Guiding technologists in México

Testing theories of sustainable technological design development to create better design guidelines in a Mexican context

Lucia Solis Paredes

Master Thesis Series in Environmental Studies and Sustainability Science,
No 2017:025

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science (30hp/credits)

LUCSUS
Lund University Centre for
Sustainability Studies

Guiding technologists in México

Testing theories of sustainable technological design development to create better design guidelines in a Mexican context

Lucia Solis Paredes

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science

Submitted May 16, 2017

Supervisor: David Harnesk, LUCSUS, Lund University

Abstract

Technological development has been used to improve human conditions over time, but has in the process created detrimental impacts on the environment. As political forces shift the focus of technology to solve sustainability-related problems, much faith is put into that technologists will change the way they conduct their work so they create technologies that are more *sustainable*. Given the lack of an operationalised definition for sustainability, technologists do not know what this change of focus implies for them. Deciphering these implications is important for technologists in México, where a transition to sustainable energy systems is demanded by national directives, but also, where salient social problems are faced, as large part of the population lives in poverty.

By testing theories that claim to explain the design process of creating sustainable technologies, this research seeks to define a set of guidelines that technologists can follow to incorporate aspects of social and environmental sustainability in their work. By analysing the guidelines against case studies of current technologies developed in México, the research aims to find some challenges technologists may face when trying to pursue the guidelines and to shed light on actions that may help to achieve them.

The guidelines created follow the concepts of *development social sustainability* for the social aspects, and criteria to meet *strong sustainability* for some of the environmental aspects. They suggest that first, technologists have to set an objective to their designs, considering the problem of poverty in México. Then, they have to rely on renewable materials and energy if possible. Additionally, they have to achieve their designs have good functionality when compared to other alternatives, so they are accepted by the public. The analysis of case studies shows that one of the main challenges technologists could face is to substitute non-renewable materials with renewables. It is shown that further research in pure science and applied science of renewable materials could be a good strategy to overcome the problem. The analysis also shows that universities may contribute to raise awareness of social problems in students and professors in technology-oriented fields by creating links of collaboration between them and organisations that work to solve social problems.

Keywords: sustainability, technology, eco-efficiency, sustainable engineering, theory testing, case study

Word count: 13,922

Acknowledgments

I would first like to thank my thesis supervisor David Harnesk. He was always open to review my drafts, to answer my questions, to correct my grammar, and to provide constructive feedback.

I would also like to thank the researchers who kindly answered my questions about their work: Jose Luis Maldonado, Armando Robledo, Juan Carlos González, Daniel Dávila, Alejandro Campos, Andrés Torres, Elan Iñaki Laredo, Vicente Bringas, y Lupita Ureña. Without their participation and input, I would have missed valuable information.

Finally, I must express my gratitude to my parents Carlos and Lucia, and to my partner Abdiel for providing me with support and encouragement through the process of researching and writing this thesis.

Lucia Solis Paredes

Table of Contents

1 Introduction 1

1.1 Thesis' aim and research questions 3

1.2 What is technology and who develops it? 4

1.3 Sustainability, technology, and eco-efficiency 5

1.4 Aspects of social sustainability in México 7

2 Methodology 8

2.1 Rationale behind the methodology 9

2.1.1 Specific details of the methodology 9

2.1.2 Justification for the location selected and number of case studies. 10

2.2 Ontology and Epistemology 11

3 Results and analysis 12

3.1 Theories 12

3.1.1 The limits of technological solutions to sustainable development 12

3.1.2 Sustainable engineering, confusion and consumers 14

3.2 Constructing guidelines 15

3.2.1 Theoretical propositions 15

3.2.2 Guidelines 16

3.3 Analysis of case studies 17

3.3.1 Case studies selected 18

3.3.2 Analyses of theoretical propositions in the case studies 23

3.3.2.1 Proposition #1. 23

3.3.2.2 Proposition #2. 26

3.4 Challenges and learnings from the case studies 29

3.4.1 Challenges 29

3.4.2 Learnings 30

4 Discussion 34
4.1 Alternative approach to the problem 34
4.2 Limitations of the study 35
4.3 Contributions to sustainability science 35
5 Conclusion 37
6 References 38
Appendix A 44
Appendix B 45
Appendix C 48

1 Introduction

Technological innovation is argued to be at the heart of the evolution, biological or behavioural, of human civilization (Schick & Toth, 1994). Since the creation of simple stone tools, humans have continued to develop technological applications which have allowed them to survive and adapt to the environment (Hughes, 2004; Schick & Toth, 1994). Technology is then, deep-rooted in human civilisation, and for Kremer (1990)[1], the capacity to develop it, is inherent in human beings.

A prominent example of the crucial role of technology in development is the invention of agriculture. This innovation resulted in the beginnings of human sedentarism and has since then, been vital to sustain human food supply (Boserup, 1976). However, agriculture has also brought environmental disruption as land-use requires to be changed and with this, areas previously rich in biodiversity are transformed into monocrop spaces (Boserup, 1976; Holdren & Ehrlich, 1974). Besides food production, there are other technological applications, such as electricity production, transportation systems, goods manufacturing, and others, that have also served as instruments to fulfil varied human needs while also leading to significant environmental impacts.

To little surprise when considering the challenges that climate change and intensive environmental disruption represent, political forces are shifting the focus of technology to solve sustainability-related problems (CambridgeIP, 2014; Rahimifard & Clegg, 2008). Then, it is especially important that technology creators know how to design *sustainable* solutions (Rahimifard & Clegg, 2008; Short, 2008). This is not a simple task given that defining *sustainability* per se has represented a huge challenge over time (Missimer, Robert & Broman, 2017), as the concept involves aspects of intra- and inter- generational equity, social justice, environmental protection, and economic development (Marsden et al., 2010; Allenby, Allen & Davidson, 2007). Since these aspects do not have objective definitions by themselves, and lack operationalisation (Allenby et al., 2007), the definition of sustainability has been qualified as vague (Missimer et al., 2017), ambiguous, and even, as a myth (Allenby et al., 2007).

While some literature attributes the link between technology and sustainability exclusively to environmental aspects (Anastas & Zimmerman, 2003; Rahimifard & Clegg, 2008), addressing them by the use of renewable energy and reducing pollution and waste; some academic authors claim the terms

[1] The author states that the probability that a person creates a technological solution is independent of the number of inhabitants, therefore, technological progress grows in proportion to population. From this perspective, if there are people, there is technology.

sustainable engineering or *sustainable technologies* call for more than solely environmental protection, and call technologists to consider also the social aspects of sustainability (Mihelcic et al., 2003; Allenby et al., 2007; Short, 2008). Thus, the lack of an operational definition for sustainability represents a problem for technologists, as they are "highly quantitative, both by inclination and by methodological choice" (Allenby et al., 2007, p.20), and usually, they are not specialists in sustainability (Short, 2008). Thus, the requirement to create technology that targets *sustainability* is also ambiguous; they "are left ignorant to what specifically implies for them" (Short, 2008, p.22). After all, they have to design products or manufacturing process to solve a certain problem, with the resources they have available (Allenby et al., 2007).

Descriptive guidelines on the assessment of environmental aspects of sustainability in technological applications (use of materials, energy, and pollution generation) are found in academic literature[2]. They are somehow easy to understand as some of them are operationalised (Allenby et al., 2007). However, there is a gap in the literature on how to direct the work of technologists to cover the social aspects, and, to cover both, environmental and social aspects together. Closing this gap of knowledge by providing more explicit directions for technologists, being them practitioners or students, is important to enable *better* technological development (Allenby et al., 2007), that is, a trajectory that is more likely to produce valuable social contributions and reduces impacts on the environment.

México is a country where recent reforms on energy aim to reduce the reliance on coal energy (SENER, 2016). Therefore, national directives are calling for the formation of more people in technology-related fields to achieve the transition to more sustainable energy systems (SENER, 2014). When considering the relevant social problems in the country, especially, the large number of population living in poverty (almost 50%) (SEDESOL, 2013), it is important that current and new technologists focus not only on designing renewable energy systems, but also, to make them accessible to the people that need them the most. Certainly, not only energy systems should be the focus of technology in this country, but also the other lacks that poverty involves. Thus, providing more tangible guidelines to students and practitioners in technology-related fields on how to create technology that considers environmental and social aspects of sustainability is important in this country, considering the environmental and social challenges it face.

[2] For example, *design through the 12 principles of green engineering* (Anastas & Zimmerman, 2003); *Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design* (Braungarta, McDonoughb & Bollingerc, 2007)

1.1 Thesis' aim and research questions

In this thesis, I seek to contribute to fill the gap of knowledge on how technologists could conduct their work to create technology (that is products or manufacturing process) that aim to target aspects of social and environmental sustainability, in the context of México. My research seeks to establish guidelines directed at Mexican students or practitioners in technology-oriented fields.

To achieve my goal, my research is separated in two steps:

First, I am studying academic literature that provides concrete guidelines directed at technologists on how to design sustainability-oriented technology. From this literature, I am summarising a set of guidelines that involve aspects of social and environmental sustainability.

And secondly, to provide validation to the guidelines, they are analysed against actual technologies in México that aim to solve sustainability-related problems. The objective of the analysis is to identify the practical challenges that arise when the guidelines are pursued, and to identify the factors that facilitate achieving the guidelines.

Hence, based on academic literature and the analysis of actual technological application the thesis seeks to answer these research questions:

RQ: What strategies can help technologists to incorporate environmental and social aspects of sustainability in the design process of technology?

Sub-RQ1: What guidelines directed at technologists can be summarised from academic literature that address aspects of social and environmental sustainability in the design process of technology?

Sub-RQ2: What are some possible challenges that arise when technologists follow the guidelines?

Sub-RQ3: What actions can be learned from the development of current technological applications that may help technologists to overcome the challenges or to follow the guidelines?

To initiate this work, I proceed with presenting in the following subsections a theoretical background on the terms and concepts that are used through the paper. The specifics on how the mentioned steps are conducted are provided in the methodology section.

1.2 What is technology and who develops it?

Here I present how I understand *technology*, important as this concept may refer to different objects and processes depending on ones' theoretical point of departure. This section also explains how technology emerges from science or human creativity. As this thesis uses examples of actual case studies of technology, it is important to explain why they fit in the concept of technology.

I start with the concept of science. Science can be categorised as pure or applied. The purpose of pure science is to investigate so something can be known (Feibleman, 1961), like knowing the internal structure of the human body, studied by anatomy. On the other hand, applied science is pure science that is applied; it "puts to practical human uses the discoveries made in pure science" (Feibleman, 1961, p.306). For example, while pure science studies the properties of a discovered material, it is until applied science finds an application for it that is considered beneficial for humans (Feibleman, 1961). Thus, pure science and applied science are connected and faded into each other: without the former, there would be nothing to be applied, and, the latter can stimulate further investigations in pure science (Feibleman, 1961).

In the field, there are pure scientists and applied scientists, and, a third type of person: a technologist (Feibleman, 1961). While the applied scientist follows theoretical hypotheses, the technologist, use skilled-based methods, like *hit or miss*, or merely experience. A technologist can understand the theoretical work of a pure scientist (if not too abstract), and knows how to apply what the applied scientist developed (Hughes, 2004). For example, a medical doctor acts as a technologist when he prescribes a drug based on the symptoms he observes in the patient and his knowledge on the drug's effects; but he does not necessarily know how the drug was synthesised, nor the properties of the substances used before its synthesis. Technology is then sometimes the step beyond applied science that puts something into practice. But, some other times, technology is simply the result of an accident (Feibleman, 1961). If we go back to the example of agriculture, it is noted that, millennia ago, it was not necessary the theoretical study of plants' reproduction to invent this technology. Hence, technologists, and the technology they develop, can or cannot be bonded to science, but they are always linked to solve a practical human need (Hughes, 2004). Certainly, a technologist that has better understandings of pure science or applied science, or both, has a greater potential to develop sound solutions.

Just as pure science and applied science, technology has purposes too. Technologists purpose is to improve technological developments, how to make them faster, or smaller. In other words, technologists constantly seek to make technology more efficient, providing a better solution with less energy or material.

Finally, it is important to mention another characteristic of technology: the relationship between technology and engineering. Feibleman (1961) explains that engineers are the perfect example of what technologists do. Engineers deal with all type of tools, materials, and situations to solve problems. Therefore, technology is sometimes attributed exclusively to the work of engineers (Hughes, 2004), but, as previously explained, any person, in any field, can perform as a technologist by applying experimentation, to solve problems or needs.

As it will be shown in section three, the case studies of technological applications that will be used to answer the research questions, fit the above-mentioned characteristics: their purpose is to solve a human problem or meet a human need. We will see that some of the people working on them perform as applied and pure scientists, as they study and test the properties of the materials they are using, to find their potential uses, but, at the end, they all act as technologists as their aim is to employ practically technology in a way that benefits humans.

1.3 Sustainability, technology, and eco-efficiency

Having touched upon the characteristics of technology, in this section, I would like to explain certain approaches to sustainability, relevant for this thesis, and their links to technology, based on academic literature. As mentioned in the first section of the introduction, the imprecise definition for sustainability has resulted in different approaches to the term. Explaining how technology is related to them broadly will introduce some terms that are used through the thesis.

