MASTER'S THESIS

Creative Methods for Sustainability Driven Innovation

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“ Homo sum: humani nihil a me alienum puto”

-Publius Terentius Afer, Heaton Timorumenos, 165 B.C

“*I am a man; and I consider nothing that concerns mankind a matter of indifference to me”*

“Sono un uomo: niente di ciò che è umano considero estraneo a me”

Preface

I have the strong belief that every student should ask himself at least once in his period of studies, which is the area that he most like and that he wants to develop for giving a contribution and to 'create' his future well-being. I tried often to ask myself this during my years of study, I even found interesting topics, but none of them was really fulfilling my real interests (innovation, environment, economical and social development, policy, history, group and single psychology).

I had always the impression to be a 'strange engineer' compared to my colleagues, and I was really concerning about what I would have done in my future. Thanks to this Master Thesis, all of my previous questions have an answer now: this is called Sustainability Driven Design.

I want to be thankful to my Thesis's supervisor, professor Peter Törlind, first to give me the opportunity to develop this thesis, then because he let me develop all my ideas without killing them when they born, and only successively guiding my work with useful comments and suggestions.

I want also to thank my supervisor from University of Padova, professor Giovanni Lucchetta, to follow my work of Thesis during my experience abroad, helping with precious comments and providing interesting references.

I would like to express my appreciation to the division of Functional Product Development at Luleå University of Technology (LTU), for supported and encouraged me during my work of thesis, for participate at all my tests and to give me all the feedbacks that I needed for the results of my methods and tools.

I am very grateful for all the nice time that I had with you at the division. I really felt part of the group.

Finally, thanks to my family and friends for all your love and support during my period of studies, the Erasmus experience and this work.

Abstract

Sustainability is a complex but extremely important issue. To achieve a new industrial revolution that focuses on sustainability, we need innovation. Just improving our technologies and our habits will not save our planet from its current gradual degradation.

In recent decades many Eco-tools have been developed; this thesis evaluates the most important and used today, how they help to consider sustainability in the product development process and identify important and missing characteristics, arguing that many eco-tools were experienced by the companies as too complex and time-consuming and often not aiding the innovation process.

These characteristics guided the development of a new framework for sustainability innovation (Sustainability Innovation Workshop- SIW) based on a multidisciplinary workshop approach. It focuses on analyzing customers from a sustainable viewpoint, understanding their real needs, using ideation tools to generate ideas in areas not usually considered in current eco-tools, e.g. changing customer behavior or the business model.

The method was developed, tested and evaluated in an iterative approach over a six-month period. A final assessment of the method shows that the SIW presents all the characteristics founded out after the literature study. Although the initial tests presents promising results, further work is necessary before drawn any general conclusion. Future work will include tests in different kind of organizations.

Keywords: Sustainability, Product Development, Radical Innovation

Summary

1 Introduction

Sustainability, Ecodesign, Design for Environment, Sustainable Product Development are terms we frequently have heard in the last years. Often we have a vague idea what they refer to, but we do not know their exactly meaning. Know the definitions are the first step to understand the challenge we have to overcome.

The human race have in the latest century made unprecedented changes in the ecosystem to meet their needs, such as food, energy etcetera. The quality of life of many certainly grew to levels never reached in the past, although gradually weakening the Earth's resource capacity. The concept of sustainability has been introduced to combine concern for the well-being of the planet with continued growth and human development. There are many definitions of sustainability, in which the basic concept is almost the same, a good definition is offered by the World Commission on Environment and Development also known as the Brundtland report 'Our common future':

"Meeting the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland 1987 [1])

This can be interpreted as a definition of both sustainability and sustainable development. In its original context, this definition was stated solely from the human point of view. In order to embrace the idea of a global ecology with intrinsic value, the meaning must be expanded to allow all parts of nature to meet their own needs now and in the future.

Though principally correct, the definition is too general to be useful for strategic planning of actions toward sustainability in business and society.

Ecodesign is a common term used to denote the work of developing environmentally adapted products. The overall meaning is:

"minimizing a product's environmental impact throughout its life-cycle by taking preventive measures during product development." (Johansson 2001 [2])

Another definition is:

"design with addresses all environmental impacts of a product throughout the complete life-cycle without unduly compromising other criteria like function, quality, cost and appearance." (Poyner and Simon 1995 [3]**)**

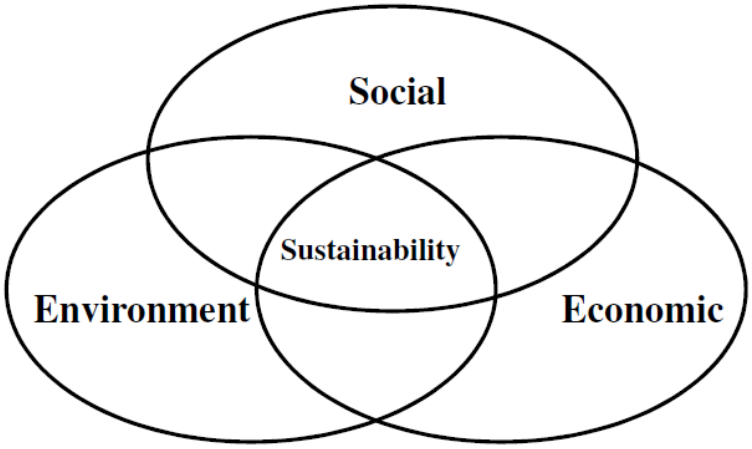
Design for Environment is a synonym and is defined as:

"systematic consideration, during new product and processes development, of design issues associated with environmental and human health and safety over the full product life-cycle." (Fiksel 1993 [4])

Applying Sustainability requires the reconciliation of environmental, social and economic demand (the "three pillars" of sustainability). This view has been expressed as an illustration using

three overlapping ellipses indicating that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing. (Figure 1) [5]

Figure 1. Definition of sustainability, often refer to the "three pillars" of social, environmental and economic sustainability [5]



The work described in this thesis in based on previous work on methods for creative multi-disciplinary workshops done at Luleå University of technology (an overview will be provided in paragraphs 3.1 and 3.2).

1.1 Aim of the thesis

The aim of this thesis is to create an easy to use method for sustainability driven innovation.

The method wants to help multidisciplinary teams in the very early stages of the product development process to create innovative solutions driven by sustainability concerns, finding new ideas and achieving advantages.

1.2 Guiding questions

Already from the beginning, some guiding questions have driven the Thesis's work:

- **GQ 1:** why is important to have a method for sustainability?
- **GQ 2:** why sustainability is still difficult to achieve in the society?
- **GQ2:** which characteristic a method for sustainability should have to help the companies to do something in reality?
- **GQ3:** what are the limitations of the current method for sustainability?

1.3 Delimitations

The research is focused on product development in industry; there are other important actors such as municipalities, governments, non-governmental and no-profit organization (the reasons will be further described in chapter 4).

1.4 Reader's guide

Chapter 2 presents why it is important to reduce the environmental impact of our products, that innovation is the only way to achieve a sustainable society, and where this process can be done. *Chapter 3* contains the literature analysis with a review of current Eco-tools, finding drawbacks and delimitations of existing methods. Before building the overall structure of the method and the specific tools it is necessary to identify the characteristics for a method for sustainability, the actors involved in the process and analyze delimitations in current Eco design tools. This analysis which leads to the characteristics of the proposed method and the evaluation of the Eco-tools is presented in *chapter 4*.

From the characteristics a method was developed, based on the previous work at the division of Functional Product Development, the method was developed in an iterative way where tools and exercises have been continuously designed, tested, evaluated and improved. *Chapter 5* is dedicated to explain the proposed SIW framework, purpose and the individual tools. *Chapter 6* describes the evaluation of the SIW framework and in *chapter 7* a discussion is made in order to find out weak spots and further improvements.

Appendix A contains the ranking of countries by Ecological Footprint (as a reference of chapter 2)

Appendix B contains all the tools of the Sustainability Innovation Workshop.

The work in this thesis is also submitted to the ICED conference (International Conference of Engineering Design).

2 The challenge of sustainability

This chapter explores more in detail the concept of sustainability. It explains what is the Environmental Impact through the use of the Ecological Footprints, and it gives the reasons why this thesis is focused on the industry and in particular in the product development process.

2.1 What is the Environmental impact?

In the introduction we have found the term 'environmental impact'. Is a word very commonly used today, we have read it in the newspapers and we have heard it by the politicians and by scientists. But what does it mean? And how we can estimate the total environmental impact that our products and services burden on the planet Earth? And who is asking to reduce it?

2.1.1 Ecological Footprint

In order to explain the real meaning of Environmental Impact, the concept of 'Ecological Footprint', introduced for first by Wackernagel M. & Rees W. in their book 'Our Ecological Footprint' [6], become very useful. Ecological Footprint analysis is a procedure that permits to compare the resource consumption and waste assimilation of a determined region or country in terms of land area.

In their work, Wackernagel and Rees argued that today there are only 1.5 hectares of such land for each person. Instead, the land 'consumed' by great part of the countries (especially the richest) is higher, with a double or triple factor. As an example the Ecological Footprint of a typical North American (4-5 ha) is three times higher that the land 'appropriable' to live sustainable.

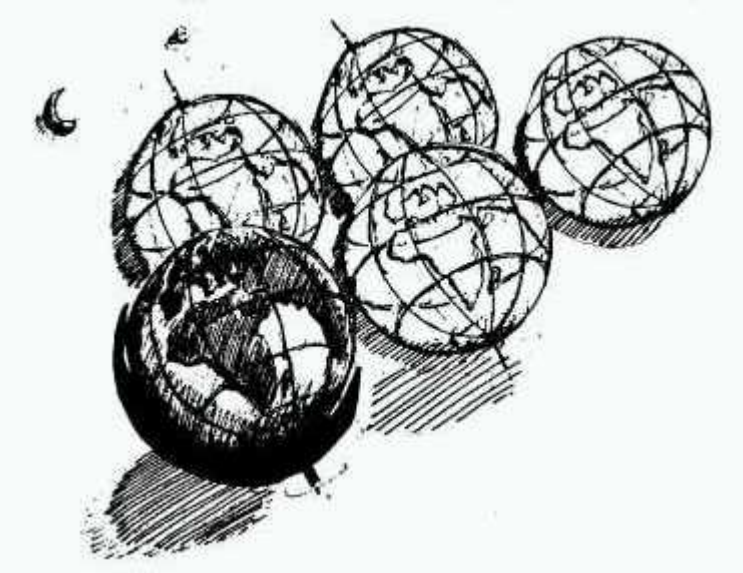
These conclusions were drawn in 1996 so not a good point of view of the current situation. More recent analysis (Global footprint network [7]) shows that the world-average ecological footprint in 2006 was 2.6 global hectares per person (17.1 billion in total). With a world-average biocapacity of 1.8 global hectares per person (11.9 billion in total), this leads to an ecological deficit of 0.8 global hectares per person (1.44 billion in total). If a country does not have enough ecological resources within its own territory, then there is a local ecological deficit and it is called an ecological debtor country. Otherwise, it has an ecological remainder and it is called an ecological creditor country.

The incompatibility of the current situation is shown by the authors in a visual way in

Figure 2. In facts, if everyone in the Earth lived like the North-Americans, we would need at least other four planets to sustain such society.

Appendix A shows the values of ecological footprint, ecological gap and ecological remainder (expressed in gha/per) for several developed, newly industrialized, developing and least developing countries, as defined by the United Nations. This table is based on 2006 data from the Global Footprint Network published in 2009. [7]

Figure 2. Wanted: Four (Phantom) Planets. If everybody lived like today's North Americans, it would take at least four additional planet Earths to produce the resources, absorb the wastes, and otherwise maintain life support. Unfortunately, good planets are hard to find… (Rees W. [8])



So it appears clear that the conventional approach to human development is unacceptable, especially in the so-called developed countries, which are responsible of the biggest ecological footprints. Although under some simplifications, Ecological Footprint is a valid instrument that can help to assess the Environmental Impact that our society burden on Earth. Moreover, its graphic clarity permits to understand immediately how large is the gap that we have to reduce and if with our methods, strategies and policies we are in the right way to overtake this difficult but extremely important challenge.

Although very visual and very useful from a cultural point of view, the method is considered too complex by the industries and its use is limited in practice to great surveys and is not used in the daily product development process.

2.2 And what about the social impact?

People often refers to sustainability as reducing the environmental impact on the Earth, forgetting sometimes how the resource consumption by the human population profoundly impacted on the human society itself. Many authors (for instance, the already cited Wackernagel and Rees [6]) or the United Nations conferences (the 'Earth Summit' organized in 1992 and 2002 [9]) highlighted the current great gap between nations, especially between the so-called 'northern world' and 'southern world' countries. This gap led to intense social problems such as great migratory flows and wars for the control of the natural resources. Unmistakably, as we well know reading the newspapers or the web, such problems are yet pervading our current society.

By these reflections, it appears clear that the concept of 'sustainability impact' is wider than the concept of 'environmental impact'. In an open talk in the division of Functional Product Development, Professor Amaresh Chakrabarti from Indian Institute of Science in Bangalore gave an interesting reflection about sustainability:

"*Sustainability is not just reducing environmental impact, but as well to provide well-being to everybody."*

'Hippo Water Roller' is only an example of innovation 'social oriented'. Hippo is a tool designed to help women and children to transport more water more easily than traditional methods. [10] The Hippo, with its large drum capacity of 90 litres / 24 gallons, frees women and children from having to spend a large portion of every day dedicated to collecting water for their households. Far less effort is required to roll the heavy weight of water (90kg / 200lbs) along the ground as opposed to carrying only one bucket (20kg / 45 lbs) on the head.

Figure 3. Hippo Water Roller [10]

By this example, two interesting reflections can be drawn. The main goal of this innovation is not to reduce the environmental impact (although the solution is harmless for the Planet), but to provide benefits. In addition, it gives an important remark on the innovation concept. Sometimes, the 'western' concept of innovation is associated to highly technological and very complex solutions. In actuality, this example shows that this is not true: this is an innovation, that can provide benefits to these populations with a very easy to implement solution.

