A Work Project presented as part of the requirements for the Award of a Masters Degree in Management from the NOVA School of Business and Economics.

Effectiveness of Incubation Programs Transforming a Cutting Edge Technology into a High Tech/High Growth Product

- Tech Entrepreneurship Field Lab-

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Field Lab Context

HiTech Program Description

HiTech is a cohort-based program that links management students, inventors of cutting edge technologies and business mentors in order to develop a business case that may lead to high-tech/high-growth business opportunities. With this program, the participants are able to develop their skills mainly in technology commercialization and entrepreneurship subjects, while experiencing an innovation environment. Moreover, considering that the program deals with a real technology for a real business plan, it is expected to be of high complexity and of ambiguous nature, hence the projects are expected to be less structured and their progression is more challenging than in the classical educational context. On these grounds, the HiTech has defined "learning-by-doing" as the fundamental learning method of the program.

In order to do so, each management student (my role) is allocated to a group of technology inventors and innovators that have developed and created a cutting edge technology to form a team, then two specific mentors are allocated to every team. These mentors are acquainted with the market of the assigned technology and they will support their allocated team throughout the HiTech program.

Role of the Management Student

As the management student in the HiTech program, my main duties were and are: Share management skills and knowledge to the development of products and services that uniquely answer market needs; Provide support to the project development including validation of market and business assumptions created through the discovery process; Provide an active and committed role in the assessment of the commercial viability of the team's technology; Execute external validation of the work done indoors, namely through the establishment of contacts with key sources of information and opinion leaders.

Abstract

Technology has completely altered the business world. The process of transforming technologies into products only recently has become target of academic research and the arrival of technology incubation programs has become essential for the commercialization of new technologies. The HiTech program was built to help technology inventors and innovators, alongside with management students and business mentors, to transform their cutting edge technology into a high tech/high growth product and eventually create a start-up. The aim of this Work Project is to critically evaluate the HiTech algorithm, propose recommendations to improve it, assess its effectiveness and enumerate what the key success factors that affect the realization of technology incubators are.

Keywords

Technology Commercialization, Innovation, Incubator, HiTech

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1. General Overview

1.1. Introduction

In the 21st century, technology has a vital role on the business world. In fact, nowadays one of the main streams of competitive advantage in the business world comes from the technological advancement of each market player and companies can only sustain growth if they continuously introduce new goods and services based on radical technical innovations that disrupt the competitors and the markets (Auerswald and Branscomb, 2003). On these grounds, the business world has created a competitive environment that forces new and existing players to bet on innovation and on the development of new technologies in order to reduce costs and/or to improve product performance. For these reasons, the business world's main trends in innovation are an increase in public-private research partnerships, in public investment programs that support research and commercial interactions between universities and firms, and an increase in technology commercialization at research universities (Markman, Siegel and Wright, 2008). The HiTech program is based on the last described trend, therefore this Work Project will focus on the commercialization of technologies that are developed in an academic environment.

Indeed, the attention of universities has been turned into technology commercialization for the last decades. To prove this, one can have in mind that the number of patents issued by universities and public research organizations has exponentially increased in the last years – from around 50 thousand in 2001 into around 225 thousand in 2013 (World Intellectual Property Organization, 2016). Moreover, the essence of academic research is the development and discovery of new knowledge that may lead to new technologies. These technologies are commonly seen as scientific methods and materials used to achieve a commercial or industrial objective, therefore the combination of both may effectively work in the business world (Anokhin, Wincent and Frishammar, 2011).

There are many methods one can use to commercialize technologies. The methodology in which the HiTech program is based on is called the TEC (Technology, Entrepreneurship and Commercialization) algorithm – developed in the North Carolina State University (NCSU), between 1995-1999 – whose purpose is to engage management students with technical subject students to innovate and be involved in entrepreneurial processes that will enable them to transform new technologies into successful businesses (Baker, Barr, Kingon and Markham, 2009). The aim of the HiTech program is to **discover** what the business opportunities that may be originated from a new technology and its potential are, **validate** the conducted analysis and map the decision-making process that will enable the technology developer to **structure** and start-up a business. The in bold designations above are the different phases of the HiTech algorithm (see Appendix 1) and they are organized to last 6, 6 and 7 weeks respectively, therefore the program is to be concluded in 19 weeks.

1.2. Theoretical Background & Literature Review

The process of technology commercialization is one that has been the target of recent studies due to its increasing interest by both companies and universities, thus it is a concept that is still evolving. On these grounds, first one needs to understand the invention to innovation transition that turns research development into economic asset. According to Auerswald and Branscomb (2003), this process is as following: (1) research, where knowledge is transformed into invention, (2) concept of commercial value that needs to be protected, (3) early stage technology development, transition from invention to innovation, (4) product development, pilot line plus getting ready for the market, and (5) production/market, commercialization and business creation (see Appendix 2). The authors also defend that the main challenges of this process are the alignment of the researchers' motivations, managing the different perspectives between the technology developers and the business managers, defining and establishing the sources of financing, and the lack of the necessary infrastructure to go from invention to innovation.

Regarding the theoretical background related with the HiTech program and its core objective, one can argue that the program is an Incubator. By definition, an incubator is an innovative system that provides a variety of support systems for entrepreneurs to accelerate new company development, speed the commercialization of technology, and contribute to economic growth (Smilor, 1987). Thus, the purpose of an incubator is to stimulate the recruitment and retention of entrepreneurial businesses, support job creation efforts, and provide access to scientific, technical and professional experts to guide entrepreneurs to transform intellectual property into marketable products, technologies and services (Al-Mubaraki and Schrödl, 2011). Furthermore, according to Lalkaka (2000) the main characteristics of an incubator are: selection of entrepreneurial firms; focused counselling, training, mentoring and networking on management, marketing and information; and an affordable workspace with common office facilities, in one integrated package. In fact, the HiTech program does not consider itself an incubator due to the absence of the last main characteristic: HiTech does not have workspace for the office facilities. Nevertheless, this is a secondary key element of an incubator (UKSPA, 2015) and HiTech uses NOVA School of Business and Economics facilities to conduct the program and in all other aspects the HiTech program is conducted as an incubator, henceforth for this Work Project the program is going to be considered a Technology Incubator.

In 2004, Akçomak and Taymaz performed an analysis on several early stage Turkish technology incubators and concluded that in fact technology incubators encourage the creation of new-firms. Moreover, most of the participants (60%) considered the incubation process as very important for the technology commercialization process. The major problems of technology incubators discovered then were: absence of Venture Capital Initiatives; low levels of business networking and interaction; lack of marketing; inadequate business support mechanisms (Akçomak and Taymaz, 2004).

When it comes to the TEC algorithm, the guiding framework of the HiTech algorithm and program, one can analyse its effectiveness by looking at its results, namely the creation of over

450 new jobs and the total amount of investments of over $170 million (Baker, Barr, Kingon and Markham, 2009). But beforehand, one needs to consider several subjects to better comprehend it. First, one needs to understand the concept of Valley of Death which is the institutional, financial and skills gap between the technical invention or market recognition of an idea and the efforts to commercialize it. This is not a linear process, nevertheless the technology developers and management students must go through all the stages when crossing the Valley of Death (see Appendix 3 and 4). The stages are: (1) discover the commercial value in the research; (2) manifest the discovery of a product; (3) communicate potential through a compelling business case; (4) acquire resources to establish potential; (5) use resources to reduce risk; (6) seek approval to enter formal development; (7) translate into the criteria used for approval; (8) decide to approve or not to approve the project; (9) develop and launch the product. To successfully go through all these stages, the teams need to use the different skills and experiences provided by each individual team member (Markham, 2002).

Second, the TEC algorithm (see Appendix 5) was designed to develop students' skills regarding technology commercialization, and to transform them in entrepreneurs or technology product champions within existing firms. The program's goal is to explore the connection between market needs, unique attributes and product features enabled by the new and emerging technology. This algorithm is put into practice in classes, where teams are created with graduated students from business and engineer/science subjects that are to be involved with 2-5 portfolio technologies. To help all members, the course content includes a diversified pool of subjects that go from marketing, to finance and intellectual property protection. Thus, a collaborative network of advisers, managers and investors is key for the success of the program. The process itself is carried out in two semesters and it is divided into the following stages: (1) Ideation Process, (2) Phase 1: Evaluate Opportunity, (3) Phase 2: Develop Opportunity, (4) Develop Commercialization Strategy, and (5) Commercialization Implementation (Baker, Barr, Kingon and Markham, 2009).

1.3. Aims and Objectives of the Work Project

In this section it is important to remind that the HiTech program is divided into three different stages (Deliver, Validate and Structure), and to state that due to time limitations and schedule incompatibility this thesis will only focus on the two first stages of the program. As such, the purpose of this Work Project is to understand the rational and the process used by the HiTech algorithm to transform a cutting edge technology into a product, and define what the key success factors for the effectiveness of technology incubation are.

To sum up what was previously stated, the research questions of this thesis are *"What is the process of transforming a cutting edge technology into a high tech – high growth product?"* and *"What characterizes the technology incubation process in order for it to effectively transform a cutting edge technology into a high tech – high growth product?"*

As a result, this thesis will focus on the process of commercializing an already existing cutting edge technology. The technology that I got involved with in the HiTech program will be designated Technology X since the HiTech coordinators requested confidentiality regarding the technology's name in the development of this Work Project.

To sum up, the objectives of this Work Project are: (1) to analyse in a meticulous way the HiTech algorithm by comparing it to the TEC algorithm, (2) to identify the distinct good practices, challenges, and limitations of the program, (3) to recommend some actions to improve the HiTech program, and (4) to enumerate the key success factors and state the effectiveness of the technology incubation process based on my experience and participation on the HiTech program.

1.4. Work Methodology

In order to develop this Work Project, the HiTech program will be examined as a case study. Consequently, I will use my participant role, involvement and experience in the program as the main source of information to the development of this Work Project. In order to do so, a critical analysis of each of the topics covered will be conducted to then examine the strengths and weaknesses of the program, the expertise needed for each phase and the limitations of the methods and guidelines used. Before starting analysing my experience in the program, it is important to describe briefly how a normal HiTech program week was conducted.

The regular HiTech work week starts on Thursdays at 2:30 pm with the HiTech session. The session is divided into three periods:

- Training session (2:30-4:30 pm): where the coordinators of HiTech spend the first hour lecturing about the concepts that are going to be explored by the teams during the week, and during the second hour two to three teams present their work developed (the deliverables), receive feedback and answer the questions from the audience.
- Seminar (4:30-6:30 pm): where guests with expertise in specific and relevant topics present their ideas and insights about the subject so the teams can get familiarized with them.
- Mentor's meeting (7-8pm): where each team discusses with their designated mentors the conducted deliverables, tips for improvement and difficulties felt in the process.

The above called deliverables are weekly assignments that each team needs to develop according to the subjects lectured in the HiTech session of that week. These are always submitted in the program's Google Drive, and they are presented in form of worksheets to be completed by the teams, thus every deliverable is to be filled according to each team's technology. The deadline of this homework is always the Tuesday after the HiTech session until 11:59 pm.

To complete such deliverables, my team (Technology X's team) developed a weekly plan to make sure that everything was delivered on time. Firstly, on Friday the technology main developer looks at the deliverables and completes them as well as he can. Secondly, the rest of the team checks the work developed over the weekend and improves the previous deliverables according to the feedback received at the HiTech session. Thirdly, every Monday the team conducts a Skype meeting from 1 to 2 pm to discuss the work developed, decide what needs to be improved and allocate the final adjustments necessary to successfully conclude the respective deliverable.

To answer the objectives established for this Work Project, weekly reports concerning my experience in the program were conducted to be used as the groundwork of this thesis and to then compare HiTech with theoretical definitions, the TEC algorithm and the incubation process.

2. Analysis of HiTech Experience

2.1. Discover Phase

When comparing the HiTech algorithm with the TEC algorithm, one can conclude that the Discover phase (see Appendix 1) is equivalent to the Ideation phase (see Appendix 6), respectively. This because in both the objective is to develop a set of prioritized *product concepts* with Technology-Product-Market (TPM) linkages between the unique capabilities of the technology - *scanning the technology* - and the customer/market needs (Baker, Barr, Kingon and Markham, 2009). To accomplish this, the teams should go through several concepts that in the case of the TEC algorithm are described as: Product Idea Generation; Product Description Refinement; Product Idea Prioritization & Summarization; Product & Market Definition and Decision, and in the case of the HiTech algorithm are described as: Technology Description; Technology Capabilities and Uniqueness; Market Needs; TPM Linkages; Value Proposition and Product Statement. The concepts related with the HiTech algorithm were explored weekly in form of deliverables to be completed outside the HiTech sessions.

