes.

According to Nassehi (2011), economic entities function according to economic purposes and therefore ask one major question only with regard to sustainability: Can we earn money with it? But what would be required by the aforementioned proposals for modified product development processes and improved selection criteria is that these economic entities adopt – at least in part – a non economic logic. Will that work in practice? How for instance will the gatekeepers in a stage-gate process deal with a new multidimensional evaluation of innovation projects including sustainability criteria? Will a sustainable but not-so-profitable innovation still be pursued once the question: “What will our shareholders say?” was raised in the boardroom? Won’t the dominant economic simply persist and wipe away the "sustainable" criteria? Is a CEO that is measured against quarterly performance in monetary terms likely to enforce sustainability induced changes that reduce profitability – even if this is a societal demand[2]? There is no way but to reconcile these perspectives. The innovator’s and engineer’s question therefore is: “Can we design the well being of nature and future generations into profitable products?” Or, at an operative level: “Is it possible for sustainability to enter the design process at the right place: The functional specification?”

4. Can we engineer sustainability?

The answer to the question is yes, if the first group of approaches towards sustainability (eco efficiency) is taken into account; if e.g. compliance with environmental regulations is demanded. Currently established design-to-X procedures (many of which are described in the engineering textbooks e.g. Pahl & Beitz, 1993) are sufficient to accomplish this goal.

[2] *2 Ironically, the shareholders demanding double-digit returns are – via pension funds – in part identical with the very stakeholders that demand sustainability in other contexts.*

The answer is yes and no for the second group of approaches (eco-effectiveness). McDonough & Braungart (2002:165-186) provide five steps and five abstract guiding principles – on as little as 10% of the book's pages. The bridge to standard everyday engineering is largely missing. So, currently technologists or engineers whether in corporations or research know only minute parts of what is required and responsibility is diluted in the complex system a modern corporation is.

With regard to the third group of approaches (sufficiency), currently the answer is most probably no. Engineers don't know how to design sufficiency with the processes and structures established. Moreover, with regard to innovation management, sustainable innovations at the stage of sufficiency clearly require radical, not sustaining innovations.

In any of the aforementioned cases, a demand for sustainability cannot be satisfied without taking into account the corporate context and larger system(s) the product to be designed will enter.

5. General corporate context

Corporate R&D is organized in a hub-and-spoke model with most of the hubs in Local locations and a few abroad. The corporate mission statement includes the economic notion of sustainability; to "... achieve sustainable, profitable growth ..." The company supports the principles of the UN Global Compact.

Corporates position in the value chain is primarily that of a second tier manufacturer of standardized and engineered components that become often critically important parts of larger technical entities such as power stations, buildings, plants, or trains. This position creates a quite complex social system on the demand side. With regard to innovations, not a single buyer or "consumer", not even a buying center but a business system with consultants, engineers, intermediaries, and other parties directly and indirectly involved is defining aspects of acceptability outside the scope of marketing or engineering. This created from the year 2000 on an increasing need for considering the larger social business-system. This need was an important co-factor in the creation of the framework described in the next section.

6. A framework for business opportunity scanning (BOS)

As a first step towards a methodology for designing sustainable innovations, the framework for business opportunity scanning (BOS) developed mostly by the author at KSB AG is proposed. In BOS, the term scanning means scanning an idea for its hidden or true potential, like in a modern imaging diagnostic apparatus e.g. a computer tomography. It is not to be confused with the 'scanning for' in trend-based ideation. The term framework is used to highlight that BOS is targeted 'one level up' from the many descriptive methodologies (how to write scenarios; how to do market research) in business, the futures field, and product development processes. It aims at designing innovations – not at designing artefacts. Framework also means that individual methods may be substituted for other methods with the same aim.

7. BOS as instance of the futures studies framework

This section highlights the key-features (cf. Table 1) of BOS using the futures studies framework (cf. Fig. 1) by Keller (2009).