2.3 How can we contribute towards a Sustainable society?

In their 'master equation' Graedel and Allenby [11] argue that three agents cause the total environmental impact of the humankind:

1. The population of the earth
2. The material standard of living (expressed as GDP per capita)
3. The environmental efficiency of our culture (expressed as the environmental impact per material standard of living)

$$\text{Environmental impact} = \text{Population} \times \text{GDP per capita} \times \frac{\text{Environmetal impact}}{\text{GDP}}$$

The first two agents are governed by socio-economic factors, instead the efficiency is highly influenced by the industry.

According to Lutz and Samir [12] the total size of the world population will increase from its current 7 billion to 8-10 billion by the 2050. The uncertainty of the foresight is due to unknown fertility and mortality trends in different part of the world.

By the paragraph 2.2 is evident the unacceptability of the current worldwide social situation, where the standard of living in the third world countries is far below the global average. Therefore, an increase in the standard of living must be reached to break down the current regional differences and create acceptable conditions everywhere. For these reasons, a double increasing in the current average material standard of living can be foreseen towards the middle of the 21st century.

Is thus foreseen that the environmental efficiency of our culture must be increased at least four times to both fulfill these needs and to maintain the current environmental impact on the Earth. This requirement has been addressed as the 'factor four' or 'factor ten' challenge (e.g [13], [14]).

In this thesis the author wants however highlighting the apparently thin difference between 'efficiency of our culture' and 'efficiency of our technology', because this is often matter of misunderstandings. Conventional analysis and policies by several European and American countries argue that the must for our society is to increase the efficiency of our technology. Taking again what claimed by Wackernagel and Rees [6], this is a partial misconception. Even in the best case, merely increasing the technology efficiency does not decrease the environmental impact, but only the efficiency of the resource use. As an example, the improving of the technology in agriculture, forestry and mining did not reduce the total consumption of the Earth's resources. In other words, only with technology innovation, we will consume more resources, with a more efficient technology.

Of course, technology can play a great role to reach a sustainable society. However, the increasing of the resource efficiency itself will not decrease our environmental impact. Here gets in the concept of 'efficiency of our culture' increase: the change in our society must be in a more extensive sense, in which the thoughts about the consumption of resources by the consumers, companies and governments (which with their choices in matter of incentives they contribute to shifting from one solution to another) have to switch over to reach more sustainable levels.

2.4 Need of a new Industrial Revolution

By what presented before, it should be apparent that the current practices by the human race in matter of consumption of environmental resources are unsustainable. Furthermore, the welfare of every human being is desirable to reach a more equal and just society. The challenges for this and the further generations are exciting: how can the humankind reduce its Ecological impact? How can it create acceptable conditions everywhere to level out the existing regional differences? What kind of future do we want to give to our children and grandchildren?

The history give us the answer: the first Industrial Revolution in the 19th century changed all the knowledge about agriculture, manufacturing, mining, transport and technology and had a profound effect on the socioeconomic and cultural conditions starting in the United Kingdom, then subsequently spreading throughout Europe, North America and successively the world. The Industrial Revolution marks a major point in human history; almost every aspect of daily life was influenced in some way [15].

In these decades we have to deal with an unprecedented challenge: a *new* Industrial Revolution, in which more aware use of resources and a more consciousness that we are part of the environment, must occur. The question is, of course: "have the humankind the ability to achieve this all-important goal?

Our greatest resource is the human mind, and the potential for innovation is unlimited. First, we have to analyze our mistakes is the past, be aware of them, and then be optimist that everything is possible. Nevertheless, optimism per se is not enough. We should use a special way of optimism: the strong belief in the return of our investments. If we spend our 'capitals' (not only economics, but in trust and enthusiasm as well) in the correct resources, the return of the investments will be assured.

2.4.1 New challenges for the designers

Pointedly, innovation is the only way to build this new Industrial Revolution. Simply improving our technologies and our habits will not permit us to attain a sustainable society.

To transform today's design artifacts into a more sustainable way of living, we as designers need to rethink the way we design. Bruce Mau once described the need for innovation regarding sustainable design [16]:

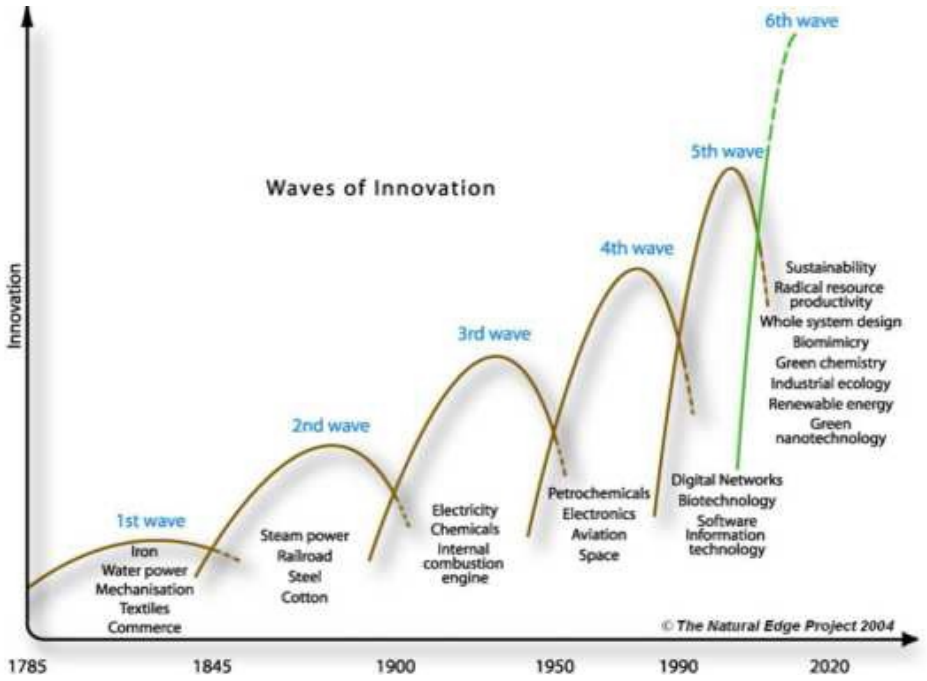
"If we do things that are damaging the environment, it's because they are stupidly designed, we do not need to do that".

Joseph Schumpeter, an Austrian-born economist, first noted the rise and flow of economies with respect to technology. Many economists claim that from the first Industrial Revolution we had got five "waves of innovation", in which an era based on semiconductors, fibre optics, networks and software has been the last wave of industrial activity (Figure 4).

According to Hargroves and Smith [17] this wave of innovation have reached its maturity, although of course the application possibilities of these technologies are yet infinite. In this decade a new wave of innovation is rising up: it is based on sustainability, whole system redesign, renewable energy, green nanotechnology.

However, there is a main difference between this new wave and the last ones, which renders it a very attractive challenge for the current designers. Indeed, all the other waves of innovation were based on an economic model that several current economists used to name 'Old Growth Model'. One of the chief architects of the 'New Growth Theory', Stanford economics Professor Paul Romer, shows that economic growth does not arise from just accumulating more capital. His work shows that is also arises from new and better ideas expressed as technological progress. [18]

***Figure 4. Waves of innovation** [17]*



All of this means that for the designers considering sustainability concerns in our current innovation processes will be more complex than ever, because we will have even to deal with often unconscious mindsets based on socio-economic models that are during since a hundred and more years. In this sense, the 'out-of-the-box" thinking will have to be higher than ever.

2.4.2 Product Innovation and Product Development

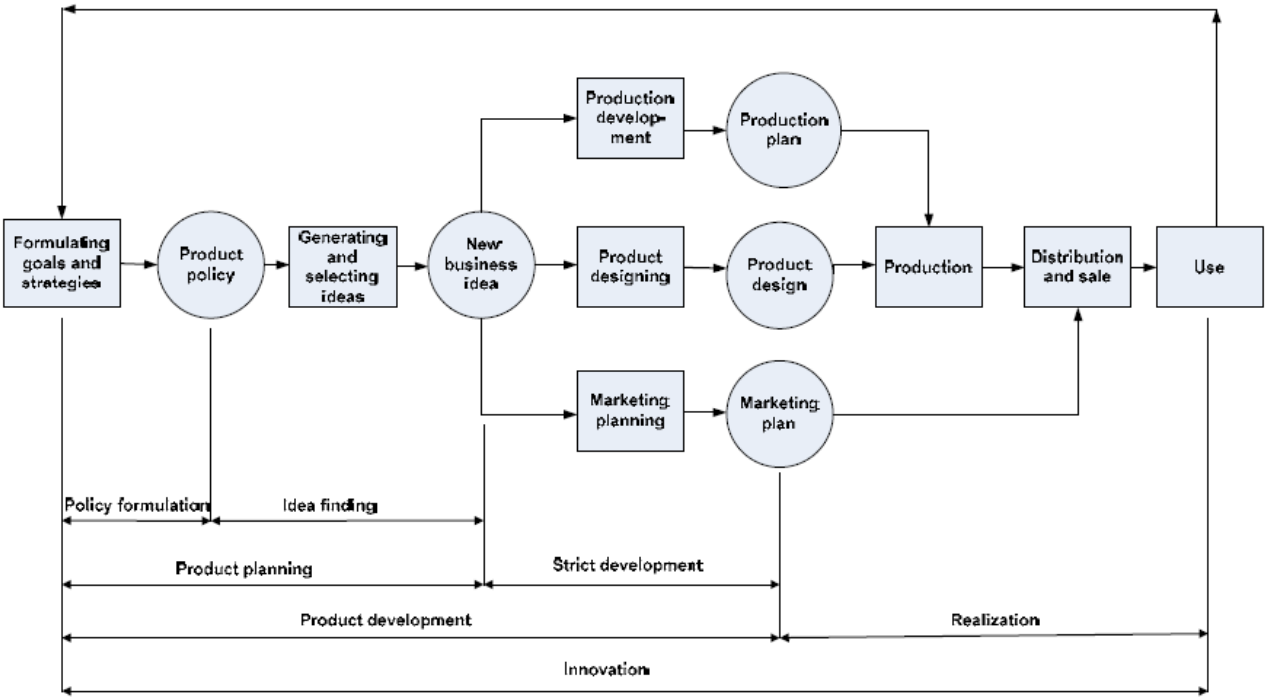
In order to understand what is argued in the next chapters, is fundamental to have in mind a basic definition of what is considered Product Development and Product Innovation.

According to Roozemburg and Eekels [19], the product development process is the early part of an industrial *innovation process* that comprise:

"All activities that precede the adoption of a new product in a market (or the implementation of a new production process), such as basic and applied research, design and development, market research, marketing planning, production, distribution, sales and after sales service".

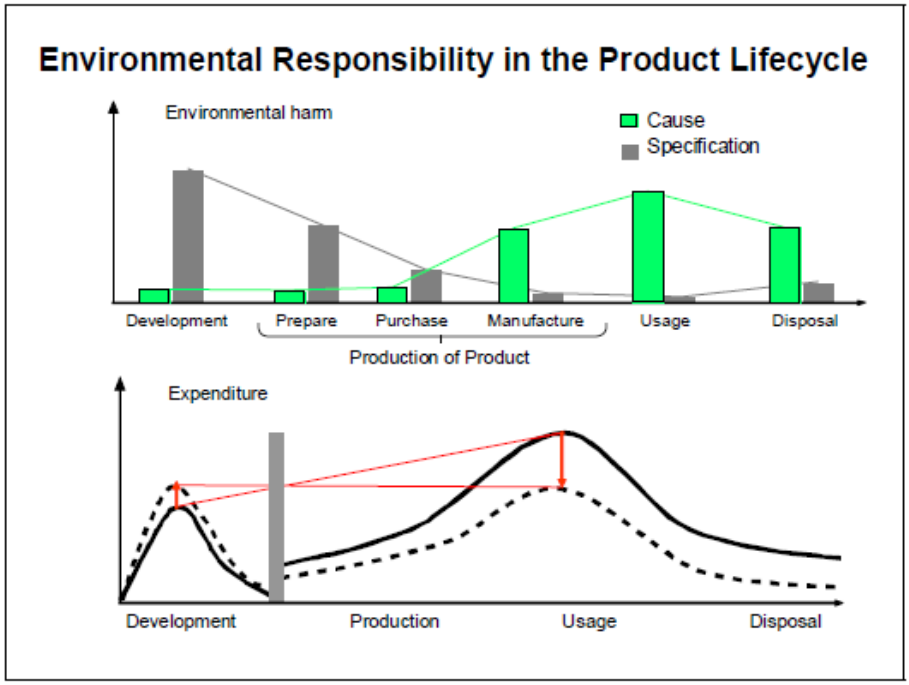
This definition is illustrated in Figure 5, and will be adopted in the next chapter, to evaluate when the existing methods for sustainability are used and their characteristics.

Figure 5. Product Innovation Process



According to Jantschgi and Mann [20] the biggest leverage of the environmental responsibility of a product lie in the development phase. Even a small amount of time more expended in this stage can assure a huge decreasing of the total life cycle's environmental impact (Figure 6). Drawn by these conclusions, our research focuses in the product development process.

Figure 6. Environmental responsibility in the product life cycle. (Jantschgi and Mann [20])



In the last decade many tools have been developed in order to consider sustainability in the product and service development process. According to Bygget and Hochschorner [21], Knight et al. [22] and Thompson [23] the existing methods currently present some weak areas that limit their

effective use in industry. Lagerstedt [24] writes:

"The most important thing for the environment is not the results of these methods, but actually doing something in reality".

She also argues that there is a need of a method that guides the user to represent the functional and environmental characteristics in the very early stages of the product development process.

2.5 Summary of the findings

As the Ecological Footprints show, the current practice by the humankind in terms of consumption of resources is unsustainable. In a few words, we are currently consuming more that the Planet Earth can offer us.

The total Environmental impact of our society on the Earth can be expressed as the product of three factors: population, standard of living and the efficiency of our culture. While the first two factors are correlated to socio-economic issues, the third factor is mostly influenced by the industries. We need to build a new industrial revolution, similar to the one in the 19th century, with a radical change of how we use resources, design and use new products, the notion of social well-being and economic growth.

To create this new industrial revolution, we need radical innovation. Merely improving our technologies and habits will not save our planet from its current gradual degradation. Although considered a very important issue by governments, mass media and population, effective sustainability implementation in society is still difficult to achieve, from both a technical and behavioral standpoint. People often confuse the quality of life ('more is better' concept [6]), misunderstanding between economic growth and consumption (the 'old growth theory' as claimed by Romer [18]), and an unconscious mindset that there is no possibility to reduce resource consumption and improve the quality of life for everyone.