Having in mind the considerations above, it is clear that despite the fact that the concepts of both algorithms are not defined and organized in the same manner, in the end when developing the Discover phase of the HiTech algorithm all the topics of the Ideation phase of the TEC algorithm were explored. It is important to emphasize the fact that the timelines of these phases are different from the algorithms – six weeks for the Discover phase and only four for the Ideation phase – which is reflected in the way the subjects are organized, namely the fact that the subjects are more divided in the HiTech Algorithm.

2.1.1. Technology Description

The act of developing the Technology Description Worksheet, the first deliverable of the HiTech, is within the Product Idea Generation of the Ideation phase of the TEC algorithm. The construction of such worksheet helps the teams to identify promising technologies by describing and expressing technology specifications that will help to develop the technology capabilities. This framework is used to: define the comprehensive review underlying science of the technology; identify how the technology specifications translate into potential uses and users; and assess how far away the technology is from commercial use (Kingon and Markham, 2004).

Regarding HiTech, such deliverable was only constructed by the technology developers since it was submitted before the first HiTech session, therefore the management student had no involvement on it. With this in mind, and in order to allow the management student to have a more comprehensive understanding of his/her allocated technology, the program was organized so that the management student had to do a presentation explaining the technology on the following week. The development of this presentation was challenging in my case because it was difficult to comprehend the Technology Description Worksheet developed by the Technology X's developers as the language was quite technical, and, at the time, my team had not yet adopted the weekly communication schedule stated previously. Nevertheless, in the second session I got more involved with my team and debated Technology X in a deeper way, which allowed me to better understand my team's technology and its description (see Appendix 7).

Before changing the topic, it is essential to emphasize that the first mentoring session was essential because both the mentors and me (the management student) were able to get to know, discuss and understand in a more detailed way how Technology X functioned and what its benefits were.

2.1.2. Technology Capabilities and Uniqueness

Regarding the development of the Technology Capabilities and Uniqueness Worksheet, which is also within Product Idea Generation of the Ideation phase of the TEC algorithm, it is important to emphasize that this is one of the crucial steps of the HiTech program. The establishment of the TMP linkages is the core objective of the Discover phase, where the goal is to turn unique technical capabilities into product features that match enduring customer needs. Those capabilities are to be transformed into product features, which may translate different product concepts that answer to distinct customer/market needs (Kingon and Markham, 2004). Technology capabilities is what the product can do for the customer and unique capabilities are the ones which are impossible or hard to replicate, therefore identifying and separating all the technology capabilities are essential for the success of the Discover phase of HiTech.

In the development of the worksheet, the team had to define Technology X's capabilities, how they were measured and their level of performance (see Appendix 8), and define what the main competitor of Technology X is to compare the level of performance of the established capabilities between the two technologies (see Appendix 9). Also, during this week the mentors asked the team to build a PowerPoint presentation with one slide describing Technology X in one sentence and another slide stating what makes Technology X unique, which allowed for the technical language to go down and the technology developers to transform the way they communicated Technology X into a clearer and more understandable way (see Appendix 10).

The main challenges at this stage were to define the capabilities as general as possible and to maintain them as separated as possible in order to enable the creation of a wide range of product concepts, and to understand some of the concepts namely how a capability is measured and how to define the level of performance of those capabilities.

2.1.3. Market Needs

As stated previously the TEC algorithm intends to explore the connection between market needs, unique attributes and product features enabled by the new and emerging technology (Baker, Barr, Kingon and Markham, 2009). Thus, the goal of the Market Needs Worksheet - which is also part of the Product Idea Generation - is to link the problem and the solution of Technology X by first focusing on the problem and exploring the customer needs and context, and second by linking the problem to the team's solution, Technology X. A crucial message at this stage is that no matter how overwhelming a technological development might be everything begins with the market; if there is no need in the market the technological development is worthless (Parded and Tony, 2018). When conducting the deliverable, the team needed to define Technology X's applicable markets, identify the needs of each potential market and classify each need as must, should, could or won't have. Here, to identify the market needs the team needed to establish the What (the benefit that has value), the Who (the customer who values the benefit), the When and Where (the context that creates the opportunity to deliver the benefit), and the Why (reason so the benefit to has value) related with the customer needs (see Appendix 11).

The main challenge felt at this stage was the lack of understanding of the guidelines and concepts regarding this worksheet, and due to the lack of time the team was not able to clarify the concepts in the mentoring meeting, which led to the re-development of the deliverable.

Furthermore, it is important to emphasize this week's seminar because it tackled Intellectual Property protection which is of great importance in the Technology Commercialization process. According to what was lectured, the team discussed that Technology X could eventually only be protected through trade secret, which was supported by an informal conversation between the technology developers and their university office that dealt with intellectual property protection.

2.1.4. Value Proposition

The Value Proposition is a well-known business concept and concerning the TEC algorithm it is also part of the Product Idea Generation of the Ideation phase of the TEC Algorithm. By definition, a Value Proposition is an explicit promise made by a company to its customers that it will deliver a particular bundle of value creating benefits (Hassan, 2012).

As for the Value Proposition Worksheet, this deliverable was to be done in a very detailed and quantifiable way (see Appendix 12) which goes a bit against what is done in business classes.

Nevertheless, because this was the concept that was explored at such an early stage, it was a good practice for it to be extensive as at this stage nothing was decided, yet and the members of the team needed to consider all the dimensions of the Value Proposition in a profound way. Moreover, it is important to say that this concept was developed without being based on a specific product concept, it was developed based on the technology capabilities and specifications, and on the end users of the technology.

2.1.5. TPM Linkages

Regarding this concept, one needs to consider that the development of TPM Linkages is the core objective of the Discover phase of the HiTech program, as well as on the Ideation phase of the TEC algorithm, where the act of developing the TPM linkages is on both the Product Description Refinement phase – where all the previous concepts developed are organized, where the team enumerates the multiple product ideas generated and identifies the multiple market opportunities for each product idea – and the Product Idea Prioritization and Summarization phase – where the team develops a set of prioritized product concepts with strong hypothesized linkages between unique capabilities of the technology and customer/market needs. It is important to note that a single TPM link is not to be taken for granted. A company must develop the product concept so that it actually meets the need of the customer rather than merely stand as a technical capacity (Kingon and Markham, 2004).

When developing the TPM Worksheet, the team needed to describe Technology X's specifications and capabilities, elaborate the features and the customer benefits from each of the product ideas, define the potential markets for each of the product concepts, and, finally, define what the needs/problems faced by the different potential customers are (see Appendix 13). This was one the most challenging deliverables developed in the Discover phase because the team had to use and link all the previously conducted deliverables of Technology X to fill this worksheet.

The week when the teams were to present the TPM Linkages Worksheet was different from the previous ones because each team had an individual meeting, one hour long, with an American Barrett Hazeltine University Professor of Entrepreneurship and Organizational Studies who is one of the creators of the TEC Algorithm (A. Kingon, personal communication, March 28, 2018). This was a very important and enriching meeting because the professor really helped the team to tackle potential product concepts that may arise from Technology X and what were the main issues that the team had yet to research and explore in order to build a successful business case. Also in this meeting, we were advised to revise the intellectual property protection topic because the American professor said that in some cases mathematical models can be patentable and that the interests of the technology developers' university may be influencing their advice towards our team. Thus, the team scheduled a formal meeting with the office of the technology developers' university to do an official assessment of Technology X's intellectual property protection possibilities and once again they advised us that Technology X could only be protected through a trade secret.

2.1.6. Product Statement

The final step of the Ideation phase of the TEC algorithm is the Product Definition plus the Market Description, and the first is equivalent to the Product Statement of HiTech. In order to develop the Product Statement Worksheet, the team needed to define the key features, the customer benefits and the technical specifications of each product concept. This deliverable allowed my team to identify what the missing information that had to be further explored in the Validation phase was. The developed work was integrated in the second version the TPM Linkages Worksheet because this information was also part of the TPM development (see Appendix 13). It is important to emphasise that the meeting with the American professor really helped the team to unfold the technology and understand what the different product concepts of Technology X were.

For that week the team also needed to develop Technology X's brochure, based on all the deliverables conducted so far as well as the brochures of competitive technologies.

2.1.7. Preliminary Market Assessment

Once again, the final step of the Ideation phase of the TEC algorithm is the Product Definition plus the Market Description, where the potential added value product concepts that are going to be considered in the next phase of the process, the Validation phase, are decided. The Preliminary Market Assessment is a market description of the potential target market of Technology X.

The elaboration of Preliminary Market Assessment Worksheet is the first of two market assessments performed during the HiTech program. This market assessment is the preliminary one, as such it is to be done based on secondary data research and developed in a top-down approach. On the one hand, secondary data analysis is the analysis of data that was collected by someone else for another primary purpose and the main advantages associated with it are the effectiveness and convenience it provides to the research process (Jonhston, 2014). On the other hand, using a top-down approach for the preliminary market assessment means that the market will be calculated by first determining the value of the total market and then estimating what the Technology X's addressable market value is, while stating the facts and the assumptions behind the numbers.

To develop the Preliminary Market Assessment Worksheet, the team had to establish first the value of the total market and second the value of the addressable market for all the distinct product concepts generated (see Appendix 14). The goal of this exercise was to see if there was a suitable opportunity for Technology X, and to see if the market had the desirable characteristics: large and growing market, with strong customer needs.

The main challenge of this deliverable was to find the right sources of information to base our calculations on, this because the use of the wrong sources of data or the use of incorrect assumptions may lead to erroneous conclusions and may be used to support future decisions made by the Technology X's, which may turn out to be a fatal flaw of the technology commercialization process.

2.2. Validation Phase

When comparing the HiTech algorithm with the TEC algorithm, one can conclude that the Validation phase (see Appendix 1) is equivalent to the Phase 1 (see Appendix 15) of the TEC algorithm, where the last one is composed by: (1) Product Definition Confirmation; (2) Functional Assessment and (3) Strategic Assessment (Baker, Barr, Kingon and Markham, 2009). The HiTech program finishes the Validation phase as the Phase 1 of the TEC algorithm, by performing the Functional and Strategic Assessment, however in order to make the Product Definition Confirmation, the program uses the following concepts: Product Statement Validation, Business Model Canvas, Market Assessment and Product Prioritization.

The main goal of this phase is to eliminate product ideas (not technologies) based on the so-called "fatal flaws" – characteristics that make a specific product concept not attractive to go to market. In order to achieve this goal, the teams during this phase of the TEC algorithm will first use a set of analytical tools and perform the so-called "cold calls" that will guide them to build the technology commercialization neophyte, and second the teams will perform the Functional and Strategic Assessment for their technologies (Baker, Barr, Kingon and Markham, 2009).

An important acknowledgement, before analysing the Validation phase, is that cold calls refer to the main source of primary data conducted by the teams to assess the opportunity, gather information about functional, strategic and financial assessments, and collect evidence regarding what should be the next steps of the team to allow the technology and the product or service to gain credibility in the market. To do so, my team contacted, via e-mail, potential customers, competitors, experts and partners to schedule a Skype or personal meeting with them during the course of the entire Validation phase, occurred more intensely in the beginning of this phase.

2.2.1 Product Statement Validation

The Product Statement Validation Worksheet is the deliverable whose goal is to describe the main findings of the first round of the cold calls performed by the team, thus confirming the assumptions that came from the Discover phase, refining the information regarding the market needs and improving the value proposition of the technology (see Appendix 16). This is one of the most important deliverables of this phase because it is where the team starts to understand the market in a profound and in-depth way which is crucial for the process of the HiTech program. The main challenge faced in this deliverable was analysing and transforming the entire information collected from all the cold calls executed so far in a concise and clear way.

Unlike many of the teams of the program, ours did not struggle to find contacts to perform the cold calls because the Technology X's main developer is part of an association of the industry of our technology and, as such, he had access to many contacts that were open to collaborate with us. This was vital for the success of Technology X's team at this stage of the process.

2.2.2 Business Model Canvas

In 2010, Osterwalder and Pigneur created and developed the nine block Business Model Canvas (see Appendix 17), a strategic management and entrepreneurial tool that describes, analyses, designs and develops business models. The Business Model Canvas is a visual chart that describes the logic behind how a company is going to make money, covering the main areas of a business: its customers, its offer, its infrastructure and its financial viability (Osterwalder and Pigneur, 2010).