I start with an approach to sustainability used in the business and industrial sectors, which is *sustainable development* (SD) (Huesemann, 2003). The term originated due to concerns for human negative impact on nature, and how it would affect future generations (Hopwood, Mellor & O'Brien, 2005). Thus, SD aims to address the conflict between human development and environmental welfare (Hopwood et al., 2005). In this view, human development is conducted through economic growth, so the income of the poor is improved. Hence, SD implies that there should be a continuing economic growth (as gross domestic product [GDP] per capita growth), while diminishing its effects on the environment (Hopwood et al., 2005). Supposedly, this could be achieved by increasing industrial activities and reducing their impacts on the environment through minimising resource's use, preventing emissions, and others (Mihelcic et al., 2003; Huesemann, 2003). These practices are known as *eco-efficiency*, and technology is what helps to achieve them by improving products and industrial processes so they reduce the use of raw materials and energy, and reduce waste and pollution (Huesemann, 2003).

Another approach to sustainability, relevant for this thesis, is strong sustainability (SS). In this approach, natural capital must be protected as it provides functions that cannot be substituted and are considered essential to human welfare (Dietz & Neumayer, 2007). The functions are: providing raw materials, assimilating waste, providing amenities, and providing essential life-support functions. To preserve natural capital, industrial production that depletes non-renewable resources must be avoided (Faran, 2010). Goods should then be manufactured with an appropriate durability, that is, avoiding practices like overdesign, and planned obsolescence, as such practices promote the unnecessary use of resources and waste creation. Technology's role is then, to enable the creation of products with such characteristics, and to promote the use of renewable energy and materials, to avoid resource depletion.

Going back to the term *eco-efficiency,* the two approaches to sustainability imply important differences for it. On the one hand, when used in the context given of SD, where industrial production should be increased to promote economic growth, eco-efficiency may have a negative connotation. According to some authors (Braungarta et al., 2007; Huesemann, 2003; Daly, 1990), in this context, eco-efficiency represents an attempt to minimise impacts on the environment, without addressing the root cause of the impacts. For example, improving the fuel consumption rate of automobiles may decrease the amount of emissions per automobile, but do not fix the problem of automobiles emitting carbon dioxide. Moreover, based on the automobile example, eco-efficiency is also criticised for creating technological lock-ins, because, by reducing the amount of resources needed, in this case, fuel, an economic incentive is created to continue relying on polluting technologies, as in this case, automobiles (Huesemann, 2003).

On the other hand, in the SS approach, which promotes the use of renewable resources and energy, eco-efficiency has a positive connotation. In this context, eco-efficiency implies using more effectively renewable resources and energy, which is desirable (Korhonen & Seager, 2008; Daly, 1990). Moreover, if eco-efficiency improves the performance of technologies that use renewable energies or materials, then it may contribute to breaking technological lock-ins, by diversifying the options of efficient technologies for consumers (Korhonen & Seager, 2008).

1.4 Aspects of social sustainability in México

Having covered some aspects of environmental sustainability in the previous section, here, I present some background information on the social aspects in México, as later, these aspects will be used to clarify the links between technology and social sustainability.

As mentioned in the introduction, a large number of population is living under conditions of poverty. Poverty in México is defined as the lack of nourishment, social security, basic utilities (water, sewage, electricity, and fuel), health services, quality housing, or education; or, when the income of a person is not sufficient to cover at least one of these essential elements (SEDESOL, 2013). National directives on social development prioritise the alleviation of poverty to improve national social welfare (SEDESOL, 2013). Vallence, Perkins, and Dixon (2011), present an approach to social sustainability named *development social sustainability.* In this approach, covering essential needs for society is a key aspect to achieve social development. However, other less tangible elements are also needed, like justice, equity, freedom, and distribution of power. The authors explain that, when people lack the basic elements, it cannot be expected that they care about climate change and other environmental problems. Thus, from this perspective on social sustainability, covering the basic needs of people living in poverty conditions is an indispensable step in achieving social sustainability. However, it is important to emphasise that the other less-tangible needs are also a requirement to achieve it. The *development social sustainability approach* is also observed in the UN´s Sustainable Development Goals (SDGs), which México has committed to implement since 2016 (UNDP, 2016). Therefore, national strategies are being conducted to achieve the targets, which involve covering needs that overlap with the ones mentioned above, for example, end of poverty, of hunger, improve health, ensure water and sanitation, and others (see appendix A) (UNDP, 2016).

2 Methodology

To provide answers to the research questions, my research is organised in two main steps.

First a literature review is conducted to look for academic literature that provide specific guidelines to address aspects of environmental or social sustainability, or both, in technology. The search engines used were LUBsearch and google scholar, and, the keywords used were "sustainability" and "technology" or "sustainability" and "engineering" or "technology" and "social sustainability". From this search, twelve articles (Thom, 1995; Anastas & Zimmerman, 2003; Huesemann, 2003; Mihelcic et al., 2003; Allenby et al., 2007; Davidson et al., 2007; Short, 2008; Segalàs, Ferrer-Balas, Svanström, Lundqvist, & Mulder, 2009; Davidson et al., 2010; Jamison, 2012; Haase, 2013; Little, Hester & Carey; 2016) were analysed. At the end, two were selected, Huesemann (2003) and Short (2008), as they provided *criteria* and *principles*, respectively, to achieve a certain approach to sustainability. The articles were studied and summarised, and specific guidelines were obtained, providing an answer to the first sub-research question. An overview of the articles is presented in the results and analysis section

Second, an analysis of case studies was conducted based on the two articles selected previously. The case studies correspond to technologies developed in México, that is, products developed in educational institutions or the private sector that attempt to solve a human problem or need. I labelled the products as *technologies* based on the theoretical background presented in section 1.2, where technology is defined as the result of humans applying knowledge based on science or experience to solve a practical problem or need. Given that I selected products developed recently, some of them are still in in the process of being tested or in research stage, thus, not available for public use yet. Table 2 presents a description of the selected products, indicating if they are still under test or if research is still ongoing.

The database from the Mexican National Council for Science and Technology[3] (CONACYT) was the source for documentation about the products. From this organisation's web repository, I listed the documents published from November 14th, 2016 to February 14th, 2017. This period was selected to ensure the products were recent. A total of 132 documents were listed (see appendix B). Then, a pre-selection was conducted. By analysing the documents' titles, those who did not state a focus on solving a sustainability-related problem[4] were discarded. After this process, a second list was created conformed by 63

[3] CONACYT is the official government agency that provides funding and keeps record of scientific-technological research and developments conducted in high level education institutions and the private sector in México.
[4] The United Nations Sustainable Development Goals (SDGs) were used to frame this selection.

documents. Using a random number generator[5], the documents were re-ordered and the first fifteen were the ones selected as case studies. Random selection was pursued to avoid any personal preference towards the problems addressed by the products, or my interest in the novelty of their techniques.

After studying the documentation on the case studies, I analysed them based on the two articles selected and against the set of guidelines obtained in the first step. Personal communication via email with the developers of the technologies was conducted to clarify aspects regarding their functionality or to obtain extra details on how the development of the product was conducted. The methodology *theory testing using case studies* framed the analysis of the cases (more details below). This analysis provided the answers for the second and third sub-research questions.

2.1 Rationale behind the methodology

The two main steps in my research are based on the methodology *theory testing using case studies* presented in Løkke and Sørensen (2014). According to the authors, this methodology is useful when the content of a theory needs to be grounded, and when learning from particularities of case studies is aimed. In this research, the articles selected from the literature review, Huesemann (2003) and Short (2008), are the theories to be tested in case studies. To qualify them as *theories*, I review the concept of that term. Doty and Glick (1994) state that a theory is a "series of logical arguments that specifies a set of relationships among concepts, constructs or variables" (as cited in Løkke and Sørensen, 2014, p.68). Similarly, Schutt (2009) defines theory as “a logically interrelated set of propositions about empirical reality…..that help us make sense of many interrelated phenomena and predict behaviour or attitudes that are likely to occur when certain conditions are met” (p.38). The perspectives from Huesemann and Short explains a certain approach to sustainability and from it, the authors formulate criteria and principles that should frame the process of designing technology. They claim that by following them; certain aspects of sustainability will be met. I consider these characteristics make these authors’ studies suitable as theories.

2.1.1 Specific details of the methodology

Løkke and Sørensen’s (2014) methodology provides guidelines on how to address specific tasks in the two main steps explained above. The authors indicate that from the selected theories, theoretical propositions are formulated. Theoretical propositions are sentences describing a certain relationship involving data

[5] Online random generator: https://www.random.org

that is looked for in the case studies (Yin, 2009). They help to decide what data from the case is important (Yin, 2009). Thus, from the two theories selected, I formulated theoretical propositions that indicate relationships between data I was looking for in the case studies, helping to frame their analysis. Also, the theoretical propositions helped to create the guidelines that answer the first sub-research question. In the results section, the two theories selected, the theoretical propositions, and the final guidelines are presented.

Løkke and Sørensen (2014) also highlight the importance of internal and external validity of the research. These steps are important to increase the credibility of the research (Yin, 2009). Internal validity is conducted to avoid formulating incorrect causal relationships (Yin, 2009). In this research, the case studies are used to validate the theoretical propositions from the theories selected. When the propositions are not met, or are met with special singularities, possible explanations are provided. On the other hand, external validity deals with the correct generalisation of findings, so they are applicable to other case studies (Yin, 2009). In this research, this type of validity is not conducted. It would be needed to observe how technologists use the guidelines proposed during the process of designing technology to find out how useful they are for them.

2.1.2 Justification for the location selected and number of case studies.

The case studies selected to test the theories are examples from México. While this country is not a leader regarding scientific research (ranks 28th in produced publications by country globally) (SCImago, 2015), it has educational infrastructure to conduct it. Since the late 1950's it has created specialised national centres to develop science and technology (Stanford, 2010). Being a developing country, many of the technology developed here aims to target social problems and to create sustainable energy systems (Molina, 2013). Such developments are created with the socio and environmental stresses inherent to the country, for example, constraints on arable land and a large number of population living under poverty (SEDESOL, 2013). Hence, I consider technology developed in México is a good example of how a developing country tackle problems of social and environmental aspects of sustainability.

Regarding the number of cases selected, Løkke and Sørensen (2014) propose that the more cases are studied, the more characteristics are to be analysed, obtaining more learning. They suggest that when the number of theories to be tested is small, choosing more case studies is a good practice as the theories can be analysed in different conditions and contexts. Since my research tests two theories, then, a higher number of case studies was selected. I considered fifteen was a number that could provide examples of technologies targeting problems in diverse areas, covering different settings and conditions in the national context.

2.2 Ontology and Epistemology

My research presents an interpretive methodological approach, which implies a relativist ontology and a subjectivist epistemology (Scotland, 2012). I selected theories presented by academic authors who present their own understanding on the relationship between sustainability and the process of creating technology, having certainly also, their own definitions for those terms. By analysing these theories, taking an inductive approach (Scotland, 2012), I constructed theoretical propositions and guidelines, which present my own perspective on how the creation of technology relates to social and environmental aspects of sustainability. To create my own perspective on these relationships, I reviewed theories on the definition of technology, social and environmental aspects of sustainability. The testing of theories using case studies is based on qualitative data: descriptions of the developers that state how the technologies work, the type of materials they require, the type of energy they use, and the objective they are pursuing.

3 Results and analysis

3.1 Theories

The theories selected, Huesemann (2003) and Short (2008), take different positions regarding the use of technology and its results. Huesemann, an American author, uses a critical approach (Jerneck et al., 2011) for his research. He considers technology has been applied wrongly because it has focused only on improving eco-efficiency to foster industrial production. Short, an English author, uses a problem-solving approach (Jerneck et al., 2011) and proposes a way to design technology focusing on customer's expectations. This section presents an overview of the theories.

3.1.1 The limits of technological solutions to sustainable development (Huesemann, 2003)

Huesemann's paper discusses the relationship between eco-efficiency and sustainable development (SD). The author takes the definition of SD from the political and business sectors, where eco-efficiency is considered the ultimate tool to achieve economic growth and environmental protection.

Huesemann advocates for achieving strong sustainability (SS), and, argues that, technological improvements in eco-efficiency are not helping to achieve it, even worse, such improvements make the transition harder to reach, because, a continuing economic growth is an unsustainable end by itself, any means that is used to achieve it will foster unsustainability. In this case, any advancement in technology and eco-efficiency used as means to achieve the SD goal, that is, economic growth combined with environmental protection, lead society farther from true sustainability.

The author states that, in order to have a sustainable economic system, that is, one that ensures that economic activities last perpetually, industrial processes and products should meet two requirements that are based on the principles of SS:

1. Raw materials used to produce goods and energy sources must be renewables, and their supply rate must not exceed the rate at which they regenerate in their ecosystem. Nor the supply rate must cause secondary negative effects in the environment.

2. In the same way, the release rate of by-products from industrial systems or energy production must not exceed the assimilation capacity of the ecosystem where they are unleashed.