The challenge for the current designer is unprecedented: he has to be conscious that with his decisions he is deciding almost all the future environmental impact of the product, especially with the earliest decisions that he make when designing the new product. That being so that appear fundamental to provide methods and tools for the designer to be used in the product development process, and particularly in the earliest phases. Many authors focused their research to provide method and tools, but for contextual factors such methods still presents some weak spots that are limiting their effective use in the industries.

3 Theoretical Framework

This section describes the theoretical framework for the research presented and consists of three important areas. The advantages and problems of multi disciplinary teams for innovation are put into context; methods for facilitating multi disciplinary teams will be focused upon; and existing methods for sustainable design and Eco design will be reviewed.

3.1 Multi disciplinary teams vs. traditional teams: advantages and problems

Introducing several disciplines into the development of products increases the probability for break through innovation [25], though the heterogeneity in the team can increase the collaboration burden; it is far more troublesome to communicate and get a common understanding in a heterogeneous team than a homogenous team [25, 26]. A homogenous team is also more prone to groupthink [27]. Team members come from different disciplines with different 'thought worlds' [28] and bring in their expertise to the team, but at the same time their 'thought worlds' complicates communication. Also the grounding - the process of reaching a common understanding to the problem takes more time in diverse teams due to the contrasted understanding of problems, ideas and solutions:

"*The contrasted understanding may be seen as a waypoint or perhaps a crossroad, where the path can lead towards creating a shared understanding or towards even more divergent conflicting understanding, i.e. the team may either have consensus or conflict. In a sense, the contrasted understanding is where you step out of the comfort zone".* [29, pp. 60-61].

This contrasted understanding is essential to the creative flow [28] and acts as an inspiration where innovations may occur. It is important to be aware of the problems above; management and facilitation of the team process are important, otherwise these diverse teams may perform worse than a homogenous team [30].

3.2 Facilitating multi disciplinary innovation workshops

At Luleå University of Technology, a method for collaboration in multi-disciplinary team innovation has been developed . The method tries to solve some of the problems mentioned above and is based on an interactive and highly collaborative workshop aided by a facilitator.

The role of the facilitator is to be an expert of the process and the method used in the process, not an expert of the particular workshop topic. The facilitator is also responsible for the design of the workshop processes (what happens before, during and after the event). An important characteristic of the facilitator is the ability to create involvement, engagement and commitment [31]. The facilitator also guides the team in the most promising direction and explains and enforces the 'rules of the game'. Other important characteristics include the ability to encourage people to step outside of their comfort zone, and to encourage personal reflection.

The method is based on a three-step process, first highlighting the current situation – *Now*; the preferred situation - *Wow!*; and finally how this can be solved - *How?* These methods are iterated from different levels of complexity, different focuses and different points of view. For each iteration, an increased knowledge about the problem and the product is gained.

The workshop is designed to be interactive and involve all participants, and it is important to encourage different views. Throughout the workshop the results from each step are visualized on large facilitation posters, enabling an overview and easy access to all the previous results of the workshop. The workshop method has been continuously tested and evaluated in industry over the last four years, with very good feedback from industry participants [26] .

3.3 Existing methods for sustainability

In order to find out the characteristics that a method for sustainability should comprehend, the research focused to analyze existing methods and tools used in the companies.

3.3.1 Eco-design tools

Bygget and Hochschorner [21] analyzed 15 different Ecodesign tools currently used in companies to prescribe design alternatives, assess environmental impacts or to compare environmental improvement alternatives. The authors focused their work in order to figure out how these tools can give a valid support in context of trade-off situations. Nine of the 15 tools analyzed included an assessment. The survey concludes proponing that for developing sustainability issues in the current product development processes, there is a need to implement a framework where goals and objectives for the product are described in the context of the sustainable society. Then the Ecodesign tools will become useful to support the daily product development practice. However, according to the authors, to be a rational tool for support trade-off situations, it should also include an assessment and have a life cycle perspective.

Lagerstedt [24] evaluated 9 Eco-tools analyzing focus, purpose, if the final result is qualitative or quantitative and in particular if the tool can be used in the early or late stages of the product development process.

The survey concludes claiming that there is a lack of methods for representing and balancing product functionality and environmental aspects in the very early phases of the product development process. In other words, there is a need for tools and methods that can aid to indentify and describe basic environmental and functional characteristics of different product concepts.

In one of the most important work in this field, Tischner at al. [32] analyzed several software Eco-tools for highlighting environmental problems, come up with ideas, assess final solutions and consider product and market aspects from a sustainable perspective. The conclusions of these descriptions are confirmed even by Knight et al. [22] in a survey among several companies ranking the use in reality of the Eco-tools.

Another trend identified, where that sustainability tools are now even integrated into commercial CAD systems such as *SolidWorks Sustainability* module [33]. These tools provide an easy access to LCA analysis and the Environmental Impact of parts and assemblies.

Another important issue was to identify how these surveys explore all the kind of companies (large, medium and small) and all the kind of actors involved in the sustainability world (as governments, municipalities, NGO and NPO). As claimed by Hallstedt [34], in a survey among Swedish small and medium sized Enterprises (SMEs) revealed difficult for them to implement Eco-tools in the product development process. The main result was that they considered the Eco-tools too complicated and time consuming, perhaps for the reason that these tools were first created and developed in large companies. The survey demonstrates a good awareness by the SMEs to increase the environmental efficiency of their products and services, but at the same time a lack of easy to use tools in order to aid the process.

3.3.2 Framework for Sustainability: The Natural Step Case

By the discussion in the paragraph above emerges the necessity to have a framework for implementing Sustainability. As claimed by Broman at al. [35]:

"A parallel can be also drawn to commonly played games. In a game like football or chess, the first order principles are the rules of the game. Once people understand these, they can interpret details, understand strategies, and anticipate changes".

The Natural Step (TNS) is a no-profit organization founded in 1989 in Sweden by Karl-Henrik Robèrt, a medical doctor who wanted to comprehend how our own Planet was gradually degrading and how was possible to do something in reality to solve the problem. TNS foundation's main objective is to describe and communicate to managers in companies and municipalities how to create strategies towards a sustainable development (TNS framework).

TNS framework is based on a four steps backcasting procedure (called A-B-C-D procedure) in which the starting point (A step) is to understand and discuss the four sustainability principles (SPs). These were obtained with a continuous dialogue with scientist, and they are based on the considerations that the ecosphere can degrade through three mechanisms: increasing the concentration from the Earth's crust, increasing concentrations of substances produced by society, and impoverishing physical manipulation or overharvesting. These led to the first three SP phrasing (for references, see Hallstedt [34] for example):

In the sustainable society, nature is not subject to systematically increasing…

- …concentrations of substances extracted from the Earth's crust (e.g. fossil carbon or metals),
- …concentrations of substances produced by society (e.g. nitrogen compounds, CFC's, and endocrine disrupters),
- …degradation by physical means (e.g. large-scale clear-cutting of forests and over-fishing),

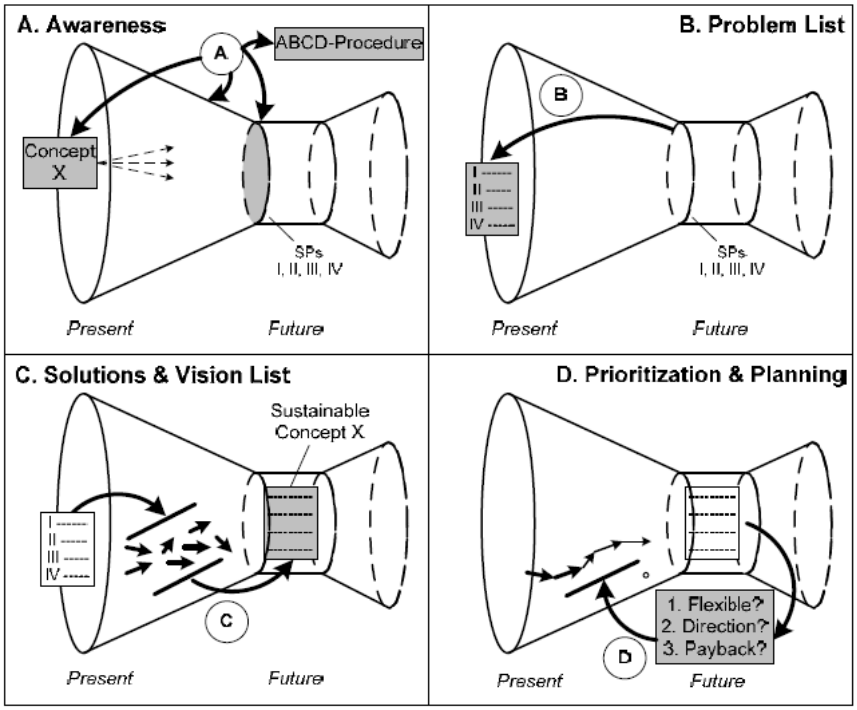
The fourth principle was drawn by the conclusion that the societal use of resources must be efficient and fair enough to meet basic human needs worldwide. This is as important as the other three principles for a society to be sustainable. Its formulation is:

In the sustainable society…

- …people are not subjected to conditions that systematically undermine their capacity to meet their needs (e.g. from the abuse of political and economic power).

Once concluded the A step, the following phase (B) is to identify present activities that are problematic to the respect of the SPs, and therefore continue with a brainstorming of possible solutions to the problems (step C). The last stage is creating a strategic plan of actions based on the B- and C- list. A schematic representation of the TNS framework is given in Figure 7.

Figure 7. The A-B-C-D procedure [34]



Based on this general structure Bygget, Broman and Robèrt [36] developed a method for sustainable product development (MSPD) based on a modular-guiding question system. The purpose of the method is to create a shared understanding of the sustainability principles (done by a introduction manual), to stimulate brainstorming in the B and C phases throughout the use of a modular system of questions and with a prioritization matrix for defining strategies and opportunities (D step). The method had been implemented in two Swedish companies, different for type and business.

Afterwards, the necessity of tools that permit a first and quick overview of current and future products from a sustainable point of view emerged by the evaluation of the MSPD. This led to the development of a new set of tools called templates for sustainable product development (TSPD, for references see Ny, Hallstedt, Robèrt and Broman [37]). This method is not a substitution of the previous, but is an improvement to get possibility for the client (in this case, top management or product development team) to understand and analyze in the earliest stages of the product development process which are the current sustainability problems to face with and, equally important, which are the sustainability result to obtain and new market opportunities. Both the systems have been implemented in the Matsushita Electric Group, and evaluated with good results.

3.3.3 Frameworks for Sustainability in India: Gandhian innovations

Prahalad and Mashelkar [38] suggest that a new way of making new products and services is currently verifying in India. They refer to these kinds of innovations as "Gandhian innovations". The overall concept behind the idea is expressed by the slogan: *"getting more from less for more people"*. In other words, each innovation should be at the benefit of everyone, and not only for people that can allow them at high prices.

Contextual factors such as political aspects, the relatively small-budgeted average Indian company (compared to the European and U.S giants), has facilitated the growth of the Gandhian Innovations. The challenge that the Indian companies are trying to overcome is very interesting: erasing the usual western's concept of "low performance, low price", they achieve "high performance, low price". In the paper, many examples strengthened this thesis. Success cases as Tata Nano (the cheapest car in the World today, price little more than US $ 2,000 [39]) or the Jaipur foot (a high performance prosthetic leg at a cost approximately U.S. $30 [40]) demonstrate the validity of the Gandhian Innovation concept.

More in detail, Indian companies achieve these fascinating goals solving problems in some key ways: disrupting current business models, creating or sourcing new capabilities, acquiring technologies from the West or developing new technologies from scratch. The authors claimed that the Gandhian Innovation concept could be spread in all the World, even in the Western countries, if they will be able to disrupt they current business models, direct their efforts to focus on ideas that seem impossible to achieve and sharing their knowledge to solve them.

As written by Mashelkar [41]:

"We have to be willing to invest in research that is highly risky. When I was director of India's National Chemical Laboratory, I dedicated 1 percent of my budget to run a "crazy idea found"- a found to support ideas with a one in 1,000 chance of success. It was only 1 percent; otherwise I would have lost my job. But it made difference, because people started asking crazy questions, trying to find solutions in areas we would typically dare not visit."

3.3.4 Conclusion of the literature study

From literature analysis the methods for sustainability can be summarized in two different types: *eco-tools* and *frameworks for sustainability*. Eco-tools are the most well known, mostly they are software-based, and their general aims are to analyze environmental impacts, improving environmental solutions and to give support considering environmental aspects compared with other criteria. The frameworks for sustainability try to go forward, analyzing the current situation from a sustainable point of view and then implementing strategies to reach a sustainable level and create advantages for the company such as cost savings and new market opportunities.

From the literature analysis two interesting types of frameworks for sustainability emerged. The Natural Step (TNS) framework could give a valid support to reach a sustainable society, especially because is based on a backcasting procedure (evaluating the product from the sustainable society's

point of view the process of planning correct strategies results easier and more feasible compared to the normal forecasting procedure). Furthermore, the four principles for sustainability are very useful for a company, because they permit to have a definition of 'sustainable society' (in the personal opinion of this thesis's author, the best definition).

However, as already expressed by the authors, the framework presents some weak areas in giving visual and easy to use methods, examples and tools to help a company in understanding sustainability problems and finding innovative solutions to solve them (and to cover this gap the Templates for Sustainability-TFS were created). In order to reach our common desire (the sustainable society) the framework could be supported by the Sustainability Innovation Workshop developed at the Luleå University of Technology and presented in this thesis.

Another interesting framework found out by the literature study is the 'Gandhian Innovations' case: however from the literature is not very clear how this kind of framework are based on and how they are performed, some interesting reflections can be drawn.

For many contextual factors the Indian companies adopt a different manner to develop products compared to the 'western countries' companies. This can permit to reach competitiveness, lowing prices, improving performances and to provide benefit for everyone. Gandhian Innovations are one of the best examples of the concept of sustainability.

By these cases, the other worldwide companies can learn that is possible to achieve sustainability, but a radical change is fundamental, especially disrupting the current business models that had based the first industrial revolution and that, with some small differences, are during nowadays as well.