In the Validation phase, only the right side of the Business Model Canvas was explored and developed because the right side entails the external components of the business and on the left the internal components, and due to the timeline of the HiTech program at this stage the team did not have the information to fill out the left side. With this in mind, when conducting this deliverable my team considered two paths for the business model canvas that are represented in different colours (see Appendix 18), because at the moment my team had not yet defined what the best product concept to enter the market was. Hence, at this stage the team decided to analyse both paths to have a better understanding of the distinct business model possibilities.

2.2.3 Market Assessment

As stated before, this is the second of two market assessments performed in the HiTech program. Contrary to the first one, this one will be based on primary sources of information (the cold calls) and it will be built on a bottoms-up approach, thus the market value is calculated by assessing the potential sales in order to estimate a total sales. To do so, the market will be further narrowed to the served market (segment of the addressable market that the firm can and actively attempts to serve considering competition, country and sales channels) where teams will do a product price estimation. This is an extensive work that takes a lot of effort but the end results are much more accurate than the ones the team had in the Preliminary Market Assessment.

When conducting the Market Assessment Worksheet (see Appendix 19), the main challenge was to define the assumptions behind the numbers, because although the market values considered in terms of operational expenditures and expenses on the industry where provided by people that are in the market (cold calls), to calculate the numbers the team had to do a number of assumptions regarding the definition of the served market and the potential value of the savings that Technology X would provide to its customers.

2.2.4 Product Prioritization

The Product Prioritization Worksheet is where the teams decide what the final product is, this is the product concept that is going to be considered in the development of the business case. In this deliverable, each of the product concepts are placed in the columns of the Excel worksheet and each row represents a key criterion to be evaluated according to the product concept, then each criterion is weighted according to the level of importance considered by the team. The number placed in each cell represents the strength of each product with respect to the criteria under consideration (see Appendix 20).

This exercise was fundamental because though my team was aware of the value of the technology and its potential - information supported by the cold calls -, defining the path to which Technology

X would be delivered to the market was a recurrent challenge. By being a service it will take a long time to reach a relevant market share, and by being a software plug-in the team needs to explore the potential partnership and how it needs to operate in order not to leave money on the table very well. When developing this worksheet, a new product concept was thought of, a cloud platform of control strategies and operational oriented models that according to my team's cold calls could be very interesting and innovative to the market.

2.2.5 Functional Assessment

The Functional Assessment Worksheet is a tool that was developed specifically by the TEC algorithm's creators and the objectives of this framework are: Force an awareness check across functional areas; Detect improvement opportunities; Detect information requirements; Prepare contacts; Compare alternatives; Define new decision criteria or update (Baker, Barr, Kingon and Markham, 2009). This framework intends to analyse the team's skills in the following areas: Technology, Legal, Marketing, Organization, Manufacturing and Financial Areas.

This was a worksheet to be completed in Excel where for each of the areas the team had to assess the potential of the solution/product opportunity and assess the actual status of development. To do so, in each area there were several parameters where the team had to define the level of importance, rate the state of it and define the level of confidence of the given parameter. After filling the entire Excel sheet, the team would get the results of their performed scores in form of Importance Rating (IR) and Importance Rating Confidence (IRC) graphs (see Appendix 21). By analysing the results, Technology X's team realized that the areas that needed to be further explored are the Legal and Operational Areas.

The major challenge conducting this deliverable was that because it was a quite extensive tool that entailed many parameters, many times the answer depended on the perspective or the product concept that the team considered at that point. Furthermore, this is a tool that brings some discussion between the members due to the fact that the extent and detail brought by the tool creates a scenario where the team members argue a lot about the values of the parameters and this makes the process to be even more time consuming. Nevertheless, this is a very important tool of the Validation phase because it gives the team an overview of what is missing and what further information the team needs from the cold calls.

During this week, Technology X's team also scheduled a meeting with Clarke Modet – a specialized firm in Intellectual Property protection – that was provided by the HiTech program.

2.2.6 Strategic Assessment

For the Strategic Assessment of the HiTech program, the teams analysed and explored the following business frameworks: SWOT Analysis, Industry Mapping and Porter's Five Forces. Before starting developing such deliverable the mentors of my team recommended us to consider a fourth framework: The Value Net.

The SWOT Analysis (see Appendix 22) is an assessment tool that analyses internal Strengths and Weaknesses, and external Opportunities and Threats, whose purpose is to identify how internal and external factors influence the business (Harmon, 2015). After completing this framework for HiTech (see Appendix 23), all teams also had to develop the Challenges, Constraints, Alerts and Dangers that may impact on their technology by cross-comparing the elements of the SWOT Analysis, in my team's case on Technology X (see Appendix 24).

The development of the Industry Mapping framework was quite challenging for my team because in this framework we needed to name some of the companies involved in the different stages of the value chain for Technology X's industry and its potential paths, and because Technology X and its innovative product concept is different from current competitors, the team needed to consider a brand-new way to enter the market that does not exist yet (see Appendix 25).

Developed by Professor Michael E. Porter, the Porter's Five Forces (see Appendix 26) is a business tool whose purpose is to understand competitive forces and stay ahead of the competition. The five key factors the model uses to identify and evaluate potential opportunities and risks are:

Competitive Rivalry; Threat of New Entrants; Threat of Substitutes; Bargaining Power of Suppliers; Bargaining Power of Customers competition (Cadiat, Michaux and Probert, 2015). The development of this deliverable (see Appendix 27) was quite smooth as the team had a great perception of the market dynamics due to the performed cold calls.

Finally, the Value Net (see Appendix 28) is a framework created by Nalebuff and Brandenburger that looks at a business situation and recognizes the way a company (or industry) operates by analysing four main interdependent groups that influence the course of any business: Suppliers; Customers; Competitors; Complements (Lendel, 2015). The development of this framework (see Appendix 29) was very helpful because the team considered more dimensions that affect Technology X.

3. Conclusions

3.1. Good Practices of HiTech,

According to the TEC algorithm creators, there are some actions that the coordinators of a technology commercialization process should adopt; these actions are: Create Temporal Checkpoints; Structure Large Blocks of Time; De-Emphasize Business Case; Emphasize and Balance Team Diversity; Generate Technology Flow; Beware of Idiosyncratic Heuristics (Baker, Barr, Kingon and Markham, 2009).

After reflecting on the HiTech program, one can conclude that most of the actions mentioned above were experienced in the program. First, considering that for each week of the program the teams had to develop and upload the deliverables, so that the coordinators and the mentors of the program could assess them, they created temporal checkpoints. Second, the fact that HiTech is divided into three phases that last for six or seven weeks makes the program to be structured in large blocks of time. Third, throughout the elaboration of the Discover and the Validation phases, minimal emphasis was given to the Business Case, this is important because the technology commercialization process not only continually evolves but also may change radically in the middle of the process. Fourth, the fact that the program combines technology researchers with management students allows the team to have members with different backgrounds that add value to the project and this was emphasized throughout the program. Fifth and final, most students in the program have limited or no prior entrepreneurial experience, thus the fact that all the participants of HiTech were aware of idiosyncratic heuristics related to the decision making process was important. The only action mentioned above that was not present in the HiTech program was to generate technology flow because the teams do not explore and choose the technologies they will work with, the members of the team, besides the management student, are the ones who actually developed the technology that is being analysed in the HiTech program.

Moreover, I would add that the support that the HiTech program provided to the teams concerning intellectual property protection, both in the weekly seminars and the meeting with Clarke Modet, was essential in the HiTech program.

3.2. Challenges and Limitations of HiTech

By analysing the HiTech program, one can enumerate the main challenges and limitations felt as a management student (see all specified challenges and limitations on Appendix 30).

Language adaptation. At the beginning of HiTech it was hard for me to understand the Technology X's developers, thus the process of adapting their language from technical to perceptible was a challenge.

Concept interpretation. Many of the concepts lectured had room for interpretation as a result, many of the deliverables conducted had to be redone and adapted to the feedback provided by both the program's coordinators and the team mentors.

Concept complexity. Most of the concepts lectured had a connection between each other, which made the development of the deliverables even more complex, because if the team decided to bet on a different path it would have to change the previously elaborated deliverables. This was mainly felt in the development of the TPM Linkages.

3.3. Recommendations

Although the HiTech program is already a well-established and well-developed cohort-based program, as a management student some difficulties (mentioned above) were felt in the process. In order to overcome those, it is recommended that in the beginning of the process an atmosphere of more interaction between the management students and the technology developers is created, as in the beginning of the process I felt that I was not part of the team; allowing for a more interactive and informal environment in the beginning of the process would be important to allow a deeper engagement of all team members since the very start.

It would also be interesting that in one of the weeks a visit to the technology inventor's laboratory was scheduled for both the management students and mentors of all teams, so everyone could see and explore the actual technology. My team arranged for me to visit their laboratory and see the technology, and this was an essential activity that made me connect more with the team, made me gain/feel/acquire a sense of belonging and made me be more integrated within/along the development of the deliverables, which allowed me to have an overall better experience than some of the other management students that participated in the HiTech program. As such, I think it would be even more interesting if also the mentors attended this visit because in the beginning much of the time in the mentor's meetings was spent explaining the technology and how it worked.

3.4. Key Success Factors and Effectiveness of Technology Incubation

To conclude and answering the first research question of this Work Project ("*What is the process of transforming a cutting edge technology into a high tech – high growth product*?"), I consider that the technology incubation process is an effective way to enable technology inventors and innovators to transform their cutting edge technologies into high tech/high growth products.

Moreover, to answer the research question *"What characterizes the technology incubation process in order for it to effectively transform a cutting edge technology into a high tech – high growth product?",* both my experience in the HiTech program and some suggestions retrieved from the literature review (Auerswald and Branscomb, 2003; Aerts, Matthyssens and Vandenbempt, 2007; Gbadegeshin, 2017; Mian, 1997) allowed me to enumerate the following key success factors for the effectiveness of the technology incubation process: Manage the perspectives and potential added value of all participants - technology developers, business managers and business mentors; Set clear objectives from the start between all team members; Adopt an in-depth network between the mentors, and potential customers, competitors, partners and investors; Set a schedule for communication outside the program to allow constant discussion throughout the process and individual network between team members; Be open and flexible to adapt to the environment in order to accept the scenario and conditions of the given technology.

Thus, HiTech is considered an effective program to facilitate technology commercialization as it embodies all the key success factors mentioned above (at least to some extent), and it offers the business support needed to allow the technology inventors and innovators (the target of technology incubation programs) to transform their cutting edge technologies into high tech/high growth products. On these grounds, the HiTech program is a challenging process that entails the right practices for the success of everyone involved. Nevertheless, the effectiveness of HiTech and other technology incubation programs also depends on the commitment and the work that the technologists put into the process, and the passion that they have towards their creations.

4. Limitations

Although this Work Project has reached its goals, any project has unavoidable limitations. The main limitation associated with this Work Project was time. On the one hand, three months is a limited amount of time to develop an extensive analysis of the process of transforming a cutting edge technology into a high tech/high growth product. On the other hand, due to the time incompatibility between the HiTech program and the delivery of the Work Project, it was only possible to critically evaluate the first two of the three phases of the HiTech, thus it was not plausible to accomplish a complete and far-reaching analysis of the entire HiTech program.

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APPENDIX

Table of Content

Appendixes

Important acknowledgements:

The version of the content in the Appendixes that concern the work developed purposely for the HiTech program is always the final version. Thus, although most of the deliverables were modified and improved over the program, the intermediary content will not be present in this thesis.

