FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Technology exploitation: the case study of Dye Sensitized Solar Cells in Building Integrated Photovoltaics

Master's in Innovation and Technological Entrepreneurship

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ABSTRACT

The Dye-Sensitized Solar Cells (DSSC's) can be the next generation of power source. Recent studies focus their application in Building Integrated Photovoltaic (BIPV), as a way of obtaining Net Zero Energy Building (NZEB). Besides the environmental concerns there is an actual depletion of fossil fuels, which offers DSSC's an opportunity to conquer markets.

This study aims to analyse the opportunity to exploit to the market the DSSC's photovoltaic technology developed by a research team from the Faculty of Engineering and already patented by the University of Porto.

DSSC's are a well-developed technology that can be placed in solar panels in buildings with a 9% efficiency even at diffuse light, and with a lifetime of more than 20 years, thus to the patented sealing process of the solar cells.

While exploiting the technology potentials as a spin-off or by licensing the technology to a company, two different pathways were developed to deliver the technology value to the market.

The Solar Cell Spin-off offers an alternative, sustainable and eco-friendly energy solution to everyone in need of electricity in their buildings. It offers higher performance, more customization by providing a wide choice of different colours and patterns and reduction in costs. Intendss to reach architects and builders and to start sales (online, own stores and partnership stores) by the middle of 2022.

Concerning the license agreement with other solar cells modules' manufacturers, the company intends to license its patents until 2028, expecting a royalty payment of 5% of manufacturers of Solar Cells net sales.

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LIST OF ACRONYMS AND ABBREVIATIONS

BAPV	Building Attached Photovoltaics
BIPV	Building Integrated Photovoltaics
CAGR	Compound Annual Growth Rate
CE	Counter-electrode
CIGS	Copper indium gallium selenide
DSSC’s	Dye-Sensitized Solar Cells
GET	Customer Acquisition
GROW	Boosting Sales
IP	Intellectual Property
KEEP	Customer Retention
NZEB	Net Zero Energy Building
PV	Photovoltaic
R&D	Research and development
RK1	New purely organic sensitizer

SEO	Search Engine Optimization
TCO	Transparent conducting oxide
TiO_2	Dioxide of Titanium
TPM	Technology-to-product-to-market
U.S.	United States
USPTO	United States Patent and Trademark Office
UV	Ultra-Violet

1. INTRODUCTION

The imminent depletion of fossil fuel has spurred the advancement of renewable energy technologies. It is believed that a new technology: Dye-Sensitized Solar Cells (DSSC's) can be the next generation of power source, not only by contributing to an effective entrance of solar devices in our daily lives but also by diversifying the common use of photovoltaics in buildings and façades. Their transparency and various possibilities of colours offer DSSC's an opportunity to conquer markets that are not attainable by typical silicon solar cells, as the building sector. This sector can significantly reduce energy consumption by incorporating energy-efficient strategies into the design, construction, and operation of new buildings. The concept of a Net Zero Energy Building (NZEB), one which produces as much energy as it uses over the course of a year, recently has been evolving from research to reality.

Therefore, technology transfer is becoming an important issue in the economic pathway of every country. The commercialization of technologies is a difficult process which includes the identification and evaluation of the technology's market potential, as one of the key elements (Dorf & Worthington, 1987)

For this kind of technology to reach consumers, one should understand that technological innovation is central to maintain the economy strong and growing in a time defined by globalization of competition, demographic changes and demanding market.

The innovation process has evolved from its beginning in the 1960´s from simple linear models to increasingly complex interactive models, adding a total of six generation models. The most recent is the **Open Innovation Model** (Chesbrough, 2006), proposed by Henry Chesbrough. This paradigm assumes that companies can and should use both internal and external ideas and technologies, as well as internal and external paths to market to advance their own technology (Figure 1).

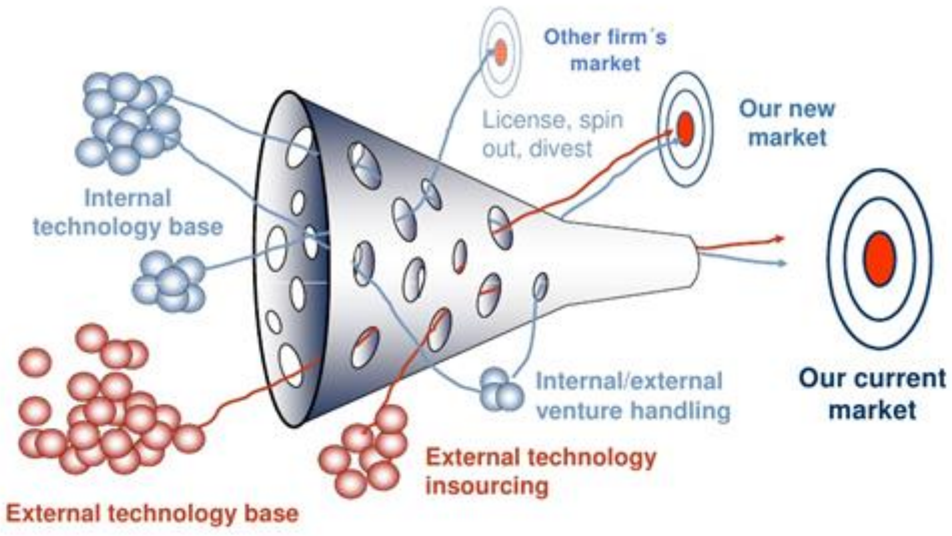

Figure 1 – "Open Innovation model", Reproduced from "Open Innovation: Renewing growth from Industrial R&D", (Chesbrough, 2004)

Considering the latest economic crisis, many industrial firms attempted to capture additional **value** from their technologies by means of open innovation strategies. Besides acquiring external technology, many firms therefore increasingly try to license their own technology to other firms either exclusively or in addition to its application in their own products (Lichtenthaler, 2010a). New **technology exploitation** is defined as the utilization of new technology or scientific developments to improve the performance of products or manufacturing processes. Lying between knowledge creation and the traditional new product development processes, it is an iterative process that requires its own set of management tools. Failure to recognize and manage new technology exploitation projects as such can result in inefficiencies and frustration. (Bigwood, 2004).

When a new **technology** arises offering great advantages, markets and customers can´t be expected to perceive its **value** or understand it. Rather than push technologies on markets, systematic planning is required to express new technical advantages as products that meet customer needs.

1.1. Objective and Motivation

This research aims to study and develop a strategy for the exploitation of Dye-Sensitized Solar Cells (DSSC´s) technology developed by a research team, from the Faculty of Engineering of the University of Porto and patented by University of Porto.

This dissertation tries to converge the knowledge acquired in the Master's in Innovation and Technological Entrepreneurship, with the R&D activity of research team from LEPABE – Laboratory for Process Engineering, Environment, Biotechnology and Energy led by Professor Adélio Mendes on the DSSC´s technology in the attempt of providing a path that enhances the strengthen and capabilities of this technology potential, so it can reach the market as a product with a competitive advantage.

1.2. Research Question

The Research Question proposed is:

"How can the technology of Dye-Sensitized Solar Cells be exploited in the market of Net Zero Energy Building?

1.3. Methodology

To deliver the research question, as it tries to understand the DSSC´s technology and the surrounding market an extensive secondary data collection was conducted, using a qualitative research method.

As the goal of this study is to develop a strategy for the exploitation of DSSC's a Case Study Research was the method used to conduct it.

Case study is a strategic qualitative research methodology and has been used in fields like industrial relations as it seeks to study phenomena in their contexts, rather than independent of context. It is an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence (Cusumano, Kahl, & Suarez, 2008).

Case study method enables a researcher to closely examine the data within a specific context. In most cases, a case study method selects a small geographical area or a very limited number of individuals as the subjects of study and investigate contemporary real-life phenomenon through detailed contextual analysis of a limited number of events or conditions, and their relationships (Zainal, 2007).

There are three types of case study: exploratory, descriptive and explanatory. In this thesis the researcher used exploratory case study, as is set to explore the phenomenon in the data: the technology exploitation pathway.

The following steps presented in the next Chapters have been taken:

Chapter 2 – a literature review surrounding the topic of this research, allowing to position the topic relevance in the actual academic context, as well as the theoretical background used to conduct the case study.

Chapter 3 - presents the Case Study itself, regarding the two paths developed to present the technology to the market and frames the main concepts of the dissertation and their interconnection, namely: Technology, Dye-Sensitized Solar Cells and Building Integrated Photovoltaics.

Chapter 4 - presents the conclusion, which outlines the limitations of this research and provides suggestions for future research.

2. LITERATURE REVIEW

To ensure a firm foundation in achieving new knowledge is essential a relevant and effective review of prior existing literature (Webster & Watson, 2016). As Watson and Webster, also stated: "It facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed".

A well conducted literature review, based upon a concept-centric approach, allows to relate the articles read for the study, tying the literature into their own study, thus providing a solid argument for the need for the study as well as spot where literature fits into the proposed study (Levy & Ellis, 2006). A review should also identify critical knowledge gaps and thus motivate researchers to close this breach. That is, writing a review not only requires an examination of past research, but means making a chart for future research. (Webster & Watson, 2016)

For this thesis, it was made a search looked for articles published from 2008 to 2018 in online databases of abstracts and citations, peer by peer reviewed, in this case EBSCO, based on the main concepts acting as keywords: "Dye-sensitized Solar Cells" and "Building Integrated Photovoltaics"; "Technological innovations" and "New Product development"; "Value creation and "Technology" and "Dye-sensitized Solar Cells" and finally "Technology exploitation and "Licensing". By reading the abstracts the articles were divided in three main categories: "Understanding the technology and the related trends", "Framing a value proposition when dealing with new technology" and "Dealing with new technology exploitation" and the following 18 articles were chosen for the purposes described above (Tables 1, 2 and 3).

Table 1 – Literature Review of "Understanding the technology and related trends", listed by growing of relevance (developed by the author)

Authors and Year	Title	*Keywords* and concepts covered	Future Research
(Ghann et al., 2017)	"Fabrication, Optimization and Characterization of Natural Dye Sensitized Solar Cell"	*Pomegranate and berry fruits, graphite as the counter electrode.* Dye extract from pomegranate fruit was utilized as the light-harvesting analogue in the fabrication of a low cost, eco-friendly dye-sensitized	

Authors and Year	Title	*Keywords* and concepts covered	Future Research
		solar cell with excellent performance.	
(Joly et al., 2014)	"A Robust Organic Dye for Dye Sensitized Solar Cells Based on Iodine/Iodide Electrolytes Combining High Efficiency and Outstanding Stability"	*Power conversion efficiency, improved performance* Reports the synthesis and complete characterization of a new purely organic sensitizer (RK1) with high efficiency.	
(Hinsch et al., 2012)	"Worldwide first fully up-scaled fabrication of 60×100cm^2 dye solar module prototypes."	*Glass frit-sealed dye solar cell modules, efficiency, cost effective* The up-scalability of dye solar modules has been shown for the first time. Specific equipment has been developed for the process steps coloration, electrolyte filling and end-sealing.	Analysis of the present module performance with the aim to promote a near future pilot production of large-scaled dye solar modules.
(Kim, Jo, Lee, Shin, & Lee, 2017)	"Design and analysis of a highly reliable large-area Z-type transparent module for dye-sensitized solar cells"	*Test cell, module design, thermal reliability*. Presents the design methodologies for large-area transparent DSSC´s, demonstrating that the cell width for the maximal efficiency strongly depended on the amount of solar irradiation, in BIPV windows.	
(Shakeel Ahmad, Pandey, & Abd Rahim, 2017)	"Advancements in the development of TiO_2 photoanodes and its fabrication methods for dye sensitized solar cell applications: A review."	*Eco-friendly production, competitive efficiency.* Attempts to introduce evolution of TiO_2 photoanode for DSSC's such as doping with other elemental ions, development of nanocomposites and synthesis of new nano-architectures to enhance the performance. Acknowledges that commercial viability of	New and cost effective photoanode materials other than TiO_2 needs to be explored. New ways have to be trialled to deposit TiO_2 to avoid melting.

Authors and Year	Title	*Keywords* and concepts covered	Future Research
		DSSC technology is possible by choice of optimum manufacturing route and choice of raw materials.	
(Castro-Hermosa et al., 2017)	“Stability issues pertaining large area perovskite and dye-sensitized solar cells and modules”	*Perovskite, stability challenge.* Presents a review of stability investigations published. Recognizes application in BIPV. Moisture, oxygen, UV light, thermal and electrical stress are the main sources of degradation.	Improvements by developing materials and interfaces of the cells and their architectures which are inherently more stable and via more effective encapsulation strategies. Not enough has been done on investigating the stability of large area devices.
(Gong, Sumathy, Qiao, & Zhou, 2017)	“Review on dye-sensitized solar cells (DSSCs): Advanced techniques and research trends”	*Easily implemented, efficiency, indoor applications.* Examines advanced techniques and research trends of this promising technology from the perspective of device modelling, state-of-art techniques, and novel device structures.	Recognizes that to make DSSC technology more competitive, it is crucial to improve the device efficiency and stability, as well as to further reduce the material and manufacturing costs. Apart from a rationale design and modelling, practical techniques are also very critical to maximize the light harvesting and minimize the electron losses.