The first requirement ensures that there are always inputs to fulfil industrial processes. The second requirement guarantees the environmental safeness of the ecosystems that receive the waste from economic activities. Recycling is then considered a practice that could delay environmental impacts while the industry moves into fulfilling the above-mentioned demands. This is because recycling could diminish the rate at which non-renewables are depleted and, at the same time, decrease the amount of waste released to ecosystems. If, waste is to be released, ideally, it should be non-toxic and biodegradable, or biologically inert. Huesemann presents figure 1 to show two flows of economy that highlight different ways to use materials and energy.

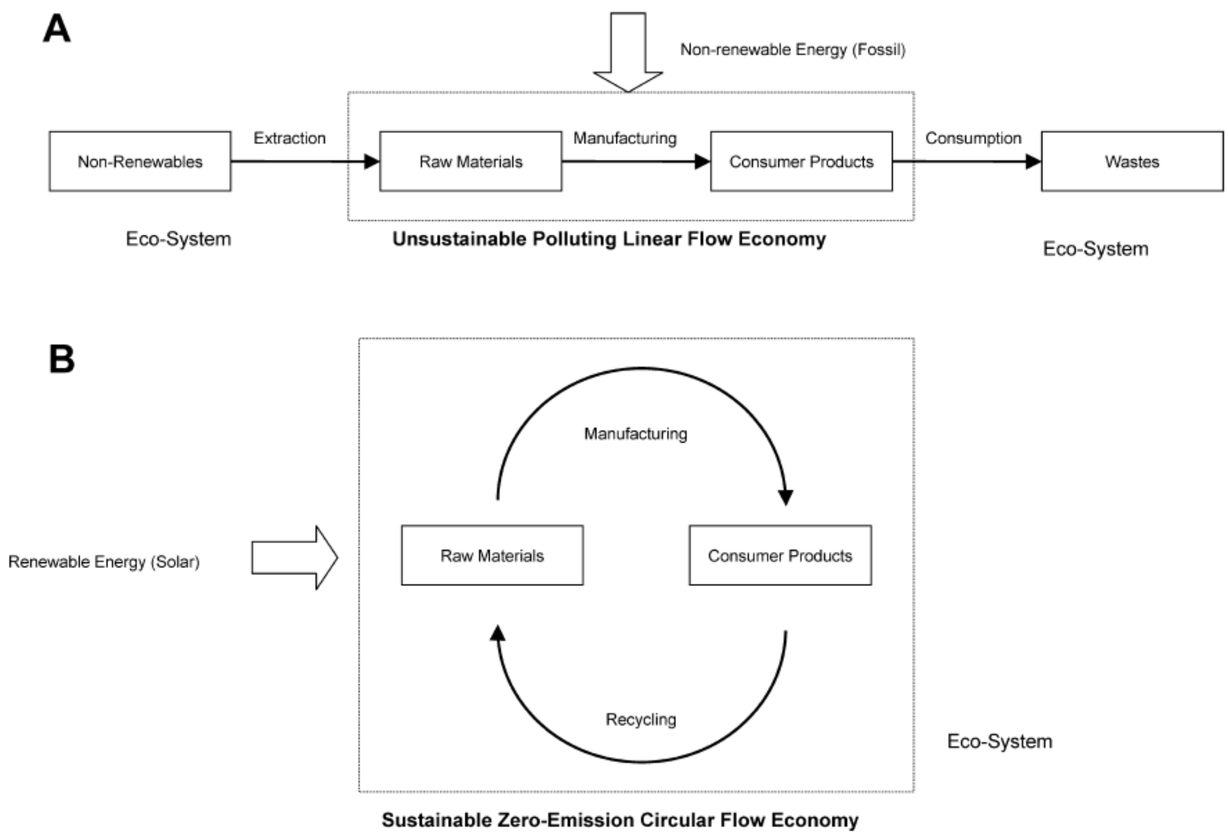

Figure 1. Linear and circular flows of economy that show different approaches in the use of materials and energy. In the linear flow (A), goods are considered waste after consumption and are disposed. In a circular flow (B), after consumption, goods are reintroduced in production systems as raw materials using recycling techniques. Source: Huesemann, 2003.

In the first one (A), products after consumption are considered waste, and end up in ecosystems, and, in the second one (B), recycling comes after consumption, and recycled materials are inputs to new processes, creating a circular flow. Therefore, recycling delays the release of materials into the environment. However, he emphasises that all materials do not have the same technical facility to be recycled (see table 1), and because of this, closing the flow of materials is not feasible always. Therefore, the use of renewable materials is preferable.

Table 1. Classes of materials based on their potential to be recycled. Adopted from Huesemann, 2003

Class of non-renewable material	Recycling technically feasible	Examples
I	Yes	Most industrial metals and catalysts
II	Yes	Packaging materials, refrigerants, solvents, etc.
III	No	Coatings, pigments, pesticides, herbicides, germicides, preservatives, flocculants, antifreezes, explosives, propellants, fire-retardants, reagents, detergents, fertilizers, fuels, lubricants, etc.

3.1.2 Sustainable engineering, confusion and consumers (Short, 2008)

Short attempts to provide a definition for sustainable engineering (SE) and its implications for engineers, being them practitioners or students. Short uses the triple bottom line to explain the concept of sustainability, that is, economic, social, and environmental pillars which overlapping area constitutes SD. In the context of engineering companies and the products they create, the entire commercial spectrum should be analysed to understand their relationship with SD. The commercial spectrum is defined as: the product, the product line, the company, and the planet. Hence, when Short compares the spectrum with the triple bottom line of SD, he concludes that the design of the product should consider aspects of environmental sustainability, but also, it is important to ensure the economic sustainability of companies, and this is achieved through constant products' sales.

Thus, the author defines SE as: "engineering that targets sustainable development", engineering that ensures "the sustainability of the entire commercial spectrum, from product to planet, across the triple bottom line …" (p.24). Moreover, he states that SE is a comprehensive way of engineering that comprises the variety of concerns that are associated with sustainability, for example, renewable energies, climate change, and important social problems, like hunger or lack of clean water and sanitation.

Short considers that products play a role in the society where they are produced. Then, he uses the millennium development goals (MDGs) (see appendix A), predecessors of the SDGs, as a framework to define if the role of a product is aligned to SD. He uses the example of a solar powered water pump and explains how its role could fit with the MDGs. For example, the water provided by the pump can be used to grow crops, fitting goal 1 “eradicate extreme poverty and hunger”, and, by providing clean water, it fits also goal 5 “improve maternal health”. Short explains that the MDGs should be kept in mind when engineers design products, as products fitting them contributes towards SD.

But, besides explaining the role of products in SD, Short also develops six principles that underpin SE. The objective of the principles is to clarify the meaning of SE for engineers and engineering companies that intend to design sustainable products (see Appendix C). The principles emphasise that considering only environmental sustainability when engineers design products is not enough, because, only 20% of consumers eagerly look for *eco-friendly* products (Joyce et al., 2004, as cited in Short, 2008). Short considers this percentage as insufficient to sustain the product line of eco-friendly products. He states that low sales are due to the lack of functionality and quality that eco-friendly products offer, like recycled tissue that is not as soft as regular tissue, or electric cars that cannot run as fast as gas cars. Therefore, he states that, if products that aim to be sustainable do not offer the functionality or quality that customers expect, based on what the most popular products offer, the products will not be preferred by the public. Therefore, identifying the expectations of consumers is a key step, but, this not an easy requirement as consumers sometimes are not truly aware of their wants. The author emphasises that when the focus is not the consumer, technological solutions misses their purpose, for example, solar water pumps that cannot provide water in the evening.

3.2 Constructing guidelines

As explained in the methodology section, before getting a set of guidelines, theoretical propositions are constructed. These propositions are useful to explain and clarify the relationships highlighted by the authors between technology and environmental or social aspects. With the help of these propositions, the set of guidelines is constructed. Later, these propositions frame the analysis of the case studies.

3.2.1 Theoretical propositions

From Huesemann’s work, I formulated one theoretical proposition that emphasises the use of technology to improve the efficiency in the use of resources that contribute to achieve strong sustainability. These are, according to Huesemann, renewable energy and materials. However, given our current reliance on non-renewable resources (Steinbach & Wellmer, 2010), the proposition also states that the use of recycled materials helps to increase the eco-efficiency in the use of resources. This is because, using recycled materials as inputs in new products’ manufacturing processes, helps to create a circular flow in material’s use, diminishing the extraction of raw materials (figure 1B). The same way, the proposition highlights that using technology to conduct practices that decrease waste creation is important. The theoretical proposition is then: *Technology contributes to increase the eco-efficiency of resources that help to transition to strong sustainability. These are: renewable energy, and, renewable or recycled materials used as inputs. Additionally, technology facilitates the refreshment, reparation, or recycling of products, which diminish waste creation.*

In this proposition, the term eco-efficiency has the good connotation explained in section 1.3, where it refers to using more efficiently resources that prevent pollution and waste. In the analysis of case studies presented in section 3.3.2.1, I explain what specific use of resources is assessed when analysing this proposition in the case studies, depending on the area where the products locate (energy, human health, transportation, etc.). This is because products in different areas target different problems, therefore, it is necessary to specify what use of resources in each area is being assessed to provide a more structured analysis.

From Short's work, the theoretical proposition formulated is: *products that aim to be sustainable should offer the same or better functional features than other alternatives.* Short describes functionality as the features that the user is expecting from a product, based on comparisons with the most consumed products. For example, customers expect that electric vehicles reach the same speed as gas-powered vehicles. This is important because only a small percentage of population seeks eco-friendly products, and, to increase this percentage, Short suggests that products that aim to be sustainable should offer the same or better features than popular products. When analysing the case studies, I selected a functional feature that I assume customers are expecting from products, depending on the area that the products are covering. This way, the analysis is based on the same functional feature in each area. in section 3.3.2.2 I explain what specific feature is assessed per area.

3.2.2 Guidelines

Based on the previous proposition and other remarks presented by Huesemann (2003) and Short (2008), I conclude the next aspects should be considered by technologists when designing technological applications, in the context of México.

First, an objective of technology should be set. Based on the idea of Short of aligning the purpose of products towards sustainability (in his research, the MDGs), I suggest that technologists set first an objective for the technologies they create, pointing their work to solve the most salient problems of social sustainability in México. To achieve this, the social problems reviewed in section 1.4, according to the approach of *development social sustainability*, could be used as the framework to determine what problems and needs technology should focus on.

And second, I suggest that technologists should pursue their designs have four ideal attributes, which are based on the theoretical propositions mentioned above. These attributes are independent from the objective, so they should be pursued regardless of the objective set. They are considered *ideal* because, even if they are wanted, given the current difficulties or lack of technological development in the use of materials and energy (emphasised by Huesemann's theory), they may not be achievable, but, they could be met partially. The aspects are listed in the right side of figure 2.

Eco-efficiency is then desirable, as it would help to improve the use of renewable resources and to diversify technologies based on these resources, breaking technological lock-ins (see section 1.3). Figure 2 shows a scheme that represents the guidelines suggested:

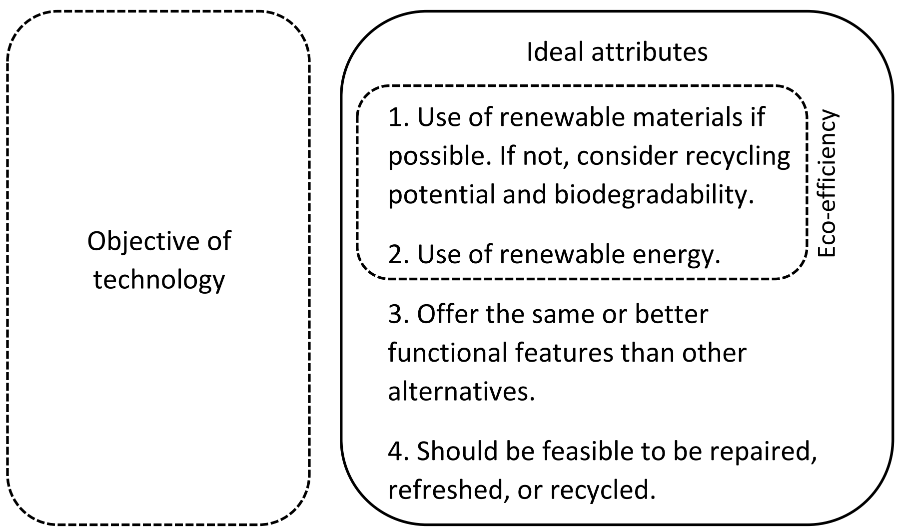

Figure 2. The conclusions from the analysis of Huesemann (2003) and Short (2008) are summarised in this scheme. The scheme suggests that technologist should have an objective in mind when they are creating technology. This objective could be oriented to solve the lacks that define poverty in México. It also suggests that technologists should pursue they products they design have some attributes, regardless of the objective set. These attributes indicate the type of materials and energy according to the criteria to meet SS, emphasise the importance of good functionality to increase public acceptance, and the importance of delaying the end of life of products.

3.3 Analysis of case studies

Following the methodology explained in section 2, I use case studies to analyse the theoretical propositions summarised in the previous sections. From this analysis, I expect to find the challenges that technologists may face to meet the ideal attributes during the design process of technology, and learn actions that help to overcome the challenges.