4 Identifying the characteristics of a method for sustainability

In this chapter, the results of the literature analysis are presented, in order to find out some important characteristics of a method for sustainability. By these characteristics, the Eco-tools were evaluated to figure out weak areas and drawbacks. The chapter concludes arguing that there is a need of a new easy to use method to highlight sustainability issues in the early stages of the product development process.

4.1 Why do we need a method for sustainability?

As stated in chapter 2, the process of achieving sustainability in the society is still difficult to reach for many reasons. The chapter concludes claiming that is necessary to focus on product development process in order to reach a sustainable society with innovative solutions.

However, considering sustainability in product development is usually based on a misconception. Since the product is created to satisfy needs, designers are treating sustainability like all the other customer's needs, 'waiting for' a specific demand in sustainability by the customer itself. And this is the point. In fact, today is very difficult for the customer, apart some exceptions, to know all the sustainability impact of his/her purchasing choice.

For instance how many times we asked ourselves, when reading a newspaper or an Internet blog, that we have bought an unsustainable product - *"but I was not aware of this!"*.

Drawn by this conclusion, an important goal of a method for sustainability is to create a sharing understanding by the team members that sustainability issues in our products should not retrieve only by the customer's demands. The concept can be summarized in: 'sustainability has to drive the designer, not the customer'.

4.1.1 Examples

To further understand what is argued in this chapter is fundamental to have in mind some example of Ecological-sound initiatives.

Example 1 - Bike sharing system

Bicycles are leased to customer that do not own a bicycle. Public bicycles [42] are a mobility service, mainly useful in urban environment for proximity travels. It is able to remove three difficulties of daily cycling use: home parking, theft and maintenance of your private bicycle.

Figure 8. Bike sharing in Barcelona

Example 2 - Automatic fresh milk vending system

This system goes back to the old system where you could bring your own container to the store. The fresh milk vending machine is created to sell fresh milk directly from the producer to consumer. One of the advantages of the machine is that it allows the farmer to sell directly to consumer realizing an immediate profit, while the consumer can enjoy fresh and genuine products at affordable prices.

Example 1 - Max Hamburger's case

In 2006 Swedish hamburger restaurant company Max Hamburgarrestauranger (Max) decided to start up a project towards sustainability in general and climate issues in particular. Together with the international NGO The Natural Step they calculated the total carbon emissions from the farmers land to the consumer's hand. The total footprint was estimated to 27,000 tones carbon dioxide equivalents per year. Max also discovered that 70 % of the emissions are emanated from the production of beef.

Max noticed that meat production will continue to account for the majority of the carbon emissions in the future, although these emissions can be reduced by continuing to use only Swedish meat and raising supplier standards. Max also offset the carbon emissions by planting trees in Africa. Max's partners plant approximately 89,000 trees each year, which is equivalent to an area of the size of 890 football pitches.

Other Eco-friendly characteristics of Max:

- All restaurants are powered by 100 percent wind energy
- Max serve only eco-certified fish
- All company vehicles are environmentally friendly
- Max only buys Swedish beef and Swedish Chicken
- All employees receive training from the Max Environment School
- An internal environmental prize for the restaurant with the best environmental initiative has been established
- All new restaurants are equipped with low-energy LED lighting instead of neon lighting
- All restaurants recycle cardboard

- Employees use one cup each per day to reduce the consumption of disposable materials
- All electrical equipment is recycled

Another interesting initiative by Max is the carbon-labelling of the menu: Max has introduced carbon labelling to all menus in order to provide customers with a clear understanding of how different menu options compare (Beef has the largest effect on carbon emissions and is responsible for the greatest proportion of Max's total emissions).

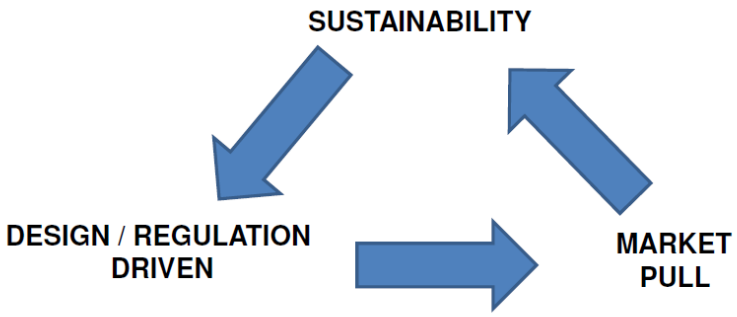
Figure 9. Max Hamburger Eco-labelling

These campaign allowed Max to win the 2009 Green Award for the best Green International campaign. [43]

4.1.2 Is sustainability market pull or design driven?

Looking at the initiatives listed above, it can be noticed that they were not generated by a requirement formally expressed by the customer. These initiatives were pulled in by the designers and successively by the clients, when they understood both the usefulness and environmental importance of the solution. It can be claimed therefore that sustainability has to be design driven for first, and only successively it can be market pull (Figure 10).

Figure 10. Sustainability has to be regulation/design driven first, and then successively market pull.



Often regulations drive sustainability, one example is the legislation about emissions for Heavy Duty vehicles in the European Union (Euro I- Euro VI) that gradually decrease the amount of emissions [44]. For these reasons is fundamental to provide tools and methods as well for governments, municipalities, non-governmental and no-profit organizations.

4.2 When to use the tools and performance characteristics

As previously stated (Figure 6), the biggest leverage for environmental responsibility in the entire product life cycle lies in the product development process. By these considerations, the same result can be drawn *within* the product development process as well. Decisions in the first phases (according to the product development scheme proposed by Rozenburg and Eekels [19, p.13]; formulating goals and strategies, product policy, generating and selecting ideas) decide the majority of the total future environmental and social impact of the product.

Hallstedt [34] argues that sustainability should be integrated as soon as possible in the product development process, in order to avoid sub-optimizations and high costs associated to 'repair' what was planned in a wrong way in the early phases. Literature analysis revealed many surveys made in order to figure out how the companies experienced the current Eco-tools and their performance characteristics, and in this sense the results are not so comforting. For instance the Life Cycle Assessment (LCA), one of the first and most studied Eco-Tool is extremely analytical and in detail, therefore it is considered too complex and time consuming (a detailed analysis could take even weeks) and its use is limited.

Moreover, as claimed in the paragraph above, the method for sustainability should even give help to non-governmental and no-profit organization in planning strategies towards sustainability. In many cases, these organizations have not the resources and the competences to implement expensive and complicated software-based environmental tools. Giving the fact that decisions made in the very early phases of the product development decide most of the environmental impact of our product; we need easy to use tools that consider the sustainability aspects already from the beginning of the process.

4.3 How the tools should be designed

By the consideration drawn after the literature analysis presented in Chapter 2 and Chapter 3 it is possible to describe and formulate the purposes by which a method for sustainability should be based on.

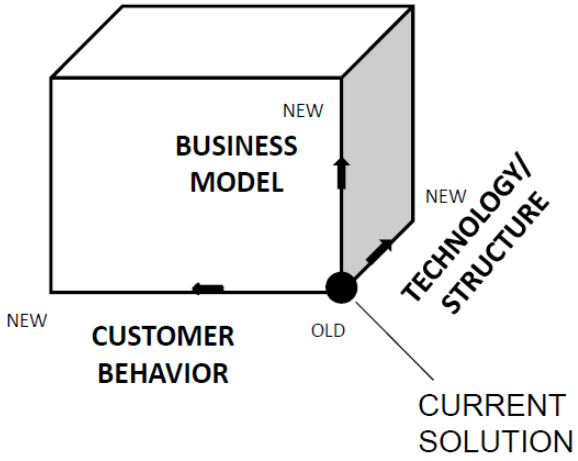
First, such a method must comprehend a tool to observe the customer and users expectations in the very early steps of the framework. This at a first sight could seem as an contradiction with what argued in paragraph 4.1.2 , so a clarification must be done. We are claiming that we need to analyze and understand the customer's expectation for driving our innovation. The customer has expectations and the designer should provide them in a sustainable manner, the customer should not have to explain the expectations regarding sustainability.

Just to give an example, the outcome from the workshop could be the understanding that a customer does not want a heater, but what he wants is warmth, and that is what he is willing to pay for. This could lead us to build an innovation in which we do not sell our heater, but in which we provide warmth by leasing the hardware to the customer.

Other unavoidable purposes for a method for sustainability are to inspire ideas and solutions drawn by sustainability, and to assess the solution from a sustainable perspective, finding for instance cases of 'hidden waste' (an apparent environmentally sound solution that instead presents a great or dangerous amount of waste in some stages of the product life cycle).

Regarding the idea finding process, the method should aid the product development team to find ideas along three dimensions. This concept is explained by the 'sustainable innovation box', see Figure 11.

Figure 11. Sustainable Innovation Box



These three dimensions are: changing the technology/structure of the product, modifying the business model or changing the customer's culture and behavior.

As an example: bike sharing is an innovation in which there is not any improvement in the technology or the structure of the product (we have the bicycles since almost two hundred years), but what change is the business model (the bicycles are not sold, but leased) and the user's behavior (customers have reached the choice to use bikes instead cars).

While in a product development team is in theory easy to think about changing technology and structure, difficulties emerge when the team wants to think 'out of the box' including the other two paths of innovation. This for many reason. They can be addressed to the cultural background of the team members (predominantly engineers or with technical formation in any case) but also to an often unintentional manner to think always with the current ways of making business and consuming products.

By this consideration a method for sustainability has to include tools and exercises that help the team to find solutions even in areas not usually considered, in order to inspire radical innovation (as the example of the 'Gandhian Innovation' shows).

4.4 Giving constraints for inspiring ideas

By performing and observing workshops, a strong conviction is that for inspiring ideas and solution we need to give at the team a strict constraint, a challenge by which they can brainstorm for solving the problems. This concept could be expressed as the slogan 'narrowing the box to think out of that'. As Åsa Ericson said in one Radical Innovation Workshop performed with a team from Volvo Construction Equipment:

"If I say to you: 'tell me', you cannot be creative. If I say 'tell me about your last evening', now you can be creative".

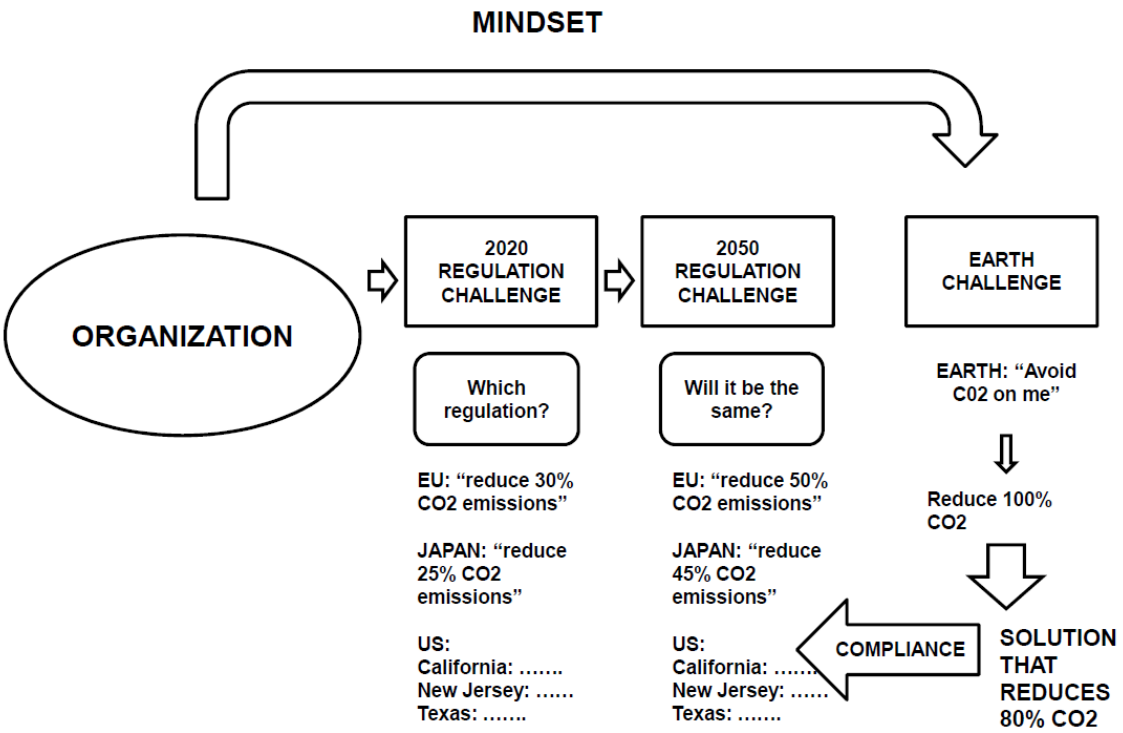
So when performing a workshop with a facilitated method for sustainability, the team should decide and clarify what are the constraints for the challenge in matter of environment, costs, time requirements etcetera.

Regarding the environmental laws, another interesting characteristic of a method for sustainability can be drawn. As we well know, one of the reasons for sustainable efforts in a company is to remain in compliance with the regulation. By personal convictions and the reflections drawn by the workshop performed and observed, a method for sustainability that wants to inspire innovation should give more strict environmental constraints than the existing in the current regulation. This is the only way to attain a 'radical sustainable innovation'. In the method this type of challenge is called 'Earth challenge', that means to build an idea that fulfill the Earth's requirement on the problem that we are focusing on. The following example (Figure 12) explains the reason why this exercise might be very useful to inspire radical innovations driven by sustainability.

Many of European, American and Japanese regulations have planned the values for the reduction of the CO_2 emissions within the year 2050.

Only for instance, let us imagine to face with the challenge to remain in compliance with a specific regulation in matter of CO_2 emission within the year 2020. Here would arise a first problem for us. There would be an uncertainty of what regulation take into account for our challenge, and there might be the risk of a bar for satisfying a specific market segment (e.g. we should limit ourselves to sell our cars in only certain American states, barring ourselves the possibility to sell cars in other American states, in Japan and in Europe, because of the more strict environmental laws existing in those countries).

Figure 12. Accept the Earth challenge for being in compliance with all the regulations



Even try to remain in compliance with the future regulation could be tricky in some cases. In fact, these might change in the years, due to a different policy in environmental laws by that specific region, country or continent. Instead, if we choose the Earth challenge as the competition in our mindset, very clear and definable (there is no misunderstandings about the Earth's needs), maybe we can find a solution that will remain in compliance with every kind of regulations and, most important for the success level of the company, pass over the competitors and to find new opportunities, in this case new markets.