Table 2 – Literature Review of "Framing a value proposition when dealing with new technology", listed by growing of relevance (developed by the author)

Authors and Year	Title	*Keywords* and concepts covered	Future Research
(Tyagi, Rahim, Rahim, & Selvaraj, 2013)	"Progress in solar PV technology: Research and achievement"	*PV materials, Cost analysis.* Reviews materials for solar cells, efficiency, factor affecting the performance of PV module, overview on cost analysis and environmental impact.	Research for recycled for PV materials to minimize environmental effects.
(de Almeida Guerra & Emília Camargo, 2016)	"The role of technological capability in the internationalization of the company and new product success: a systematic literature review"	*New product success; Technological capability.* Acknowledges the importance of a better understanding about the new product success in international markets and the importance of technology transfer for the formation of technological capability.	Proposed framework should be tested to verify the theoretical findings shown in this study and it should perform further study on technology transfer, since it affects with technological capability.
(Bohnsack & Pinkse, 2017)	"Value Propositions for Disruptive Technologies: Reconfiguration Tactics in the case of electric vehicles"	*Value proposition innovation*. The article develops a framework showing three value proposition reconfiguration tactics: compensating, enhancing, and coupling tactics	Future research should study the actual gap between desired transactions and actual technology transactions. Use of more generic data in terms of regions and trading agents should be undertaken to fortify the generality of the study.
(Zhao, Pan, & Lu, 2016)	"Business model innovation for delivering zero carbon buildings"	*Challenges to Zero Carbon Buildings; Created and captured value.* Examines and explores how business model innovation can help to deliver Zero Carbon Buildings. Developed a value-based conceptual framework of business model comprising four layers.	Future research should investigate the effect of external change initiatives on business model, and cross-compare business model innovations in various contexts. Measuring and benchmarking business performance is

Authors and Year	Title	*Keywords* and concepts covered	Future Research
			required to evaluate the effectiveness of business model innovation.
(Baldassarre, Calabretta, Bocken, & Jaskiewicz, 2017)	"Bridging sustainable business model innovation and user-driven innovation: A process for sustainable value proposition design"	*Sustainable business model innovation; User centred design*. Proposes a process for sustainable value proposition design which adopts a dynamic perspective (talking to stakeholders, thinking about the problem, testing the product/service) that leads to an actual sustainable value proposition.	Testing the process proposed in this paper in different contexts.

Table 3 – Literature Review of "Dealing with new technology exploitation", listed by growing of relevance (developed by the author)

Authors and Year	Title	*Keywords* and concepts covered	Future Research
(Chang, Hwang, & Peng, 2013)	"Technology Licensing in Multiple Markets"	*Technology transfer; Two-part tariff licensing.* Sets up a model in which the licensee firm can produce two goods, one is homogeneous to and the other is horizontally differentiated from that produced by the licensor firm.	
(Jeong, Lee, & Kim, 2013)	"Licensing versus selling in transactions for exploiting patented technological knowledge assets in the markets for technology"	*Technology exploitation strategy; Technology licensing; Technology transfer* Examines the determinants of the types of technology transactions in the markets for technology.	Future research should study the actual gap between desired transactions and actual technology transactions. Use of more generic data in terms of regions and trading agents should be undertaken to fortify the generality of the study.
(Ziegler, Ruether,	"Creating value through external	*Intellectual property commercialization;*	Study other type of firms besides

Authors and Year	Title	*Keywords* and concepts covered	Future Research
Bader, & Gassmann, 2013)	intellectual property commercialization: a desorptive capacity view"	*External patent exploitation*. Explores how firms manage their external patent exploitation based on a multiple case study research design with fourteen firms.	pharmaceutical industry. Large scale study testing the influence of the identified factors should be of interest.
(Bianchi, Frattini, Lejarraga, & Di Minin, 2014)	"Technology Exploitation Paths: Combining Technological and Complementary Resources in New Product Development and Licensing"	*Extract Value; Technological resources; Licensing* Develops and tests a conceptual framework considering the successful implementation of New Product Development and licensing strategies on firm profitability.	Assess the effects of access and use of specialized resources on technology exploitation performance. How the integration of these different resources occurs and how it translates into superior exploitation outcomes.
(Lichtenthaler, 2009)	"Organizing for external technology exploitation in diversified firms"	*Markets for technology; Technology exploitation* Examines two essential dimensions of designing the corporate/business unit interface in diversified firms: the centralization of the activities on the corporate level and the alignment between the organizational levels.	Investigate the relation between external technology exploitation and firm performance. Study the effects of centralization and alignment in universities
(Lichtenthaler, 2010b)	"Technology exploitation in the context of open innovation: Finding the right "job" for your technology."	*Open innovation; Roadmapping; Strategic planning; Technology exploitation*. Presents the concept of an integrated technology exploitation roadmap, which allows firms to use the job-related markets to integrate technology licensing in their strategic planning processes.	

This analysis allows making the bridge between these issues and correlating them with the existing articles. Looking out for the future research enhances this study, understanding where there are flaws or where further research is needed.

To develop the theory of technology exploitation another literature review was done, and several cases were selected. Some were chosen to help to draw the Research Question (see above) but the following three handbooks (Table 4) were selected as the theoretical framework to develop the case, which represents the interesting topic of the study.

Table 4 – Literature Review of Case Study theoretical background (developed by the author)

Authors and Year	Title	*Keywords* and concepts covered
(Markham, 2007)	"Turning Technical advantage into Product advantage"	*Technology-to-product-to-market linkage; Technology value; Product capabilities.* The TPM model provides a process with tools to identify promising technologies
(Osterwalder & Pigneur, 2009)	"Business Model Canvas"	*Designing Business models; Strategy.* Develops an innovative model of value creation.
(Erauw & Stonier, 2005)	"Exchanging Value: Negotiating Technology Licencing Agreements"	*Licensing; Valuation of technology; Intellectual Property;* Provides a basic knowledge and understanding of negotiating technology licensing agreements.

For better understanding of this thesis conceptual literature work a Mindmap (Figure 2) was developed. This is a visual tool that allows to establish connections between a main concept and several ideas around it, allowing to organize and structure ideas, founding connections and interconnections between them.

Considering the branches of the Mindmap below the following chapters of the literature were developed: "What is technology?", "Understanding the Technology and related trends", "Framing a Value Proposition when dealing with new technology", "Dealing with new technology exploitation", "Future research needed in this field", "TPM Model to identify promising technology", "Business Model Canvas to deliver value creation", "Developing Licensing Agreements".

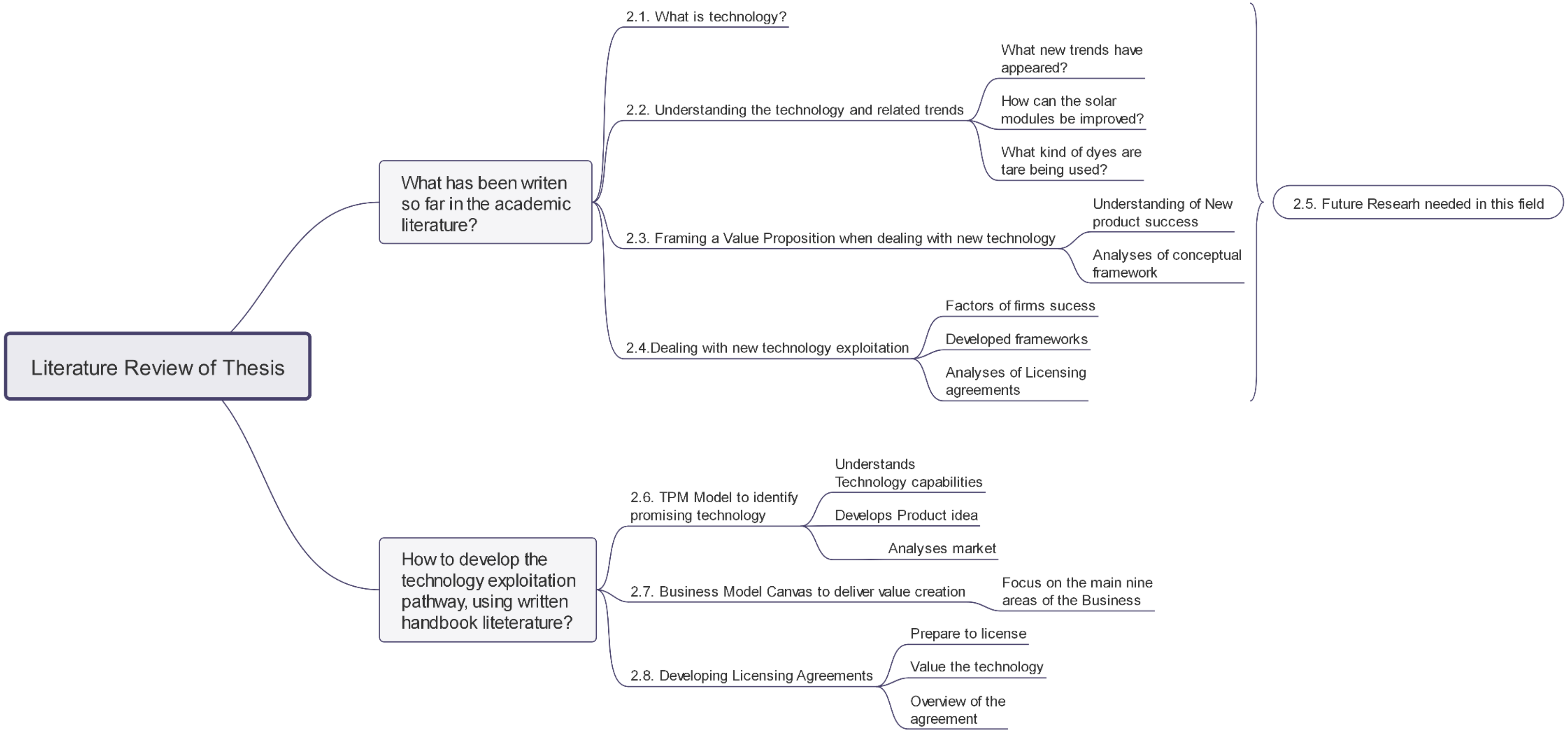

Figure 2 - Literature Review Mindmap (Developed by the author)

2.1. What is Technology?

What is technology? Table 5, presents different definitions of technology over the last years.

Table 5 – Technology definitions over time (developed by the author)

Definition	Author/Year
Technology is as old as humankind. It existed long before scientists began gathering the knowledge that could be used in shaping and controlling nature. (…) technology, unaided by science, is able of creating elaborate structures and devices.	George Basalla, 1988
Technologies are products of their time and organizational context, and will reflect the knowledge, materials, interests, and conditions at a given locus in history.	Orlikowski, 2003
Technology refers to methods, systems, and devices which are the result of scientific knowledge being used for practical purposes.	Collins English Dictionary, 2018

Analysing previous technology definitions over the years, we can define technology as the use of all knowledge gathered with the goal of make it useful for society. So, technology is essential for development and is based on knowledge and research.

Knowledge is that which is known, by its very nature it depends on thought and it is also transferred by thought, thought and behaviour both based on values. Transfer of knowledge is understood as moving of knowledge from lower to higher agency levels in explicit or tacit form. (Banerjee, Wahl, & Panigrahi, 2018). Technological progress through research is a key factor in economic growth, but in order to actually create value, inventions need to be successfully transferred to the market (Banerjee et al., 2018).

2.2. Understanding the Technology and the related trends

Ghann (2017) as many others are using nowadays new dyes extracted from fruits to use as more efficient sensitizers rather than the transition metal used currently. Joly (2014) in the other hand designed a simple, easy to prepare and efficient organic sensitizer: the RK1. They are doing so to use natural resources, because metals tend to run out on Earth.

Hinch (2012) has produced modules to an area of 60×100 cm^2 on single substrates using equipment specific developed for this, while Kim (2017) fabricated a small sized DSSC for BIPV windows favourable for practical manufacturing and thermal reliability and can be applied to other types of DSSC's and the design method for the DSSC's module can be used to produce DSSC-based BIPV windows.

Shakeel (2017) reviews the attempts to introduce evolution of TiO_2 photoanode for dye sensitized solar cells such as doping with other elemental ions, development of nanocomposites and synthesis of new nano-architectures to enhance the performance of DSSC's. As most of the outdoor experiments revealed deficiency in this technology, reports showed only 2 years lifetime for outdoor modules, so the outdoor lifetime of this technology must be improved to commercial viability be possible, choosing the optimum manufacturing route and raw materials. While Son (2012) confirms that the increase in the thickness of the light-scattering layer induces the improvement of the DSSCs' performance by enhancing the light-scattering effect in the long-wave region and by increasing the dye-loading which could be a positive factor in setting the standard conditions in the commercial DSSCs' fabrication process.