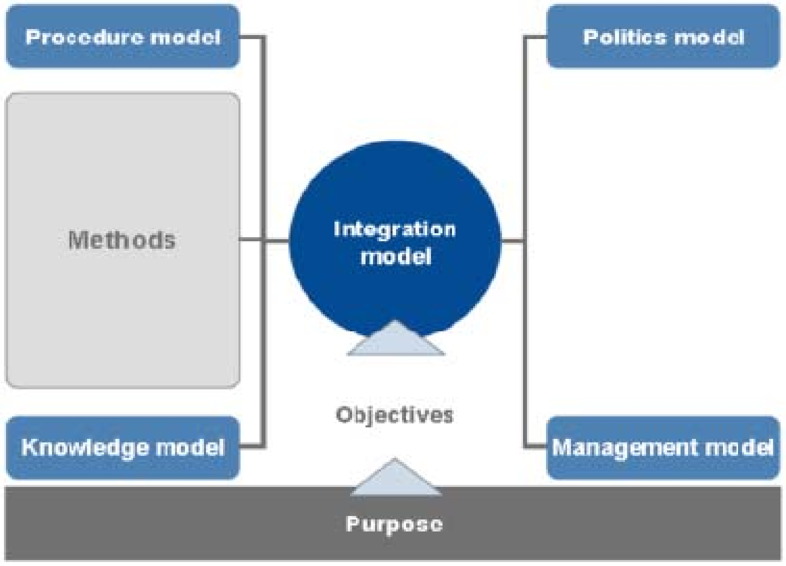

Figure 1. Dimensions of futures studies projects. Source: Author

While BOS is pragmatic by necessity, every part of it has a solid ground in established methodologies and science. The main ingredients – so to speak – of BOS are approaches from futures studies, especially multi perspective methodologies (e.g. Linstone's (2002) technical, organisational, and personal (TOP) perspectives), systems thinking (cf. Gharjedaghi. 2004.). The very foundation of the framework is an understanding of futures studies "as an 'action science' dealing with 'images of the future'" (Voros 2007) where accomplishment takes precedence over knowledge, similar to engineering, many of the social, and the medical sciences (cf. König 2006:85).

Table 1. Description of the futures studies framework's elements. Source: Author

Element	**Description**
Purpose	Why the study is being made, the expected contribution, including the stakeholder's (especially sponsor's) expectations.
Objectives	What the expected outcome of the study and the deliverables are.
Integration model	The mode of operation 'next level up'. A model that integrates all of the other elements. In futures Studies the integration model typically is systems thinking or action research rather than empiricism.
Procedure model	Process-steps, how the time for the study is structured.
Knowledge model	How structuring and ordering of knowledge happens, the ontology at work.
Methods	Methods are sequenced by the procedure model and create knowledge into the knowledge model. They are the bridge between content and doing in the study,
Management model	How the project itself is managed, progress is traced etc. e.g. by "classical" Project Management or more modern methods like SCRUM.
Politics Model	How power is being handled in the project. Most important: is the project designed to fit in existing structures or to challenge them?

Most important, BOS does not touch the established management model (project management) and politics model (Stage-Gate). It is compatible with existing corporate structures.

The procedure model chosen is the generic foresight process framework (GFPF) by Voros (2003) with its emphasis on interpretation was selected as the underlying approach and topmost procedure model for the BOS framework.

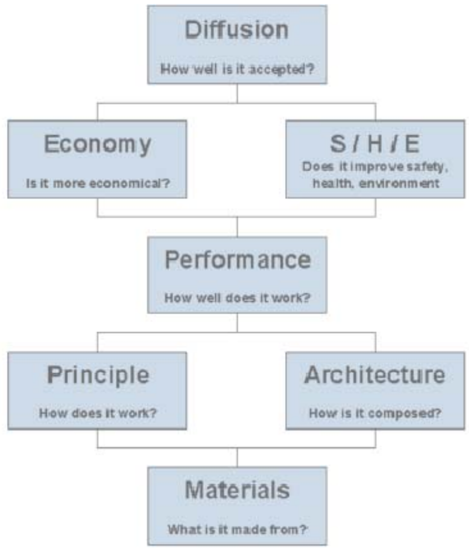

Figure 2. Cascade model of technology. Source: van Wyk 2004 with modifications by the Author

As the meta-model for knowledge organisation in the research part, the cascade model of technology by van Wyk (2004:39-41) provides an integral framework spanning the whole range of the socio-technical system, from materials and technical details to the society as a whole. (Fig. 2). For the BOS framework, this span is divided into the two "systems perspectives": the business system and the technology system with the innovation to be designed at the intersection of these systems. The technology and business systems are influenced by the two "segmentation perspectives": application and region (Fig. 3). The segmentation perspectives provide for an adequate scoping of the systems perspectives. Clearly, business in India, Europe is different from business in Japan (or in China, Arabia or wherever else), so the model of the business system has to be adapted to the region. On the other hand, the application, what the product is being used for, has also a large influence on the business system as different industries have established different procedures and have different needs. All study of these four perspectives is embedded in the study of the contextual environment with the long-term societal, technical, economical, environmental, and political changes.

The analysis is performed as desk-research, until a certain level of understanding is available, then interviews with representatives from the relevant roles in the business system add a further level of detail and understanding. The interviews are semi-structured with the four BOS-perspectives plus the context as a guideline for enquiry.