4.5 Conclusion: characteristics of a method for sustainability

Summarizing the results drawn by the previous analysis, a sustainable innovative method should be:

- utilized in the early stages of the product development process,
- easy to use and not time and cost expensive,
- observing the market to understand the expectations of the customer in order to drive the innovation,
- helping the innovation process in three different paths: changing the business model, changing the technology/structure and changing the customer's behaviour,
- assessing and valuate the solutions from a life cycle perspective,
- creating constraints to challenge the team in order to achieve radical innovation.

4.6 Eco-tools evaluation and need for a new method for sustainability

After the discussion and formalization of the characteristics of a method for sustainability, an evaluation of the current Eco-tools is necessary.. As already explained, the method for sustainability presented in this thesis is not comparable with the frameworks for sustainability (in fact, the Sustainability Innovation Workshop might be used in a framework for sustainability such as The Natural Step, that is composed by many workshops).

Firstly, the evaluation process started to sort the current Eco-tools according to the survey proposed by Knight at al. [22], in order to include only the most used tools. After the sorting phase, the Eco-tools have been evaluated according with three criteria:

- When the tool is used in the design phase (in the early or late phases);
- Performance characteristics: the complexity/time requirements to implement the tool (in order to reduce the complexity of the analysis, costs of implementation were assumed to have the same trend of the complexity/time requirements column so they were not included);
- The purposes listed in the paragraph above: 'x' in the table means that the Eco-tool was born in order to fulfill that particular purpose.

The Eco-tools evaluation is presented in *Table 1*.

Table 1. Eco-tools evaluation

Tools	Characteristics						
	When in the design phase	**Complexity/ Time requirements**	**Use in the companies**	**Aiding the innovation process**	**Final assessment of solutions**	**Observe products/market**	**Life cycle perspective**
LCA [45]	Late	●	◖		x		x
MIPS [46]	Late	◖	◖		x		
MET [47]	Late	◖	◖	x	x		x
Eco-compass [47]	Early	◖	◖	x	x		
Eco-LiDS Wheel [32]	Early	◖	◖	x	x		x
Cecklists [32]	Early	○	●		x		
Spiderdiagram econcept [32]	Early	○	○	x	x	x	
House of Environmental quality [32]	Early	●	◖		x	x	x
Solid works Sustainability module [33]	Late	○	●		x		x
NOTE: The legend on complexity/time requirements and use in companies columns is: ● high ◖ medium, ○ low. In order to reduce the complexity of the analysis and evaluation, costs of implementation were assumed to have the same trend of complexity/ time requirements.							

Analyzing *Table 1* some interesting conclusions can be drawn. Not all the Eco-tools are used in the early stages of the product development process, when is extremely important to take the right decisions in order to minimize the total environmental impact of the product.

Many tools were experienced by the companies as too complicated and time consuming (an LCA analysis, for instance, could take even weeks).

All the Eco-tools analyzed include an assessment of the solutions originated after the design phase. This result was expected, due to the fact that these methods were born in the middle of the

'90s basically to give aid to the designers to assess the environmental impact of the designed products.

However, this evaluation is not in every tool from a life cycle perspective. In the MIPS, Eco-compass, Cecklists and Spiderdiagram Econcept the analysis does not focus into every phase of the life cycle. In other words, such tools do not assess the solution in all the phases of the life cycle (MIPS for instance, based the analysis focusing in the production phase), with potential risks of 'hidden waste' behind the product that was not revealed by the Eco-tool during the product development phase.

Other interesting conclusions can be drawn on the purposes by which the methods were developed. Some of the tools are aiding the innovation process, even if not always in the three paths of innovation argued in paragraph 4.3 and showed by the 'innovation box' in Figure 11. Mostly important, a very few of them analyze the customer before taking decisions towards sustainability.

That being so sustainability concerns appear 'separated' in the currently product development process, in which understand the customer's needs and expectations are one of the first steps. Instead, as previously stated, is fundamental to analyze the customer and to drive the innovation process by sustainability.

By this conclusions it appears necessary to develop a new method for sustainability based on the characteristics summarized in paragraph 4.5.

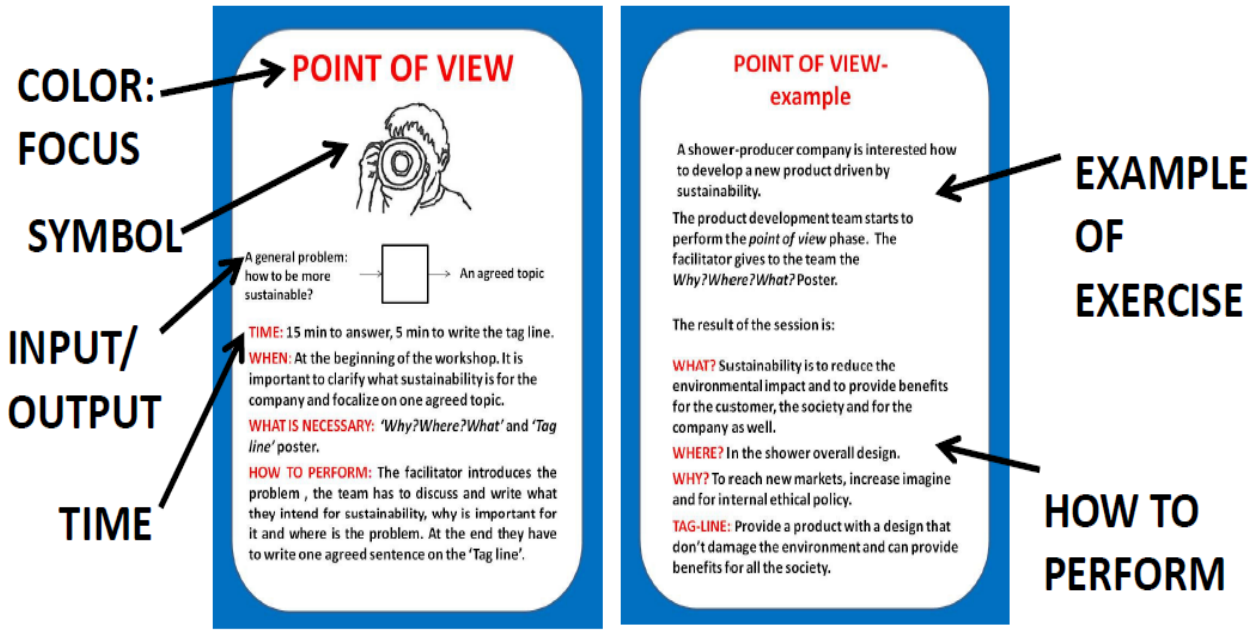
5 Sustainability Innovation Workshop

The workshop is based on a system where a symbols and colors are used in order to structure the method, drive the team through the different steps and explain the exercises. The tools for the workshop consist of four different types of material:

1. Handbook for the facilitator (one A4 page) containing the explanation of aim and purposes, the overall structure of the SIW, the color and symbol system;
2. Set of cards (for the facilitator) explaining every phase, tools to use and time to perform each exercise;
3. Set of facilitation posters (for the team) containing exercises and examples to perform the workshop;
4. Set of templates (for the team) for writing and sketching the result of the workshop;

The cards are designing in a very simple way in order to help the facilitator to perform the workshop. One card example is shown in Figure 13.

Figure 13. Facilitator cards' example.



5.1 Overall structure

Sustainability Innovation Workshop is a seven steps procedure, see *Table 2*. Each phase has dedicated exercises for understanding, voting and solving problems. Each phase is distinguished by a symbol and color labelling system.

The color legend is:

- BLUE: *focus,* this colors represents those exercises that help the team to focus on the topic;
- YELLOW: *explore,* for exercises with the aim of exploring, analyzing and discovering problems and challenges (divergent phases);
- RED: *selection,* for exercises with the purpose of selecting and sorting ideas (convergent phases);
- GREEN: *result,* for exercises with the aim of creating results from the exercises.

In order to give a visualization of the different phases, a explanation poster is provided to the facilitator (called 'play your snakes and ladders', see Figure 14).

Figure 14. SIW overall structure

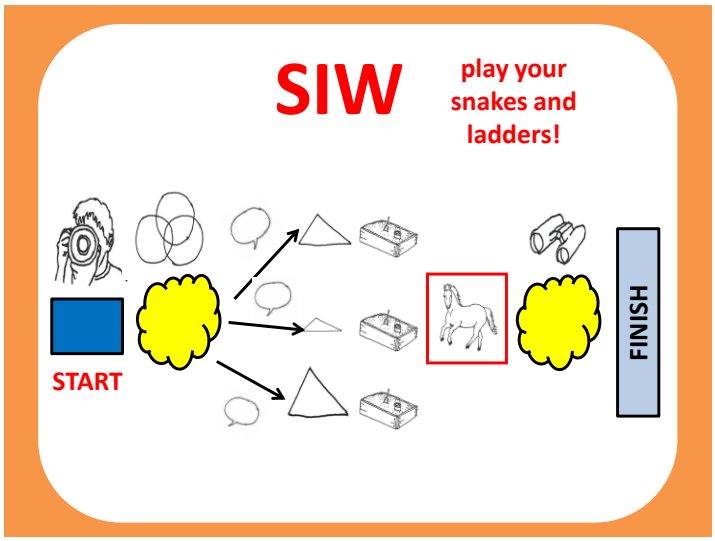


Table 2. SIW dedicated exercises

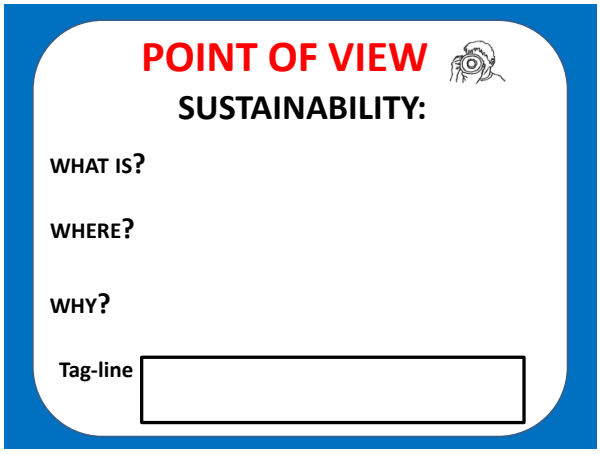
Symbol	Name	Type	Dedicated tools	Converging/Diverging	Outcome
	Point of view	Focus	Why?, Where?, What?	Converging	Agreement of the problem area
			Tag line	Converging	An agreed topic
	Customer Templates	Explore	Customer's quotes	Diverging	Brainstorming about customers behaviors and expectations
			Creating personas	Converging	A shared understanding of the customer expectations
	Choose one quote	Selection		Converging	Choice of one quote/persona to explore more in detail

	Sustainability challenges	Result	Sustainability triangles	Diverging	Set of challenges for the team
			Bumper car sticker	Converging	Formalization of the challenges
	Sand box play	Concepts	Roles templates	Diverging	Set of concepts
	Choose one concept	Selection	Camel/horses ranking	Converging	Ranking of the concept (risk and opportunity) and decision about future direction
	Analyzing the idea	Explore	'Hidden waste', Waste management, Back to future	Diverging	Analysis of the chosen concept and weak spots of the current solution
			Recording	Converging	Set of issues to develop and improve

5.2 Exercises presentation

In this section the different kind of SIW exercises are presented. All are described in terms of purpose, materials necessary, how to perform and by how many members the tool is performed (single, group or the entire team together). For further explanations, Appendix A contains all the tools described in this section.

5.2.1 Point of view



Purpose: create a sharing understanding by the team members what is sustainability, why is important and focusing on the problem.
Dedicated exercises: Why?Where?What?, Tag line.
Material: What? - Where? -Why? and *Tag line* templates.
How many members are performing: Team.
How to perform: The team has to discuss where is the problem, what they intend for sustainability and why the topic should be important for them. This is done answering in the *What? - Where? -Why??* template. After this exercise, the team has to summarize the concept expressed in one line, writing in the *Tag line* placed at the end of the template.

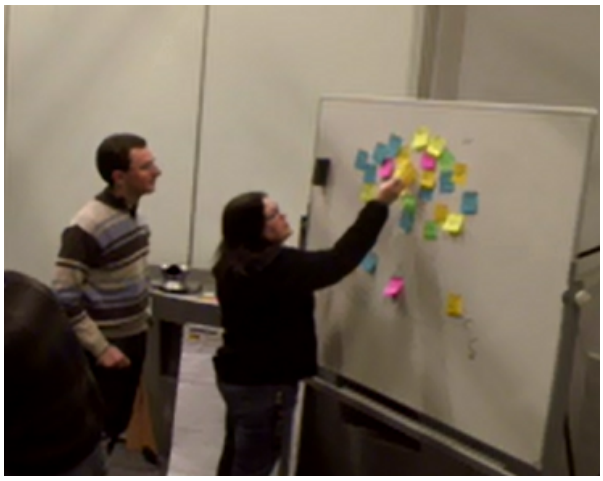
5.2.2 Customer Templates

Purpose: Understanding all the kind of customer's expectations, having an overview of which kind of customers focus the innovation process.
Dedicated exercises: Customer's quote, creating personas.
Material: 'Customer's quote' 'personas' posters, post-its.
How many members are performing: Team.
How to perform: The team performs a brainstorming posting all the quotes they consider belong to all the kind of customers involved in the topic under focus. After this step, they cluster them in order according if the quote is mostly referred to an interest about the single's needs, the others' needs, planet or money.

5.2.3 Choose one quote

Purpose: Choice of one quote/persona to explore more in detail.
Dedicated exercises: none.
Material: none.
How many members are performing: Group.
How to perform: the team discusses the quote collected and decides which one to explore more in detail. After divided into groups, each of them chooses a quote or a set of quote related to each other.