Castro-Hermosa (2017) enhances that as long as the research focus is on just one of the major technological areas: stability, efficiency and cost, progress towards application of this technology is anticipated to be slow as a breakthrough in one of the areas is very unlikely to automatically grant solutions in the other two areas. It is thus important that the focus is on all three together: power output, long-term performance, and cost-effective materials and fabrication procedures.

Gong (2017) concludes that DSSC's are on the verge of commercialization and the manufacturing cost estimates for the technology are close to the projected costs of other Photovoltaic (PV) technologies. For DSSC to become more competitive it is crucial to improve the device efficiency and stability, as well as to further reduce the material and manufacturing costs.

2.3. Framing a Value Proposition when dealing with a new technology

Tyagi (2013) illustrated about the worldwide status of PV technology, research in materials for solar cell, factor affecting for PV efficiency, present cost of solar cell and environmental impact. The paper acknowledges that thin film, polymer based solar cell and third generation based solar cells are in development stage and extensive research work is going for efficiency improvement for commercial use and solar cell production has some disadvantages on environment during manufacturing and process time, but it gives much more advantages during use.

Almeida Guerra (2016) work led to four important theoretical contributions: the importance of a better understanding about the new product success in international markets, there is theoretical evidence for the moderating effect of technological capacity, importance of technology transfer for the formation of technological capability and the uniqueness of the proposed framework.

Bohnsack (2017) uses a case study of electric cars to reconfigure firm´s value proposition, increasing its attractiveness, and this can be helpful to other new technologies.

While Zhao (2016) identifies the challenges to Zero Carbon Building on the political, economic, social, technological, environmental and legal analytical framework and developed a value-based conceptual framework of business model that comprises of four layers (i.e. strategy, value offering, value creation and delivery, and value capture) and eight components (i.e. product/service, value proposition, target customer, resources and capabilities, internal organization and activities, competitive strategy, role in value network, and revenue generation logic). This article findings demonstrate that business model innovations help to facilitate companies to address challenges to Zero Carbon Building and accelerate its uptake.

In his paper, Baldassarre (2017) focuses on combining sustainable business model innovation with user-driven innovation for addressing the challenges of sustainable development through the design of sustainable value propositions that combine economic and environmental objectives. The process for sustainable value proposition design proposed in this paper goes a step further, adopting a dynamic and iterative perspective (talking to stakeholders, thinking about the problem, testing the product/service) that leads to an actual sustainable value proposition and to a superior problem-solution fit. And has it state can be tested in different contexts.

2.4. Dealing with New Technology exploitation

In his paper, Chang (2013) examined the optimal licensing contract of a cost-reducing innovation and found that licensing is always profitable for a licensor company. But he considers that a pure fix-fee licensing could emerge as the best licensing strategy for the licensor firm, because it generates a large efficiency gain by making the more efficient licensee firm produce more.

Jeong (2013) analyses the determinants for the decision of whether to license out or sell patented technologies, finding that companies prefer licensing their patents when uncertainty is low, or transaction cost is high, whereas they tend to prefer selling their patents under opposite conditions.

Ziegler (2013) focuses on what factors influence firms' success in external patent exploitation and identified the following four: the type of value creation for the firm, the firm's organizational structure, the locus of initiative and the extent of know-how transfer, concluding that requires commitment and internal effort. Bianchi (2014) goes a step further and develops a conceptual framework considering internal and external paths to market considering antecedents affecting the successful implementation of New Product Development and licensing strategies on firm profitability, as well as the strategies the effects of the interplay between technological resources and three types of complementary resources: marketing, manufacturing and relational.

Lichtenthaler (2010) collects data from 152 firms and examines two dimensions of designing the business unit interface: the centralization of the activities on the corporate level and the alignment between the organizational levels and found that it seems necessary to balance the influence of both organizational levels, even in a corporate-focused organization. In other article he developed an integrated technology commercialization roadmap to help companies overcome their managerial difficulties in actively licensing technology and acknowledges that product marketing and technology licensing are complements rather than substitutes as commercialization channels.

2.5. Future Research Needed in this field

As this is a field of only ten years of knowledge there is a long way of opportunities for further research around this topic. Ma (2014) intends to use its framework to investigate macro-technological development and do it with semi-automate method. Hinsch (2012) intends to analyse the studied module and to promote a future pilot up-scale production. Shakeel Ahmad (2017) pursues the idea that new and cheaper photoanode materials must be found. Castro-Hermosa (2017) enhances the requirement for developing materials and interfaces of the cells and their architectures and as other authors the need to investigate the stability of large area devices. Tyagi (2013) proposes the uses of recycle materials to minimize environmental effects. Gong (2017) recognizes that DSSC need more reasearch mainly in the field of efficiency to become more competitive, especially to maximize the light harvesting. De Almeida Guerra (2016) recognizes that the proposed framework should be tested and Baldassarre (2017) that the process proposed in this paper should be tested in different contexts. Zhao (2016) proposes that future research should investigate the effect of external change initiatives on business model, and cross-compare business model innovations in various contexts. When searching how companies deal with the process of licensing technology, Jeong (2013) finds useful to understand why there is a gap between desired and actual technology transactions and considers that more data should be collected in terms of trading agents and regions over study. Ziegler (2013) intends to study the proposed factors to other firms and at large scale. Lichtenthaler (2009) thinks it lacks to investigate the relation between external technology exploitation and firm performance and also to study the effects of centralization and alignment not only in companies but universities as well. Bianchi intends to assess how specialized resources affect technology performance and in a wider type of companies and countries and how does the integration of these different resources occur and translates into superior exploitation outcomes.

2.6. TPM Model to identify promising technology

To help understand a technology and its technical advantages in the way of turning them in product advantages the **Technology-to-product-to-market (TPM)** linkage was adopted (Markham, 2007). This linkage requires specifying product features based on new technology capabilities and testing them for receptiveness with potential customers as described by the TPM linkage method (Figure 3 and 4).

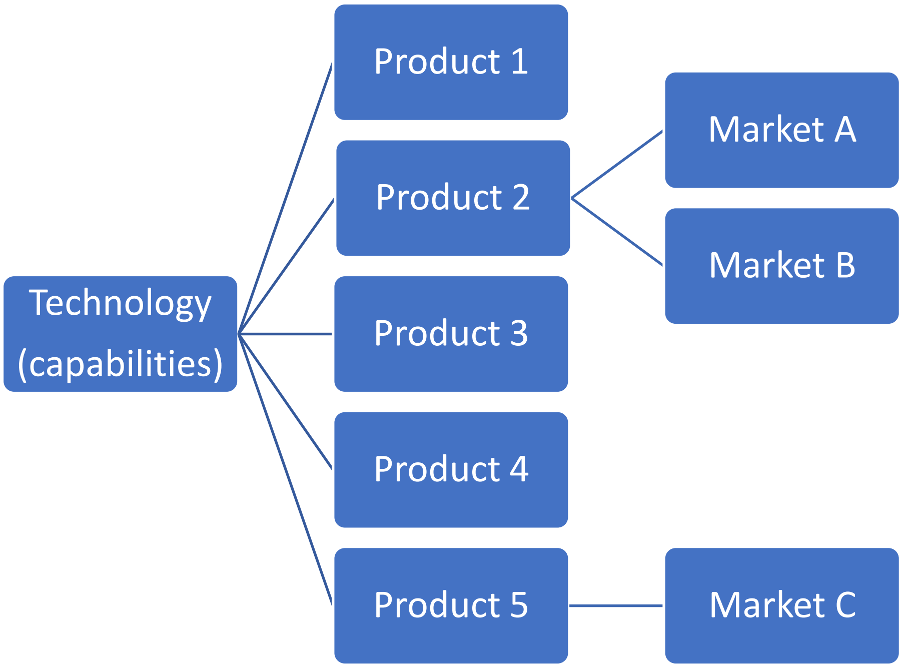

Figure 3 - Technology-to-product-to-market (TPM) linkage (Markham, 2007)

Technology	Product	Market
• Specifications • Superior advantages • Possible applications • Possible users • Patent efforts • Technology development	• Unique capabilities • Describes customer needs • Specify exact product features and benefits	• List all product attributes and market segments • Identifies high potential for a dominant product attribute in a market segment with a high need for those attributes.

Figure 4 - TPM linkage process (Markham, 2007)

The **TPM linkage method** is an industry-tested process to turn a single technology into multiple products and to consider multiple market opportunities for each product idea. For this the TPM linkage uses three worksheets based on:

- technology description and the magnitude of its capabilities advantages (Appendix A)
- development of a successful product idea that combine technical capabilities with customer needs (Appendix B)
- identifying the market segments suitable for the product idea (Appendix C).

The **TPM** is an iterative tool and useful for companies trying to perceive its technology unique advantages so then can be used for specific product features in product development phase. When these product concepts are defined they must be shown to lead customers in specific market segments to be tested.

2.7. Business Model Canvas to deliver value creation

Furthermore, to write the case of DSSC´s to be commercialize as a product the Business Model Canvas (Osterwalder & Pigneur, 2009) was also used as theoretical background. This model is organized through nine basic building blocks (Figure 5) that show the logic of how a company intends to make money: Key partners, Key activities, Value Proposition, Customer Relationships, Customer Segments, Key Resources, Channels, Cost Structure and finally Revenue Streams.

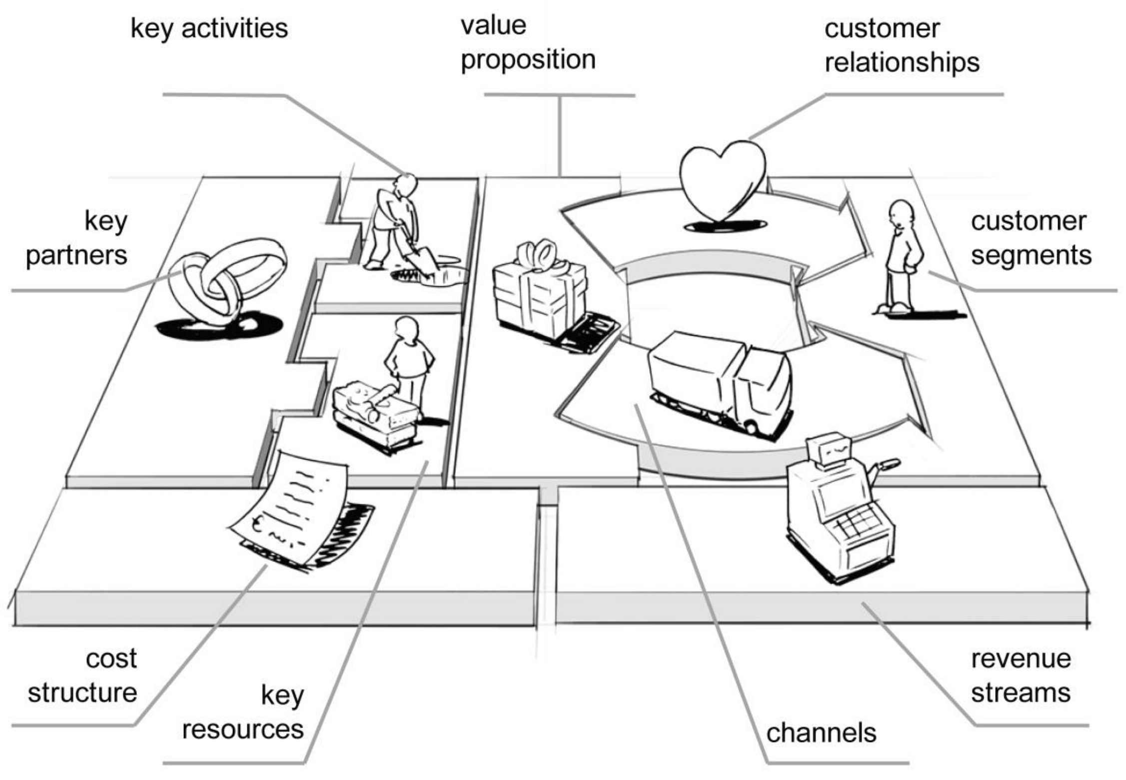

Figure 5 - Business Model Canvas Building Blocks. Source: Business Model Canvas (Osterwalder & Pigneur, 2009)

The nine blocks cover the four main areas of a business: customers, offer, infrastructure, and financial viability. The business model is like a blueprint for a strategy to be implemented through organizational structures, processes, and systems (Osterwalder & Pigneur, 2009).

2.8. Developing Licensing Agreements

For the matter of licensing the "Exchanging Value: Negotiating Technology Licencing Agreements - Training Manual" (Erauw & Stonier, 2005) brought the insights necessary to design a license agreement, understanding its main subjects: Preparing to License, Valuation of technology, Overview of a License Agreement and Licensor and Licensee Obligations.

