Methodologies for Pricing Intellectual Property

Application to a Solar Patent

João Francisco Pinheiro Dias Eirinha

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Supervisor: Prof. João Manuel Marcelino Dias Zambujal de Oliveira

Examination Comittee

Chaiperson: Prof. Francisco Miguel Garcia Gonçalves de Lima
Members of the Committee: Prof. Maria Isabel Craveiro Pedro
Prof. Margarida Martelo Catalão Lopes de Oliveira Pires Pina

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Abstract

One of the most valuable assets for companies originated from academia in the fields of technology are patents. Start-ups typically base their activity in scientific work and novelty technologic advancements and frequently use industrial property rights to protect their inventions. In contrast to most tangible assets, the value of intangibles such as trademarks, or patents, is harder to estimate. This work's objective is to contribute to this field by showcasing the application of a combined approach of Monte Carlo simulation and Real Options analysis to estimate the value of a patent acquired from EFACEC by Dyesol, an Australian solar company. The applied methodology derives the patent value from a series of positive cash flows considered to be a result of additional sales due to the patent, subtracted by its acquisition costs. In addition, the option to the delay the incorporation of the patented technology in the Dyesol production process thus postponing the royalty payment is also computed and added to the project value. The resulting Net Present Value (NPV) is compared to the value attributed to the patent by the stock market as measured by the difference in Dyesol's market capitalization after the press release of the transaction.

Keywords: Patent Valuation, Real Options, Monte Carlo, Solar Cells, Dyesol, EFACEC

Resumo

Um dos maiores ativos das empresas com origem em ambiente académico nas áreas tecnológicas são patentes. Tipicamente as *start-ups* baseiam a sua atividade em trabalho ou evoluções científicas e frequentemente usam patentes como forma de proteger essas invenções. Ao contrário dos ativos tangíveis, o valor de certos ativos como marcas, ou patentes, é mais difícil de estimar. O objetivo deste trabalho é contribuir para evolução desta área de estudo demonstrando a aplicação de uma abordagem mista recorrendo a simulação de Monte Carlo e Opções Reais para calcular o valor de uma patente adquirida pela Dyesol, uma empresa solar Australiana, à EFACEC. A metodologia aplicada estima o valor da patente a partir de uma séride de *cash flows* gerados pelas vendas geradas a partir desta, subtraindo os custos de aquisição da mesma. Adicionalmente a opção de atrasar o incorporação da tecnologia patenteada no processo de produção da Dyesol atrasando desse modo o pagamento de uma royalty é também considerada e somada ao valor do projeto. O Valor Atual Líquido (VAL) resultante é comparado com o valor atribuído à patente pelo mercado de ações medido a partir da diferença na capitalização bolsista da empresa verificada depois do anúncio público da transação.

Palavras-chave: Avaliação de Patentes, Opções Reais, Monte Carlo, Células Fotovoltaicas, Dyesol, EFACEC

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List of Acronyms

ASX – Australian Securities Exchange

a-Si – Amorphous silicon

BIPV – Building-integrated photovoltaics

c-Si – Crystalline silicon

CIGS – Copper indium gallium selenide

DCF – Discounted Cash Flows

DSC – Dye Solar Cell

DTA – Decision Tree Analysis

EPO – European Patent Office

GWp – Gigawatt peak

GDP – Gross Domestic Product

INPI – Instituto Nacional da Propriedade Industrial

IPR – Intellectual Property Rights

IP – Intellectual Property

KBC – Knowledge-based Capital

MPPT – Maximum power point tracker

mc-Si – Multiple crystalline silicon

NPV – Net Present Value

OECD – Organization for Economic Co-operation and Development

OEM – Original Equipment Manufacturer

P/E – Price to Earnings Ratio

PSC – Perovskite Solar Cell

PV - Photovoltaic

sc-Si – Single crystalline silicon

TCE - Thermal coefficient of expansion

TTM - Trailing twelve months

USA – United States of America

WACC – Weighted Average Cost of Capital

1. Introduction

1.1. Context and Relevance

In a progressively more knowledge based economy the role of technologic innovation becomes decisive to social and economic development. New inventions have the power to use inputs – capital goods, labor, and natural resources – more productively, hence creating value to society. Nowadays, in a few developed countries, such as the USA (Figure 1), companies invest more in Knowledge-based Capital – patents, copyrights, software, databases, brands, etc. – than in physical capital such as machines, equipment and buildings - , and research finds a clear positive correlation between the investment in KBC and GDP per capita (Corrado et al. 2012).