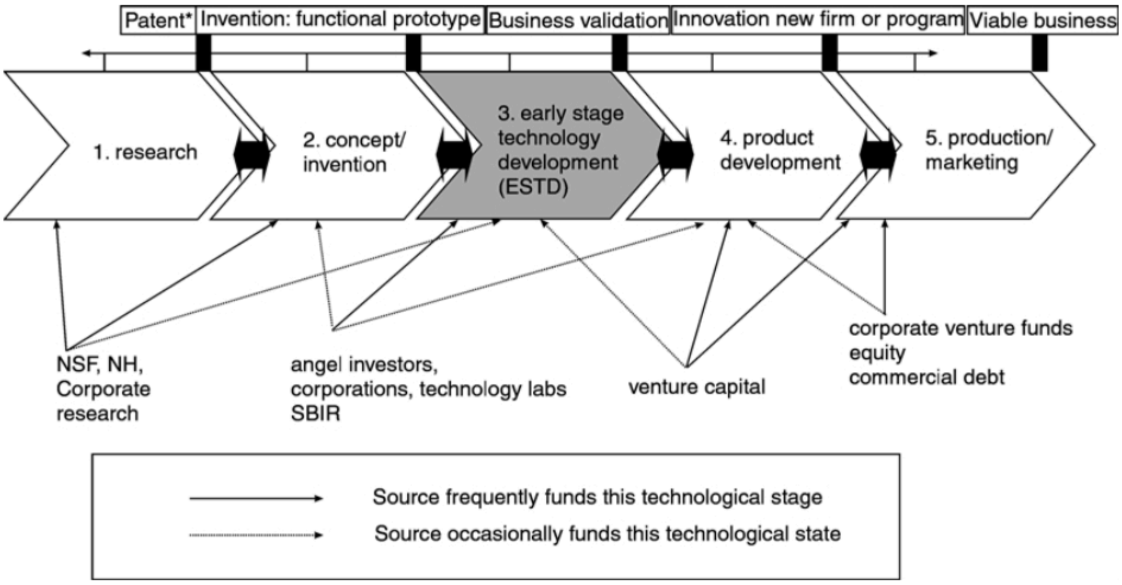
Moreover, the way the work developed purposely for the HiTech program is presented in this appendix is not equal to the one delivered during the program. For the program, we had extensive and detailed templates to be completed, thus the content was transformed and summarized to be presented in this thesis.

Appendix 1: The HiTech Algorithm

	OBJECTIVE	STAGES
Discovery Phase	Develop a set of prioritized product concepts with strong Technology-Product-Market (T-P-M) linkages	1.Describe technology capabilities 2.Identify markets with greatest need that the capabilities addresses 3.Develop multiple product ideas to match identified markets
Validation Phase	Gather information to validate the previous phase, by contacting potential customers, competitors, specialist in the matte	1. Start with emphasis on selection to eliminate product ideas (not technologies) based on fatal flaws. Look for MUST HAVE products 2.Gradually shift to building a case to develop product and business concepts
Structure Phase	Define Strategy and Plan to commercialize the technology through the development of a Business Case	1.Organize the information previously acquired in a way that makes sense 2.Built a strategy to put the product in the market 3.Write the Business Case for implementation

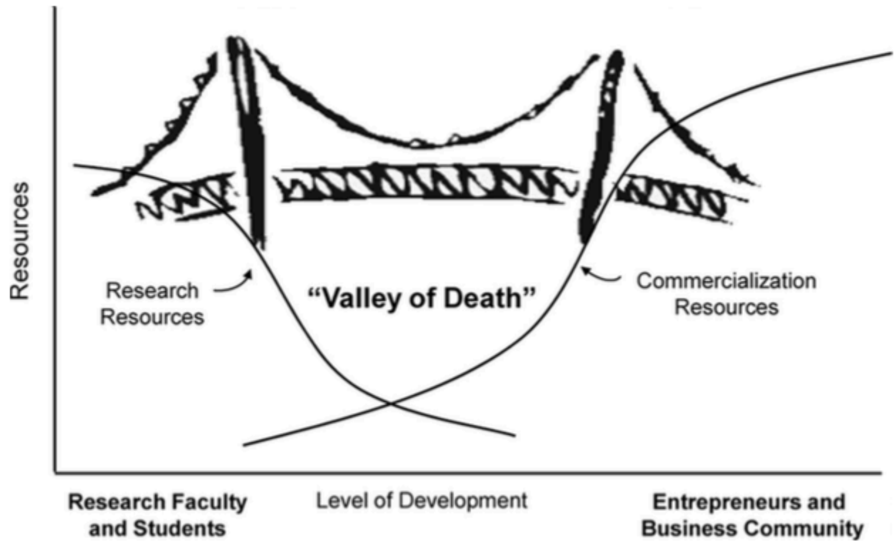
Source: HiTech (2018)

Appendix 2: The "invention to innovation" transition framework



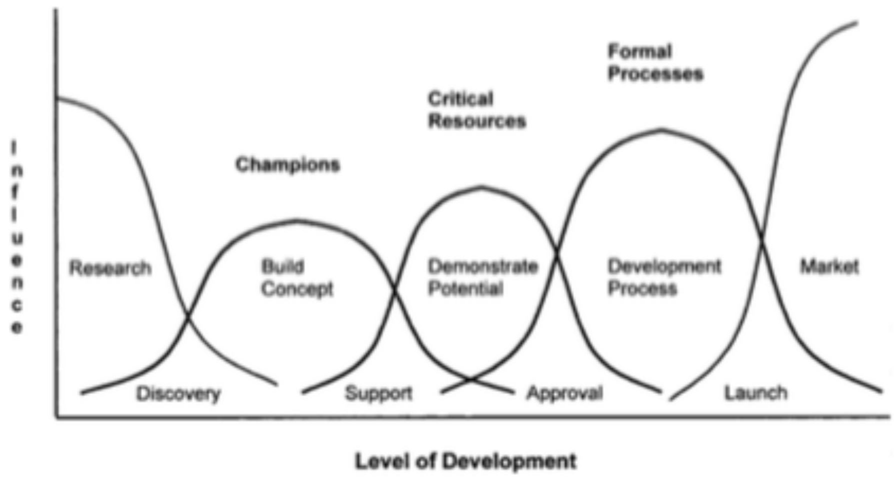
Source: Auerswald and Branscomb (2003)

Appendix 3: The Valley of Death



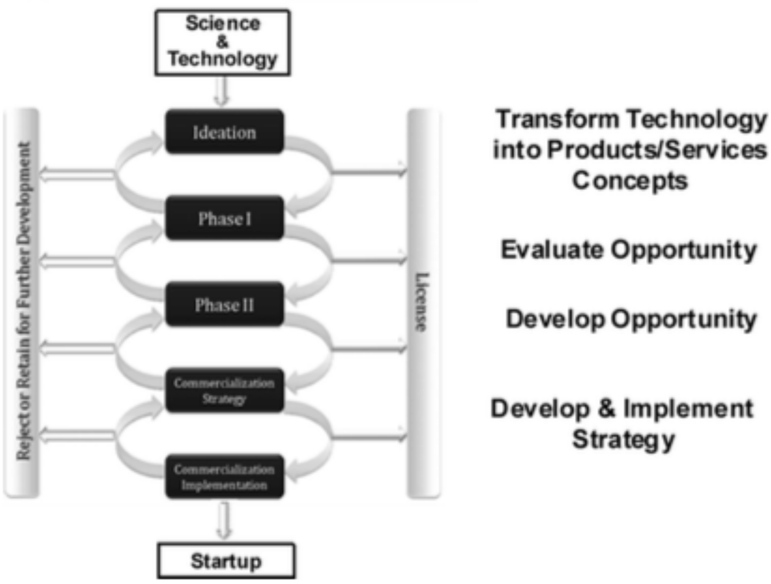
Source: Markham (2002)

Appendix 4: Crossing the Valley of Death



Source: Markham (2002)

Appendix 5: The process of the TEC Algorithm



1st Stage: Ideation– Transform technology info product/services concepts (4 weeks)

- Product Idea Generation: Students first investigate the technology and discover how it works and what unique capabilities it may create or enable. They are encouraged to use a wide variety of sources to generate ideas, this based on T-P-M (Technology⇒Product⇒ Market)
- Product Description Refinement: generate multiple product ideas that might be developed for each technology and multiple markets for each product (or service). Then students are asked to identify multiple market opportunities for each product idea
- Product Idea Prioritization and Summarization: develop a set of prioritized product concepts with strong hypothesized linkages between unique capabilities of the technology and customer/market needs
- Product Definition and Market Description: Identifying diverse market needs guides the process of further specifying product attributes and guides the search for technologies with the needed performance characteristics. Development of the Value Proposition

- Decision: Making the final choice regarding what the final concept is, to be used and considered in the next phases

2nd Stage: Phase 1 - Evaluate Opportunity

- Use of a series of questions and analytical tools that guide technology commercialization neophyte to ask fundamental questions about a variety of topics covering technology, legal, marketing, organization, manufacturing, financial, industry and competitive issues
- Functional and Strategic Assessment
- Identify "fatal flaws" of any sort that would warrant setting a technology or product idea aside at least for the time being
- Goal: Eliminate product ideas, not technologies

3rd Stage: Phase 2 – Develop Opportunity

- In both Phases 1 and 2 students use the guide questions and analytic tools to direct their research into whether they have identified a valuable opportunity
    - Heavy use of product development and market research tools
- Begin building the business case and becoming expert in the technologies, products, and markets that have survived
- In this phase the teams start to interact with and begin building relationship with dozens of external parties (scientist, managers, potential competitors and clients, suppliers)
- Goal: Build the business case
- At the end of this stage, teams need to build a set of criteria that will help them to choose the venture/industry where to start commercialization (using the T-P-M framework). The criteria will be ranked, and this ranking then becomes the primary basis for the selection of what opportunity will be carried forward.

4th Commercialization Strategy – Development of Implementation Strategy

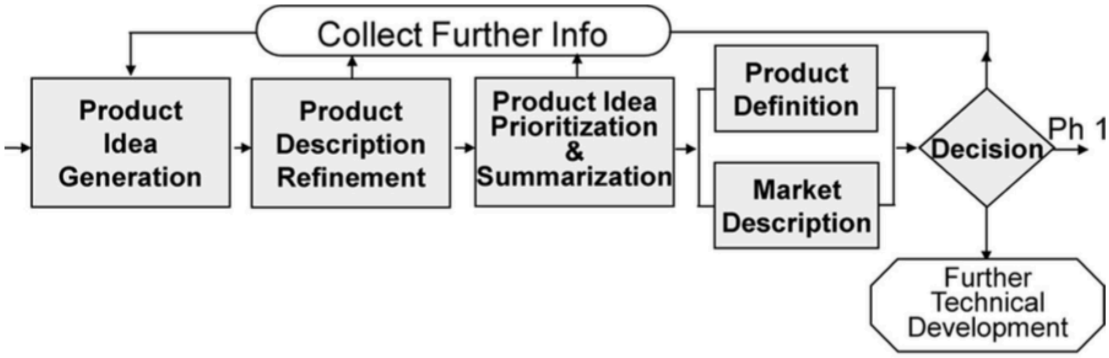
- Based on the Value Proposition previously developed and market needs that the technology resolves (who, when, where, what, why).
- Development of the Business Model ⇒ Business Proposal

5th: Commercialization Implementation – Start-up

- The actual launching of the business typically takes place after the end of the formal coursework

Source: Baker, Barr, Kingon and Markham (2009)

Appendix 6: TEC algorithm: Ideation Phase



Source: Baker, Barr, Kingon and Markham (2009)

Appendix 7: Technology X Description

Contextualization

Water is of major importance to all living things, as such it is not only a biological but also everyday life necessity. Therefore, the treatment of the water used by homes, industries and businesses before it is release back to the environment is of great importance to our planet.

The Wastewater Resource Recovery Facilities (WRRF) are the ones in charge of the process of removing contaminants and potentially recover resources from the wastewater or industrial effluents. To do so, the WRRF uses biological, physical and chemical processes to treat the water, but right now all the solutions available on the market are costly, which makes it hard for WRRF to be sustainable and profitable.

Moreover, this is a highly regulated, and rightfully so, sector due to the fact that in the end if the WRRF release to the environment contaminant water it can threat the public health and the environment. As such, regulations are very detailed and the non-compliance of the law requirements may lead to fines of great value.

Further clarifications and problem definition will be focused on the biological processes as the technology in question is a biological water treatment process.

Problem

One needs to consider that the biological water treatment processes are unstable because these processes deal with living organisms that are hard to control and also because one can never be sure of the biological conditions of the wastewater or industrial effluents when it arrives to the WRRF. The main problems associated with this type of processes can be succinctly described as following:

- High Operational Costs: the constant need for calibration and troubleshooting is costly;

- High Energy Consumption: the need for aeration of the wastewater for the biological process alone can count for 45-75% of the WRRF total energetic bill;
- Process upsets: due to the lack dynamism of the current processes there is lack of understanding between the engineers and operators that run the WRRF, so the operators do what they are told without understanding the consequences of their actions in the process, as such sometimes there might be communication or process control issues;
- Lack of Resource Recovery Tools: this is mainly explained by the fact that with the current technologies the disposal of residuals is costly, therefore there is a loss of potential value because wastewater and residues can be converted in added-value substances, namely nutrients that can be turned into organic acids, biogas and bioplastic.

Solution

The technology which is going to be explored during the HiTech program, Technology X, is an innovative Advanced Process Modelling Tool that monitors, models and controls the biological processes of WRRF. This technology has already developed a number of dynamic microbial community-based models that have been proven to optimize WRRF. To understand why this solution is better than any other in the market. the following arguments were developed.