3.3.1 Case studies selected

In this section I present an overview of fifteen technologies developed recently in México (from November 2016 to February 2017). As explained in section two, technologies refer to products developed by researchers in the academic or private sectors, that aim to solve a problem. In the case studies, the products target social and environmental problems. They are grouped in five categories: energy, human health, housing and construction, transportation, food, and ecological conservation. Table 2 present a short description of the products. The table also indicates the potential the products have to meet the above mentioned theoretical propositions (TP). The details of the analysis are presented in sections 3.3.2.1 and 3.3.2.2, where each TP is evaluated in the products, provided more information about why the potential is high, medium, or low. The ID assigned to each product is used as a reference in the upcoming sections.

Table 2. Case studies per area (Aldecoa, 2016; Cacelín, 2017b; Gatica, 2017; Gómez, 2016; Guerrero, 2016; Narváez, 2016; Navarro, 2016; Pérez, 2017; Sánchez, 2017; Sánchez, 2016a; Sánchez, 2016b; Sánchez, 2016c; Valencia, 2016).

Product (Place and date of publication)	ID	Description	Potential to meet theoretical propositions	
			TP #1	TP #2
Energy				
Safer nuclear fuel Chihuahua Feb 10, 2017	A1	Scientists are studying the encapsulation of uranium-based nuclear fuel used in energy plants. The encapsulation is done at a very low physical level: each uranium dioxide (UO_2) particle is covered in layers of carbon and silicon materials. When the fuel's fission occurs, the encapsulation avoids that the radioactive particles generated get dispersed, staying trapped inside the capsule. Specifically, the scientists involved in this research are trying to improve the properties of the materials that encapsulate the nuclear fuel, to ensure they resist the high temperatures that may occur in a nuclear accident.	LOW Does not increase energy conversion, nor diminishes nuclear waste produced.	MEDIUM Less intermittency than solar and wind, but still, intermittent due to system failures and maintenance.
Low-cost solar water heater Campeche Dec 25, 2016	A2	Researchers from the private sector, together with academic researchers, designed a low-cost water heater which is already in production. Like the metal-based designs, this heater is installed on the roof of houses. The difference is that the tubes through which the	MEDIUM Less heat loss than metallic alternative. Could be recycled at	MEDIUM Solar radiation intermittency affects

		water circulates are made of thermoplastics. The diameter and length of the tubes were carefully calculated to warm up the water quicker. The heater is complemented with a thermoplastic tank where heated water is stored. The tank has the capability to keep the water at 50^{o}C for five days. Another advantage is that its manufacturing process is nine times faster than the metallic alternative.	end of life, but this is not confirmed as product has just been launched	service provided.
Graphene-based solar cells Chihuahua Dec 6, 2016	A3	Scientists are studying graphene's properties with the aim to learn how to improve its efficiency in converting solar energy into electricity. Also, they aim to build a solar cell that is 100% built with graphene-based materials. This aim requires significant effort and time, as they have to figure out how to reproduce all the parts of a solar cell with these new materials. Solar cells based on graphene would be semi-transparent, flexible, light, and cheap. Such characteristics are an important advantage over the cells based on silicon.	LOW Energy conversion still in research stage. Manufactured with non-renewable material.	
Microalgae-based biofuel Baja California Sur Nov 16, 2016	A4	Scientists are developing a pilot biodiesel plant that is produced with microalgae. Microalgae accumulate lipids in their cells, which can be transformed into fuels. The process involves different stages. First, microalgae are grown in urban black water in a photobioreactor. Then, they are harvested and lipids are extracted from them. The lipids are processed to obtain the fuel. The scientists intend that the plant runs exclusively on solar energy. Part of the solar energy collected will be used to keep the photobioreactors working at night. A challenging part of the project has been the selection of the species of microalgae as the objective is to select algae that produces the highest amount of lipids and that resists the high solar radiation in the region.	MEDIUM More fuel is obtained per kg of biomass compared to crops. Energy to run plant will be renewable. Pilot plant not ready yet.	

Human health

Motorised walker for children's rehabilitation México City Feb 09, 2017	B1	Academic researchers developed a walker to assist children during leg rehabilitation. The developers added electric motors to a traditional walker that are controlled wirelessly. This avoids the need for the care-taker to push the walker when the child is in it. Instead, the care-taker can help the child to move the walker from distance. This device's	LOW Introduce use of electric devices	NA Products' functional features are specially designed to meet users' necessities,

		main purpose is to avoid the care-taker suffers severe back pains or injures, a condition that was observed by one of the researchers in a rehabilitation centre.		but comparison with other alternatives is not feasible.
Autonomous wheelchair Germany[6] Nov 30, 2016	B2	Academic researchers are developing a wheelchair that adapts technology created for autonomous (self-driving) cars. The user indicates what part of the house he or she wants to go and the wheelchair self-drives to that point. Video-cameras, radars and processing units allows the chair to move around a house's interior avoiding obstacles. The researchers are now improving the system so it navigates safely in an urban setting.		
Acoustic aid device for people with blindness Nayarit Nov 17, 2016	B3	High school students are developing a device to assist people with blindness. The device consists on a video-camera, a speaker, and an image processing unit. The images captured by the video-camera are processed by algorithms that translate images to literal descriptions. Then, the descriptions are told to the blind person through the speaker. The device should be carried by the blind person so he or she gets the descriptions while walking. The students have already a functional device, but they are trying to make it smaller, lighter, and wireless so it is portable.		

Housing and construction

Cement-like material based on anhydrite México City Feb 12, 2017	C1	Researchers from the private sector created a cement-like material which is based on a waste from the hydrofluoric acid[7] production industry. The material has similar strength to conventional cement and has better acoustic and thermal isolation properties. The company that patented this material also invented a system to speed up the process of house construction in rural areas. The system consists on the use of a house-shaped mould that can be dismantled for its transportation. Once put together, it is smeared with the cement-like material. The material dries and the mould is removed. The process can be conducted by the community inhabitants as it does not require previous knowledge on house construction.	HIGH Require less energy to be fabricated than cement. Anhydrite is waste from other industry.	HIGH Mechanical properties comply national standards.

[6] Mexican PhD students are working in this development in Berlin.
[7] The hydrofluoric acid is used mainly to produce refrigerant gas

Plant-based concrete additive Queretaro Jan 16, 2017	C2	Academic researchers studied the properties of opuntia (a type of cactus) mucilage to apply it as a concrete additive to increase its durability. As opuntia has calcium, the researchers were interested in its potentials as construction material. When adding it to concrete, they found out that the mucilage inhibits concrete's corrosion and pitting. The researchers are conducting mechanical tests on concrete added with mucilage to find how it affects concrete's properties. Given that opuntia is easily grown in México, the objective of the research is to spread its use in the construction industry.	HIGH Product is renewable. Decreases need for concrete's reparations.	MEDIUM Mechanical properties research in progress. So far, results show product improves properties.
Brick based on urban waste México City Dec 01, 2016	C3	A group of undergraduate students are developing a brick based on urban solid waste and recycled plastics. With this development, the students aim to create a brick that is lighter than conventional bricks and that involves less GHG emissions during its manufacturing. They claim that the high weight of conventional bricks makes its transportation more expensive, and this elevates the costs of construction. Thus, this alternative is more accessible from an economic perspective. They also claim the block resist water and humidity better than conventional alternatives. The students are conducting mechanical tests to the brick to make sure it complies with the national standards on construction.	HIGH Require less energy to be fabricated than cement Input material is waste.	MEDIUM Mechanical properties research in progress. So far, tests show compliance.

Transportation

Products to improve metro services México City Dec 08, 2016	D1	A large group of researchers from different institutions are working to develop diverse technologies that provide the maintenance of the metro system in México City. The metro system used to rely exclusively on the import of mechanical and electrical components to support its functionality. Recently, the supply of these components has been compromised as the foreign manufacturers have discontinued the fabrication of components that the metro needs. To address the lack of components, Mexican authorities have facilitated the creation of three laboratories in which research on materials, mechanics, electronics, and more will be conducted. The aim is that these laboratories, together with other research institutions provide the	HIGH Public transportation is more eco-efficient than private.	HIGH Improves service by providing extra wagons and trains' scheduling

		full maintenance for the metro, by manufacturing the components that were imported before. Also, it is planned that the service to the users is improved by scheduling the arrivals and departures and by adding wagons to the trains.		
Mobile app for public transportation Sinaloa Dec 10, 2016	D2	An entrepreneur developed a mobile application that provides information about Culiacan's public transportation routes. While these apps are popular in developed countries, in Mexican cities are not used as public transportation is not scheduled. This app overcomes the problem by using geo-localisation in the buses. In this way, the app reports how far a bus is from the user. The entrepreneur received support from the private sector so she can expand the app to other cities in the state of Sinaloa. She aims to expand the use of the app to all the country with the objective of improving the public transportation service everywhere.	HIGH Public transportation is more eco-efficient than private.	HIGH Improves users' experience by providing location of buses.

Food

Fungi-based hormone used as crop controller Coahuila Nov 30, 2016	E1	Academic researchers studied a fungus[8] that affects cacao crops to use it in other crops (like tomato, garlic, and onion) as biological control (biocontrol). The researchers isolated the fungus from cacao plants in the field. Then, it was taken to the lab where it was fermented. The products from the fermentation were studied and isolated. One of the products, a vegetal hormone, was then applied to other crops in a greenhouse. The vegetal hormone increased the growth rate of the crops and improved their immune system. Application of the product in greenhouses has produced healthy vegetables. The researchers are now working on finding an optimal way to apply the hormone to open fields, as some factors like air humidity can affect its concentration.	MEDIUM Replaces agrochemicals. Product is renewable. Research ongoing to expand use.	MEDIUM Product applied in greenhouses produces healthy products, research aims to enable application in open fields.
Biosensors to keep comestibles nutritious Coahuila Dec 14, 2016	E2	Researchers are using small food-shaped devices (e.g. pea or bean shapes) called biosensors, to know more about the properties that the food keeps or loses during the thermal processes in their manufacturing. The biosensors are devices conformed by enzymes inside a plastic capsule. These devices are	MEDIUM May help to reduce energy use during food production if food is	HIGH Product's main aim is to improve nutritional content of food.

[8] *Botryodiplodia theobromae*

		mixed with raw food that is going to be taken into thermal processes to kill pathogens (like pasteurization). The devices then, pass through the same heating and cooling processes as the food. When the processing finishes, the enzymes are studied, as they provide important information about the pathogens and nutrients present in food, and how they change their concentration over time. The researchers argue that often, food is over or under cooked in the industry, and with this, nutrients are lost, or pathogens are not eliminated. By studying the information provided by the biosensors, the researchers can find the optimal time and temperatures at which food should be submitted to keep it nutritious and safe for consumers.	overcooked, otherwise, energy use increases. Enzymes are a renewable resource.	

Ecological conservation

Genetic modified orchids Yucatán Jan 11, 2017	F1	Academic researchers aim to preserve endangered orchid species using synthetic seeds. Such seeds are created by the artificial encapsulation of an orchid embryo, which later produces seeds. First, the researchers collected orchids' embryo samples in the field; then, they took them to the lab to produce seeds. In the lab, they also add substances to the seeds that can help the orchid to control pathogens during its lifetime. The researchers look to propagate the improved orchids in natural habitats, and to increase the number of orchid species in their lab bank. Additionally, they aim to reproduce widely the most popular variations to help the ornamental sector to increase their sells and exports.	HIGH The SS approach emphasises importance of preserving species.	LOW Compared to other practices to preserve species, like habitat conservation, this product has less potential to offer ecosystem services.

3.3.2 Analyses of theoretical propositions in the case studies

In this section I present the analysis of the theoretical propositions in each of the technologies studied.

A summary of the main challenges found and the learnings is presented in section 3.4.

3.3.2.1 Proposition #1. Technology contributes to increase the eco-efficiency of resources that help to transition to strong sustainability. These are: renewable energy, and, renewable or recycled materials used as inputs. Additionally, technology facilitates the refreshment, reparation, or recycling of products, which diminish waste creation.

Most of the products analysed aim to improve the efficiency of renewable or recycled resources, and, some of them try to reduce waste creation. Most of them also diversify the technological options available to the public, contributing to break technological lock-ins (see section 1.3). Table 3 analyses how the products per area increase or not the eco-efficiency in the use of certain resources:

The products in energy are analysed based on how they increase the efficiency in energy conversion, that is, decreasing losses when transforming one type of energy into another, when compared to products carrying out the same energy conversion to provide a service, for example, providing hot water.

In human health, eco-efficiency is assessed by analysing the type of resources that are being used to create these products. In the case of the examples presented, they introduce the use of electronic devices, which consist in metals, minerals, and plastic (Kumar, Holuszko & Espinosa, 2017).

In housing and construction, to analyse how eco-efficiency is improved, the products are compared to the use of cement. Cement manufacturing is considered to have a large carbon footprint as it produces 5% of annual CO_2 emissions globally (Crow, 2008). This is because the manufacturing process is energy intensive, and, because of the CO_2 release from the calcination process that occurs during manufacturing[9]. Therefore, the products are considered eco-efficient if they reduce the reliance on cement.

In transportation, the proposition is not easily evaluated as the transportation system in México, public and private, relies mainly in fossil fuels, which are a non-renewable source of energy. Therefore, these products are assessed depending on how they help to reduce the energy used per user of a transport.