Two system-models are created for the business system. A structural model, showing the organisation and timing of a typical project in the targeted business system. A project is defined as the sequence of steps (e.g. Consult, Plan, Build, Operate, Service) involved in the creation of the final technical system (plant, building, ...) in which the innovation will be incorporated. This is at least "one level up" from the innovation i.e. the containing system. The structural model also incorporates all the roles (e.g. Consultant, Owner, Finance, Planner, Manufacturers of components, &c.) involved in creating this final technical system, how they work together, when they enter and leave the project, their scope and responsibilities, and their decision criteria (when is an innovation a 'good' innovation). The MACTOR method (Godet 2006:245-279) is used for creating the detailed actor model.

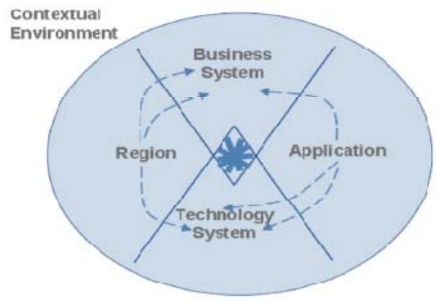

Figure 3. Sketch of the four perspectives of BOS. Source: Author

The conclusions from the MACTOR analysis allow valuable insights into the structure of the business system, which routes are feasible for entering the business, which actors are in favour or opposed of the innovation, what the prerequisites for diffusion of the innovation are, &c. Technology is viewed as a system subject to combinatorial evolution and structural deepening. (Arthur 2009) Relevance trees (The Futures Group 2003) structure the study of the technology system. The potential innovations are most likely embedded in further “onion skins of technology” with their corresponding compatibility requirements. Therefore, new as well as the currently available technologies are considered in depth. This often includes a detailed analysis of patent activities and research.

The technology analysis considers also (functional) substitutes from technological super systems or sub-systems. The maturity, feasibility and potential acceptance across the business system is assessed for every relevant technology.

The final step of analysis is the creation of scenarios from the knowledge acquired on the technological and business system perspectives. The time-horizon takes into account the relevant technical substitutions, length of technology life-cycles (up to 60 years in the corporate context of KSB), ongoing or expected changes in the business system, and the time required for the creation of an innovation by the firm itself.

The findings of diffusion research (Rogers 2003) provide a bridge between the insight gathered and the design of an innovation. Rogers (2003:15-16) gives a list of attributes of an innovation that allow to check ideas for business opportunities against the preferences and objectives of the relevant roles in the business system. This allows for a multidimensional and multi-actor analysis of success potentials and acceptance criteria within the business system for each possible innovation.

An iterative learning loop (Fig. 4) was chosen as the integration model for the innovation-design part, to facilitate the design of innovations that fit with the business system, anticipated technological developments and the enterprise. This learning loop, together with the richness of social analysis preceding it, enables to reconcile “people, profit, and planet”-the three pillars of sustainability in a unique way by designing suitable and acceptable innovations. The “one idea -one project -one product” paradigm at the basis of the process models for product development discussed above is abandoned in favour of learning and creativity. This creates a new paradigm for innovation processes; not “drowning the puppy” when an idea turns out inferior but first trying to elicit the full potential from it. Therefore, over the process of BOS, a business opportunity is changing and changed as further knowledge is acquired and more criteria for success become uncovered. It matures from idea to concept; gets merged with or spawns other ideas.

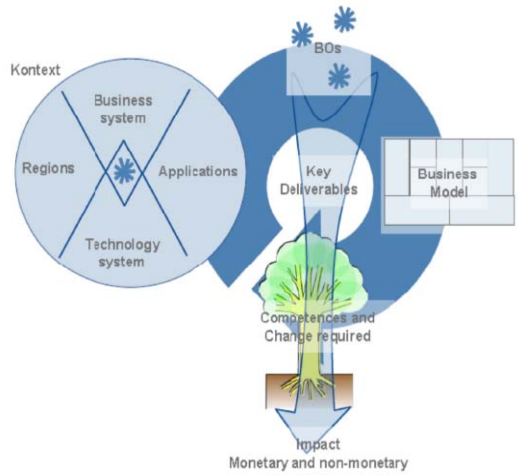

Figure 4. Interaction of analysis and design in the BOS framework. Source: Author.