Firstly, Technology X needs no or minimal calibration as it has been tested and it has been proven that it has minimal levels of error – which is a great advantaged when comparing with the current technologies present in the market that can have error levels until 100% -, thus it is able to reduce the operational costs of the process.

Secondly, the model by using scenario analysis – based on historical data – is able to predict and simulate the microbial population dynamism of the wastewater and industrial effluents, therefore the technology provides better definition of the biological process. As such the WRRF team will make decisions based on information and not based on a trial error approach, thus the facilities will be able to take less and more certain actions and consequently reduce costs, which can also positively impact the levels of energy consumed.

Thirdly, because the technology in the end is a mathematical tool it allows for every employee involved to observe the consequences of their actions. As such a bridge of communication can be created between engineers and operators to have a more knowledgeable and trustable work environment.

Fourthly and last, the technology has been tested and in fact is able to enhance resource recovery, consequently this model is able to remove and recover nutrients that can be eventually transformed into organic acids, biogas and bioplastic and add value to the WRRF.

Source: HiTech Deliverables

Appendix 8: Technology X Capabilities

	Objective	Measure	Level of Performance
Precision in terms of accuracy	Technology X models are very precise since they can predict process outputs under dynamic conditions	Optimal fits have coefficient of determination r^2=1.	- Prediction of phosphorous: 1) anaerobic tank: r^2 = 0.96 2) aerobic tank: r^2 = 0.97 3) anoxic tank: r^2 = 0.86 - Prediction of nitrate removal: r^2 = 0.93
Minimal Calibration Requirements	The models incorporate all the recent literature about WRRF, including the effect of conditions that cause process upsets. Due to these reasons, the model does not need to be intensively calibrated to describe different phenomena. In addition, the model can be applied into different WRRF with minimal requirements for calibration because they capture the dynamics of the biological processes under study. Calibration of models requires additional measurement campaigns	Number of parameters that require calibration	None of the maximum kinetic rates required calibration for the description of 27 different data sets from lab-scale, pilot and full-scale experiments of biological nutrient removal systems.
Prediction of the process dynamics as unction of operational conditions	It allows the selection of the most suitable operational conditions (pH, temperature, type of carbon source, flow, etc) that increase the efficiency of the process	Binary measure	Technology X is capable of selecting the most efficient way to operate according to the operation conditions
Data reconciliation and gross error detection	Technology X has methods to automatically correct measurements in the biological processes under study and detect gross errors in the data collected and stored	Binary measure	Technology X is capable of correcting measurements of in the biological processes
Modularity	The model approach can be applied in different WRRF of different sizes and in different industries (e.g. waste from food; drink industries, petrochemical and refinery wastewater treatment processes) as well as in different biological systems. This approach can be customized according to the needs of the clients, combined with other type of models and implemented in different commercial software	Binary measure	Technology X is capable of adapting to the different WRRF

Source: HiTech Deliverables

Appendix 9: Technology X Unique Capabilities

The main competitor of Technology X are the models of the International Water Association. These models are activated sludge models and mechanistic models developed by experts from the International Water Association that describe the simultaneous removal of phosphorus, nitrogen and chemical activated sludge in activated sludge systems. Anaerobic digestion models simulate the dynamics of anaerobic digestion processes.

Technology X	TECHNOLOGY COMPARISON	Main Competitor
MINIMAL	Calibration requirements	PLENTY
HIGH	Level of Precision	MODERATE
POSSIBLE	Prediction of process dynamics as function of operational conditions	NOT POSSIBLE
POSSIBLE	Gross error detection and data reconciliation	NOT INTEGRATED
POSSIBLE	Modularity	POSSIBLE
COMPLEX	Level of Simplicity (in terms of structure)	SIMPLE

By performing this comparison, it is clear that Technology X's superior capabilities are (all are considered sustainable from the technology developers):

- Minimal calibration requirements
- Precision
- Prediction of process dynamics as function of operational conditions

Source: HiTech Deliverables

Appendix 10: Technology X Extra Homework

Technology X in one sentence

Technology X is a platform of reliable and robust models that predict with minimal requirements for calibration long-term performance of mixed microbial population dynamics as function of operational conditions.

What makes Technology X Unique?

UNIQUE CAPABILITIES	PROCESSES	PEOPLE
Precision Minimal Calibration Requirements Prediction of process dynamics as function of operational conditions	Technology X has a unique approach for the modelling of mixed microbial processes, which is different from any technology present in the market	The team has experts with a unique know-how, leading the modelling of bioprocesses for nutrient removal and bioplastic production

Source: HiTech Deliverables

Appendix 11: Technology X Market Needs

WHAT The benefit	WHO The Customer	WHEN and WHERE The context	WHY The reason	
Predict the conditions that will lead to instability and develop operating strategies to avoid them	Water Resource Recovery Facilities	Difficult monitoring, control and prediction of bioprocess dynamics	Biological processes are unstable and susceptible to failure	**MUST**
Decision support system for supporting the selection of sustainable treatment technologies	Water Resource Recovery Facilities	Selection of the most appropriate technology/ process configuration for resource recovery	There are different types of wastewater and waste with different properties	**SHOULD**
Estimate the minimal energy requirements for the successful operation of the biological systems. Enhance the potential of current technologies to recover resources. Scale-up and process design based on real needs	Water Resource Recovery Facilities	Current process configurations are highly energy demanding and not sustainable	Conventional systems rely more on aeration for the wastewater treatment and most of the plants are over dimensioned (pumps, aeration systems, reactors, etc). Current resource recovery processes are not optimized	**MUST**
Metadata collection and organization	Water Resource Recovery Facilities	Wrong practices for the collection of data, management and storage	Monitoring biological systems requires online and offline measurements through different sensors and analytical methods, respectively	**MUST**
Specialized know-how on the development/customization and calibration of different mathematical models for new bioprocesses	Consulting Companies, Manufacturers	Development/customization and calibration process of new mathematical models is time consuming and costly	Development of new models requires expertise and conditions that are generally unnecessary for the daily-life of engineering companies	**MUST**

Source: HiTech Deliverable

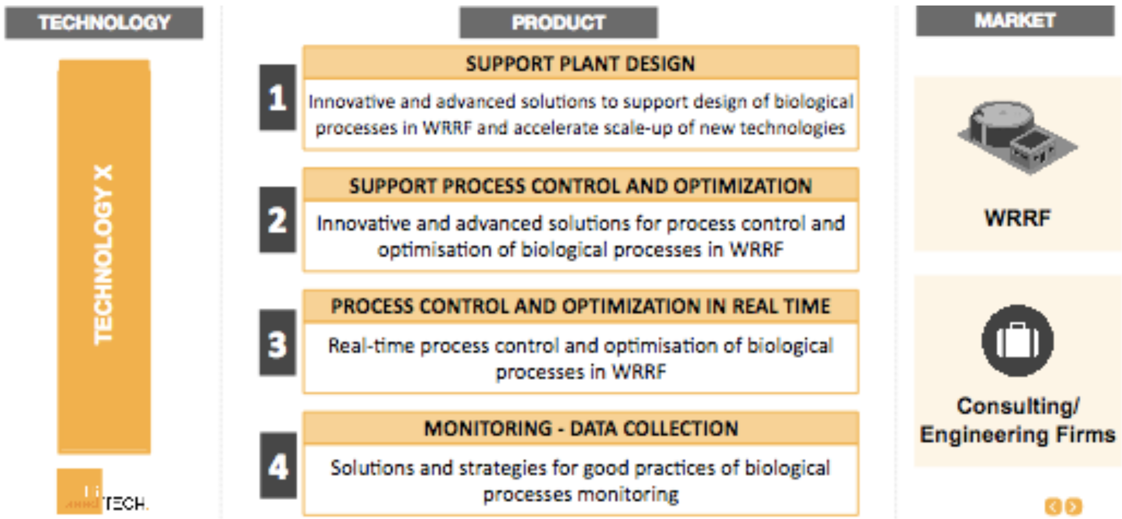
Appendix 12: Technology X Value Proposition

FOR	Water Resource Recovery Facilities (WRRFs)
WHO	have limited budget to comply with stringent effluent limits and difficulties to monitor, control and predict bioprocess upsets that typically increase **≥3 times** the typical operational and maintenance costs in order to continue meeting the limits through alternative methods. (For a small country like Portugal with **990 WRRFs**, the volume of water treated in 2016 was **533.6 x10^6 m^3** and only **476.1 x10^6 m^3** was invoiced, which means that these plants have to improve their sustainability).
THE	Texhnology X
IS A	Service based on the use of dynamic microbial-based mathematical models and simulation tools
THAT	Provides innovative and advanced solutions for monitoring, modelling and control of biological processes through a less time consuming (**less 28%** of the **time** allocated for calibration in a modelling project) and costly approach
UNLIKE	The International Water Association mathematical models and other metabolic models
OUR	Solution supports simultaneously **design** and **operational decisions** due to the fact that predict and describe **precisely** (r^2: 0.86-0.97) **the process dynamics as function of operational conditions with minimal requirements for calibration (less than 3 parameters)**. These features enable customers to improve biological process performance and meet effluent requirements with less chemical dosing. This service can provide time and **cost savings** of **$608,000/year** to WRRFs

Source: HiTech Deliverables

Appendix 13: Technology X TPM Linkages

TPM Linkages Overview



Singular TPM Linkages Analysis

1 SUPPORT PLANT DESIGN

Technology ➡ Product

Consulting/ Service Provider

Technology X provides innovative and advanced solutions for monitoring, modelling and control of biological processes, and it supports operational decisions (one time or ongoing services)

Features

- Chose Operating modes
- Set operating parameters
- Prediction of conditions that lead to instability
- Minimize the competition of side populations
- Ensure process efficiency with minimal energy requirements
- Optimisation of chemical dosing needs
- Ongoing support (optional)

Benefits

- Simulation of new process configurations
- Prediction of conditions that lead to instability
- Choose operating modes and predict differences between them
- Set operating parameters

Product ➡ Market

Wastewater Resource Recovery Facilities

Needs

- Predict the conditions that lead to instability and develop operating strategies to avoid them

Customer benefits

- Operational cost savings
- Process Troubleshooting
- Decision making support in real-time (optional)
- Improve biological process performance
- Meet effluent requirements with less chemical dosing

Consulting/Engineering Companies

Needs

- Development of robust and reliable models

Customer benefits

- Time and costs savings in the development and calibration of new models

2 SUPPORT PROCESS CONTROL AND OPTIMIZATION

Technology ➡ Product	Product ➡ Market
Consulting/ Service Provider *Technology X provides innovative and advanced solutions for monitoring, modelling and control of biological processes, and it supports operational decisions (one time or ongoing services)* **Features** - Chose Operating modes - Set operating parameters - Prediction of conditions that lead to instability - Minimize the competition of side populations - Ensure process efficiency with minimal energy requirements - Optimisation of chemical dosing needs - Ongoing support (optional) **Benefits** - Simulation of new process configurations - Prediction of conditions that lead to instability - Choose operating modes and predict differences between them - Set operating parameters	**Wastewater Resource Recovery Facilities** **Needs** - Predict the conditions that lead to instability and develop operating strategies to avoid them **Customer benefits** - Operational cost savings - Process Troubleshooting - Decision making support in real-time (optional) - Improve biological process performance - Meet effluent requirements with less chemical dosing **Consulting/Engineering Companies** **Needs** - Development of robust and reliable models **Customer benefits** - Time and costs savings in the development and calibration of new models

3 PROCESS CONTROL AND OPTIMIZATION IN REAL TIME

Technology ➡ Product	Product ➡ Market
Consulting/ Service Provider *Technology X Provides Innovative and advanced solutions to support design of biological processes in water resource recovery facilities and accelerate scale-up of new technologies* **Features** - Support the design and selection of process configurations - Estimate carbon source needs for different process configurations - Accelerate scale-up to reduce the number of pilot trials **Benefits** - Ensure process efficiency with minimal energy requirements	**Wastewater Resource Recovery Facilities** **Needs** - Improve current technologies to recover resources - Scale-up and process design based on real needs **Customer benefits** - Reducing financial overspending and failure - Saving scale-up costs and time - Improve biological process performance - Ensure process efficiency with minimal energy requirements **Consulting/Engineering Companies** **Needs** - Development of robust and reliable models **Customer benefits** - Time and costs savings in the development and calibration of new models