A. Preparing to License Technology

Licensing a technology implies dealing and trading with Intellectual Property (IP). IP refers to creations of the human mind. The legal system of intellectual property rights converts this innovative and creative output into property and thus into valuable tradable assets (Erauw & Stonier, 2005).

IP includes new and improved technology, know-how, confidential, software and databases information, creative expression in several forms (movies, music, books, etc.), the image, reputation and goodwill linked to trustworthy names of goods and services, business identifiers, etc., and can be protected by a range of intellectual property laws.

Before embarking in a process of licensing is important to gather as much information as possible on the technologies available in the market or being developed, the potential licensee, the market, the legal and business environment and all needed to provide the company to be better informed.

Innovative technologies, are protected by patents and for that is useful to consult and research the accumulated database of patent applications and granted patents, known as "patent information". Since the patent system requires patent applicants to make public disclosure of their inventions, all inventions for which patent protection has been sought are documented, catalogued and made freely available for public consultation either 18 months after the filing of the patent application and/or immediately after the grant of the patent. Patent laws require that the disclosure be made in a manner sufficiently clear and complete for the invention to be carried out by a person skilled in the art in the technological field concerned, so these documents provide more detailed information about a technology than most other publications becoming a unique, large and useful tool source of information. As owner of the technology wishing to license out the information provided by the patent database repository is very useful to gain an idea how this technology is placed in the market vis-à-vis that of others and who could be interested in it.

The negotiation process cannot be based in pure trust, as not all negotiations end in an agreement. To safeguard against eventualities the parties should enter into a mutual non-disclosure agreement, also referred to as confidentiality agreement or secrecy agreement, always reviewed by a legal professional advisor.

Prior to formal negotiations both parties may need a preliminary understanding in the form of a Memorandum of Understanding or Letter of Intent but is not always necessary.

B. Valuation of Technology

Valuation process is a difficult and subjective exercise and has the final objective of both the licensor and licensee share in the profits associates with the use of the technology in a fair and reasonable manner.

Some years ago, the valuation of assets reflected their historical cost, as adjusted by depreciation, and their value was directly related to their expected profitability. However, this link is no longer automatically applicable, because companies use their intangible assets, namely technology and valuing them is more subjective and difficult.

However, according to Erauw &Stonier (2005) there are some methods (Figure 6) to be used to value technology, providing some guidance by establishing certain parameters within which the financial arrangements could be negotiated, including the amounts and the ways in which payments are to be made.

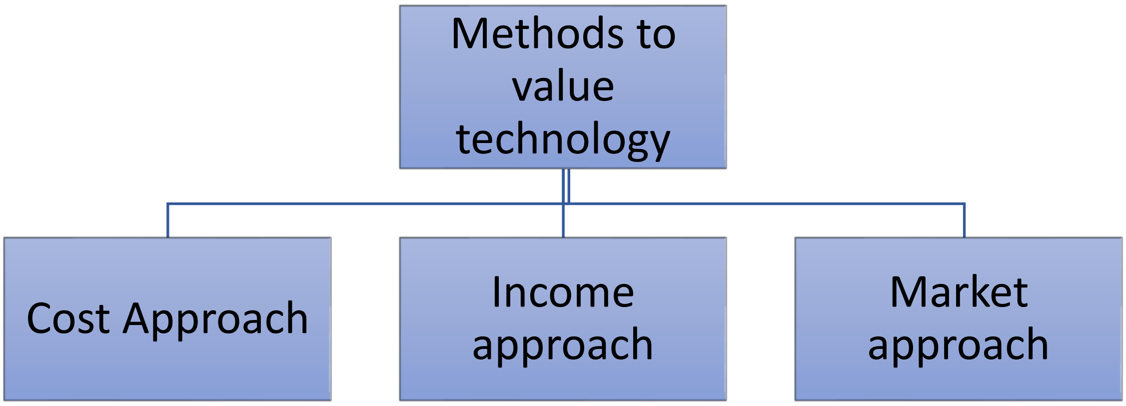

Figure 6 - Methods to value technology. Based on "Exchanging value: negotiating technology licensing agreements" (Erauw &Stonier, 2005)

- Cost Approach: The licensor's investment in the technology is represented by those costs associated with developing, protecting and commercializing the technology. They represent the base, or minimum that the licensor will want to recover, with interest.

- Income Approach: Involves making educated guesses or measures as to the amount of income that the new technology will generate. Then the determination of the respective shares the parties should each have of the benefits and find a royalty formula that matches that calculation.

- Market approach: this method compares similar market transactions to determine to determine the value of the technology in the negotiation, although identical technology and intellectual property packages may be difficult to find.

As Erauw &Stonier (2005) also stated that intangible assets are difficult to value every approach has its limitations and many more considerations can and should be take into account, such as:

- Intrinsic Quality (e.g., significance of technology and stage of development)
- Protection (e.g., scope and enforceability)
- Market Considerations (e.g., size and share)
- Competitive Considerations (e.g., third party)
- Licensee Values (e.g., capital, research and marketing)

- Financial Considerations (e.g., profit margins, costs of enforcement and warranty service)
- Risk (e.g., product liability and patent suits)
- Legal Considerations (e.g., duration of the license rights)
- Government (e.g., local laws on royalty terms and currency movement).

Each license agree is unique and is designed according to the licensor and the licensee expectations. And for that an infinite variety of agreements are possible, limited only by the needs of the parties and by the demands of the relevant laws and regulations.

Considering the types of payments (Figure 7) to the licensor for the use of the technology in licensing agreements there are usually two types: lump sums and royalties.

Lump sums are payable on the happening of a particular event or date. Time-based payments are certain in that the amounts are known and agreed, and they are risk-free in that they will be paid when the specified period has elapsed. Performance-based payments, on the other hand, depend on the occurring of certain events, such as the first commercial sale.

Royalties are regular payments to the licensor, which reflect the use of the technology by the licensee. The royalty base could be the cost of manufacturing or the profit from selling the licensed products, or even the gross or the net sales receipts of the licensee.

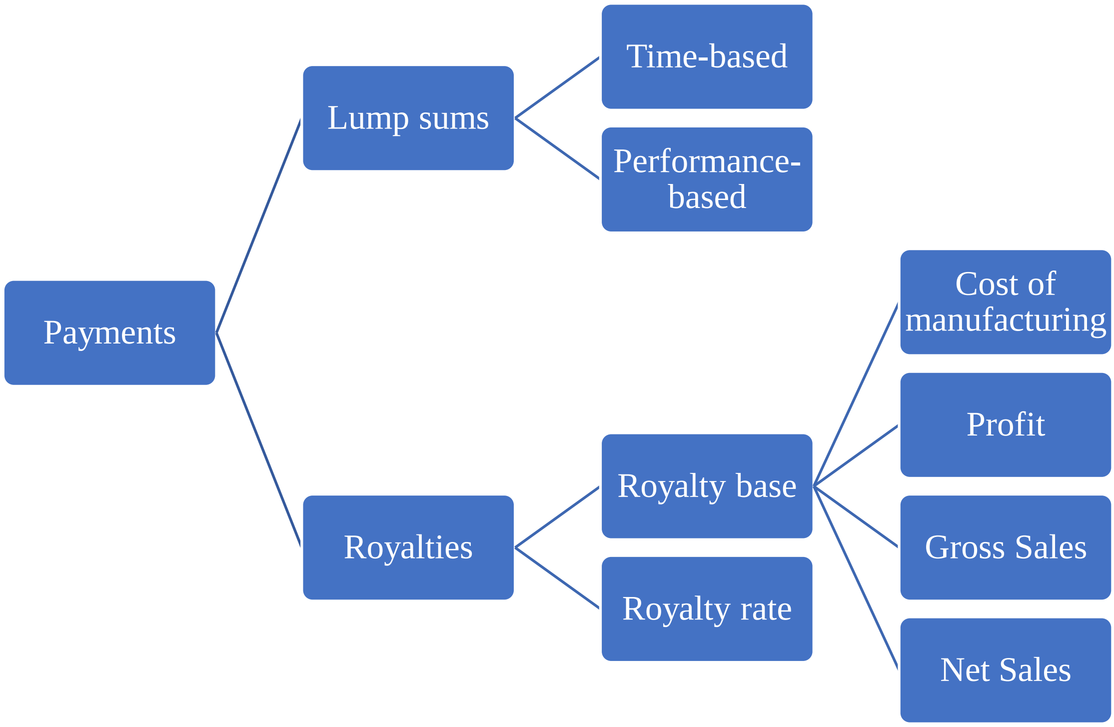

Figure 7 - Types of payments (Developed by the author)

C. Overview of a License Agreement

A license agreement is a binding and enforceable contract between two parties. The licensor and the licensee agree on legal requirements, which include that the parties have the legal capacity and the intention to enter into a contract, that there is offer and acceptance and that there is valid consideration, such as a payment on signing.

i. Subject Matter

A license agree is a distinctive agreement since the subject matter is intellectual property which the licensor grants the licensee the right to use.

It should also include the clearly identification of the subject matter of the license such as: the patent number, the detailed description and what the type of use for it, as well if the technology is complete or only in a state of development. It should also be ensured that the licensee has or undertaken to put in place procedures for restricting the use of the information; provide for liability in the case of accidental or negligent disclosure of the information to third parties and clarify as to how long these provisions will continue after the termination of the agreement.

ii. Extent of Rights

The license agree should also state the extent of rights, whether the license is exclusive, sole or non-exclusive (Figure 8) and the geographic territory for which the license is granted.

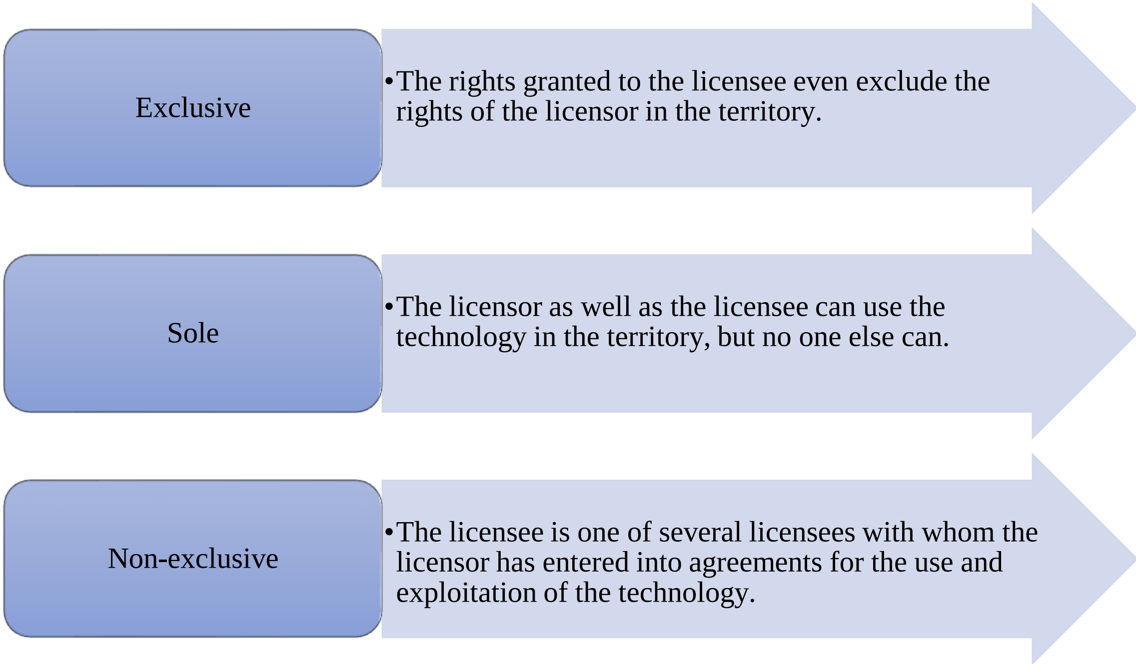

Figure 8 - Extent rights (developed by the author)

iii. Termination and Expiration

License agreements may come to an end in one of two ways:

- The term or period of the agreement expires because of the occurrence of an agreed event.
- The agreement is terminated by one party before it has expired. The events that can give rise to a party having the right to terminate the agreement are usually set out in detail and relate to a failure to perform in some way and breach of a condition of the agreement.

iv. Infringement

The license contract should also contain financial administration provisions such as: obligations on the licensee to keep accounts and records and the issues of currency and taxation when the parties are from different countries.

The contract should also include an Infringement section, in case of a third party is using the protected technology but does not have a license or third-party claims that the licensee is using technology in respect of which the third party has obtained protection.

D. Licensor and Licensee Obligations

The objective of a Licensing Agreement is the mutual benefit of both parties involved: the licensor and the licensee. For that it is necessary that both parties understand that both have something of value to bring to the relationship and make it a mutually satisfactory and rewarding one. Understanding what that value is and understanding the needs and expectations of both parties in entering into such an agreement is the key to a successful and long-lasting relation.