The link between the company and the business system is the business model (See Osterwalder & Pigneur 2010; Osterwalder 2004 and Stähler 2002 for an extensive discussion of this concept). It describes how the company participates actively in its business system. At this point, the perspective of the study changes from passive (scientifically informed) gathering of knowledge about the business system to designing an active role for the company. The business model therefore is an object of design also. It is expected to answer the question: How do we establish our company's contribution in the business system, where (in which role), and how is the company able to economically sustain the new business?

The competence tree (Godet, 2006:118-120) is used as a compact map of the current competencies, capabilities, and value propositions of the company. It allows determining the degree of change required by each of the business opportunities under consideration. The design process iterates, over the potential business opportunities recognised studying the four perspectives, especially the business system, and tries which business models are possible for the enterprise, given the current competence tree and the enterprise's potentials for developing its competencies and capabilities. A first estimate of the economic potential is performed also.

The flow of evaluation considers the business opportunity, competencies and impacts (monetary and non-monetary) on the enterprise. Typical questions are: Can the enterprise make a sustained profit out of the business opportunity? How much does this profit require the company to change? Is the change required justified by the potentials for learning and earning? Does the business opportunity fit with the anticipated changes in technology, business, and contextual environment?

The most relevant outcome of a BOS is the key-deliverables for the innovation project to follow. These key-deliverables typically fall into three groups: Technical key-deliverables (the technical part of the innovation -the 'product'); company-internal key deliverables (e.g. modifications to business processes or the ERP-system); and diffusion relevant non-technical key deliverables.

In one project, a key-deliverable of the latter category was to give a blueprint for a system using a new component away for free to help the system integrators adopt the new technology. Another project instituted a project-council with relevant stakeholders identified in the MACTOR analysis as a sounding board to help continuously checking the progress in the innovation project against the relevant expectations of these groups.

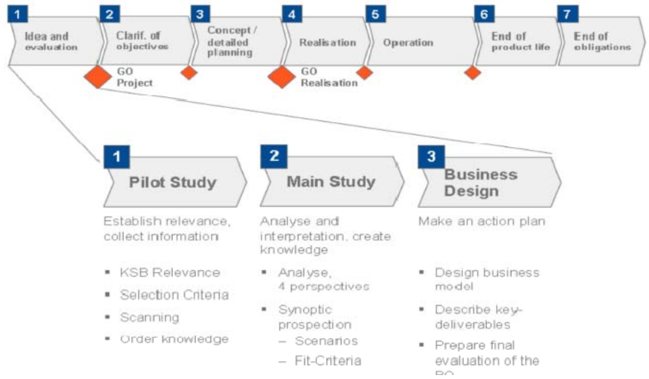

Figure 5. Integration of the BOS-Framework with the Product Lifecycle Process. Source: Author.

(Figure 5 -shows, the process reduced to a linear progression, confirming with management expectations and to enable the integration into the corporate product lifecycle process.)

8. Case study

For confidentiality reasons, the case study has to be restricted to a single instance of an innovation that is currently undergoing the field tests. The River-Turbine (KSB 2010) represents a new category of hydropower installations without transverse structures blocking the migration paths of aquatic species. A further positive side effect is that the flow velocities of straightened rivers are reduced. Figure 6 shows one prototype while being installed.

It is the only kind of hydroelectric power station that improves the environment and fulfils the requirements by the European Water Framework Directive. The prototypes were installed near the town of St. Goar on the river Rhine in the UNESCO world heritage of the middle Rhine valley; a region that also has the highest possible protection for a nature reserve as a Habitat Protection Area where any other hydropower plant is virtually unthinkable. The River-Turbine coexists with other uses of the river, namely as a waterway and is hardly visible from above the waterline. It emerges from the core-competencies of the company, especially hydraulic design and structural mechanics but, on the other hand, requires a deliberate creation of a new business model in a not yet established business system.

Figure 6. The River-Turbine prototype during installation. Source: KSB 2010. © KSB Aktiengesellschaft (2010)

Further, according to KSB (2010) there is a market for ‘small hydropower’ internationally, for example in China, India or Russia, where the problem of supplying rural areas with electricity calls for creative solutions.

9. Conclusion

This paper demonstrates that corporations do not have to wait for sustainable innovations to happen (and sort out all other possible innovations in a funnelled process). The basic idea behind the framework outlined is, that in order to do so, the process as to consider "one level up" from designing an innovative product i.e. designing an innovation according to a wider set of criteria than the techno-economic ones used predominantly today.

The case study shows an instance of a sustainable innovation achieved with this novel Framework for the front-end of innovation that allows reconciling the different notions of sustainability by designing an innovation. This framework currently exists in a small pocket within a global organization of 14,500 employees that targets the creation of highly innovative and future oriented projects.

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