4 MONITORING – DATA COLLECTION

Technology ➡ Product	Product ➡ Market
Consulting/ Service Provider *Technology X provides solutions and strategies for good practices in sampling and data analysis. It also provides new tools and guidelines for data collection and data quality analysis.* **Features** - Gross error detection and data reconciliation - Definition of monitoring objectives **Benefits** - Improvement of data quality through > Procedures/guidelines > Methods for data collection > Data Storage	**Wastewater Resource Recovery Facilities** **Needs** - Guidelines/methods and tools for metadata collection and organization **Customer benefits** - Cost and time savings - Better decisions and improved treatment - Improvement of process monitoring and operation practices **Consulting/Engineering Companies** **Needs** - Tools/guidelines for new technologies that have been developed and implemented in WRRF **Customer benefits** - Time and costs savings in the development of new tools

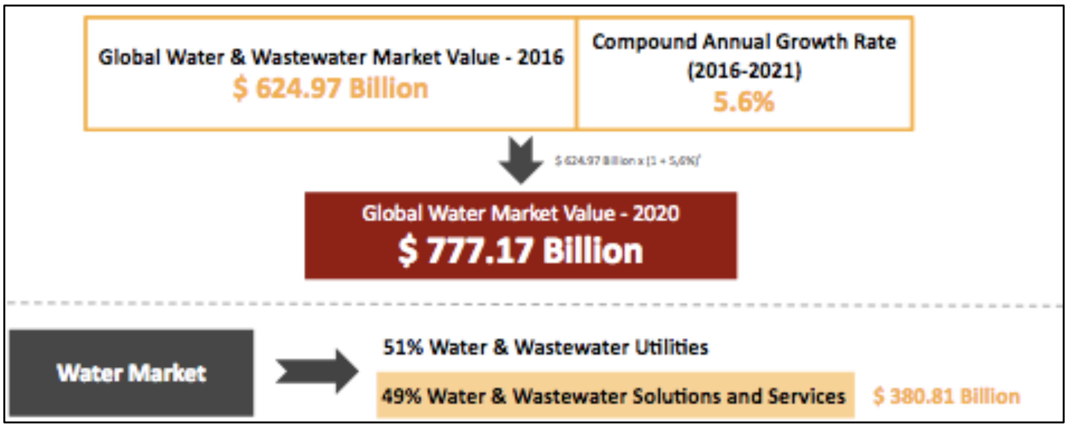
Source: HiTech Deliverables

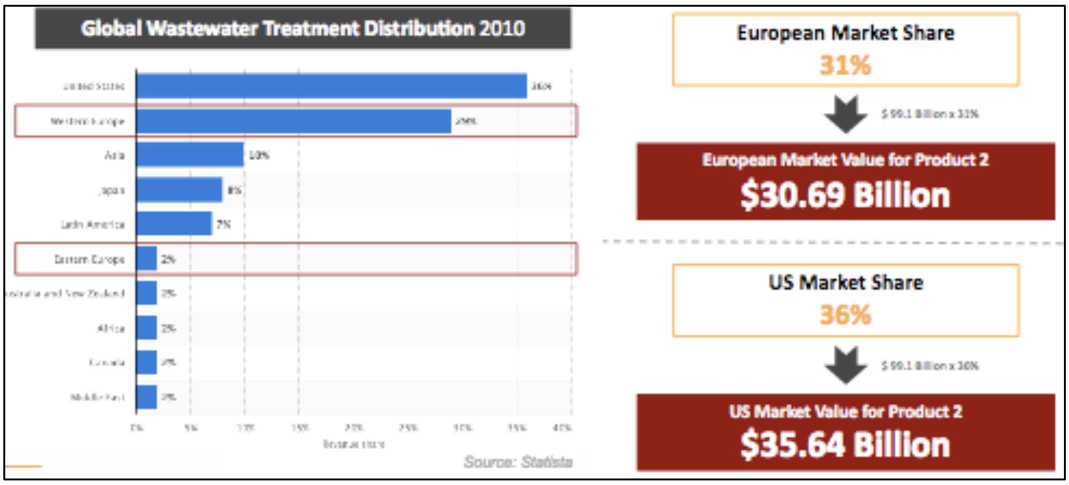
Appendix 14: Technology X Preliminary Market Assessment

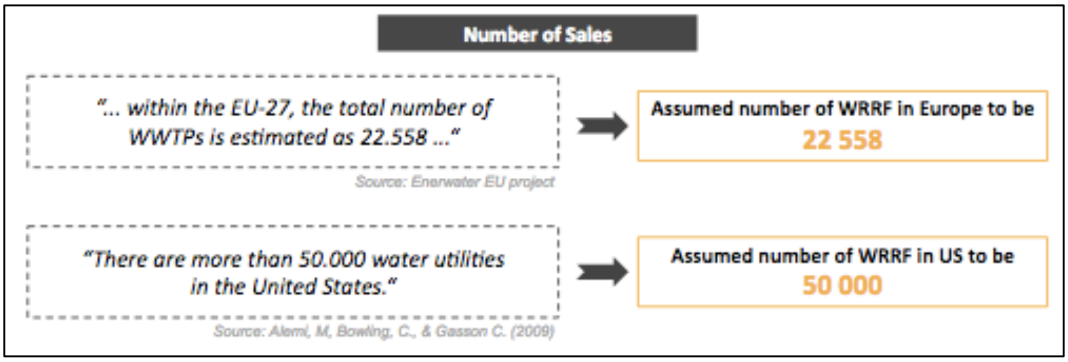
Preliminary Market Assessment Overview

Technology	Product	Market	Number of Sales	Product Price	Market Value (B)	Market Growth Rate
Aqua in Silico	**SUPPORT PLANT DESIGN** Innovative and advanced solutions to support design of biological processes in WRRF and accelerate scale-up of new technologies	EUROPE Water & Wastewater Treatment Solutions & Services *9% Design / Consulting*	-	-	$10.62	2,6% - Municipal Segment 4,6% - Industrial Segment
Aqua in Silico	**SUPPORT PROCESS CONTROL AND OPTIMIZATION** Innovative and advanced solutions for process control and optimisation of biological processes in WRRF	EUROPE Water & Wastewater Treatment Solutions & Services *19% Operation Services + 7% Maintenance & Monitoring Services*	22 558	-	$30.69	3,0% - Municipal Segment 4,4% - Industrial Segment
Aqua in Silico	**PROCESS CONTROL AND OPTIMIZATION IN REAL TIME** Real-time process control and optimisation of biological processes in WRRF	EUROPE Water & Wastewater Treatment Solutions & Services *19% Operation Services + 7% Maintenance & Monitoring Services*	22 558	-	$30.69	3,0% - Municipal Segment 4,4% - Industrial Segment
Aqua in Silico	**MONITORING - DATA COLLECTION** Solutions and strategies for good practices of biological processes monitoring	EUROPE Water & Wastewater Treatment Solutions & Services *19% Operation Services + 7% Maintenance & Monitoring Services*	22 558	-	$30.69	3,0% - Municipal Segment 4,4% - Industrial Segment

Assumptions behind the numbers (Support Process Control and Optimization – Europe)







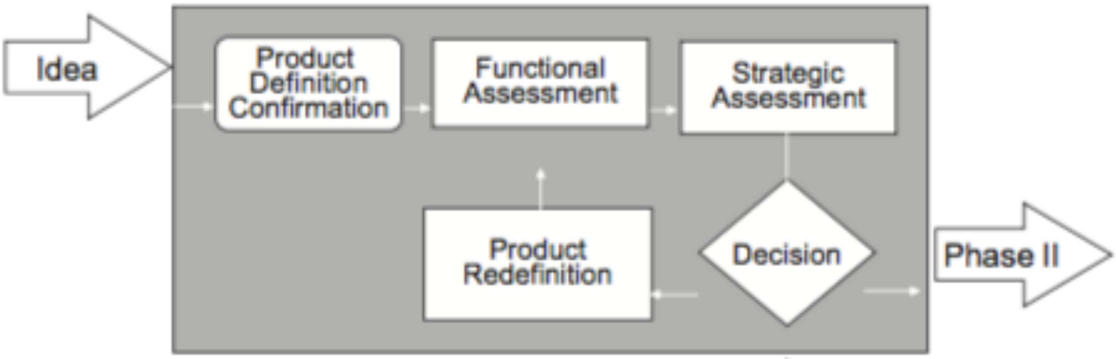
Growth Rates

	Municipal Segment	Industrial Segment
Design & Engineering	2,6%	4,6%
Operations & Maintenance	3%	4,4%
Process Control & Management	4,2%	9%
Chemicals	1,4%	3,9%
Water & Wastewater Technology	4,2%	5,8%

Source: Royan, F. (2016)

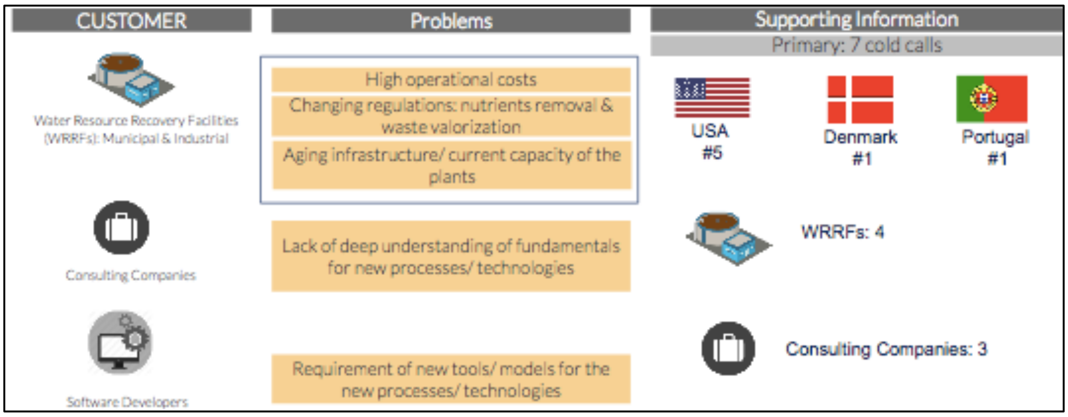
Source: HiTech Deliverables

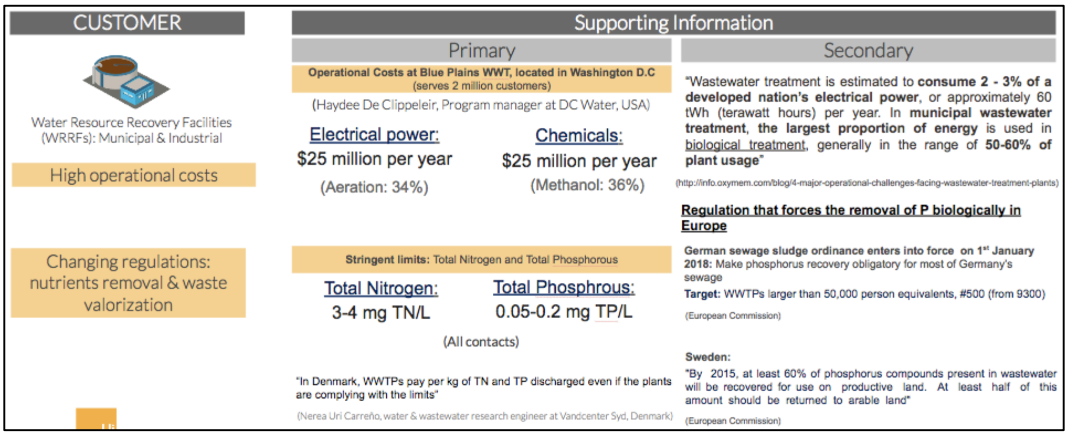
Appendix 15: Phase 1 of the Tech Algorithm

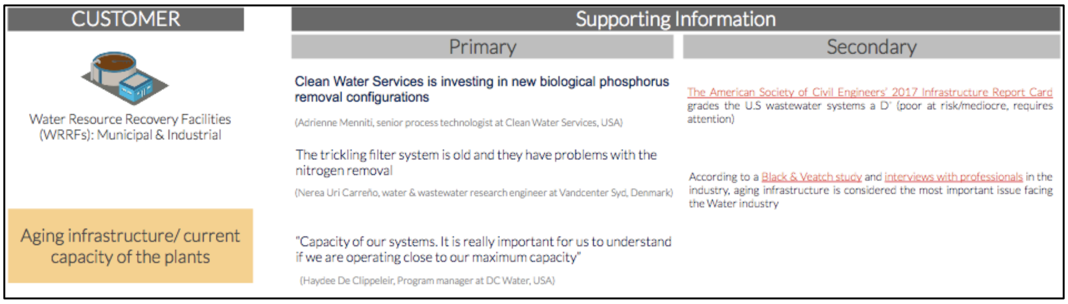


Source: Baker, Barr, Kingon and Markham (2009)