In the food category, the proposition is assessed depending on how the product contributes on reducing the use of energy to produce food. Also, it is evaluated if the source of the product is renewable.

Table 3. Analysis of proposition #1 per category

Category	Analysis
Energy	In the energy sector, three of the products achieve or expect to achieve larger renewable energy conversion percentage, when compared to other alternatives. The solar water heater (A2), offers an improvement in eco-efficiency as its collector's design allows a quicker transformation of solar radiation into heat. This means that less heat is lost during energy conversion. Additionally, the thermotank stores this thermal energy in water longer than the metal-based version. Other benefits are that the collector and tank can be manufactured with recycled plastic, and that the company claims they will collect them at their end of life to recycle them (J. Diaz,

[9] Cement manufacturing requires taking raw materials to about 1400 °C. Also, during manufacturing a chemical reaction occurs that transforms $CaCO_3$ to CaO, releasing CO_2 (Crow, 2008).

	personal communication, March 3, 2017). However, as the product has just been introduced in the market, it is not possible to determine if the recycling practices are going to be indeed performed. Regarding the research on graphene (A3), it has the aim of improving graphene's physical properties to achieve a greater energy conversion percentage, from solar radiation into electrical energy, than silicon-based cells. Given that the development of this product is still in research stage, and, that graphene is a recently discovered material (in 2010), it is not possible to determine if recycled graphene can be used as input material to manufacture new solar cells. Biodiesel production from microalgae biomass (A4) is more eco-efficient than crops' biomass when considering fuel obtained per mass harvested (Posten & Schaub, 2009). This biofuel's manufacturing will offer the additional advantage of using black water as an input material. As the pilot plant is not completed yet, it is not possible to determine if it will be feasible to run the plant solely on solar energy, as the harvesting of microalgae is an energy intensive process (Borowitzka & Moheimani, 2013). Finally, the research on nuclear fuels (A1) aims to create a fuel which waste will be safer to store; however, there are not improvements in eco-efficiency as the new fuel is still not renewable, it does not affect the efficiency in the conversion from nuclear energy to electricity, and, the amount of nuclear waste produced is not reduced.
Human Health	The three product examples targeting human health problems introduce the use of electronic devices (like electric motors, sensors, video cameras and processing units) to substitute functionalities of the human body. As the proposition indicates, eco-efficiency refers to using more efficiently renewable energy, and, renewable or recycled materials, and, electronic devices consist mainly on resources which are not renewable, like plastic, mineral, and metals (Kumar et al., 2017). Moreover, only a very small percentage (15%) of electronic devices are recycled (Kumar et al., 2017), and the not recycled waste is considered a potential hazard for the environment and humans, given their content of heavy metals that pollute soil and water (LeBel, 2016). Even their recycling process represents a problem for human health because of the toxic fumes generated when the waste is burned (LeBel, 2016). These issues make these three products having difficulties to be considered as eco-efficient.
Housing and construction	The three cases of technologies in construction involve improvements in eco-efficiency as they contribute to reduce the use of cement. The use of substitutes for cement, or additives that increase its durability, are essential in reducing the carbon footprint of cement manufacturing (Crow, 2008). In the first example, the anhydrite's preparation to use it as construction material (C1) produces eight times less CO_2 emissions than the fabrication of conventional cement (Sustpro, 2011; D. Davila, personal communication, February 21, 2017). Also, the construction system invented by the researchers offer the additional advantage of diminishing the amount of materials and transportation needed to build houses in rural areas. This represents savings on fuel use and emissions. In the second technology (C2), the use of opuntia mucilage to improve concrete's durability diminishes the need for concrete's reparations with more cement[10]. In the third example, the manufacturing of a brick based on urban waste and recycled plastics (C3) eliminates the use of cement as main material. The researchers claim this brick's manufacturing requires less energy compared to cement-based bricks as it does not require taking the input

[10] Cement is the main ingredient of concrete (Crow, 2008)

	materials to high temperatures. There are additional advantages in these products. In the first and third examples, anhydrite, and urban and plastic waste, are materials being recycled and used as inputs. In the second example, opuntia is a renewable material; moreover, the mucilage can be obtained from opuntia's waste (A. Torres, personal communication, February 21, 2017).
Transportation	In the field of transportation, the two technologies presented promote the use of public transportation. When energy use per user is considered, public transportation is eco-efficient as less energy and emissions per person are produced when comparing with private transportation (Sinha, 2003). In the first example shown (D1), products developed to sustain the maintenance of the metro system secures its subsistence. In the second example (D2), the mobile app has the potential to increase the schedule coordination of urban public transportation, which in consequence, may have the side effect of increasing the number of users (Newman, 2012), or at least, keeping current users satisfied with the service, avoiding they pursue private transportation.
Food	The first technology in food, the fungi-based hormone (E1), can fit in the proposition as its use replaces the use of pesticides and fertilisers, which represent savings on non-renewable materials, like minerals, and energy that they require to be produced (Worrell et al., 2000). This technology offers additional potential benefits, like being based on a renewable material, and, decreasing the soil and water pollution agrochemicals generate. Also, the researcher that developing this product claims the by-products generated during the hormone production are not harmful to the environment (E. Laredo, personal communication, February 25, 2017). The second example (E2) has the aim to keep food as nutritious as possible by optimising its thermal processes timing. Thus, energy savings may come as a side effect if it is found that food is overcooked during its production, which would result on reducing the duration of thermal processes which require energy use (A. Robledo, personal communication, February 27, 2017).
Ecological conservation	The assessment of this product is not straightforward. While not improving the efficiency in the use of renewable or recycled materials, or energy, still, the product is considered to be aligned with the proposition based only on the objective it pursues, as conservation of species is an essential element in the SS approach (see section 1.3).

3.3.2.2 Proposition #2. Products that aim to be sustainable should offer the same or better functional features than other alternatives.

This proposition emphasises the importance of customers' experience with products that aim to be sustainable. Thus, to simplify the analysis, I selected functional features that I assume users are expecting to obtain from products. Such features are different for each area:

In energy, the products are analysed based on the intermittency of the service they aim to provide. In energy sources, continuous energy supply is an important feature to offer as it ensures the user will be able to use services energy provides whenever they are needed. Contrary to solar energy, fossil and nuclear energy sources may be considered more reliable as generally they do not depend on weather conditions to be available (Lovins, Sheikh & Markevich, 2009)[11].

In human health, the products are designed to overcome specific disabilities in the human body. In these developments, functional features refer to the way these products tackle the disabilities they are focusing on. For example, in the acoustic aid device (B3), blindness is compensated by video cameras and processing units that provide the function of transforming images into words that are transmitted to the user.

In the analysis of products in housing and construction, functional features refer to the mechanical properties of materials that are required to ensure they will provide a reliable infrastructure. In México, national standards exist for these properties; therefore, if the products studied comply with these standards, it is assumed that they offer the same functional features than other alternatives.

In transportation, the two examples target the public transportation sector, therefore, the analysis considers how the products will enhance the service for users.

In food, the functional feature assessed is the capacity these products have to produce nutritious food. It is assumed that customers expect to have more nutritious and healthy foods[12].

In ecological conservation, similar to the first preposition, the assessment of the second one is not straightforward. However, I considered that ecosystem services (explained in section 1.3) could be the functional feature used to assess this product. This enables the comparison with a different conservation practice, which is habitat conservation. Table 4 presents the analysis in all the categories:

Table 4. Analysis of proposition #2 per category

Category	Description
Energy	The solar water heater (A2) compared to a gas-based alternative could interrupt the supply of hot water in a series of cloudy days. The graphene-based solar cells (A3), would also be less reliable than electricity supplied by fossil fuels on adverse weather conditions. The production of microalgae biodiesel (A4) also depends on solar radiation, as this affects algae growth (Posten & Schaub, 2009). Therefore, these

[11] These authors highlight that none energy supply is completely reliable as unexpected failures may occur in all energy systems.

[12] This assumption is based on information provided by the developer of the biosensors (E2) through personal communication, where he states that the research to develop this product started because consumers demanded to increase the nutritional content of certain food product (A. Robledo, February 27, 2017).

	three products may be considered less reliable than other energy supplies based on fossil fuels. The new nuclear fuel (A1) do not affect the intermittency of this type of energy, thus, when compared to alternatives based on solar or wind energy, the supply provided by this fuel is considered more reliable (Lovins et al, 2009). However, shut downs are common for plants' maintenance and failures (Lovins et al, 2009)
Human Health	In the technologies in the health segment (B1, B2, B3), the main focus of the products is to provide functional features that meet user's needs. A lack of functionality in these features may lead to injures, thus, achieving an appropriate functionality is a key aspiration from the developers. However, this proposition emphasises the comparison of products with other similar alternatives to determine if the features they offer are the same or better. Therefore, there is difficulty in assessing the proposition in this type of products as they may be offering customised functional features that may not be comparable with other options. For example, the self-driving wheel chair could be compared only to other self-driving wheel-chairs produced by different makers. Or, it could be compared to a manual-operated wheel chair, and, in this case, it could be assumed that the studied product is indeed offering better functional features, because it would offer independent mobility to users that are not able to operate other type of wheel chairs, like manual-operated. Given these different perspectives, the potential to meet the proposition is indicated in table 2 as *not applicable.*
Housing and construction	In the construction segment, the materials developed must comply with the national standards and norms on specific properties for construction materials. This ensures that all the products have at least the minimum mechanical properties expected by constructors and final users. In the examples, only the cement-like material made of anhydrite (C1) is complying with the norms. The other two products (C2 and C3) are currently under test to verify they comply with them, and so far, they have shown good results. It is notable that, according to the developers of the products, they offer advantages over cement, like better thermal isolation (C1), larger durability (C2), and less weight (C3).
Transportation	Providing maintenance to the metro system in México City with the domestic creation of products that were imported previously (D1) improves the metro service as it ensures that trains will be available for users. The mobile app (D2) also allows that the service of public transportation is improved by allowing users to plan their commutes. If users of public transportation are satisfied, it is less likely they will pursue private transportation (Newman, 2012).
Food	The functionality of the fungi-based hormone as biocontrol (E1) have proven to provide nutritious vegetables in greenhouses. However, the hormone should be able to function also in open fields so it can be compared to agrochemicals that work in these conditions. Research is in progress to achieve this functionality. The biosensors (E2) comply with the proposition as the main aim of this product is to adapt the thermal processes in food production so more nutritious food is delivered to consumers.
Ecological conservation	The developers of this orchid based on synthetic seeds aim to reintroduce it in habitats; however, this reintroduction does not imply the habitats will be preserved. Therefore, compared to habitat conservation, where the aim is to preserve a set of biodiversity, the use of this products is less likely to ensure ecosystem services are preserved.

3.4 Challenges and learnings from the case studies

3.4.1 Challenges

In section 1.3, I explained that, eco-efficiency has a bad connotation when the improvement in the use of resources fosters technological lock-ins of polluting technologies, and, when it only delays the rate at which waste or pollution is produced, but do not fix the root-cause of pollution. In the case studies, some of the technologies may represent this bad connotation. The research to increase the safety of nuclear fuels (A1) may prevent negative effects of radioactive waste, but do not address the root cause of pollution. In México, nuclear energy is not banned. There is one active nuclear plant and national strategies consider the construction of future plants to decrease the share of coal energy (SENER, 2016). Thus, this research, has the potential to diminish the risks of nuclear accidents in the future, but still, increases the lock-in on nuclear energy systems which represent a threat to humans and nature. Therefore, this case shows that national directives may influence the work of technologists, driving them to work in technologies that do not follow the proposed guidelines.

Another technology that may create a technological lock-in is the one used to preserve endangered species of orchids (F1). This technology may not represent a problem in the use of materials or energy, but, is not fixing the root cause of the problem it tries to solve. Preserving endangered species with technology may propitiate that other conservation practices that could fix the root cause, for example, avoiding the destruction of habitats, are not implemented. Then, technologists may face the challenge of deciding what are the right solutions to problems they observe, especially when imminent problems, like species extinction, may not be fixed on time with solutions focused on the root cause.

As explained in the tables 8 and 9, the technologies in the human health category (B1, B2, B3) introduce the use of electronic devices to overcome physical disabilities. While they not improve eco-efficiency, they help to increase the efficiency with which people with disabilities perform everyday tasks. As explained above, the incorrect disposal and recycling of electronic devices is a risk for the environment and human health (LeBel, 2016). Based on the scheme in figure 2, we can see that the problem with these technologies resides on practical aspects and not in the objective they are pursuing, which fits with objectives of social development in México. The scheme clarifies that the problems of electronic devices exist regardless of the objective they pursue, being this directed to social development, or other type of objectives, like communication or entertainment. Then, these cases show that technologists may set an objective that aligns to the proposed guidelines, but, the functionality they aim to provide in their designs, may be only provided by devices that do not fit the guidelines on materials.

The same conclusion can be drawn from other developments. For example, the technologies that collect renewable energies rely on non-renewable materials to work. The developers of the solar water heater (A2) chose plastic as the base material because of its thermal insulation properties. These properties ensure that the product have the functionality they want to offer, which is, that water is heated quicker and is kept a certain temperature when stored. This shows that certain materials are chosen because they offer functionalities that are not found in other materials, confirming that there could be potential trade-offs between achieving good functionality and use of renewable materials.