2.9. Conclusions

Analysing the literature above it became clear that most research focus on the capabilities of the technology existing and being enhanced in some studies for environmental purposes or economic reasons but anyone has been able to bring it yet to the market as a finished product and much less considered licensing it. Furthermore, there is still the lack of designing a value-based conceptual framework of business model to this type of technologies necessary to place the product in the marketplace with consumer perceived value stablished and the ways to license it as a complementary or substitute path.

To understand the exploitation of this technology (DSSC'S) the literature done on the topic was valuable to formulate a theoretical framework which formed a structure for this study.

3. CASE STUDY

3.1. Methodology considerations

For this case study the TPM methodology (Figure 9) was used to provide information for the Dye-Sensitized Solar Cells technology as they can be exploited as a valuable product reaching the market as a spin-off company or as a license to other companies.

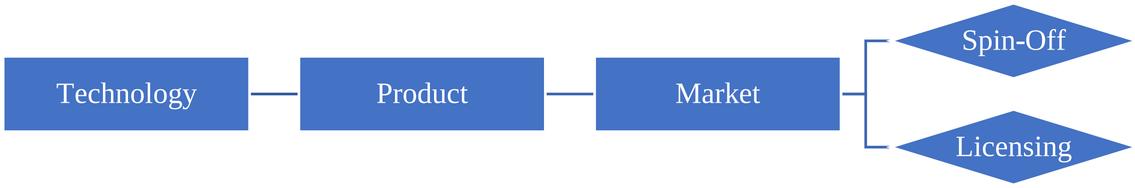

Figure 9 - TPM model used for case study (developed by the author)

The Business Model Canvas was used to build the main categories of the spin-off business as well as for the licensing, which includes: Key partners, Key activities, Value Proposition, Customer Relationships, Customer Segments, Key Resources, Channels, Cost Structure and Revenue Streams.

The "Exchanging Value: Negotiating Technology Licencing Agreements" was used to develop the main topics of a licensing agreement: Valuation of technology, Overview of a License Agreement and Licensor and Licensee Obligations.

3.2. Structure of the Case Study

The case study was organized as follows:

- Presentation of DSSC's technology
- Technology and Market analysis
- Developing exploitation strategy for a spin-off company
- Developing exploitation strategy for licensing.

3.3. Presentation of DSSC´s technology

The technology studied in this project is a Dye-Sensitized Solar Cell (DSSC) technology that consists on a porous nanocrystalline TiO_2 layer deposited onto a transparent conducting oxide (TCO) glass substrate and coated with a monolayer of dye. Light harvesting is accomplished by this monolayer of dye chemically bonded to the surface of TiO_2 particles (Figure 10).

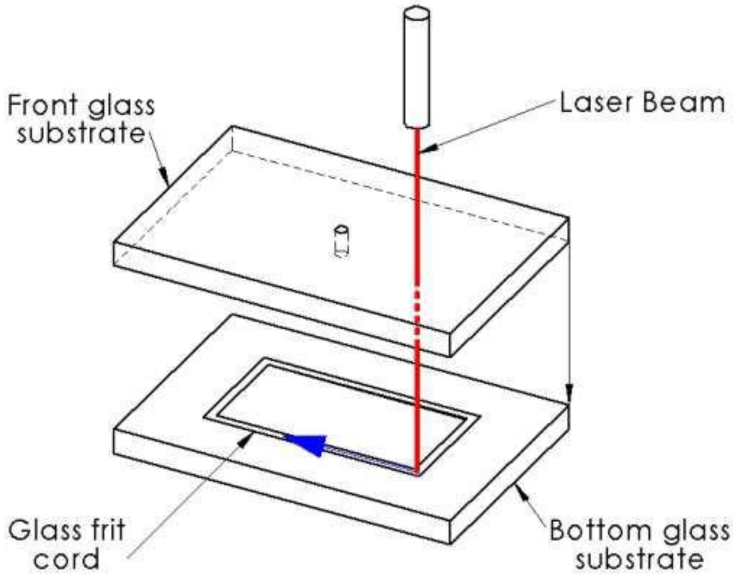

Figure 10 - Laser-assisted glass frit bonding process schematic. Reproduced from "Solarsel Business Plan 2012" (Luísa Andrade et al., 2012)

Under illumination, the dye absorbs the radiation and, once excited, electrons are injected into the conduction band of TiO_2. The photoinjected electrons then percolate through the semiconductor network, being collected at the TCO. Following electron injection, oxidized dye molecules are regenerated by electron donation from the electrolyte solution containing a redox couple of iodide/triiodide. The triiodide ions formed in the semiconductor's surface during the redox reaction diffuse to the Pt-catalysed counter-electrode (CE), where they are reduced back to iodide by the electrons from the external circuit.

A basic requirement for all solar cell technologies and for DSSC's in particular is the long-term stability. Despite all the efforts to enhance DSSCs' performance, long-term stability was the major issue limiting market implementation. In fact, for construction-integrated applications it is expectable that DSSCs' performance remains stable for no less than 20 years. Encapsulation of DSSC's is typically made with a polymer hot-melt seal foil (Surlyn), but this kind of material does not withstand temperatures above 65 to 80 ºC. In fact, up to now, the results obtained with these sealants do not guarantee long-term stability in outdoor conditions for more than 3 years.

So, a laser-assisted glass sealing process, was developed, able to achieve hermetically sealed devices. The sealing material is a low temperature fusing glass powder. This sealing method allows a hermetically sealed DSSC that is mechanically stable, withstanding thermal shocks and being helium leak proof. This sealing allows a lifetime of 20 years, compliant with the common PV standards. The sealing process is patented (PCT/IB2009/055511 WO2010064213A1).

3.4. Technology and Market Analysis

3.4.1. Present status of dye sensitized solar cells

It is expected that today's 7.5 billion people will increase to nearly 10 billion by 2050, of which about 65% will live in urban areas (Gomez-Exposito et al., 2018). This will pose major challenges at the global and local level, related with resource availability and economic sustainability, including energy consumption.

So, the ever-increasing demand in energy supply has accelerated fossil fuel depletion. It is projected that the reserves of fossil fuels throughout the world could only last 40 years for oil, 60 years for natural gas and 200 years for coal (Gong et al., 2017). Even though fossil fuels are still leading energy source nowadays, new renewable sources are arising such as solar energy. In order to convert solar energy in energy forms usable for human needs there are several thermodynamic pathways. In general, heat, kinetic energy, electric energy and chemical energy can be provided via solar energy conversion. In particular photovoltaics (PV) is the direct conversion of solar energy into electricity.

Photovoltaics is a fast-growing market with the Compound Annual Growth Rate (CAGR) of PV installations of 40% between 2010 to 2016.

In 2016, China and Taiwan leaded the PV module production with a share of 68%, followed by the rest of Asia with 14 %, Europe contributed with 4% and USA and Canada with 6% (Fraunhofer 2018 report).

Solar cells work based on the photovoltaic effect to convert the solar optical power to electricity. The existing technology in solar cells are presented in Figure 11.

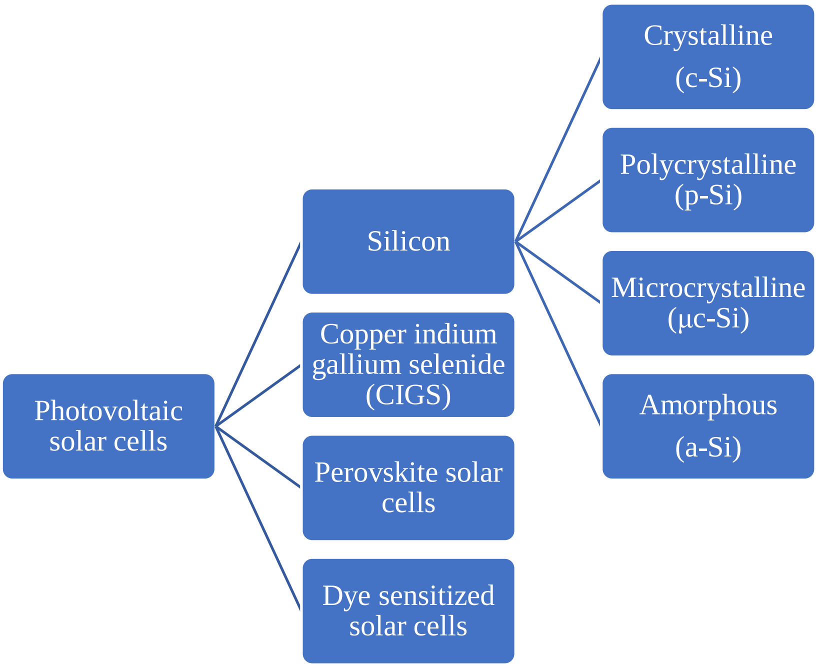

Figure 11 - Types of photovoltaic solar cells (developed by the author).

In 1991, Brian O´Regan and Michael Grätzel described for the first time a three-dimensional heterojunction applied to the fabrication of Dye-Sensitized Solar Cells (DSSC´s). This new device was based on the use of semiconductor films consisting of nanometre-sized Ti-O_2 particles, together with newly developed charge-transfer dyes. These authors reported an astonishing efficiency of more than 7%. DSSC´s are a new thin-film generation of photovoltaic devices differing from the conventional ones in what concerns the light absorption function, which is separated from the charge carrier transport.

Global DSSC market (reported by Grand View Research) value was estimated to be 49.6 million US Dollars in 2014 and is estimated to grow at a compound annual growth rate of over 12% from 2015 to 2022 (Shakeel Ahmad et al., 2017).

The efficiencies of DSSC's have increased considerably in the last 20 years, with the confirmed record now standing at 14,1%. Typical DSSC's employ a monolayer of dye adsorbed to a mesoporous oxide with pores filled by an electrolyte. Dye molecules absorb light and inject electrons into the oxide, where they are transported to the substrate. The dye is regenerated by a redox couple in the electrolyte, which then diffuses to the platinized counter electrode to complete the circuit (Baxter, 2012) (Figure 12).

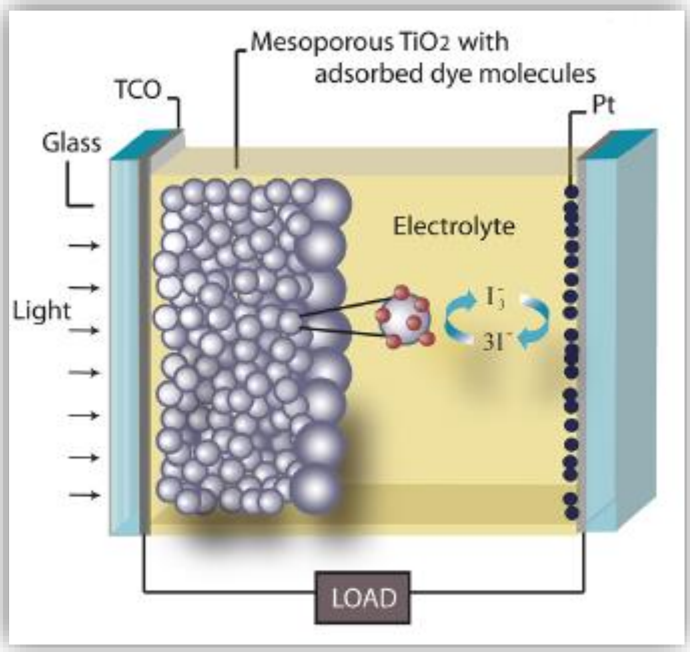

Figure 12 - Schematic of a DSSC. Reproduced from "Commercialization of dye sensitized solar cells: Present status and future research needs to improve efficiency, stability, and manufacturing." (J.Baxter, 2012)

It is believed that DSSC's can be the next generation of power source, not only by contributing to an effective entrance of solar devices in our daily lives but also by diversifying the common use of photovoltaics in buildings and façades. Their transparency and various possibilities of colours offer to DSSC's an opportunity to conquer markets that are not attainable by typical silicon solar cells.

Advances in their design, their incorporation on flexible substrates, the development of solid state modules, their enhanced stability in outdoor environments, and their scalable fabrication tools and techniques have allowed DSSC's to move from the laboratory to real-life applications. Although photo conversion efficiencies are not on a par with commercially available copper indium gallium selenide (CIGS) or single crystalline silicon solar cells, or even the very recent perovskite solar cells technology, they possess many features that compel the further development of DSSC modules, including transparency, light weight, flexibility, conformability, workability under low-light conditions, and easy integration in buildings, as on solar windows. In fact, DSSCs' panels have shown to deliver even more electricity than their silicon and thin film counterparts of similar power ratings when exposed to low light operating conditions due to their workability in such conditions; thus, they are potential market leaders in BIPV and indoor light harvesting photovoltaic technology (Fakharuddin, Jose, Brown, Fabregat-Santiago, & Bisquert, 2014).