Appendix 16: Technology X Product Statement Validation

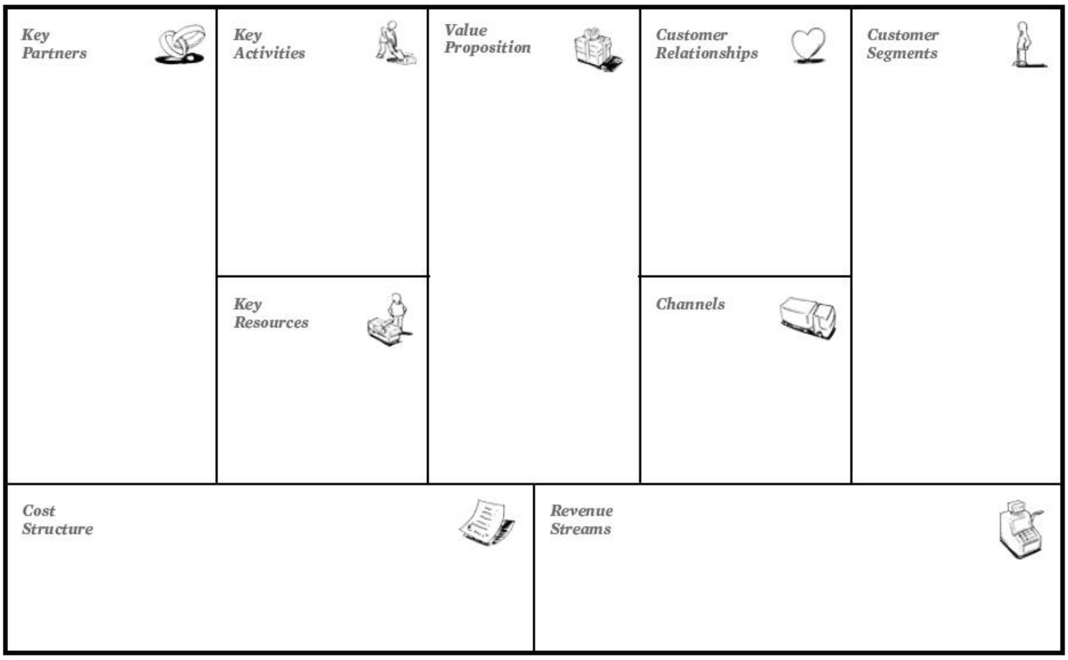






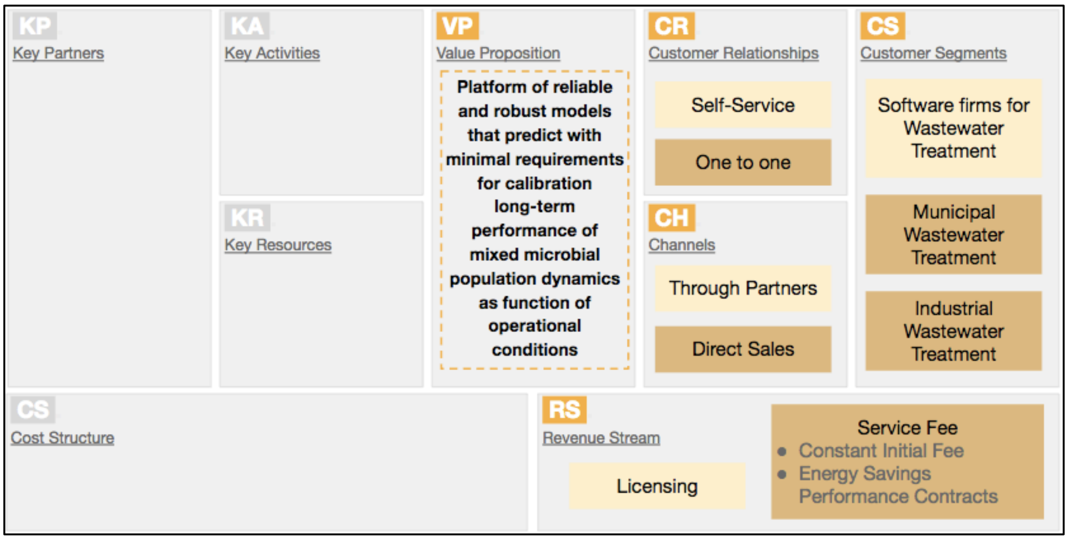
Source: HiTech Deliverables

Appendix 17: Business Model Canvas



Source: Osterwalder and Pigneur (2010)

Appendix 18: Technology X: Business Model Canvas (right side)



Source: HiTech Deliverables

Appendix 19: Technology X Market Assessment

Market Assessment Overview

TOTAL MARKET

Technology	Service	Market	Number of Sales	Average Market Product Price	Market Value
Dynamic microbial community-based models	Support process control and optimisation	WWRFs < 50,000 p.e	93,170	5,500 €	512.43 M €
		WWRFs > 50,000 p.e	5,947	45,000 €	267.62 M €
Total			**99,117**	**-**	**780.05 M €**

ADDRESSABLE MARKET

Technology	Service	Market	Number of Sales	Average Market Product Price	Market Value	Market Growth rate
Dynamic microbial community-based models	Support process control and optimisation	WWRFs > 50,000 p.e	4,603	45,000 €	207.15 M €	**Urban growth population (2020-2025):** 1.63% **Process control & Management growth in municipal WRRFs:** 4.2% **Process control & Management growth in Industrial WRRFs:** 9.0%

SERVED MARKET

Technology	Service	Market	Number of Sales	Product Price	Market Value	Market Growth rate
Dynamic microbial community-based models	Support process control and optimisation	WWRFs > 50,000 p.e	813	45,000 €	36.58 M €	**Urban growth population (2020-2025):** 1.63% **Process control & Management growth in municipal WRRFs:** 4.2% **Process control & Management growth in Industrial WRRFs:** 9.0%

Assumptions behind the numbers (Support Process Control and Optimization – Europe)

Number of WRRFs

Addressable Market
- Europe (3618)
- USA (875)
- Canada (76)
- Australia (35)

Served Market
- Switzerland (50)
- Sweden (75)
- Germany (578)
- Austria (111)

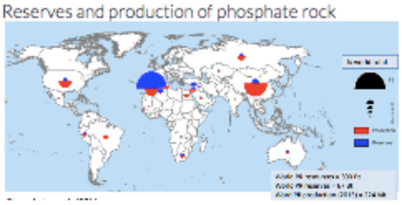
WRRFs > 50,000 p.e

Stringent limits

REGULATIONS
Phosphorous recovery obligated from sewage sludge in WRRF > 50,000 p.e

Eutrophication and Hypoxia (↑ conc. Nutrients)

Reserves and production of phosphate rock



- High operational costs
- Aging infrastructure/ current capacity of the plants
- Changing regulations: nutrients removal & waste valorization

Europe imports 92% of phosphorous and suffer from eutrophication in the aquatic systems

Market Value & Growth

Problems	Services
High operational costs	2 Support control and optimisation
Changing regulations: nutrients removal & waste valorization	3 Process control and optimisation in real-time
Aging infrastructure/ current capacity of the plants	

Addressable Market (€ 207.15 M)
- WRRFs > 50,000 p.e. (with Biological P removal)
- Regions with stringent regulations (Europe, USA, Canada, Australia)

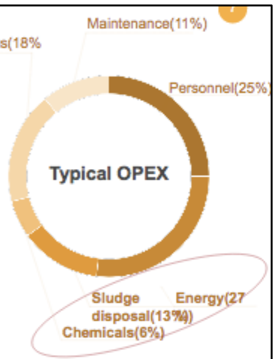
Served Market (€ 36.58 M)
- Countries making P recovery and recycling from sewage sludge waste obligatory (Switzerland, Sweden, Germany, Austria)

Product price estimation (explanation)

WRRF of Boavista, Algarve, Portugal	
Population Equivalents (p.e)	6,590
Energy, aeration tank (€/year)	17,671.8
Chemicals for P removal (€/year)	11,917.8
Sludge disposal (€/year)	21,271.6
Total costs (€/year)	50,861.3
Savings with our service (%)	20
Savings (€/year)	10,172.3
Service price (% of the savings)	
1st year	50
2nd year	40
3rd year	30
4th year	20
Service price (€/p.e) for 4 years	2.2

WRRF of Blue Pains, Washington DC, USA	
Population Equivalents (p.e)	4 M
Energy, aeration tank ($/year)	8,500,000.00
Chemicals for P removal ($year)	12,500,000.00
Sludge disposal ($/year)	12,037,037.04
Total costs (€/year)	33,037,037.04
Savings with our service (%)	20
Savings ($/year)	6,607,407.41
Service price (% of the savings)	
1st year	50
2nd year	40
3rd year	30
4th year	20
Service price (€/p.e) for 4 years	1.89

Assuming average 80,000 p.e (WRRFs > 50,000 p.e)	
Average service price (€/year)	43,218. 5
Assuming average 10,000 p.e (WRRFs < 50,000 p.e)	
Average service price (€/year)	5,402.3



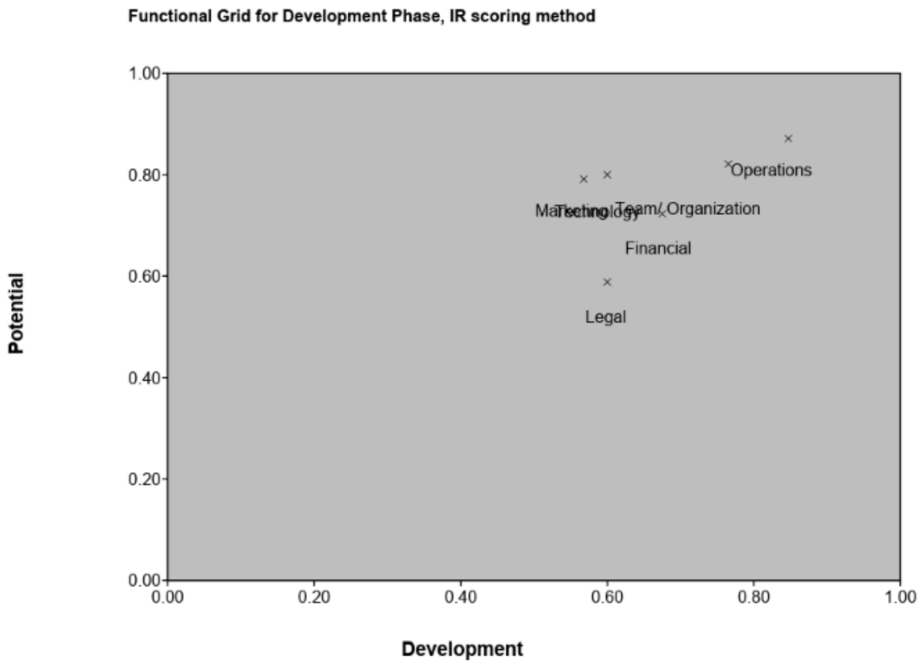
Source: HiTech Deliverables

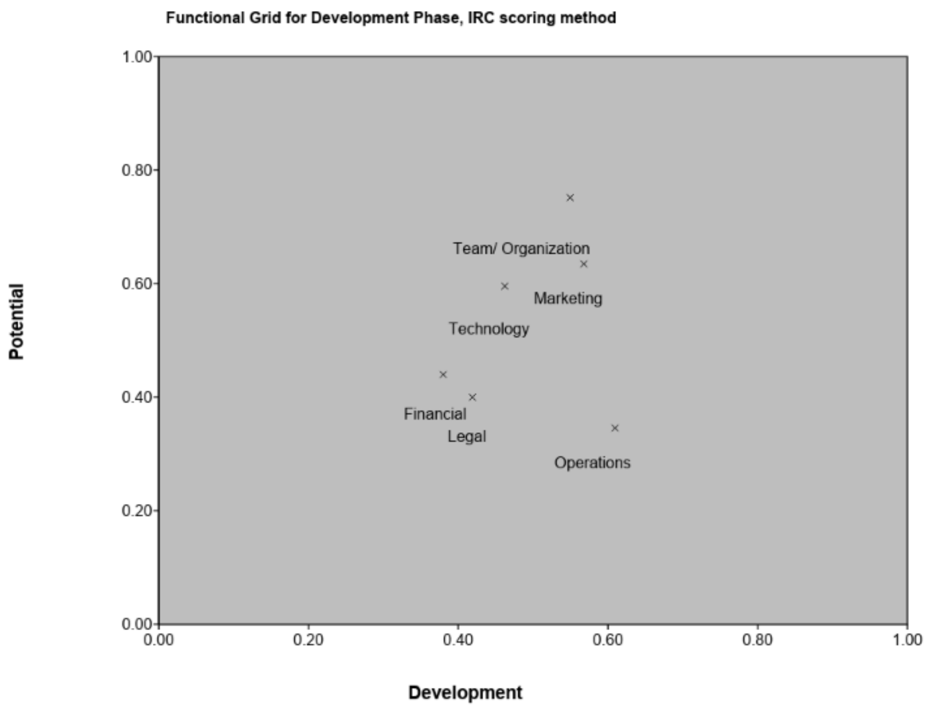
Appendix 20: Technology X Product Prioritization