3.4.2 Learnings

From the particularities of the case studies, I consider there are learnings than can help technologists to incorporate the proposed guidelines in the design process of technology, and, to overcome the challenges mentioned in the previous section.

Regarding the use of materials, while most of the technologies studied are not based on renewables, some of them take waste as the base material (A4, C1, C3). This shows that, in some cases, waste offer the same, or even better functionality than conventional materials. Thus, technologists that do not find the functionality they expect on renewables, can turn into non-conventional materials, like waste from industries, to find an alternative, before recurring to non-renewables.

Regarding achieving a good functionality, technologists should also be aware of the physical contexts where they plan to develop a product, as they may benefit them. For example, the solar water heater makers claim they will sell the product in a Mexican region where solar radiation is high. Thus, this technology shows that, even if a product has a constrain on its functionality, like solar intermittency, the specific physical conditions of a region are aspects that contribute to get the expected functionality.

There are also learnings from the technologies based on renewable materials (C2 and E1), which have proved to have good functionality in laboratory tests. I consider that, what is important to learn from them is the process of how they were achieved. One of the researchers working with a renewable resource, the fungi-based hormone (E1), states that the research started by studying scientific documentation about the properties of the hormone and the types of agents that produce it (E. Laredo, personal communication, February 25, 2017). From this, the researchers started to work with the fungi that produces the hormone (found in cacao crops) and started to identify its chemical properties. When investigating the properties, they wanted to find out how the hormone would affect the growth of certain vegetables and how it would impact pathogens, so they conducted tests in selected vegetables and discovered the benefits of the hormone. If we go back to Feibleman's (1961) arguments (see section 1.2), this research confirms that working with science and applied science facilitates the creation of technology. On the other hand, the researcher working with the opuntia-based mucilage (C2) state that the research started as an aim to create scientific documentation on opuntia, as he knew it had been used as a construction material by ancient civilisations, and more recently by restorers of old buildings, but scientific bases for its use have not ever been developed. Thus, while there is empirical knowledge about its use, the researcher was interested in providing scientific backgrounds for its properties as construction material. The research on investigating its properties led to the discovery on how it improves concrete's mechanic properties. During the research, other similar plants were studied, leading to more discoveries (A. Torres, personal communication, February 21, 2017). This also confirms Feibleman's (1961) description of technology, in which sometimes, technology with no scientific fundaments leads to further discoveries on science or applied science (see section 1.2), and in turn, this facilitates the creation of other technologies. From these two examples, we learn that science and applied science play an essential role when working with new materials. Scientific knowledge backing up technology improves the understanding and control of its functionality over time, and this is important to define specific applications for materials, and, to predict and avoid undesirable results (Feibleman, 1961, Holdren & Ehrlich, 1974). Thus, it can be concluded that one factor that could help to achieve the use of renewable materials and energy, is the work of scientists developing pure science and applied science. Such work should focus on studying the properties of renewable materials and materials that are feasible to recycle, and on finding potential applications for them. As seen in the case studies, many of the researchers have the capacity to act as pure and applied scientists, but also as technologists, finding concrete applications for the studied materials.

Many of the technologies seen in the case studies, eight out of fifteen, where developed in institutions with laboratories specialised in certain fields, or, private laboratories. For example, the fungi-based hormone (E1) was developed in a university's department in agricultural parasitology, and, the graphene's research (A4) is being conducted in the national laboratory for graphene materials. The undergraduate students trying to develop the waste-based brick (C3) aim to set up their own laboratory to conduct all the necessary mechanical tests for the materials they develop. This shows that having specialised centres with appropriate laboratories is important for researchers to conduct their work properly. Then, in a national context, I think the creation of more laboratories specialised in renewable materials with specific applications may be a good strategy to follow. Recently, in December 2016, CONACYT opened the national laboratory for energy conversion and storage, specialised in renewable energies (Cacelín, 2017a). While this is a good initiative, the creation of laboratories focused on renewable materials is necessary too.

Other learnings are with regards on how the objectives are set. Some researchers claim that they identified social problems through direct observation. The idea of the motorised walker (B1) and the acoustic aid system (B3) were developed from direct observation of people who had certain disability. Also, the researcher that developed the construction system based on a dismantling mould (C1), claims he got the idea after observing the housing problem in rural areas and in the cities' periphery. He noticed houses were very low quality, or were incomplete, as taking materials to remote areas of the city or to rural areas was too expensive or complicated (D. Davila, personal communication, February 21, 2017). From these cases, we can learn that direct observations of social problems may be a good way to spark ideas in technologists on how to solve them.

Also, the motorised walker (B1) and the acoustic aid systems (B3) were two technologies, developed by undergraduate students, where the professors (in electronics) were the ones detecting the problem, by observation, and then, communicated it to the students. One of these professors claimed that the development of the project made him change the structure of the courses he imparts: he teaches students to find a social problem first, and then to design a solution based on electronic devices (A. Campos, personal communication, February 22, 2017). The other professor suggested that, one way in which more social problems can be tackled in México is by changing the collaborations that universities have with the productive sector and the government (J. Gonzalez, personal communication, February 27, 2017). Currently, universities in México collaborate with the productive sector to improve industrial processes, this way, students learn how to solve technical problems in the industry and the industries obtain free work assistance from students. The researcher claims that, a different collaboration is needed so 'real social problems' are tackled, and not only industrial technical problems. These two ideas from the professors align with the proposed guidelines, by stating that the first thing needed before developing a new solution is to find a social problem, and set it as the objective.

From these last cases, we can learn that, educational institutions could play a key role in orienting students in technology-related fields on how to focus on social problems. They could create links between students and professors, and, other organisations that are focused on solving social problems, with the purpose that the organisations communicate to them the problems with which they deal. These organisations could also facilitate students and professors observe directly social problems.

One last important think to learn from the technologies is that it is possible to create economical solutions that create less environmental impacts than other alternatives, and at the same time, solve social problems. This is observed in the housing system based on anhydrite (C1), the solar water heater (A2), and the fungi-based hormone (E1). While their practical aspects are not ideal, these technologies cause less environmental damage than conventional technologies (cement, fossil fuels and agrochemicals respectively) and their developers claim they are the cheapest alternative compared to the construction of conventional houses, other types of water heaters, and, agrochemicals, respectively[13]. These technologies show that, it is possible to create economic technologies for consumers that, while not meeting completely the guidelines suggested, comply with them better than other alternatives.

[13] Still, it would be necessary to study how accessible these developments are for people living in poverty.

4 Discussion

4.1 Alternative approach to the problem

Based on academic literature, I find there is another approach to solve the problem defined in the introduction of this thesis. Some academics (Mihelcic et al.,2003, Allenby et al., 2007; Davidson et al., 2007; Jamison, 2012) suggest that engineering curricula is improved so engineers are able to create technology that is oriented to *sustainability*. Besides courses that address the impacts on the environment of products' manufacturing, consumption, and disposal (Segalàs et al., 2009), academics think including courses that cover concepts and language of social sciences are important too (Davidson et al., 2007), because, engineers need "considerably more awareness of the nature of politics and of social processes and, especially, the influence of institutions on sustainability choices" (Mihelcic et al., 2003, p.5317). In practice, incorporating this type of courses have been challenging. A five-years evaluation of engineering students, before and after taking courses on the environmental, institutional, social, and economic aspects of sustainability[14] shows that students, before the courses, associate sustainability mainly to environmental aspects, considering technology can help to solve environmental problems, and, they barely link sustainability to social aspects. After the courses, the results are almost the same; still the social aspects are the least considered to have a relation with sustainability (Segalàs et al., 2010). This shows that improving the curricula in engineering is indeed challenging, but still needed. In México, basic education on sustainable development is provided in elementary school (SEP, 2012), but in general, higher education in technology-oriented fields do not cover comprehensively both social and environmental aspects of sustainability. Environmental engineering and architecture cover some aspects of environmental sustainability (Gaona, Chan, Corona, 2010). Then, I think that taking the approach of improving engineering curricula in México is required, but needs efforts to determine what type of courses and what pedagogical methods fit better the students´ learning skills.

One other approach I consider could work is backcasting. By investigating what products or projects created by technologists are specially contributing to *development social sustainability,* or, incorporating soundly the criteria of SS in México, it could be possible to find out what aspects are facilitating the creation of these technologies. Differently to the way this research selected case studies, that is, looking for online documentation of technologies in the CONACYT´s repository, this approach would need a larger search-scope, one that includes broader online searches, observations in rural and urban communities,

[14] Social aspects include quality of life, ethics, future generations, and equity (Segalàs et al., 2010)

and communication with institutions working to solve social problems as they may be aware of technological projects or products that provide good solutions.

4.2 Limitations of the study

I consider that one important limitation in this research is the number of theories chosen in which the guidelines are based, probably making them oversimplified. The research presents two theories (see section 3.1), which underlie all the analyses and conclusions presented. The use of more theories could have provided more elements to create the guidelines and to analyse the case studies. This limitation was given due to the lack of literature I found giving guidelines on how to connect technology to aspects of social sustainability. While I consider my search was intensive, probably, extending the time in this step of the research could have given better results. One way to overcome this problem could have been to reduce the number of case studies, to reduce the time on the analysis. However, less case studies reduces the possibilities of finding particular challenges and learnings from them. As mentioned in the methodology section, the external validity of the guidelines is out of the scope of this research, but, I consider that external validity is a step that would help to improve the guidelines too.

My research also presents the limitations characteristic to the ontology and epistemology it employs (see section 2.3). By analysing the case studies with qualitative data, this research misses to evaluate the bio-physical aspects of the technologies studied with evidence based on measurements. My research qualifies the developments as ‘more’ or ‘less’ eco-efficient based on the descriptions in the documentation and my own understanding of the technologies. A positivist approach would have provided numeric evidence that would have allowed me to describe accurately how eco-efficient the developments are compared to other alternatives, for example, the energy they use, the amount of materials they require, and the emissions they release. However, this type of approach would have required more time and knowledge in Life Cycle Assessment techniques, which I do not have. Additionally, my research misses to be critical on the cases selected. All the case studies were selected from the same source (CONACYT press agency), thus, they present the information that the source wants to publish. This research does not present further discussion on the origin of the researches, their funding, or the political forces that promote them.

4.3 Contributions to sustainability science

This research, investigating how technologists could conduct their work incorporating aspects of social and environmental sustainability, contributes to the understanding of the relationships between technology, the natural environment, and social problems. I consider that this contribution fits in the aims of sustainability science. As Kates et al. (2001) point out, this science's objective is to understand "the interactions between nature and society......and the responses of nature-society systems to multiple and interacting stresses" (p. 292). In line with the argumentation provided in the introduction, technological development can be considered as a stressor which interacts with the natural and human social systems. Yet while, being considered a stressor, Clark and Dickson (2003) highlight science and technology as integral components and key contributors in achieving sustainability. Thus, understanding how to conduct technology in such a way that contributes to address social aspects of sustainability, and at the same time, stops being a stressor for environmental sustainability, is a challenge that need multiple research approaches, from multidisciplinary perspectives, and that will take significant time and effort. While my research presents limitations, it proposes a set of guidelines which could help students and practitioners, to create technology that stresses less the environment and contributes to solve social problems in the Mexican context.

5 Conclusion

This thesis presents a set of concrete guidelines (figure 2), based on academic literature that could guide Mexican technologists, usually not specialists in sustainability, in creating technology that considers aspects of social and environmental sustainability. The guidelines suggest that first, technologists have to set an objective to their designs, considering the main social problems in México, specially the lacks that define poverty. Then, they have to pursue the criteria to meet SS, which is the use of renewable materials and renewable energies. Additionally, they have to achieve their designs have good functionality when compared to other alternatives. By testing the guidelines in case studies of actual technologies, it is found that one of the main challenges technologists could face is to substitute non-renewable materials with renewables, as the latter do not offer the same functionality. The analysis of case studies also shows that further research in science and applied science of renewable materials could be a good strategy to overcome the problem. This requires that laboratories specialised on these materials are established. The analysis also shows that universities could play a key role in helping students in technology-oriented fields to know about the social problems México face. Universities can create links of collaboration between students and organisations that work to solve social problems, so the organisations communicate the problems and facilitate students to make direct observations of them.

6 References

Aldecoa, J. (2016, Dec 10). Crean app que optimiza uso de transporte público de Sinaloa. *Agencia Informativa Conacyt*. Retrieved from http://conacytprensa.mx/index.php/tecnologia/tic/12137-crean-app-que-optimiza-uso-de-transporte-publico-de-sinaloa

Allenby, B., Allen, D., & Davidson, C. (2007). Sustainable engineering: From myth to mechanism. *Environmental Quality Management*, *17*(1), 17-26.

Anastas, P., & Zimmerman, J. P. (2003). Design Through the 12 Principles of Green Engineering. *Environ. Sci. Technol*. 37, 94A-101A.

Borowitzka, M. A., & Moheimani, N. R. (2013). Sustainable biofuels from algae. *Mitigation and Adaptation Strategies for Global Change*, 18(1), 13-25.

Boserup, E. (1976). Environment, population, and technology in primitive societies. *Population and Development Review*, 21-36.

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions–a strategy for eco-effective product and system design. *Journal of cleaner production*, *15*(13), 1337-1348.