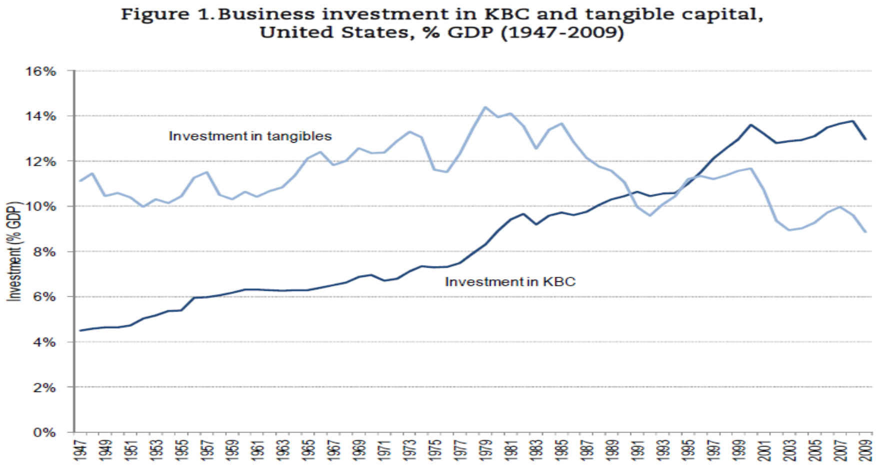

Figure 1 – Business Investment in KBC and tangible capital, United States, % GDP (1947-2009), (Corrado et al. 2012)

As an example of the importance of Intellectual Property Rights and how they can leverage economic value: the iPod, while it created almost twice the jobs outside the United States than inside (27 000 abroad and 14 000 in the US), retained 735 million dollars in workers' compensation onshore versus 318 million dollars that went to workers in other countries. This was due to the fact that the activities performed in the US – Design, R&D, software development – yielded much more added value than those done abroad – mainly outsourced manufacturing (OECD 2012). Many features of this, at time, novelty product: design, software, and technology pertaining to its characteristic scroll wheel where patented by Apple.

It is then obvious that patents can hold a significant economic value, representing an asset for its holder. This asset can be traded, licensed, used as bank guarantee, etc. Therefore determining a value for these assets in transactions as the ones mentioned, is of major importance, both in Academic context, where many inventions are created and then spun-off into start-ups, or in a Business context where many companies use IPR to protect themselves and gain an edge over their competition. The role that IP valuation plays in each company depends highly on the market it operates and its strategy: ranging from non-technologic companies who may only need to protect their brand name, from technology companies such as Qualcomm whose main activity is to produce new inventions in the wireless communications field and manage its patent portfolio collecting royalties from smartphone OEMs. For technology start-ups, IP valuation is also crucial, given that many rely on novelty product or technology.

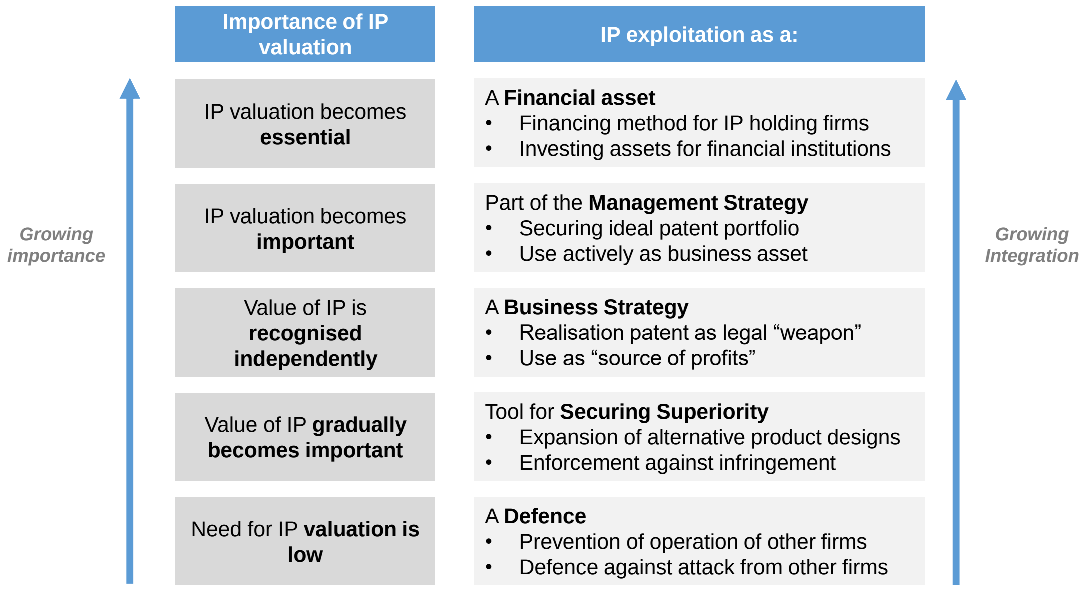

Figure 2 – IP exploitation and demand for valuation, (Kamiyama et al. 2006)

Intangibles valuation in general and specially patent valuation constitute a challenge due to several reasons, for instance: i) patents are by definition unique and novel hindering a comparison with other comparable assets, ii) patents are frequently used in products/processes in fast shifting markets hurting the predictability of the income derived from the patent, and iii) the patent validity may be contested in Court adding more uncertainty to its value.