The lifetime of the DSSC is dependent where they will be used. For building integrated modules a lifetime of over 25 years is required to avoid premature repairs or replacements but for indoor applications, such as chargers integrated into devices or portable electronics a 5-year lifetime is acceptable. The most stable DSSCs are sandwiched between two pieces of glass. However, this is also the most expensive, rigid, and heavy configuration.

3.4.2. Preparing buildings for Net Zero Energy Building (NZEB)

Photovoltaic (PV) systems used on buildings can be classified into two main groups: Building Attached Photovoltaics (BAPVs) and Building Integrated Photovoltaics (BIPVs). It is rather difficult to identify whether a PV system is a **Building Attached (BA)** or **Building Integrated (BI)** system if the mounting method of the system is not clearly stated. BAPVs are added on the building and have no direct effect on structure's functions. On the other hand, BIPVs are defined as PV modules, which can be integrated in the building envelope (into the roof or façade) by replacing conventional building materials, such as tiles.

Building-integrated photovoltaics (BIPV) are dual-purpose: they serve as both the outer layer of a structure and generate electricity for on-site use or export to the grid. BIPV systems can provide savings in materials and electricity costs, reduce pollution, and add to the architectural appeal of a building.

Therefore, BIPVs have an impact of building's functionality and can be considered as an integral part of the energy system of the building. There are many parameters that need to be considered for the integration of PVs into the building envelope and they are shown in Figure 13. (Biyik et al., 2017)

Figure 13 – Parameters to be considered for BIPV, Reproduced from: A key review of building integrated photovoltaic (BIPV) systems (Biyik et al., 2017).

The first installation of BIPV was accomplished in 1991 in Aachen, Germany (Kibert, 2016). The photovoltaic elements were integrated into a curtain wall façade with isolating glass. Today, photovoltaic modules for building integration are produced as a standard building product, fitting into standard façade and roof structures creating a whole new market: BIPV. Since then building integration is one of the fastest growing market segments in photovoltaics. An impressive solar installation, the Academy Mont-Cenis in Herne, Germany (Figure 14) with more than 10 000 m^2 of photovoltaics integrated into the roof and façade was finished in March 2000.

Figure 14 - Roof and Façade of Academy Mont-Cenis (reproduced from http://www.herne.de)

The BIPV market has high potential to increase in the next years. Globally, buildings account for more than 40% of total primary energy use and a third of greenhouse gas emissions (Kibert, 2016). The building sector can significantly reduce energy use by incorporating energy-efficient strategies into the design, construction, and operation of new buildings and undertaking retrofits to improve the efficiency of existing buildings. It can further reduce dependence on fossil fuel derived energy by increasing use of on-site and off-site renewable energy sources.

The concept of a Net Zero Energy Building (NZEB), one which produces as much energy as it uses over the course of a year, recently has been evolving from research to reality. Currently, there are only a small number of highly efficient buildings that meet the criteria to be called "Net Zero". Because of advances in construction technologies, renewable energy systems, and academic research, creating Net Zero Energy buildings is becoming more and more feasible.

So BIPV is becoming a niche market with large expectations considering NZEB concept and the goals defined by the EU 2020 that requires 3% of all public buildings should be renovated per year until 2020.

Even though the tonic growth of the PV market, BIPV still makes up a relatively small part of that, although the concept already exists for many years. The main reason for this slow deployment is that BIPV installations are still more expensive than conventional PV installations. The commercial application of BIPV became more mainstream from the beginning of 2012, when the use of BIPV becomes more widespread and makes more sense economically as costs decrease, and as the residential sector in new markets like Portugal, Greece, France and Italy begins to stabilise and manufacturers look to other sectors to sustain growth.

The largest market for BIPV in Europe is the German market. The country started its BIPV programme in 1999 with its 100 000 roofs programme.

In the upcoming years, the BIPV market is expected to grow strongly (Figure 15) driven mainly by the revival of the construction industry. New constructions, retrofits and refurbishment works in both commercial and residential sectors are also expected to drive up strong demand for BIPV products in the coming years. Future growth prospects in the global BIPV market are significantly dependent on the extent of efforts by key members of the BIPV supply chain to enhance design and integration of PV into building structure, development of BIPV specific building codes and standards, and availability of attractive incentives at local and federal level to ensure cost-effectiveness of BIPV products (Tabakovic et al., 2017).

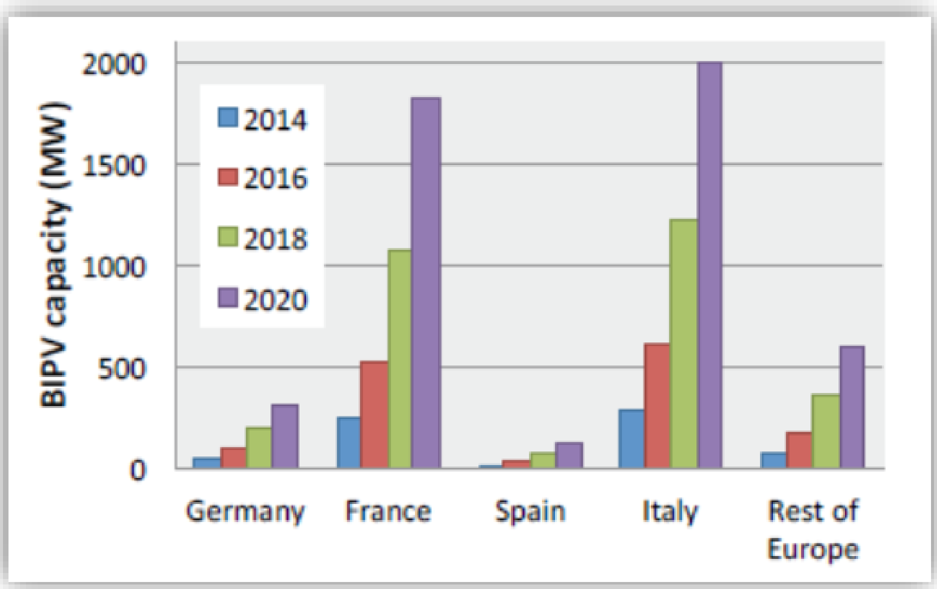

Figure 15 - Analysis of BIPV market. Reproduced from "Status and Outlook for Building Integrated Photovoltaics (BIPV) in Relation to Educational needs in the BIPV Sector" (Tabakovic et al., 2017)

3.4.3. Photovoltaic Market

Competitors analysis

In this market and considered this type of technology the main competitors were segmented according to:

- Companies that produce and commercialize photovoltaic modules with dye - sensitized solar cells based technology as they offer the same technological solution- **direct competitors**.
- Companies that produce and commercialize other types of solar cells technology as they offer similar products and target the same market (BIPV)- **indirect competitors**.

<u>Direct Competitors</u>

The main reference companies in the field already using DSSC´s as their technology for providing solar energy solutions are: Exeger, H. Glass, Solaronix and GCell (Table 6).

Table 6 - Direct Competitors (developed by the author)

Company	Founded in and Location	Description	Source
EXEGER	Founded in 2009 and located in the city centre of Stockholm, Sweden.	Its solar cell technology is based on the dye-sensitized solar cell originally invented in 1988, with developed new proprietary materials to improve overall performance of the cell.	http://www.exeger.com/
H. GLASS	Founded in 2011 and located in Villaz-St-Pierre, Switzerland.	The company is the owner of Grätzel cell licence, a transparent and coloured DSSC and has also developed an industrial process for manufacturing	http://h.glass.com/

Company	Founded in and Location	Description	Source
		pigmented and photosensitive solar cells, encased in glass.	
SOLARONIX	Founded in 1993 and located in Aubonne, Switzerland.	The company serves a worldwide customer base from materials production to solar panels and testing equipment manufacturing.	https://www.solaronix.com/
GCell	Founded in 1999 and located in Newport, South Wales, United Kingdom.	The company has the capability of manufacturing more than 500,000 linear meters of GCell modules per year. Its main product is the iBeacon, a device to broadcast Bluetooth® signals that a smartphone can receive and understand.	http://gcell.com/

Indirect Competitors

The increasing concerne for NZEB is leading smaller companies, such as Polysolar, Onyx Solar, EnergyGlass and Solaria (Table 7), to create products specifically targeting the construction industry and the BIPV market.

Table 7 – Indirect Competitors (developed by the author)

Company	Founded in and Location	Description	Sources
Polysolar	Founded in 2007 and located in	The company is specialized in developing and producing BIPV solutions, defining themselves as a	http://www.polysolar.co.uk/

Company	Founded in and Location	Description	Sources
	Cambridge, United Kingdom.	low-cost, solar photovoltaic glass provider for the architectural market.	
onyx	Founded in 2009 and has offices in Spain, United States and China.	The company is a manufacturer of transparent photovoltaic glass for buildings. Has also developed the first photovoltaic pavers in the world, which can be used as terrace floor, sidewalks and other outdoor surfaces.	https://www.onyxsolar.com/
ENERGYGLASS SOLAR & GLASS ARCHITECTURE	Founded in 2007, in Cantù, Italy.	The company has the objective of designing, manufacturing and marketing architectural elements to produce renewable energy. In 2012 has expanded its offer by including the production of photovoltaic ceramic.	http://h.glass/
SOLARIA	Founded in the early 2000s, in Fremont, U.S.A.	The company has developed a technology platform with over 100 patents encompassing materials, processes, applications, products, manufacturing automation and equipment.	http://www.solaria.com/

This Table 8 synthesises the competitors mentioned above, both direct and indirect, the technology they are using, their efficiency and the main capabilities and applications of companies' products.

Table 8 - Competitors, Technology in use, Efficiency, Features and Applications (developed by the author)

	Exeger	**H.Glass**	**Solaronix**	**GCell**	**Polysolar**	**Onyx**	**EnergyGlass**	**Solaria**	**FEUP DSSC**
Technology	DSSC	DSSC	DSSC, nc-DSSC	DSSC	a-Si	a-Si; c-Si	c-Si	c-Si	DSSC
Practical Efficiency	4-5%	4-5%	4-5%	4-5%	5-8%	5-8% (a-Si) 17-20% (c-Si)	17-20%	17-20%	9%
Features	Freedom of choice in colour, dimensions, shape, level of transparency, and material Superior efficiencies under indoor illumination	Transparent and coloured modules.	Available with a palette of different colours and adjustable transparencies Function in diffuse and relatively low light conditions	Lightweight and thin, yet robust and durable to withstand everyday use.	Efficiency in low light and at poor angles Heat tolerance panels Variable transparency and high efficiency	Customized in shape, colour, size, thickness, and semi-transparency degree	Glass can be customised in measures, thickness, power, transparency and colours. Thermal insulation and Acoustic insulation properties	Design Flexibility and Custom Configurations	Captures solar diffuse and artificial radiation with great performance, allows colour and stamping customization
Applications	Consumer electronics, IoT, Automotive, BIPV	Curtain walls, Ventilated façades, Glass Shadings and Urban Furniture	Rooftop and façades Standalone Devices Portable electronic devices	Indoor and portable devices	Façades, curtain walls, green-houses, car park canopies, rooftops	Façades, curtain walls, atriums, canopies and terrace floor	Façades, Roofing glass, Railings and Balconies, Canopies and shading, Greenhouse, Acoustic barriers	Skylights, windows, façades	Façades and windows

According to their marketing strategy, each company presents the positioning presented in table 9.

Table 9 – Positioning according to marketing strategy (developed by the author)

	Façades	Rooftops	Consumer electronics	Curtain walls	Windows	Urban Furniture
Exeger						
H.Glass						
Solaronix						
GCell						
Polysolar						
Onyx						
EnergyGlass						
Solaria						
FEUP DSSC						

This type of companies is addressing the market providing customization to the façades and rooftops mainly or committing themselves to the need of frequent charge of every indoor device that consumers use nowadays, like tablets or cell phones.

Portuguese DSSC's Intendsss to position itself as a company who works side by side with architects and builders, allowing these professionals to customize their buildings as they desire (Figure 16).