CambridgeIP (2014). The acceleration of climate change and mitigation technologies: Intellectual property trends in the renewable energy landscape. Global Challenges Brief, WIPO. Geneva. Retrieved from http://www.wipo.int/edocs/pubdocs/en/wipo_pub_gc_1.pdf

Cacelín, J. (2017a, Mar 11). Laboratorio Nacional de Conversión y Almacenamiento de Energía. *Agencia Informativa Conacyt*. Retrieved from http://conacytprensa.mx/index.php/tecnologia/energia/15252-laboratorio-nacional-conversion-almacenamiento-energia

Cacelín, J. (2017b, Feb 9). Innovador diseño de andadera motorizada para niños discapacidad. *Agencia Informativa Conacyt*. Retrieved from http://conacytprensa.mx/index.php/tecnologia/robotica/13086-innovador-diseno-de-una-andadera-motorizada-para-ninos-con-discapacidad

Clark, W. C., & Dickson, N. M. (2003). Sustainability science: the emerging research program. *Proceedings of the national academy of sciences*, *100*(14), 8059-8061.

Crow, J. M. (2008). The concrete conundrum. Chemistry World, 5(3), 62-66.

Daly, H. E. (1990). Toward some operational principles of sustainable development. *Ecological economics*, *2*(1), 1-6.

Davidson, C. I., Hendrickson, C. T., Matthews, H. S., Bridges, M. W., Allen, D. T., Murphy, C. F., ... & Austin, S. (2010). Preparing future engineers for challenges of the 21st century: Sustainable engineering. *Journal of cleaner production*, *18*(7), 698-701.

Davidson, C. I., Matthews, H. S., Hendrickson, C. T., Bridges, M. W., Allenby, B. R., Crittenden, J. C., ... & Austin, S. (2007). Viewpoint: Adding sustainability to the engineer's toolbox: A challenge for engineering educators.

Dietz, S., & Neumayer, E. (2007). Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological economics*, *61*(4), 617-626.

Faran, T. (2010). Sustainable Development: A Typology of Perspectives. Draft 3. *LUCSUS (GLOBIS) on 30th September*.

Feibleman, J. K. (1961). Pure science, applied science, technology, engineering: an attempt at definitions. *Technology and Culture*, *2*(4), 305-317.

Gaona, T., Chan, D., & Corona, E. A. (2010). La sustentabilidad en el proceso de enseñanza aprendizaje del diseño integral: una perspectiva del caso de la Facultad de Arquitectura y Diseño de la Universidad Autónoma de Baja California, Mexicali BC. In *6to. Cogreso Internacional Ciudad y Territorio Virtual, Mexicali, 5, 6 y 7 Octubre 2010*. Centre de Política de Sòl i Valoracions.

Gatica, G. (2017, Feb 12). Desarrollan sistema constructivo a partir de cemento ecológico. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/materiales/12973-desarrollan-sistema-constructivo-a-partir-de-cemento-ecologico

Gómez, C. K. (2016, Nov 17). Estudiante de Conalep crea sistema de asistencia acústica para personas con discapacidad visual. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/tic/11606-estudiante-de-conalep-crea-sistema-de-asistencia-acustica-para-personas-con-discapacidad-visual

Guerrero, A. L. (2016a, Dec 6). Desarrollan celdas solares orgánicas a base de grafeno. *Agencia Informativa Conacyt*. Retrieved from http://conacytprensa.mx/index.php/tecnologia/energia/12096-desarrollan-celdas-solares-organicas-a-base-de-grafeno

Guerrero, A. L. (2016b, Dec 8). Desarrollan tecnología mexicana para mejorar servicio del Metro. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/transportes/11788-desarrollan-tecnologia-mexicana-para-mejorar-servicio-del-metro

Haase, S. (2013). An engineering dilemma: Sustainability in the eyes of future technology professionals. *Science and engineering ethics*, *19*(3), 893-911.

Holdren, J. P., & Ehrlich, P. R. (1974). Human Population and the Global Environment: Population growth, rising per capita material consumption, and disruptive technologies have made civilization a global ecological force. *American scientist*, *62*(3), 282-292.

Hopwood, B., Mellor, M., & O'Brien, G. (2005). Sustainable development: mapping different approaches. *Sustainable development*, *13*(1), 38-52.

Huesemann, M. H. (2003). The limits of technological solutions to sustainable development. *Clean Technologies and Environmental Policy*, *5*(1), 21-34.

Hughes, T. P. (2004). *Human-built world: How to think about technology and culture*. University of Chicago Press. Chicago.

Jamison, A. (2012). Turning engineering green: Sustainable development and engineering education. In *Engineering, Development and Philosophy* (pp. 7-21). Springer. Netherlands.

Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E., ... & Persson, J. (2011). Structuring sustainability science. *Sustainability science*, *6*(1), 69-82.

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., ... & Faucheux, S. (2001). Sustainability science. *Science*, *292*(5517), 641-642.

Korhonen, J., & Seager, T. P. (2008). Beyond eco-efficiency: a resilience perspective. *Business Strategy and the Environment*, *17*(7), 411-419.

Kremer, M. (1993). Population growth and technological change: one million BC to 1990. *The Quarterly Journal of Economics*, *108*(3), 681-716.

Kumar, A., Holuszko, M., & Espinosa, D. C. R. (2017). E-waste: an overview on generation, collection, legislation and recycling practices. Resources, Conservation and Recycling, 122, 32-42.

LeBel, S. (2016). Fast machines, slow violence: ICTs, planned obsolescence, and e-waste. *Globalizations*, *13*(3), 300-309.

Little, J. C., Hester, E. T., & Carey, C. C. (2016). Assessing and Enhancing Environmental Sustainability: A Conceptual Review. *Environmental science & technology*, *50*(13), 6830-6845.

Lovins, A., Sheikh, I., & Markevich, A. (2010). Nuclear power: Climate fix or folly?. *The Energy Reader*, 9.

Løkke, A. K., & Sørensen, P. D. (2014). Theory testing using case studies. *Electronic Journal of Business Research Methods*, *12*(1), 66-74.

Marsden, G., Kimble, M., Nellthorp, J., & Kelly, C. (2010). Sustainability assessment: the definition deficit. *International Journal of Sustainable Transportation*, *4*(4), 189-211.

Mihelcic, J. R., Crittenden, J. C., Small, M. J., Shonnard, D. R., Hokanson, D. R., Zhang, Q., ... & Schnoor, J. L. (2003). Sustainability science and engineering: the emergence of a new metadiscipline. *Environmental science & technology*, *37*(23), 5314-5324.

Missimer, M., Robèrt, K. H., & Broman, G. (2017). A strategic approach to social sustainability–Part 2: a principle-based definition. *Journal of Cleaner Production*, *140*, 42-52.

Molina, M. (2013, Mar 11). La Estrategia Nacional de Energía: en la ruta hacia una economía de bajo carbono. *Centro Mario Molina*. Retrieved from http://centromariomolina.org/wp-content/uploads/2013/03/Articulo-DrMolina_Estrategia-Nal-Energ%C3%ADa_11marzo2013.pdf

Narváez, M. (2016, Dec 25). Diseñan colector solar de bajo costo. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/energia/12293-disenan-colector-solar-de-bajo-costo

Narváez, M. (2017, Jan 11). Mejoramiento genético y preservación de orquídeas. *Agencia Informativa Conacyt*. Retrieved from http://conacytprensa.mx/index.php/tecnologia/biotecnologia/12382-mejoramiento-genetico-y-preservacion-de-orquideas

Navarro, K. (2016, Dec 6). Energía verde: biocombustible de microalgas. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/energia/11479-energia-verde-biocombustible-de-microalgas

Newman, P. (2012). Why Do We Need A Good Public Transport System. *Research Paper, Curtin University Sustainability Policy (CUSP) Institute*.

Pérez, I. (2017, Jan 16). Elevan durabilidad de materiales de construcción con nopal. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/materiales/12414-elevan-durabilidad-de-materiales-de-construccion-con-nopal

Posten, C., & Schaub, G. (2009). Microalgae and terrestrial biomass as source for fuels—a process view. *Journal of biotechnology*, *142*(1), 64-69.

Rahimifard, S., & Clegg, A. J. (2008). The role of the engineering community in sustainable development. *International Journal of Sustainable Engineering*, *1*(1), 1-2.

Sánchez, F. (2016a, Dec 14). Desarrollan biosensores para alimentos libres de microorganismos. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/biotecnologia/12084-desarrollan-biosensores-para-alimentos-libres-de-microorganismos

Sánchez, F. (2016b, Nov 30). Hongos en biocontrol de cultivos. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/biotecnologia/11772-hongos-en-biocontrol-de-cultivos

Sánchez, V. (2016c, Nov 30). Mexicanos desarrollan en Alemania silla de ruedas autónoma. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/robotica/11939-mexicanos-desarrollan-en-alemania-silla-de-ruedas-autonoma

Sánchez, F. (2017, Feb 10). Científicos del Cinvestav experimentan combustibles nucleares seguros. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/materiales/12557-cientificos-del-cinvestav-experimentan-combustibles-nucleares-seguros

Schick, K. D., & Toth, N. P. (1994). *Making silent stones speak: Human evolution and the dawn of technology*. Simon and Schuster. New York.

Schutt, R. K. (2009). *Investigating the social world: The process and practice of research*. Pine Forge Press. Los Angeles.

SCImago. (2015). SJR - SCImago Journal & Country Rank. Retrieved from http://www.scimagojr.com/countryrank.php?year=2015

Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English Language Teaching*, *5*(9), 9.

Secretaría de Desarrollo Social [SEDESOL] (2013). *Programa sectorial de desarrollo social 2013 - 2018*. Retrieved from http://www.sedesol.gob.mx/work/models/SEDESOL/Transparencia/DocumentosOficiales/Programa_Sectorial_Desarrollo_Social_2013_2018.pdf

Secretaría de Educación Pública [SEP]. (2012). *Educación ambiental para la sustentabilidad*. Retrieved from http://www.dgespe.sep.gob.mx/public/rc/programas/lepree/educacion_ambiental_para_la_sustentabilidad_lepree.pdf

Secretaría de Energía [SENER] (2016). Ley de Transición Energética. In *Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles Más Limpios* (section 1.4). Retrieved from https://www.gob.mx/cms/uploads/attachment/file/182202/20161110_1300h_Estrategia_CCTE-1.pdf

Secretaría de Energía [SENER] (2014). Objetivos, estrategias y líneas de acción. In *Programa Nacional para el Aprovechamiento Sustentable de la Energía 2014-2018* (chapter 3). Retrieved from http://www.gob.mx/cms/uploads/attachment/file/224/PRONASEpendt.pdf

Segalàs, J., Ferrer-Balas, D., & Mulder, K. F. (2010). What do engineering students learn in sustainability courses? The effect of the pedagogical approach. *Journal of Cleaner Production*, *18*(3), 275-284.

Segalàs, J., Ferrer-Balas, D., Svanström, M., Lundqvist, U., & Mulder, K. F. (2009). What has to be learnt for sustainability? A comparison of bachelor engineering education competences at three European universities. *Sustainability Science*, *4*(1), 17.

Short, T. (2008). Sustainable engineering: confusion and consumers. *International Journal of Sustainable Engineering*, *1*(1), 21-31.

Sinha, K. C. (2003). Sustainability and urban public transportation. *Journal of Transportation Engineering*, *129*(4), 331-341.

Stanford (2010). Technology trends in Latin America and their social and economic impact. Retrieved from https://cs.stanford.edu/people/eroberts/cs181/projects/2010-11/TechnologyTrendsLatinAmerica/mexico.html

Steinbach, V., & Wellmer, F. W. (2010). Consumption and use of non-renewable mineral and energy raw materials from an economic geology point of view. *Sustainability*, *2*(5), 1408-1430.

Sustpro (2011). Anhidrita. Retrieved from http://www.sustpro.com/ES/es-ES/anhidrita-f574.htm

Thom, D. A. (1995). The Need for “Environmental Engineering Education Fundamentals”. *Elms DG and Wilkinson D ((1995) The Environmentally, Educated Engineer: Focus on Fundamentals*, 25-37.

United Nations Development Programme [UNDP] (2016*). Implementing the 2030 Agenda and the Sustainable Development Goals in Mexico*. Retrieved from: https://sustainabledevelopment.un.org/content/documents/10762Brochure%20on%20SDGs%20implementation%20in%20Mexico.pdf

United Nations Development Programme [UNDP] (2017). *Sustainable development goals, background on the goals*. Retrieved from http://www.undp.org/content/undp/en/home/sustainable-development-goals/background.html

Valencia, H. (2016, Dec 1). Fabrican tabique ecológico con residuos sólidos urbanos. *Agencia Informativa Conacyt*. Retrieved from http://www.conacytprensa.mx/index.php/tecnologia/materiales/11489-tabique-ecologico-hecho-con-residuos-solidos-urbanos

Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum*, *42*(3), 342-348.

Worrell, E., Phylipsen, D., Einstein, D. & Martin, N. (2000). Energy use and energy intensity of the U.S. chemical industry. University of California. Berkeley.