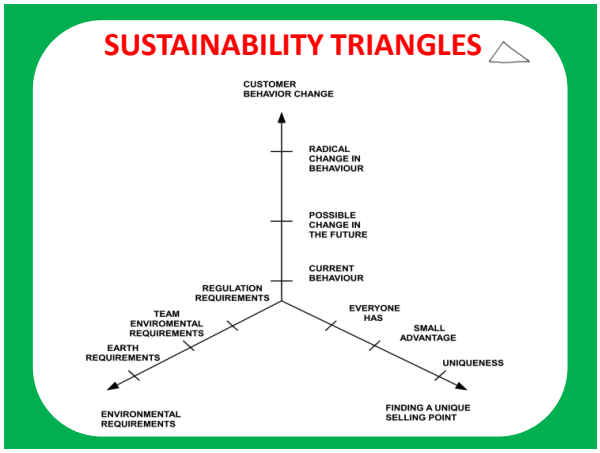
Figure 15. Choose one quote



5.2.4 Sustainability challenges

Purpose: To create a challenge for the team in order to drive the innovation process.
Dedicated exercises: Sustainability triangles.
Material: 'Sustainability triangles' templates, bumper car sticker.
How many members are performing: Group.
How to perform: The tool is developed to explore three different dimensions of sustainability. In the exercise the team members have to discuss, decide and write their challenges for solving the problem in three different aspects. These are:

1. *Change customer behavior*, how the team wants to change the customer's behavior with the design,
2. *Environmental requirements*, which environmental boundaries it wants to fulfill,
3. *USP*, which kinds of market advantage the company wants to attain from the solution.

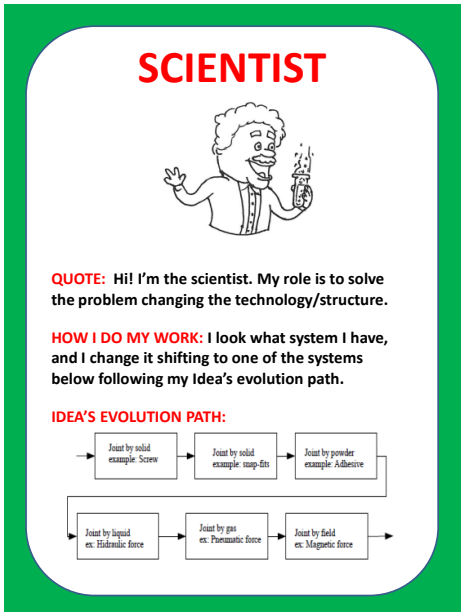


5.2.5 Sand box play

Purpose: Brainstorming about solutions playing roles.
Dedicated exercises: Sand box play.
Material: 'Sand box play' exercise, roles badges (Figure 16) and templates (Figure 17).
How many members are performing: Group.
How to perform: After the discussion and the decisions made in the 'sustainability triangles' exercise, the group decide from which perspectives (and so, which roles) it wants to solve the problem. The roles are:

- *Scientist,* that has to solve the problem changing the technology/structure;
- *Anthropologist,* that has to solve the problem changing the customer's behavior;

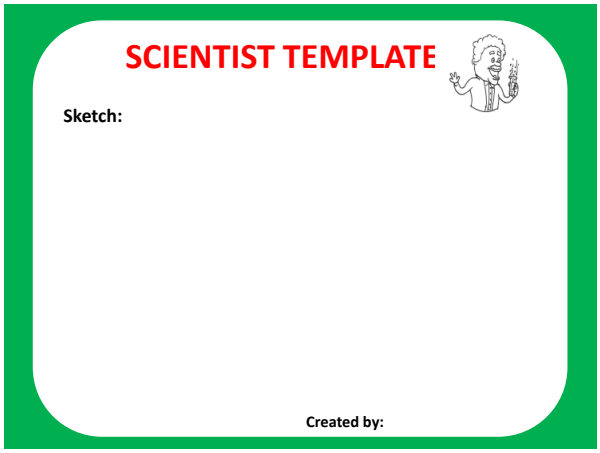
Figure 16. Scientist badge example



- *Business man,* that has to solve the problem changing the business model,
- *Green thumb,* that has to solve the problem looking at how the problem was solved in the past (assuming that many practices in the past were more sustainable) or looking at how the nature usually solve the problem,

For every role the 'roles templates' are provided: they consist in one poster (role template) for sketching the idea and in one badge, with examples and guiding questions in order to drive the innovation process. (idea's evolution path).

Figure 17. Scientist template.

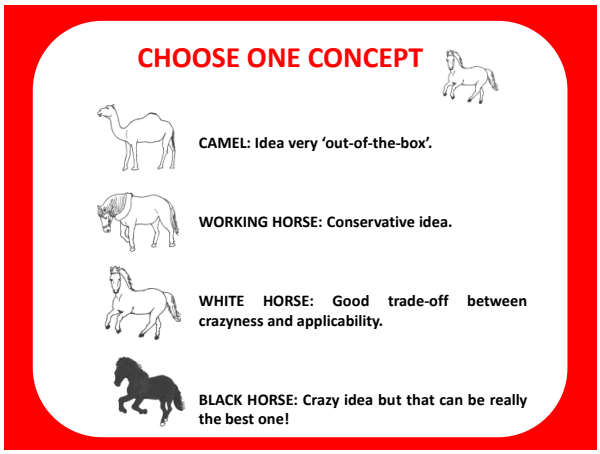


5.2.6 Choose one concept

Purpose: Ranking of the concept and decision about the one to develop.
Dedicated exercises: Camel/horses ranking.
Material: Camel/horses stickers.
How many members are performing: Team.
How to perform: After the presentation of the concepts, each team ranks the solutions with four different stickers:

- *Camel,* for an idea very 'out-of-the-box',
- *Working horse,* a very conservative idea,
- *White horse,* an idea that seems a good trade-off between craziness and applicability,
- *Black horse,* a crazy idea but that might bring many advantages,

After the ranking, the team decides which of this 'horses' it wants to develop.



5.2.7 Analyzing the idea

Purpose: Analyzing the idea from a sustainable perspective, and make decisions about what topic to develop in the next session.

Dedicated exercises: Waste management, Reward: hidden waste, Back to future.

Material: 'waste management', 'reward: hidden waste', 'back to future' posters, post-its, phases stickers.

How many members are performing: Group.

How to perform: The team divides into group, each group performs a different exercise, analyzing the solution chosen finding actual 'sustainability problems' of the new solution, such as cases of 'hidden waste' (a apparent environmentally sound solution that instead present a great or dangerous amount of waste in some stages of the product life cycle). After this brainstorming each group presents the results and through a dot voting the team decides the topic to analyze in the next meeting with another iteration of the SIW.

Figure 18. 'Reward: hidden waste' exercise.

Figure 19. 'Waste management' exercise.

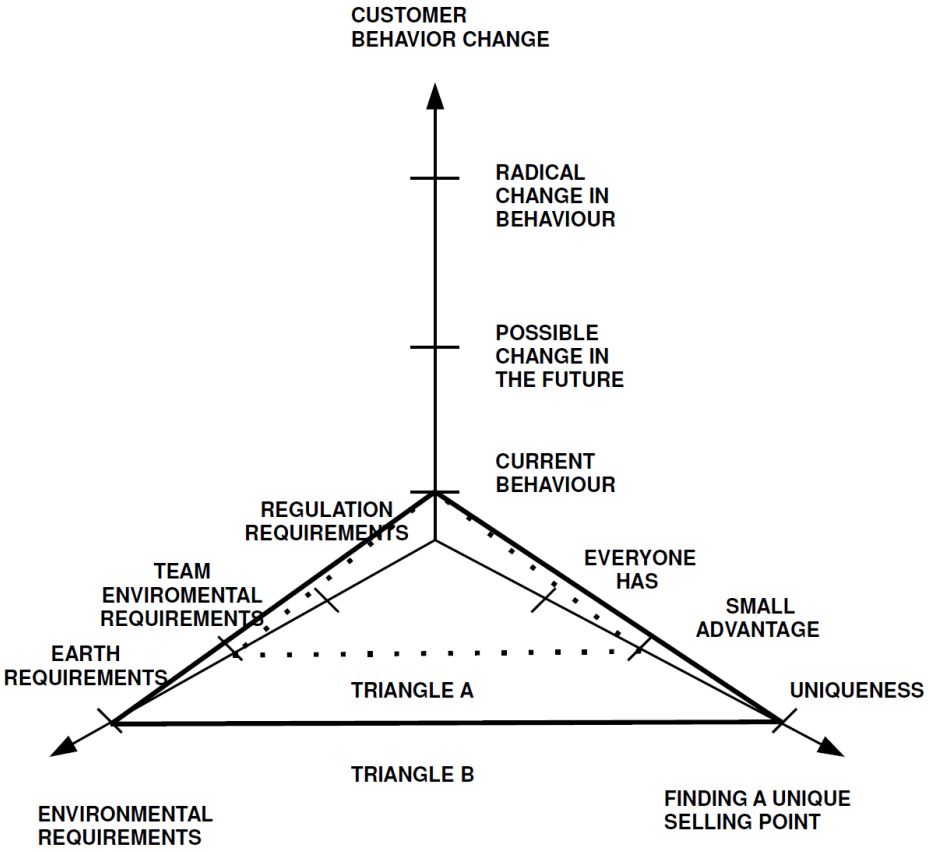
5.3 SIW example: shower radical innovation

To exemplify the usage of SIW framework an example is presented:

A shower-manufacturer company is interested how to develop a new product driven by sustainability. With the *point of view* phase, they approach the problem deciding that building a sustainable product is not only to design it more environmentally sound, but even that it fulfills everybody's expectations everywhere in the world (social part of sustainability). After the *customer templates* step, the team explore the customer's behavior, understanding that there are many kind of behaviors, from customers with a more sustainability friendly behavior (5 minutes of shower) to customers that do not think about environmental issues (takes a 30 minutes hot shower because the cost of clean water and heating is very low compared to the satisfaction of the hot shower). In this case the team decides (*choose one quote*) to build an idea for the last persona, believing that this is the most difficult kind of customer to satisfy from a sustainable point of view, and a solution that fulfills this customer will be attractive even for the other personas.

The team divides in two groups, and they perform the *sustainability triangles* exercise. The results are shown in Figure 20.

Figure 20. Sustainability triangles exercise

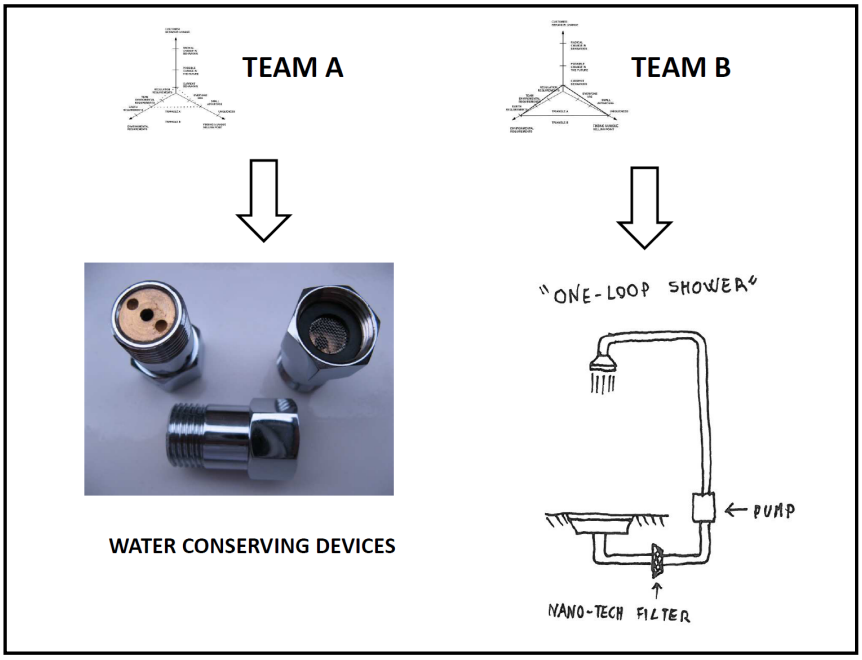


- *Triangle A* (dotted line): the group decides to find a solution in which there is no change in the customer behavior, that fulfills an environmental requirement decided by the group (i.e to save 30% of the water used per minute), and to have a small advantage compared to the competitors.

- *Triangle B* (continuous line): the group decide to find a solution in which there is no change in the customer behavior, that fulfill the Earth's requirement about water (i.e formalized in 'do not waste any drop of water') and to have a unique product (compared to other competitors).

The two groups start to work separately using the *Sand box play*, after the phase each group presents a concept, see Figure 21:

Figure 21. Shower product concepts



- Group A product concept: shower with water conserving devices (restricts the flow of water),
- Group B product concept: 'one loop shower' concept, the water is collected after the use, filtered with a nanotech filter and then returns in loop with an electric pump.

The workshop continues starting to rank the two ideas (*choose one concept*) and deciding to continue with the second concept, arguing that this solution is more environmentally sound (huge decreasing of water consumption) and, respecting what stated in the first step, more socially sound.

Indeed, it fulfills every customer's expectations, from the 5 min shower customer to the 30 minutes shower customers (that in theory he/she can have a shower all day long if he/she desire so). And Furthermore, this concept can provide benefits in every part of the world, and in special way in some areas (for instance Africa giving an actual aid to prevent diseases caused by hygienic problems). In addition, the nanotech filter might be convert even filthy water into washable water, because of the cutting-edge nanotech (as shown in the Michael Pritchard's 'Life saver' [48]).

After this step the team continues through the next phase (*analyzing the idea*) valuating if the solution presents some weak spots from a sustainable point of view. From the analysis (an example of *reward: hidden waste* exercise is provided in Figure 22) emerges the problem of the 'hidden waste' of electricity connected to the use of the electric pump (that is not needed in the concept A).

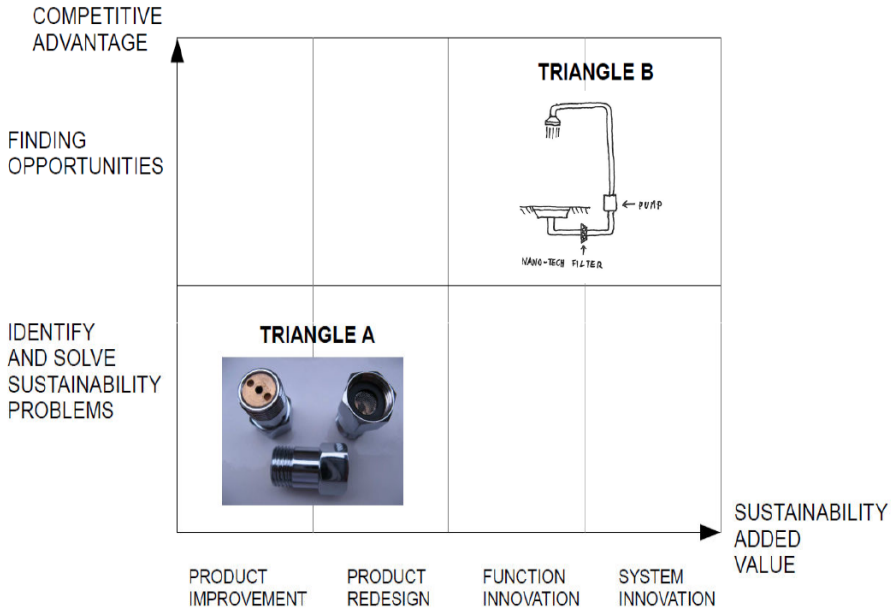
Figure 22. 'Reward: hidden waste' example

The SIW concludes and the team decides to continue and in the next meeting focus on the electric pump (and maybe already some members could suggest the use of a solar panel to power the system).