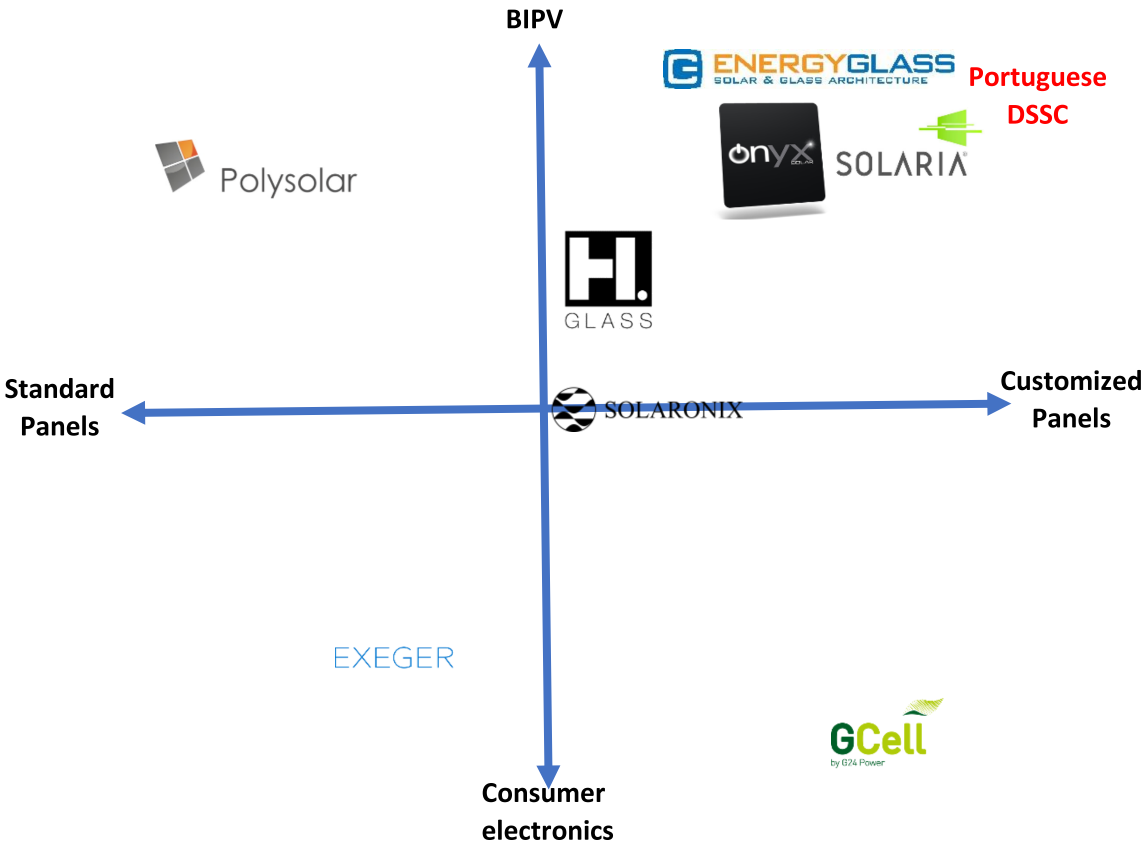

Figure 16 - Positioning (developed by the author)

3.5. Developing exploitation strategy for a spin-off company

University spinoffs have remarkably strengthened the linkage between universities and industry. The number of technology patents and spin-offs coming out of university research has a significant impact on regional economic and social development (Pattnaik & Pandey, 2014). In the last years the visibility of academic entrepreneurship has increased, and universities are considered a source of creation of high-technology companies.

Spin-offs provide a way for firms to commercialize inventions that have very high uncertainty, translating the invention into a business process finally reaching the customers.

In this thesis, for DSSC´s technology studied, a TPM linkage method was used to explore the possibility of a product with the features capable to reach a targeted segment of the market.

For that the following exercise was made using the worksheets (Tables 10, 11 and 12) referred below:

Table 10 – Technology description Worksheet of DSSC's (developed by the author)

DSSC´s capabilities	**Scientific description of technology:** Photovoltaic devices made of porous nanocrystalline TiO_2 layer deposited onto a transparent conducting oxide (TCO) glass substrate and coated with a monolayer of dye. Light harvesting is accomplished by this monolayer of dye chemically bonded to the surface of TiO_2 particles. A laser-assisted glass technology is used to achieve hermetically sealed devices. **Description of what technology does and does not:** It absorbs light and converts it in electricity.
	Describes superior advantages of technology: More efficient in capturing the diffuse light so higher efficiency under vertical position. Aesthetically versatile. Easily incorporated on flexible substrates. Enhanced stability in outdoor environments. **Lists possible applications:** Building-integrated photovoltaics, windows, urban furniture, curtain walls and consumer electronics. **Possible users:** Builders. Architects. Public Authorities (e.g.: Town Halls). Consumer electronics companies. **Discusses possible advantages to users:** Lower instalation costs, more than 20 years lifetime, non toxic, lighter weight. **Discusses patent efforts**: Sealing process is patented (WO/2010/06421 and PCT/IB2009/055511.
	Describes technology's current stage of development: Laser-sealed 10 x 10 cm2 sub-modules with 9% efficiency and stable. **Describes technology's progress toward demonstrating commercial potential:** Upscalling of the production of laser-sealed 30 x 30 cm2 modules ongoing.

Table 11 – Product feature Worksheet of DSSC'S (developed by the author)

Product Features	**Identifies the unique capabilities of the technology:** More efficient in capturing the diffuse light and so demosntrating higher efficiency in vertical. Aesthetically versatile. Enables different patterns and colours. Complies with energy sustainability directives, in particular, EU Directive 2010/31/EU for NZEB.
	Describes what customers need in terms of the unique capabilities: Building-integrated photovoltaics with better design and versatility. More efficient under non-standard conditions. Lower costs. Lower maintenance. Attached to an electronic device allows ever-lasting battery.
	Specifies exact product features: 23%-37,5% price reduction. Solar cell with 9% efficiency. Multiple colors and patterns solar cells.

Table 12 – Product feature and market matrix Worksheet of DSSC's (developed by the author)

		Markets and Segments			
		Battery Power Industry		Building Integrated	
		Consumer Electronics	Household appliances	Façades/Rooftops/ Curtain Walls	Urban Furnitures
Product Attributes	More efficient in diffuse light	5	5	5	5
	Lower Cost	5	5	5	5
	Lifetime over 20 years	1	2	5	5
	Lighter weight	5	4	5	5
	Lower maintenance	4	4	5	5
	Better design	2	2	5	5

Considering the most important features of the product, the building integrated market of Façades/Rooftops/ Curtain Walls and Urban Furnitures will be the market to focus for developing the following Business Model Canvas (Osterwalder & Pigneur, 2009).

3.5.1. Business Model Canvas

A business model describes the rationale of how an organization creates, delivers, and captures value (Osterwalder & Pigneur, 2009). The Business Model Canvas by Osterwalder offers a shared language that allows companies to describe their businesses and compare assumptions.

Customer Segments

This block defines the different groups of people the company aims to reach. Customers are the heart of every business model and without them no company can survive for long. As our Solar Cells intend to address the construction market, two types of customers were identified: the Builders and the Architects. They were considered two different segments as their addressed needs are different: Architects are more concerned with the aesthetical advantages of the product and Builders with legislation and regulations compliance.

Customer Relationships

This section describes the type of relationships the company establishes with each customer segment. These relationships can be driven by several motivations: Customer Acquisition (GET), Customer Retention (KEEP) and Boosting Sales (GROW). To acquire customers Solar Cells company intends to create a website to present the company and promote the product, as well as establishing online support and sales if requested by customers. Also developing a Search Engine Optimization (SEO) that is a set of rules that helps to optimise the website for search engines improving the website ranking. Basically, SEO makes the website easy for both customers and search engine robots (e.g. Google) to understand and to find. The means to create a SEO include: selection of the right keywords, optimization of website's pages, creation of relevant content and creation of links around the terms customers are searching for, such as solar energy or Europe 20/20 or photovoltaic.

Also, to make the company stand out it is important to attend events like Intersolar (Figure 17), a well-known exhibition for the solar industry and its partners, with the purpose of disclosing the product.

Figure 17 Intersolar 2018 Poster

As the achievement of Net Zero Buildings is an imposition of the European legislation, the company wants to engage relations with countries' governments such as Germany, U.S.A, Switzerland and Austria (Figure 18) already well committed with decreasing the total consumption of buildings, for the purpose of introducing the product in their markets.

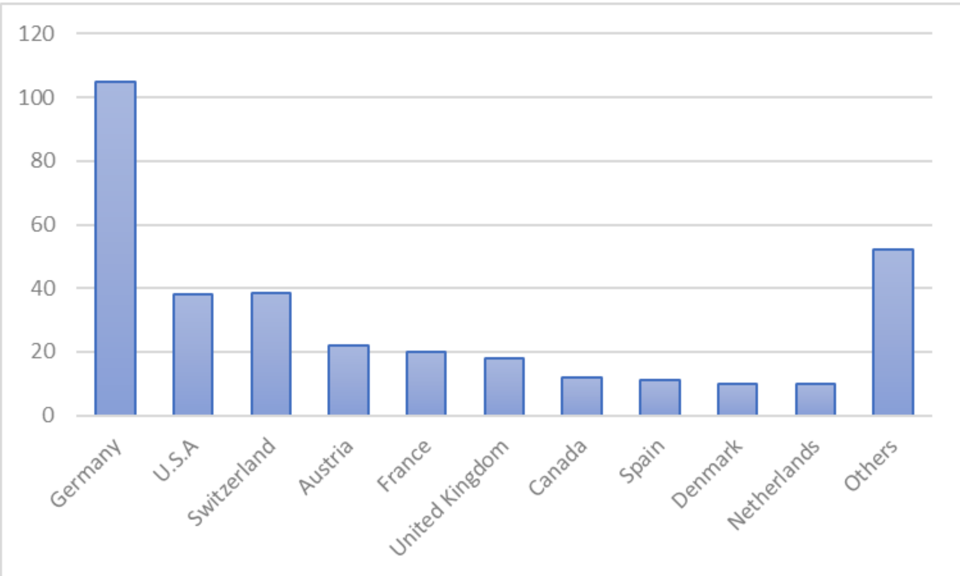

Figure 18 - Frequency of known Zero Energy Buildings per country (Source University of Wuppertal)

To retain customers a well-designed Customer Service is of interest to solve eventual problems with maintenance, guaranty or installation, integrated in the website and with a 12h call centre personal assistance.

With all the company's effort is intended that for growing the customer relations the word-of-mouth provided by every customer acquired will be enough.

Channels

This block describes how a company communicates with and reaches its Customer Segments to deliver its Value Proposition. To communicate Solar Cell to the market the company will develop digital and magazine campaigns, namely in Facebook and magazines addressing environmental issues like "Discover".

The company intends to sell its panels through its website and directly in a store open to public. A sales representative placed in a store like Ikea or Leroy Merlin should be able to expand products' sales.

Value Proposition

The section describes the bundle of benefits that create value for the specific Customer Segment and is the reason why customers turn to a company rather than others. Solar Cell offers an alternative, sustainable and eco-friendly energy solution to everyone in need of electricity in their buildings. It offers higher performance, more customization by providing a wide choice of different colours and patterns and reduction in costs.

Key Activities

This block describes the most important things a company must do to make its business model work. Solar Cell company main activity is the production of the solar cells itself. To deliver the panels with superior quality, Solar Cell Company must have a Research and Development department to design and develop even more efficient cells and cut-of-the-edge technology, as well as maintenance issues that might arise from post-service requests.

Key Resources

This section describes the most important assets required to make the business model work. This company main resources are the factory building and warehouse, the machines and materials to build the panels. As a manufacturing company it requires human resources, important in production and in development of the product. For this company intellectual resources like proprietary knowledge and the following patents are important components of the business:

- International Patent PCT/IB2009/055511, date of deposit 05-12-2008, status under examination.
- U.S. Patent nº US20110306161A1, date of deposit 04-12-2009, status granted.
- International Patent PCT/IB2012/051376, date of deposit 22-03-2012, status completed.

Key Partners

This part describes the network of suppliers and partners that makes the business running. Companies create alliances to optimize their business models, reduce risk, or acquire resources. They contribute significantly to the success of the company and influence its future trajectory.

Solar Cell Company establishes relations to its raw materials suppliers, including glass, metal and dye. Maintains strategic alliance with non-competitors like installers, sellers, distributors (Ikea and Leroy Merlin) and with known and influential architects, like Souto Moura.

Intends to engage relation to investors in a way to develop new ventures and with governments, trying to win public contests to new projects related to NZEB legislation.

Cost Structure

This block describes the most important costs incurred while operating under this business model. This company has few fixed costs namely salaries of employers and rents of machinery and factory. Variable costs are affected by the price of raw materials such as glass, metal and dye and the energy spent on production and they intend to grow 2,5% over the years[1]. These costs also include R&D efforts to develop cheaper dyes and more efficient ones. Marketing costs may increase as the need to enter new countries and the way to boost sales.

[1] This information was obtained of a confidential financial exercise done by a promoter team of the Business Ignition Program 2018

Revenue Streams

This section represents the cash the company generates from its customer segments. The company set its price in a fixed price mechanism, based on the quality of Value Proposition features. Company revenues is based on solar cells modules sales.

The unit price for each square meter of glass will be 170 €, a price that should increase 1.5% annually below inflation, despite the average investment of 4% in R&D efforts to develop increase improve the product. Revenues are based on market assessment and expected to grow from 5000 m^2 number of units (in m^2) to near 67500 m^2, expecting the revenues to reach 12 million euros in the first 4 years[2].

Figure 19 illustrates what was described above, presenting FEUP Solar Cell Business Model Canvas.