Yin, R. K. (2009). Case Study Research: Design and Methods: SAGE Publications. Los Angeles

Appendix A

Sustainability Development Goals

1. End poverty in all its forms everywhere
2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
3. Ensure healthy lives and promote wellbeing for all at all ages
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5. Achieve gender equality and empower all women and girls
6. Ensure availability and sustainable management of water and sanitation for all
7. Ensure access to affordable, reliable, sustainable and modern energy for all
8. Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all
9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
10. Reduce inequality within and among countries
11. Make cities and human settlements inclusive, safe, resilient and sustainable
12. Ensure sustainable consumption and production patterns
13. Take urgent action to combat climate change and its impacts
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and halt biodiversity loss
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

Millennium Development Goals

1. To eradicate extreme poverty and hunger
2. To achieve universal primary education
3. To promote gender equality and empower women
4. To reduce child mortality
5. To improve maternal health
6. To combat HIV/AIDS, malaria, and other diseases
7. To ensure environmental sustainability
8. To develop a global partnership for development

Source: UNDP (2017)

Appendix B

Publications from CONACYT's web repository from November 14th, 2016 to February 14th, 2017

14 de febrero de 2017. Computo bioinspirado
14 de febrero de 2017. Estudian mecanismos de defensa en plantas
13 de febrero de 2017. Algas mexicanas: los biocombustibles del siglo XXI
12 de febrero de 2017. Desarrollan sistema constructivo a partir de cemento ecologico.
10 de febrero de 2017. Científicos del Cinvestav experimentan combustibles nucleares seguros
10 de febrero de 2017. Diseñan interfaz para mover silla de ruedas con señales cerebrales
10 de febrero de 2017. Realidad virtual en las aulas
10 de febrero de 2017. Casa ecológica, un futuro sustentable en el sureste
9 de febrero de 2017. Desarrollan biopelícula con semilla de chía
9 de febrero de 2017. Diseñan casa inteligente en la Sierra de Zongolica
9 de febrero de 2017. Innovador diseño de andadera motorizada para niños con discapacidad
8 de febrero de 2017. Bioetanol: el combustible alternativo para México
8 de febrero de 2017. Crean alimento para tilapia con semillas de yaca
8 de febrero 2017. Estudiante de nanotecnología participará en encuentro científico internacional
8 de febrero 2017. Biocombustibles: retos y oportunidades en México
7 de febrero 2017. Empresa mexicana innova con sistema de step stencil
7 de febrero 2017. Desarrollo industrial en área de polímeros
7 de febrero 2017. Desarrollan técnicas para la construcción de códigos correctores de errores
7 de febrero 2017. Diseñan semáforo inteligente
5 de febrero 2017. Diseñan sistema híbrido de energías renovables
3 de febrero 2017. Mexicano desarrolla nanoled mil veces más eficiente
3 de febrero 2017. Investigadora de la UABC optimiza sistema de reconocimiento de imágenes
2 de febrero de 2017. Biosensores para detección de deslaves
2 de febrero de 2017. Investigadores producen cosméticos a partir de la piel de borrego
2 de febrero 2017. Google y la UAS documentan biodiversidad de Sinaloa
2 de febrero 2017. Mopin, método para incentivar a pequeños investigadores
1 de febrero 2017. Biodiesel avanzado para México
1 de febrero 2017. Desarrollan sistema integrado de monitoreo de ganado de engorda
30 de enero 2017. Estudiantes de Celaya y Querétaro triunfan en certamen de robótica en China
29 de enero 2017. Orquídea silvestre: un cultivo con potencial económico
27 de enero 2017. Becario Conacyt diseña sistema para enjambres robóticos
27 de enero 2017. Mathematic, innovación y tecnologías de la información
27 de enero 2017. Destacan estudiantes de Querétaro en tecnología espacial
26 de enero 2017. Desarrollan app de apoyo en terapia psicológica a menores
25 de enero de 2017. Participan jovenes sinaloenses en el Global Game Jam
25 de enero de 2017. Diseñan recubrimientos anticorrosivos amigables con el medio ambiente
25 de enero 2017. ¿Cuál es el costo energético de las nuevas tecnologías?
25 de enero 2017. Goparken, ¿en dónde estaciono mi automóvil en la CDMX?
24 de enero 2017. Crean método para estudio de nuevos materiales
23 de enero 2017. Presentan vehículo eléctrico mexicano de carga ligera
23 de enero 2017. Investigadores de la BUAP diseñan software para detectar conductas depedofilia en Internet
20 de enero 2017. Centrogeo desarrolla prototipo de videovigilancia inteligente
20 de enero 2017. Alexandria, educación para médicos y estudiantes a través de realidad virtual

19 de enero 2017. Estudiantes crean empaque biodegradable con almidón de avena
19 de enero 2017. Laboratorio Nacional de Identificación y Caracterización Vegetal
18 de enero 2017. Evalúan efectos de nanopartículas de óxido de zinc en semillas de pepino
17 de enero 2017. Proyecta Cinvestav laboratorio de nanopelículas en Querétaro
17 de enero 2017. En busca de enzimas termoestables
7 de enero 2017. ANES: 40 años de impulsar el aprovechamiento de la energía solar
1 de enero 2017. ¿Cómo está relacionada la ciberseguridad con el derecho a la libertad deexpresión?
16 de enero 2017. Elevan durabilidad de materiales de construcción con nopal
16 de enero 2017. Tecnología para un vida incluyente
16 de enero 2017. Conoce las salas de realidad virtual de la Facultad de Odontología de la UNAM
16 de enero 2017. Ceener: desarrollo tecnológico en energías renovables
13 de enero 2017. El desafío de la innovación tecnológica
12 de enero 2017. Becario Conacyt diseña modelos 3D de piel
12 de enero 2017. Estudiante de la UAZ diseña nanotubos de carbono
12 de enero 2017. Destaca la Unaq en el Certamen Nacional Innovación Aeroespacial México 2016
11 de enero 2017. Bendable sound, innovación interactiva para niños con autismo
11 de enero 2017. Mejoramiento genético y preservación de orquídeas
10 de enero 2017. Tecnología RFID para optimizar líneas de producción
10 de enero 2017. Impulsan interés por la robótica
10 de enero 2017. Crean laboratorio de prototipado rápido
9 de enero 2017. Universitarios investigan importancia del Sol
9 de enero 2017. Investigador construye microscopios de efecto túnel
9 de enero 2017. Diseñan sistema para el reconocimiento del lenguaje de señas
1 de enero 2017. Telemetría para salvar vidas
31 de diciembre 2016. Laboratorio de Micropropagación y Mejoramiento Genético
27 de diciembre 2016. Cicatec: biotecnología agrícola en Querétaro
25 de diciembre 2016. Diseñan colector solar de bajo costo
24 de diciembre 2016. Tecnologías de la información en la competitividad del turismo
23 de diciembre 2016. Crean app para conocer calidad del aire en Guadalajara
22 de diciembre 2016. Desarrollan nanosensores para identificar contaminantes en el agua
21 de diciembre 2016. Nanotecnología para el tratamiento de aguas residuales
19 de diciembre 2016. Investigan nuevas aplicaciones para el grafeno
16 de diciembre 2016. Sustituirán antibióticos en la crianza de lechones
16 de diciembre 2016. CICESE impulsa seguridad de la información en centros científicos
16 de diciembre 2016. PetroBloc, innovación en sistemas constructivos
15 de diciembre 2016. Promueve Reeduca interés por la robótica en niños y jóvenes
15 de diciembre 2016. Cómo realizar diseño de arquitectura de software aplicado a la industria
15 de diciembre 2016. Diseñan app para usuarios de transporte público en Puebla
14 de diciembre 2016. Desarrollan biosensores para alimentos libres de microorganismos
12 de diciembre 2016. Crean app para optimizar reparto de mercancías
12 de diciembre 2016. Estudiantes de Aguascalientes destacan en competencia de programación
12 de diciembre 2016. Innovación abierta y nanotecnología
10 de diciembre 2016. Crean app que optimiza uso de transporte público de Sinaloa
9 de diciembre 2016. Instruyen en herramientas informáticas para el uso de datos genómicos
9 de diciembre 2016. Modelos matemáticos para optimizar redes de transporte
8 de diciembre 2016. Celebran taller de inteligencia artificial en Xalapa
8 de diciembre 2016. Desarrollan tecnología mexicana para mejorar servicio del Metro
8 de diciembre 2016. Científicos de Coahuila desarrollan biopelícula para aguacate Hass

8 de diciembre 2016. Jalisco albergará primer centro dedicado a internet de las cosas
8 de diciembre 2016. Investigan toxinas del ciempiés del desierto
7 de diciembre 2016. Retos legales de los vehículos autónomos
7 de diciembre 2016. Crean sistema ahorrador de energía para máquinas soldadoras
6 de diciembre 2016. Crean app para optimizar rutas de transporte público de Zacatecas
6 de diciembre 2016. Laboratorio de nanoelectrónica
6 de diciembre 2016. Desarrollan celdas solares orgánicas a base de grafeno
5 de diciembre 2016. Foro de Electrónica de la BUAP
5 de diciembre 2016. Diseñan app para monitoreo de cámaras de refrigeración
5 de diciembre 2016. Desarrollan repelente natural y de alta eficacia contra moscos
2 de diciembre 2016. Nuevas técnicas en biotecnología acuícola
2 de diciembre 2016. ¿Cómo reaccionan los peatones ante vehículos autónomos?
1 de diciembre 2016. Fabrican tabique ecológico con residuos sólidos urbanos
30 de noviembre 2016. Identificarán derrames de hidrocarburos mediante análisis de imágenes satelitales
30 de noviembre 2016. Mexicanos desarrollan en Alemania silla de ruedas autónoma
30 de noviembre 2016. Hongos en biocontrol de cultivos
30 de noviembre 2016. Diseñan dispositivo para mantenerte alerta al volante
28 de noviembre 2016. Congreso Seguridad en Cómputo: hacia una cultura de seguridad de la información
25 de noviembre 2016. BIONN: investigación en salud humana y animal
25 de noviembre 2016. Científicos desarrollan Aurora, software auxiliar para un mejor diagnóstico de cáncer
24 de noviembre 2016. Investigador de la UAN crea simulador de crecimiento urbano con tecnología satelital
23 de noviembre 2016. CICESE UT^3 desarrolla plataforma para promover sus servicios en Nayarit
23 de noviembre 2016. Crean edulcorante natural libre de conservadores
23 de noviembre 2016. Diseñan prototipo para estudios de diagnóstico médico
20 de noviembre 2016. Un algoritmo de película
19 de noviembre 2016. Zeolita líquida para tratar la diabetes
18 de noviembre 2016. Cinvestav desarrolla recubrimientos nanoestructurados contra la corrosión
18 de noviembre 2016. Patentan artificio pirotécnico chispeante
18 de noviembre 2016. Crean cubierta plegada de fibra de coco para construcción
17 de noviembre 2016. Plantea Raúl Rojas las oportunidades y problemáticas de las TIC
17 de noviembre 2016. Control biotecnológico de bacterias en tomate
17 de noviembre 2016. Estudiante de Conalep crea sistema de asistencia acústica para personas con discapacidad visual
16 de noviembre 2016. Científicos del INIFAP emplean técnicas de diagnóstico fitomolecular
16 de noviembre 2016. Energía verde: biocombustible de microalgas
16 de noviembre 2016. Neurosoft, una aplicación para conectarse con el mundo
16 de noviembre 2016. Centro de Investigación de Inteligencia Artificial
15 de noviembre 2016. Crean alimento funcional con microalgas
15 de noviembre 2016. Identifican huella genómica de maíces criollos de Nayarit
14 de noviembre 2016. Diseñan sistema de control de energía para autos eléctricos
14 de noviembre 2016. Proponen regeneración de esmalte dental con hidroxiapatita
14 de noviembre 2016. El potencial geotérmico del golfo de California

Appendix C

Short's six principles that underlie sustainable engineering (Short, 2008):

1. "While the varied understandings of SE are all valid in themselves, a full understanding requires all three aspects of the Triple Bottom Line" (p.26); designs that address only one or two dimensions of sustainability cannot be considered sustainable.

2. "Designing for the environment is not designing for sustainability" (p.26); because, only 20% of consumers eagerly look for eco-friendly products (Joyce et al., 2004, as cited in Short, 2008). Short considers this number is not enough to sustain the product line and the company.

3. "Product line longevity is a requirement, and can lead to economic and social sustainability" (p.27); because of the previous principle, economic sustainability should be the baseline to design a product.

4. "A product must satisfy its key functions if it is to be economically sustainable" (p.28); when designing with only environment in mind, the product can be out of functionality when compared to non-green similar products, for example, electric vehicles that run slow.

5. "The quality of sustainable products must be at least as good as that of the equivalent non-sustainable product, if not better" (p.28); the author emphasises that quality is expected from consumers and, if green products do not offer it, consumers will not prefer such products.

6. "Economic sustainability, and thence, all sustainability, relies on a true understanding of the consumers wishes and demands, and the consequent product functionality required" (p.28); identifying the expectations of consumers is a key step to ensure there will be demand of a product. This is not an easy requirement as consumers sometimes are not truly aware of their wants. The author emphasises that when the focus is not the consumer, technological solutions misses their purpose, for example, solar water pumps that cannot provide water in the evening.