This is just an example, but is useful to figure out how the SIW evolves and how the idea is continuously improved.

An interesting reflection can be drawn in the 'sustainability triangles' exercise. By this exercise, we can measure the 'degree' of our innovation. The concept is expressed in Figure 23. In facts, smaller triangles (triangle A, in this case) correspond to a solution that is easy to implement but with a small possibility to get a competitive advantage. Larger triangles mean a more radical solution (in this case, reach every type of customer, that can satisfy his expectations and even to save money) with a great advantage for both the environment and the society.

Figure 23. Relation between sustainability triangles and competitive advantage

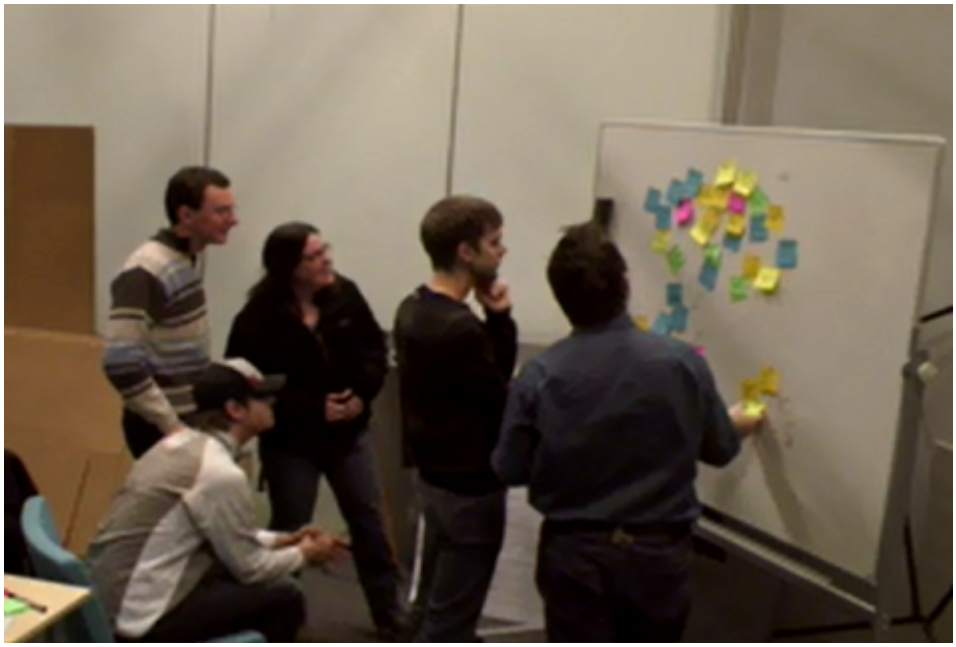


Drawn by this reflection, this tool permits the workshop users to understand the 'added value' of a sustainable solution. This is always important in a company, and clarifies to the team members why a sustainable driven design can bring advantages for the organization (the 'success level', according to Broman, Holmberg and Robèrt [35]).

6 Evaluation of the SIW

The method presented is a result of an iterative testing, evaluation and redesign during six months at Luleå University of Technology (one example is shown in Figure 24).

Figure 24. SIW performed



From an educational point of view, since already from the first meetings with Professor Peter Törlind, an important task of the thesis was even to find out how the methodology evolved during the development of the method in order to draw reflections about the product development process.

This was a part very engaging and enjoyable for me, because I treated myself as a 'product developer', in which the SIW was my product. First, I tried to answer important questions, which were my possible 'customers', why and where there was a need for a new product (hence figure out which were my product requirements) and how I could build a method to cover this gap. An interested tool that I experimented was the writing of a 'press release', a brief document (is not supposed to be more than a page) in which I wrote a quote from the customer, how easy is to start to develop the product (the method), and why the new product should be better than the existing ones.

It was an easy to communicate method to assess the attractiveness of the product concept to my 'top manager' (the Professor in this case).

From a methodological point, after each test data were collected (through video recording in the design observatory, reflections from the users, and the documentation from the workshop) in order to find out and improving the weak spots, treating the method as a product concept itself.

Below some examples of the collected sweet spots are listed:

" I like the roles: scientist etc"
"I like to try new methods; the first one and the discussions that it made"
"I like the role method"

"I like that makes it visual"

Some of the weak spots were:

" I wish idea generation to be done some steps before"
"I wish the schedule should be better organized"
"I wish sustainability triangles exercise to be more useful"

One important experience was that each exercise has to be very focused, the earlier versions of the method tried to combine several steps into one exercise. It appeared fundamental that the goal and how to perform the exercise has to be clear, and with good examples to guide the participants trough the exercise.

One exercise that gained positive response from the users was the sandbox play that was used instead of the classical brainstorming. The team also appreciated using quotes in the 'customer templates' exercise, and found it easier to use than the traditional way of creating personas.

In chapter 4 the characteristics for a method for sustainability was identified and formalized in paragraph 4.5. As well as with the other Eco-tools, is important to evaluate the SIW according to these characteristics (making again a parallel between the SIW and a product concept; final assessing the respect of the initial requirements).

- **utilized in the early stages of the product development process:** the SIW is designed to be used in the very early stages of the product development process in order to analyze the current product, understand the customer's expectations and drive innovative solution by sustainability concerns,
- **easy to use and not time and cost expensive:** all the tools of the SIW are quite inexpensive (only posters, posts-its and stickers are necessary) and are relatively quick to perform (it requires around half of a working day),
- **observing the market to understand the expectations of the customer in order to drive the innovation:** in the first stages of the SIW the 'customer templates' exercise analyze the customer with the use of quotes, which then are used in the rest of the process,
- **helping the innovation process in three different paths: changing the business model, changing the technology/structure and changing the customer's behaviour:** the 'sand box play' exercise is designed to explore the problem from different perspectives and it helps to find solutions in the three paths already cited,
- **assessing and valuate the solutions from a life cycle perspective:** the latest exercises in the workshop, such as the 'hidden waste' or 'back to future' is used to analyse the solution finding out possible cases of 'hidden waste', cost of implementation problems etcetera,
- **creating constraints to challenge the team for achieving radical innovation,** with the 'sustainability triangles' exercise the team creates the constraints that drives the innovation process. Furthermore, the already cited 'sand box play' is another exercise to give constraints of the team. In fact, solving the problem from one perspective (e.g. using the scientist's point of view) is another way to narrow the solution space.

7 Conclusions and future work

In this thesis, a new method for sustainability (Sustainability Innovation Workshop-SIW) is presented. Before the developing of the method, a literature research was performed where weak areas of existing methods for sustainability were exposed.

The main conclusion of the literature study was that there is a need for an easy-to-use method to incorporate sustainability aspects during the very early phases of the product development process. Although the decisions made during these steps determine almost all the future environmental impact of our product, no detail design is done at this stage. Hence, it is difficult to use an analytical and precise method, such as LCA analysis, due to the lack of quantitative data.

In addition, there is a necessity to implement easy-to-use methods in organizations, such as small companies, municipalities and non-profit organizations that might not have the expertise and the resources to implement expensive and detailed software-based eco-tools.

By these considerations the characteristics required in a method for sustainability were analyzed and discussed. These characteristics can be formalized in: a method to use early in the product development process (as already expressed), inexpensive from a time and costs point of view, that analyzes the customer's needs to drive innovative solutions based on a change in the customer's behavior, the business model and the technology. Finally, such a method has to analyze the different solutions finding out possible cases of 'hidden waste', implementation costs problems etcetera in order to set up the topics for the successive workshop iteration.

Based on these characteristics, an evaluation of the existing Eco-tools has been done. The evaluation concludes arguing that the current Eco-tools present some weak spots and that a new method for sustainability is necessary. The method developed - Sustainability Innovation Workshop (SIW) is a result of an iterative testing, evaluation and redesign during six months at Luleå University of Technology. A final evaluation shows that the method presents all the characteristics previously exposed. The initial tests show promising results, but further evaluation must be done before any general conclusions can be drawn. Future work will include tests in different types of organizations.

Furthermore, other interesting research areas will be:

- Focusing to improve the method with exercises that explore more in detail the social part of sustainability: currently there is a good interest around the environmental part of sustainability, lacking the focus on social problems such as obesity, health (the social part of sustainability, as we can see in Figure 1),
- Working with advertisement companies, helping to understand how they contribute to create a sense of identity in the customer and how they can give aid to shift towards a sustainable society,
- Understanding how a company can collaborate with a non-profit organization, that might be a source of inexpensive and useful informations,

- Exploring in the companies the human rights' respect along the supply chain, including collaborating with no-profit organizations and non-governmental organizations (i.e UN departments);
- Understanding how innovation in sustainability can satisfy more fundamental human needs compared to the environmentally unsound. For instance, shifting from the motorized transport to the bicycles the customer can discover the fulfillment of other needs, such as health and create a new sense of identity (introducing the concept of Well-being Driven Innovation).

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Appendix A

List of countries by ecological footprint. The table shows the ecological footprint, the ecological gap (difference between the country's ecological footprint and the world-average biocapacity) and the ecological remainder expressed in gha/pers. This table is incomplete. Only 61 countries are listed. The reference [7] have 185 or more states and territories.

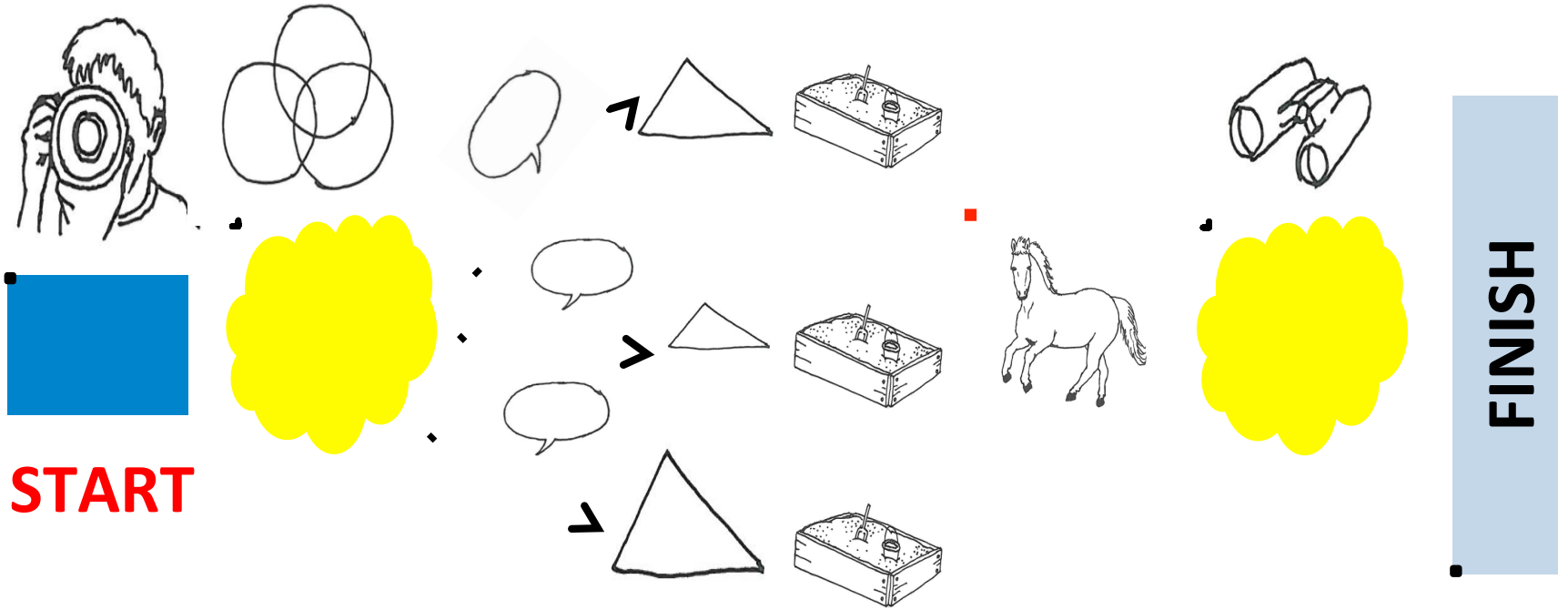
Country	Ecological Footprint	Ecological Gap	Ecological remainder
Algeria	1.9	-0.1	-1.6
Argentina	3.4	-1.6	7.4
Australia	7.1	-5.3	10.1
Austria	4.9	-3.1	-1.9
Bahrain	7.0	-5.2	-5.9
Belgium	5.7	-3.9	-4.6
Botswana	3.9	-2.1	0.4
Brazil	2.3	-0.5	6.6
Burkina Faso	1.4	0.4	0.0
Canada	5.8	-4.0	11.3
Chile	3.2	-1.4	0.2
China	1.8	0.0	-1.0
Czech Republic	5.3	-3.5	-2.7
Denmark	7.2	-5.4	-2.7
Egypt	1.4	0.4	-1.1
Estonia	6.4	-4.6	2.6
Fiji	3.7	-1.9	-1.2
Finland	5.5	-3.7	7.5
France	4.6	-2.8	-1.8
Gabon	1.9	-0.1	30.7
Germany	4.0	-2.2	-2.2
Greece	5.8	-4.0	-4.4
Guyana	2.5	-0.7	62.2
India	0.8	1.0	-0.4
Iran	2.7	-0.9	-1.7
Ireland	8.2	-6.4	-3.9
Israel	5.4	-3.6	-5.1
Italy	4.9	-3.1	-3.9
Japan	4.1	-2.3	-3.5
Kazakhstan	4.4	-2.6	-0.1
South Korea	3.7	-1.9	-3.4
Kuwait	7.9	-6.1	-7.4
Libya	3.2	-1.4	-1.6
Mauritania	3.1	-1.3	3.2

Mexico	1.9	-0.1	0.4
Namibia	3.0	-1.2	5.7
Netherlands	4.6	-2.8	-3.6
New Zealand	7.6	-5.8	4.5
Norway	4.2	-2.4	1.9
Poland	3.9	-2.1	-2.0
Portugal	4.4	-2.6	-3.2
Qatar	9.7	-7.9	-5.8
Russian Federation	4.4	-2.6	1.9
Singapore	4.5	-2.7	-4.5
Slovakia	4.9	-3.1	-2.3
Somalia	1.5	0.3	0.1
South Africa	2.7	-0.9	-1.0
Spain	5.6	-3.8	-4.3
Sudan	2.2	-0.4	0.6
Sweden	2.8	-1.0	7.7
Switzerland	5.6	-3.8	-4.3
Thailand	1.7	0.1	-0.7
Tunisia	1.9	-0.1	-0.7
Turkey	2.8	-1.0	-1.4
Turkmenistan	3.8	-2.0	-0.4
United Arab Emirates	10.3	-8.5	-8.9
United Kingdom	6.1	-4.3	-4.5
USA	9.0	-7.2	-4.6
Uruguay	6.6	-4.8	4.1
Zambia	1.2	0.6	1.7
Zimbabwe	1.0	0.8	-0.3

Appendix B. SIW tools

SIW

play your snakes and ladders!