Criteria	Weight	Process control and optimisation service	Cloud platform of control strategies and operational oriented models	Software plug-in
Short Time to Revenue	15%	8	6	9
Growth rate	5%	3	9	8
Time spent for each sale	20%	3	10	9
Stage of Product Development	10%	9	2	8
Fit with Team Knowledge	10%	8	4	8
Scalability	20%	3	10	9
Customer Demand	20%	7	9	7
	Totals	5.65	7.75	8.35

Source: HiTech Deliverables

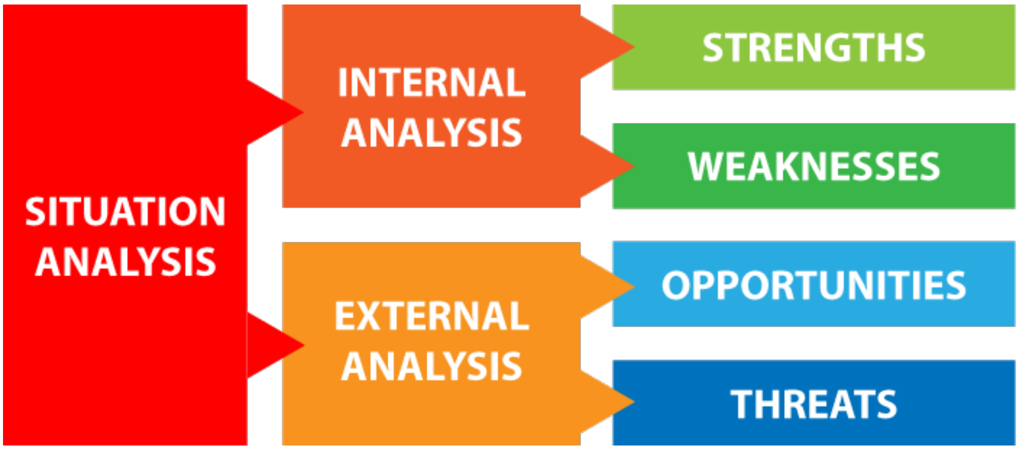
Appendix 21: Technology X Functional Assessment





Source: HiTech Deliverables

Appendix 22: SWOT Analysis



Source: Harmon (2015)

Appendix 23: Technology X SWOT Analysis Part I

	POSITIVE (Helpful factors)	NEGATIVE (Harmful Factors)
INTERNALIZATION	**STRENGTHS**	**WEAKNESSES**
	• Trade Secret has been kept • Product with great value for money • Great experts in the team from the development side: PhD Researchers • Robust and versatile product • High product quality, scalability, reliability and flexibility • High value product real options	• Not Patentable Models • Limited Entrepreneurial Experience • Limited Business Network • Poor Strategy Development and Roadmap • High Complexity • Small financial capacity • Product Development is not completed • Challenging market penetration
EXTERNALIZATION	**OPPORTUNITIES**	**THREATS**
	• Large Market with potential growth • Defined Market Segments • High Desirability of the product - recognition • Lack of optimal solution to the market • Product with higher performance than competitors • Weak of Direct Competition • Technical network	• Lack of testability - product not tested as a case study • Strong Indirect Competition • Complex product development • No established partnerships with the market

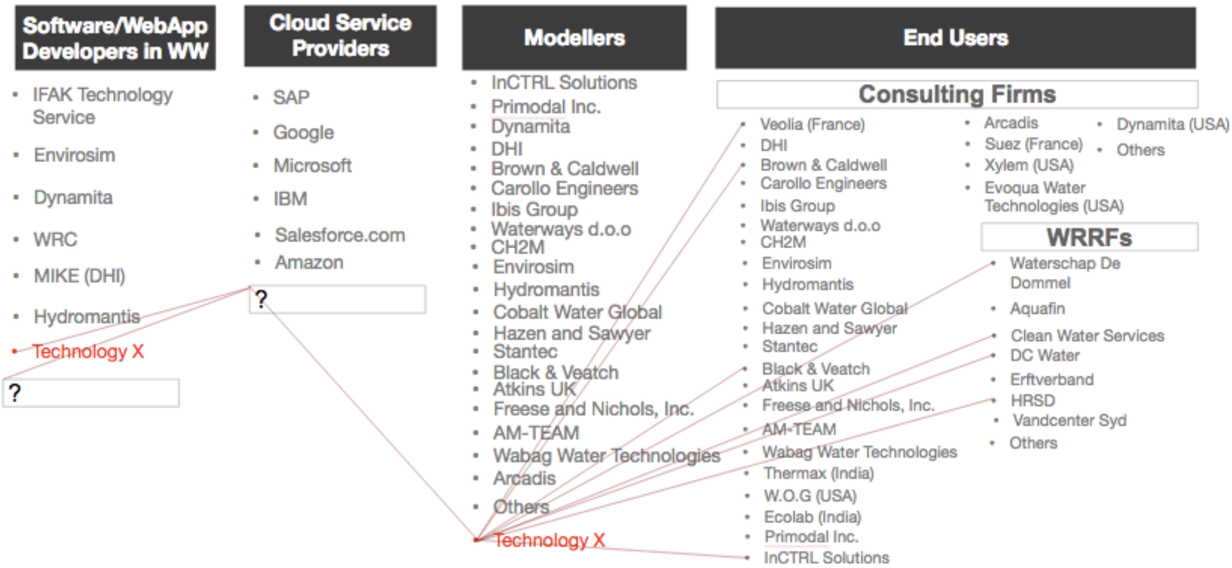
Source: HiTech Deliverables

Appendix 24: Technology X SWOT Analysis Part II

	STRENGTHS	WEAKNESSES
OPPORTUNITIES	**CHALLENGES** • S - Trade Secret has been kept • O - Large Market Potential • S - High product quality, scalability, reliability and flexibility • O - Lack of optimal solution to the market	**CONSTRAINTS** • W - Product Development is not completed • O - High Desirability of the product • W - Not Patentable Models • O- Large Market Potential • W - Challenging market penetration • O - Technical network
THREATS	**ALERTS** • T - Lack of product testability • S - High product quality, scalability, reliability and flexibility • T - Complex product development • S - Great experts in the team	**DANGER** • W- Not Patentable Models • T - Strong Indirect Competition • W - Limited Business Network • T - No established partnerships with the market

Source: HiTech Deliverables

Appendix 25: Technology X Industry Mapping



Source: HiTech Deliverables

Appendix 26: Porter's Five Forces

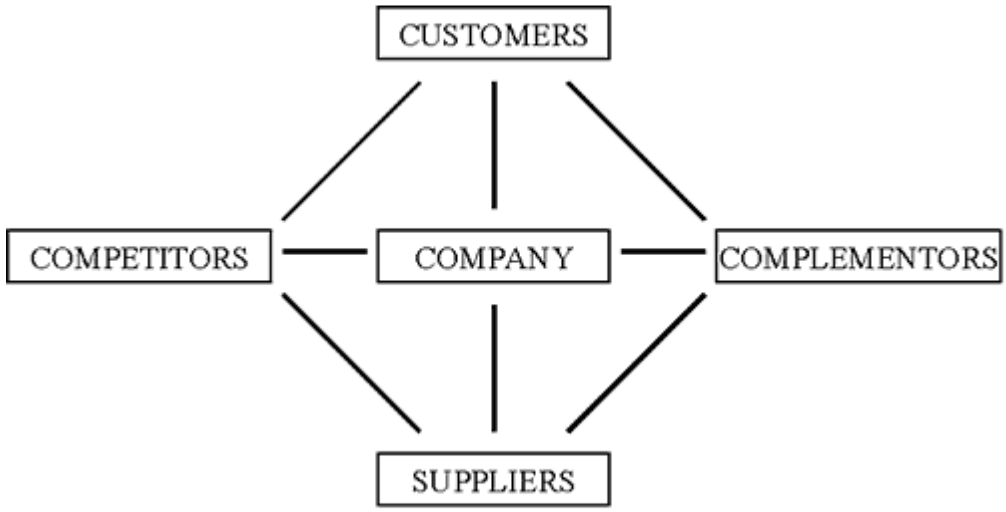
Source: Cadiat, Michaux and Probert (2015)

Appendix 27: Technology X Porter's Five Forces

	Industry Name (your industry)	
	Strength	Analysis
Bargaining Power of BUYERS	H	WRRF can easily use the existing models in the market. They look for the best solution, thus there is no loyalty
Bargaining Power of SUPPLIERS	L	Supplier are numerous and easily replaced
Threat of NEW ENTRANTS	L	High technical knowledge is necessary to enter the market to develop a competitive product.
Threat of SUBSTITUTES	L	New metabolic models for WRRF may be developed, however all current approaches are still academic exercises so far.
Rivalry among COMPETITORS	M	Despite the offered models are public and distributed through licensing, Aqua in Silico offers a new, innovative and better solution.

Source: HiTech Deliverables

Appendix 28: Value Net



Source: Lendel (2015)

Appendix 29: Technology X Value Net

	Industry Name (your industry)
	Analysis
COMPANY	AQUA IN SILICO
SUPPLIERS	Own employees, Cloud computing systems (SaaS)
COMPLEMENTORS	Chemical and physical treatment in WRRF
CUSTOMERS	WRRF
COMPETITORS	Cloud based softwares, commercial softwares and WRRF consulting services

Source: HiTech Deliverables

Appendix 30: Challenges and Limitations of the HiTech program

1. **Language adaptation**: as a management student at the beginning of the program it was hard to understand the technology developers explain Technology X, as the process of adapting their language from technical to perceptible was a challenging process for them.
2. **Concept interpretation**: this was one of the main challenges felt throughout the HiTech program, because many of the concepts lectured left room for interpretation as such the team could choose the wrong interpretation, and as a result many of the deliverables had to be redone and adapted to the feedback provided by both the HiTech program coordinators and the team mentors, during the weekly HiTech session
3. **Concept complexity**: most of the concepts lectured had a connection between each other, which made the development of the deliverables even more complex. Thus, when my team decided to adopt a different approach regarding Technology X, it would have to change several of the deliverables developed so far. This was mainly felt during the development of the TPM Linkages.
4. **Understanding the concepts**: although most of the concepts lectured were business related, some of them were presented to me for the first time as such not only the technology developers but also myself needed to get familiarized with the concepts and explore them.
5. **Lack of concept support and development**: although the HiTech algorithm is based on a 'learn by doing' learning method, many times I, as the management student, felt that I did not play a significant role because the formulation deliverables are very based on the technical knowledge of Technology X, which I don't have. Thus, most of the work was conducted by the technology developers and I was only able to offer support when it came to the organization and the design of the deliverables, and the development of some business tools.

6. **Lack of brainstorm among members, especially in person**: although the team created a weekly schedule that allowed the successful development and submission of the deliverables on time, with the participation of every member, the team only met in person on the weekly HiTech sessions. Hence, I believe that the work developed might not have reached its full potential because the only deep discussion carried out by my team was during the weekly one hour Skype call, which in my opinion is not enough. Mainly because in regular academic environment – where most of the times the work developed is not conducted for real life business cases – the time spent together for each group work is much higher than the time my team spent together during the HiTech program
7. **Technology communication**: even with a common language it is challenging to explain Technology X to others as it is intangible and based on complex mathematical models, which makes it difficult to translate and make the technology perceptible to the general public.
8. **Formulating the deliverables**: in the case of the technology developers it is a challenge to adapt Technology X to the template concepts of the deliverables, while in my case, as a management student, it is a challenge to transform the technical language used by the technology developers in the deliverables in a way that I and the public in general can understand.

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