Key Partners	**Key Activities**	**Value Proposition**	**Customer Relationships**	**Customer Segments**
Raw materials Suppliers (Glass, TCO, Titanium Dioxide, Dye, Electrolyte, Platinum, Glass Frit, Silver paste) Installers Sellers	Research & Development Manufacturing Sales Post sales services	For everyone in need of eco-friendly and sustainable electricity our Solar Cells are aesthetical, long-lasting, very efficient in capturing	GET- Website, SEO, Events like Intersolar, Government partnerships KEEP- Customer Service GROW-Word-of-mouth	Architects Builders

[2] This information was obtained of a confidential financial exercise done by a promoter team of the Business Ignition Program 2018

Distributors Architects Investors Governments	**Key Resources** Raw Materials Factory Human Resources Intellectual Property	diffuse radiation and able to be integrated in buildings.	**Channels** Own Sales Online Sales Partner Stores Digital and Magazine Ads	

Cost Structure Fixed costs: salaries, rents. Variable costs: raw materials, R&D, marketing	**Revenue Streams** Solar cell sales based on a fixed price of 170 €/m^2

Figure 19 - Solar Cell Business Model Canvas (developed by the author)

3.5.2. Implementation plan

Assumptions and Considerations

- FEUP Solar Cell intend to address 3% of Portuguese public buildings as well as others European Member States (France, Netherlands, Sweden) and the U.S.
- Initial investment will be provided by Venture Capital.

3.5.3. Implementation Roadmap

The implementation plan (Table 13) embraces Investment pursuit, Research and Development improvements, defines industrial's organizational standards and product development.

Table 13 – Implementation Roadmap (developed by the author)

	2019				2020				2021				2022			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Venture Capital search																
Factory assembly																
Laboratory assembly																
Hire Specialized personnel																
Initial laboratory tests																
Raw material search and buy																
Development of scalable manufacturing																
Development of product line																
Continuous Research & Development																
Sales																

The initial phase includes financing search followed by factory full assemble until de beginning of 2020. Until that year end the hole physical and personnel structure will be finished. In 2021 the production phase will be defined, including lab tests, finding of materials needed and development of manufacture methods. Sales will start at mid-2022, while R&D efforts will be performed since the beginning of testing and during the production process.

3.6. Developing exploitation strategy for Licensing

It is a recent trend that companies attempt to capture additional value from their technologies by increasingly try to license their own technology to other firms. Under today's challenging economic conditions, successful licensing may strongly contribute to sustaining superior performance by capturing value from a firm's technologies (Lichtenthaler, 2010a).

Technology licensing constitutes the external mode of technology exploitation in addition to internal technology application in a firm's own products. In particular, technology licensing provides monetary and strategic benefits (Lichtenthaler, 2010a). But this approach can also include risks, such as strengthening competitors by diffusing company's know-how.

When starting to prepare this licensing agreement a search for sealing patents in the "United States Patent and Trademark Office" (USPTO) was conducted and only revealed a "Composition for solar cell sealing film, method for producing same and solar cell sealing film" with the International Patent PCT/JP2014/063713, date of deposit 16-11-2015, but no patent was found for sealing DSSC´s, strengthening the idea that there is a market yet to explore.

In the case of this study, the license agreement has as its Licensor FEUP Solar Cell company that developed and patented a long-lasting sealing process for DSSC's and for potential licensees the manufacturers of solar cells glass.

In the way of valuating the technology, it was used the cost approach, considering the R&D expenses and patent assignment, as well as a market approach considering royalty reports of energy companies. And as for payment type it was considered a royalty base of 5% of Net Sales, considering what has been practice in the market.

The subject of matter in this agreement are the patents and respective the know-how. The patents of FEUP SolarCell are the following:

- International Patent PCT/IB2009/055511, date of deposit 05-12-2008, status under examination.
- U.S. Patent nº US20110306161A1, date of deposit 04-12-2009, status granted.
- International Patent PCT/IB2012/051376, date of deposit 22-03-2012, status completed.

The extent of rights adopted is a non-exclusive license to the European and U.S. territory since the risks and rewards are spread through several licensees. The licensor can provide a chance for the technology and the process to develop since many licensees are using it and in different markets and the expiration period is the last to expire of the licensed patents (2029).

As this is a patent and knowhow agreement, the licensor is expected to take the necessary actions to transfer the technology and assist the licensee to commence commercial production. In the other hand, the licensee is expected to successfully manufacture and market the licensed product in the territory. Both parties have the right to assign the license, but the licensee as no right to sub-license. Table 14 illustrates the main categories of the Licensing Agreement.

Table 14 – Licensing agreement of the process (developed by the author)

Licensor	FEUP Solar Cell
Licensor's Activities	Licensor has developed a long-lasting sealing process for Dye-Sensitized Solar Cells.
Licensee	Manufacturers of solar cells glass
Licensee's Activities	Licensee develops, manufactures and sells solar cells modules.
Description of Agreement	Licensee has no right to sublicense; Both parties have a right to assign the license. Licensor has to take the necessary actions to transfer the technology and assist the licensee to commence commercial production and the licensee is expected to successfully manufacture and market the licensed product in the territory
Subject of Matter	License under technology and patent rights to make, use and apply certain technology and know-how known as "Glass sealing of dye-sensitized solar cells"

Stage of Development	Technology well developed.
Extent of Rights	Non-exclusive license
Expiration	The license includes the use of European patent with an expiration date of 2028 (International patent) and 2029 (U.S. patent)
Territory	Europe and U.S.A.
Payments	The Licensee shall pay royalty of 5% of its Net Sales.

As licensing is a way of maximizing the value of the company's assets, a Business Model Canvas helps to organize this created, delivered and captured value.

Customer Segments

Solar cell company intends to license its sealing process to manufactures of solar cell glass, namely DSSC's manufactures, such as Exeger, H.Glass and Solaronix, three of its direct competitors, since they can all benefit from the agreement: Solar Cell company gains extra revenues for improving its how R&D and the other manufactures extend their panels lifetime, bringing extra-value to customers. Permanent contact with Customer Service personnel will provide improvement to the technology.

Customer Relationships

As in the spin-off approach, Solar Cells company intends to present and promote its sealing process in its own website as a way of Customer Acquisition as well as maintaining its participation in field events.

To retain customers a Customer Service developed to transfer the appropriate know-how to the licensee and benefiting from this interaction. For growing the customer relations, the word-of-mouth provided by the surrounding market will be enough.

Channels

To reach its licensees the company intendss to communicate in its website and deal with the negotiating process of the agreement itself, with its own legal team.

Value Proposition

Solar Cell company offers manufacturers of Solar Cells, in Europe and in the U.S.A. a long-lasting sealing process for their panels, which allows them to address the arising market of BIPV.

Key Activities

For the licensing strand, Solar Cell company must maintain and develop its R&D activities, in order to enhance its process and to stay ahead of the market. Its Customer Service has to provide the necessary know-how to assist the manufacturing in the licensee facilities and also guarantee an easy licensing procedure, since the preliminary negotiations to the final Agreement.

Key Resources

For the licensing the key resources are their Intellectual Property, namely the patents and the know-how and the human resources, capable of developing and improving the sealing process and the legal team capable of engaging the licensing procedure.

Key Partners

Solar Cell Company establishes financial relations to its customers (the manufacturers) but also of partnership as they can provide helpful insights to improve the sealing process. As such its R&D Team is a fundamental part of this activity, as well as the Legal Team, as they can diminish the barriers of a tricky License Agreement.

Cost Structure

Company has fixed costs only in keeping the salaries of the teams directly related to the licensing process: R&D and Legal Teams. The variable costs are related to R&D expenses related to the ever-ending process of improving and new findings and marketing expenses that may arise for expanding the market.

Revenue Streams

Company's revenues are based in royalties of 5% of licensees' Net Sales.

Figure 20 resumes the Business Model Canvas for the Licensing Approach

<table>
<tr>
<td rowspan="2">Key Partners
Manufacturers of Solar Cells Glass
R&D Team
Legal Team</td>
<td>Key Activities
Research & Development
Licensing transactions
Customer Service</td>
<td rowspan="2">Value Proposition
For manufacturers who wants a sealing process for their Solar Cells' Glass, which will last over 20 years.</td>
<td>Customer Relationships
GET- Website, Events like Intersolar,
KEEP- Customer Service
GROW-Word-of-mouth</td>
<td rowspan="2">Customer Segments
Manufacturers of Solar Cells Glass</td>
</tr>
<tr>
<td>Key Resources
Human Resources
Intellectual Property</td>
<td>Channels
Own Transactions
Online Communication</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Fixed costs: teams salaries
Variable costs: R&D, marketing</td>
<td colspan="2">Revenue Streams
License royalties</td>
</tr>
</table>

Figure 20 - Business Model Canvas for Licensing (developed by the author)

4. DISCUSSION AND CONCLUSION

Dye-Sensitized Solar Cells (DSSC's) are a well-developed technology that can be placed in solar panels in buildings with a 9% efficiency even at diffuse light, and with a lifetime of more than 20 years, thus to the patented sealing process of the solar cells.

Photovoltaics is a fast-growing market with the Compound Annual Growth Rate (CAGR) of PV installations of 40% between 2010 to 2016. Nevertheless, the Building Integrated Photovoltaic market still makes up a relatively small part of that with strong expectation to grow, mainly to the European 20/20 Guidelines demanding.

Comparing the two pathways to reach the market, the following table is presented:

Table 15 - Comparative table of exploitation pathways for DSSC´s (developed by the author)

	Spin-Off Company	Licensing
Value Proposition	For everyone in need of eco-friendly and sustainable electricity our Solar Cells are aesthetical, long-lasting, very efficient in capturing diffuse radiation and able to be integrated in buildings.	For manufacturers who wants a sealing process for their Solar Cells' Glass, which will last over 20 years.
Market Segment	Architects, Builders	Manufacturers of Solar Cells Glass
Revenue Streams	Solar Cells sales Revenues are based on market assessment and expected to grow from 5000 m^2 number of units (in m^2) to near 67500 m^2, expecting the revenues to reach 12 million euros in the first 4 years.	Royalties of 5% on Licensee Net sales
Costs	Fixed costs: employers salaries and rents of machinery and factory. Variable costs include: the price of raw materials, R&D expenses and marketing efforts.	Fixed costs: Legal and R&D teams salaries. Variable costs: R&D expenses and marketing efforts.

Main activities	Manufacturing, R&D, Sales and Post-sales	R&D, Licensing transactions and Customer Service
Risk assessment	Wider market range; Revenues depending on sales and sales representative's performance Highly dependable on dye costs and other materials and its assembly as well as R&D expenses	Selective and smaller customer segment Revenues depending on licensee company net sales Fewer costs as it needs less employers and less R&D investment

With a strong value proposition, FEUP Solar Cell offers an alternative, sustainable and eco-friendly energy solution to everyone in need of electricity in their buildings. It offers higher performance, more customization by providing a wide choice of different colours and patterns and reduction in costs. Intendss to reach architects and builders and to start sales (online, own stores and partnership stores) by the middle of 2022.

Value proposition for licensing intendss to reach all solar cells' glass manufacturers offering a process that allows the solar glass to overcome demanding weather conditions and last for a longer time in use.

When comparing the two pathways the spin-off market embraces a bigger target market, while licensing the process is for a specific and smaller segment – the glass manufacturers.

The revenues of the Spin-off depend on sales numbers and the price units, while licensing revenues depend on a 5% fixed royalty base on the manufacturers net sales. The Spin-off depends on dyes and raw materials fluctuation price of the market and have more expenses on salaries, facilities and salaries, as it needs more employees. The licensing approach has less costs and needs less investment.

Although licensing approach seems to have less risk, it seems more advantageous to combine the two strategies: while the spin-off sells the solar cells for integration in buildings to a wider market (the architects and builders), the exploitation pathway of licensing sells the sealing process to the manufacturers. These two technology commercialization strategies are complements rather than substitutes.

Future research should be carried out by validating the developed strategies using other types of technologies as well as validate the proposed strategies within the field where they will be applied, by interviewing builders and architects. It would also be meaningful to study how new technology in other fields is being handled and what kind of strategies are being used to validate them.

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APPENDIX

Appendix A - TECHNOLOGY DESCRIPTION WORKSHEET (MARKHAM, 2004)

	Scientific description of technology. Description of what technology does and does not.
Technology capabilities	Describes superior advantages of technology. Lists possible applications and users. Discusses possible advantages to users. Discusses patent efforts.
	Describes technology's current stage of development. Describes technology's progress toward demonstrating commercial potential.

Appendix B – PRODUCT FEATURES WORKSHEET (MARKHAM, 2007)

	Identifies the unique capabilities of the technology.
Product Features	Describes what customers need in terms of the unique capabilities.
	Specifies exact product features.

Appendix C – PRODUCT FEATURE AND MARKET MATRIX WORKSHEET (MARKHAM, 2007)

		Markets and Segments			
		Market A		Market B	
		Segment C	Segment D	Segment E	Segment F
Product Attributes	Attribute 1				
	Attribute 2				
	Attribute 3				
	Attribute 4				
	Attribute 5				
	Attribute 6				