POINT OF VIEW

SUSTAINABILITY:

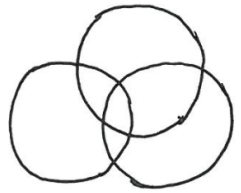
WHAT IS?

WHERE?

WHY?

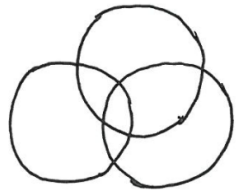
Tag-line.

CUSTOMER QUOTES

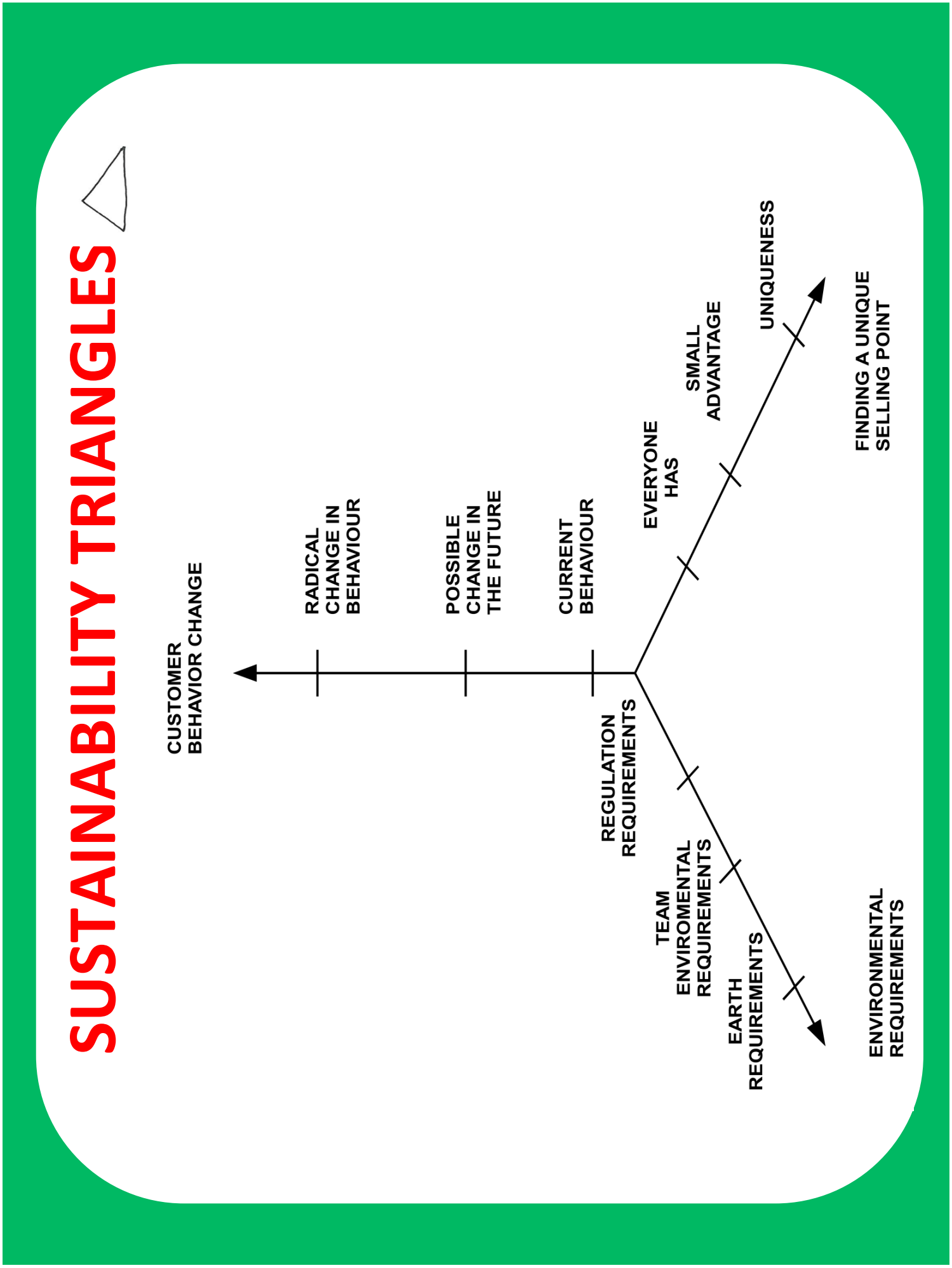


post your customer's quote!

CUSTOMER TEMPLATES



cluster the quotes creating personas


SUSTAINABILITY TRIANGLES
CUSTOMER BEHAVIOR CHANGE
RADICAL CHANGE IN BEHAVIOUR
POSSIBLE CHANGE IN THE FUTURE
CURRENT BEHAVIOUR
REGULATION REQUIREMENTS
EVERYONE HAS
SMALL ADVANTAGE
UNIQUENESS
FINDING A UNIQUE SELLING POINT
TEAM ENVIROMENTAL REQUIREMENTS
EARTH REQUIREMENTS
ENVIRONMENTAL REQUIREMENTS

BUMPER CAR STICKER

- We want to feed the wolf!
-

WRITE YOUR CHALLENGE AS A BUMPER CAR STICKER!

SAND BOX PLAY

SOLVE YOUR PROBLEM PLAYING YOUR ROLE!

SCIENTIST: Has to solve the problem changing the Technology/Structure

ANTHROPOLOGIST: Has to solve the problem changing the customer's behavior

BUSINESS MAN: Has to solve the problem changing the business model

ANTHROPOLOGIST TEMPLATE

Sketch:

Created by:

SCIENTIST TEMPLATE

Sketch:

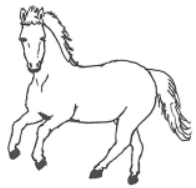
Created by:

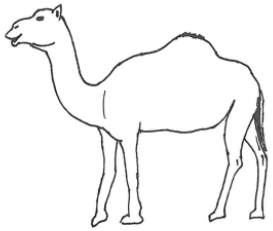
BUSINESS MAN TEMPLATE

Sketch:

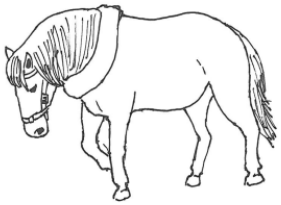
Created by:

CHOOSE ONE CONCEPT

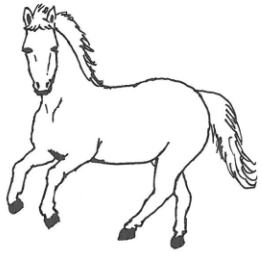




CAMEL: Idea very ‘out-of-the-box’.



WORKING HORSE: Conservative idea.



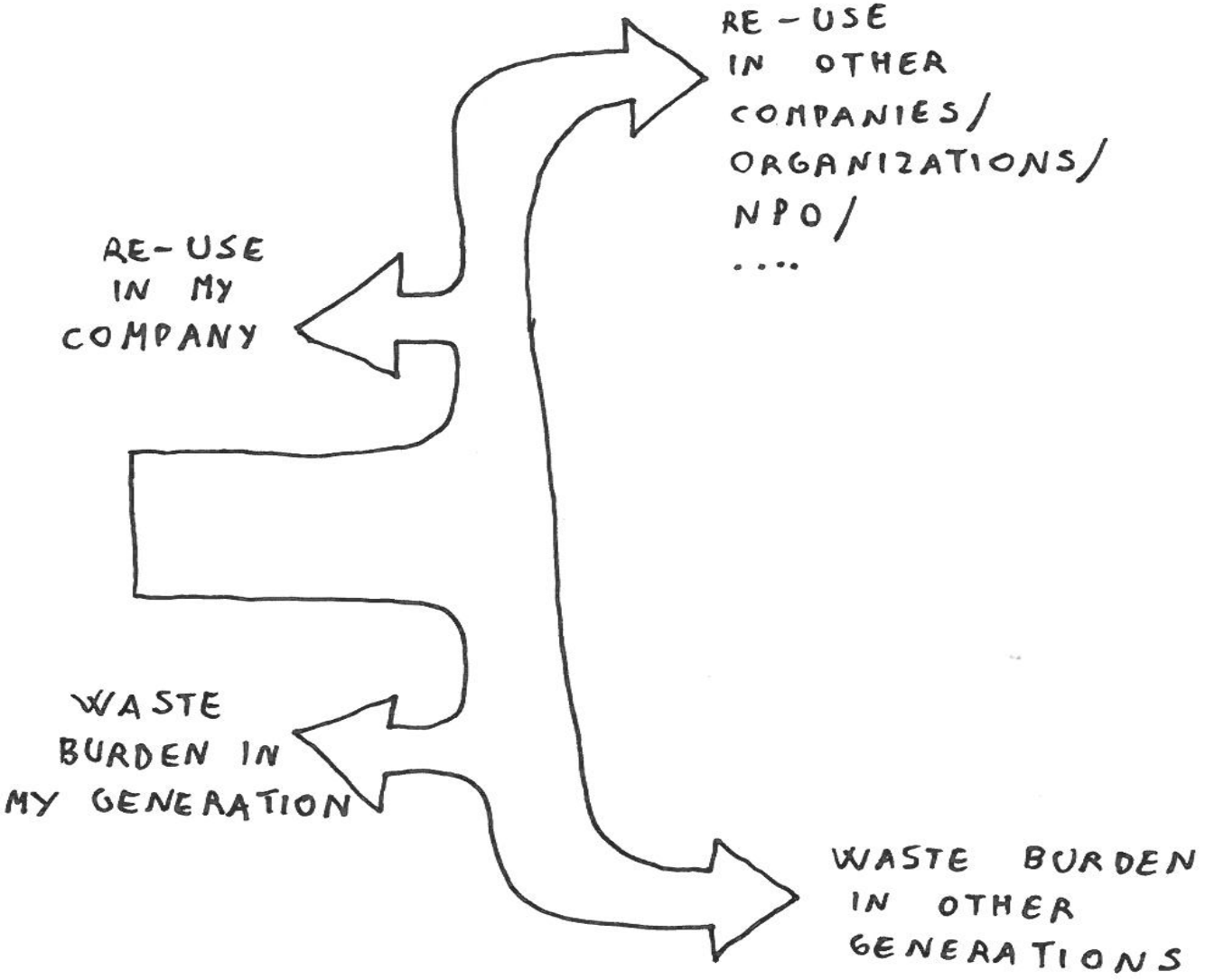
WHITE HORSE: Good trade-off between crazyness and applicability.

BLACK HORSE: Crazy idea but that can be really the best one!

REWARD: HIDDEN WASTE

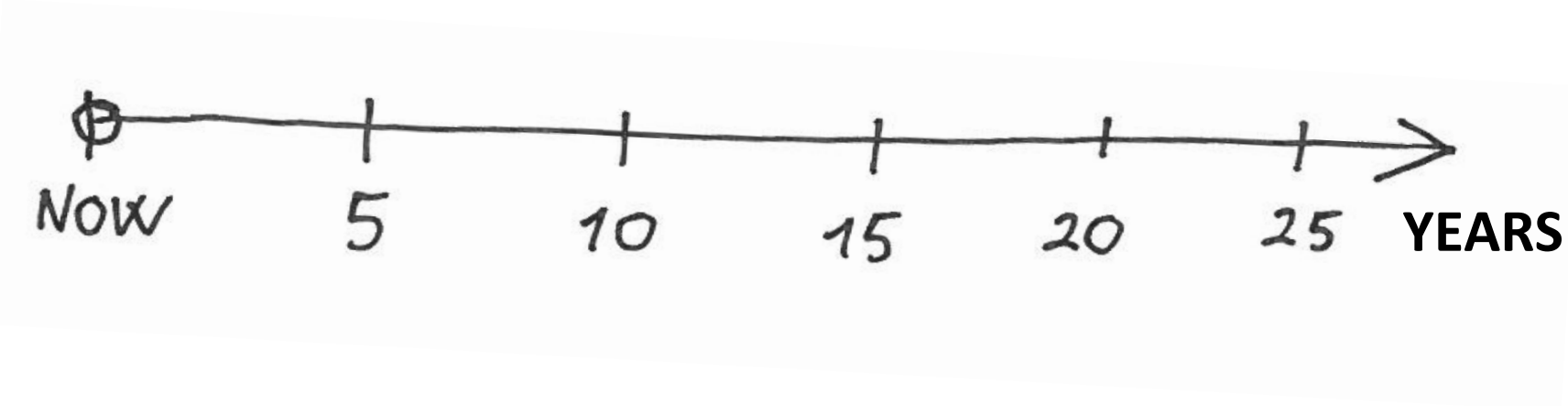
What is the waste behind our solution?

WASTE MANAGEMENT



How are we managing our waste?

BACK TO FUTURE



What will be the consequences of our solution?