Given its importance and related challenges a broad understanding of these instruments, including methods for their valuation, is paramount to an increasing number of companies if they wish to thrive in an economic context driven by technologic innovation.

1.2. Patent Value to Society

While providing an incentive for inventors to produce new technology, designs, etc. by allowing them to profit from their efforts, these rights constitute an important tool for promoting innovation. Although on the other hand, patents exclude part of society from benefiting immediately from it. This negative factor is often emphasised when new medical treatments are released at extremely high prices, as illustrated in the recent debate over the price of Gilead Sciences' drug Sovaldi used to treat hepatitis C (PÚBLICO 2015) . This protection versus exclusion trade-off is known as the "patent bargain" (Jensen et al. 2007). Research indicates that the positive effects of IPR far outweigh the negatives and establish a connection between IPR use, innovation, growth and economic development.

Patents have other value other than the one explored from this economic perspective. Because patents are public and contain an explanation over its features and use, they also often contribute to scientific development.

1.3. Objectives and Structure

This study's objective is to determine an economic value of a solar cell technology patent acquired from EFACEC and FEUP by Dyesol, an Australian company leader in solar cell technology. This deal was carried out in January of 2015 and its conclusion is conditional on the successful modification of the technology for use in perovskite based photovoltaics. In the 15 months following an initial payment of € 0.5 million researchers from Universidade do Porto will perform an adaption to the technology which will allow it to be applied to another type of solar cell. Upon the conclusion of the technical specifications another € 1.7 million payment phased out in 24 months, and an additional € 2.8 million will be paid as royalty when the patent starts being used commercially (Portugal Startups 2015; Dyesol 2015b).

The first part of the work will be dedicated to the understanding of the problem, including the research over the technology, namely about its use and applicability. A more detailed analysis regarding the terms of the deal and its possible outcomes will be required. Additionally, the second chapter will provide an overview about Dyesol and the solar technology it develops.

In a third phase the work shall summarize current techniques used to determine the economic value of a patent, interpreting each method limitations and advantages. Considering the preceding problem description one or more valuation methods will be chosen based on their adequacy to the problem.

Following the valuation method selection this study will outline a methodology for its application. Applying the methodology will produce a monetary value estimation of the patent. The work shall evaluate the quality of the result obtained through a robustness and sensitivity analysis, and a comparison with the market value. It also hopes to draw conclusions concerning the appropriateness of the performed analysis to other patents or asset classes.

1.4. Introduction to Patent Rights

Patents are part of a broader category of Intellectual Property Rights (IPR), which also includes copyrights and trademarks. IPR constitute a legal mechanism that allow IP producers to protect their creations from appropriation by others. The holders of such rights have the monopoly on the commercial exploitation of the invention, and other entities may only rightfully explore the IP with its owner consent upon a licensing agreement.

Intellectual Property (IP) as defined by the World Intellectual Property Organization, "refers to creations of the mind, such as inventions; literacy and artistic works; designs; and symbols, names and images used in commerce".

A Patent is an exclusive right granted by the State which allows the holder of such patent to produce and commercialize an invention. Inventions can be protected through two types of industrial property rights: Patents and Utility Models (INPI 2015).

In Portugal, INPI – *Instituto Nacional da Propriedade Industrial* is the public office responsible for all matters related with the protection of patents, trademarks, utility models and industrial design.

1.4.1. What can be protected?

These rights can be associated with the invention of new products or processes in any field of technology provided that the invention is:

a. Novel

The invention must be new, i.e., not be a part of the state of the art, which includes anything which either through scientific publication, public presentation, or simply usage in public was disclosed to the general public.

An exception to the criteria stated above is given in case of international exhibitions if the three following criteria are met:

- The presentation must have been made by the inventor(s) himself/themselves;
- It must have occurred within a 6 months period before the application;
- The occurrence of such public communication must be indicated in the patent application with a certification of the disclosure attached.

b. Inventive Step

The patent must result from an inventive step. For a patent this means that the invention must be non-obvious in the sense that it is at an “adequate distance beyond or above the state of the art” (Barton 2003) for a person specialized in the topic. Whereas a utility model only requires that the invention represents a practical or technical advantage for the production or use of a particular product or process.

c. Industrial Applicability

For the patent application to be accepted the invention must be considered susceptible to be “made or used in some kind of industry”.

d. Other General Criteria

In addition to these criteria the commercial exploitation of the patent must not involve creations such as:

- Processes for cloning human beings;
- Processes for modifying the initial genetic identity of a human being;
- Discoveries, scientific theories and mathematical methods;
- Materials which are already present in nature;
- Aesthetics creations;
- Presentations of information;
- Methods for surgical and therapeutic treatment, and diagnostic.

1.4.2. Patent vs Utility Model

The application process of the utility model is simpler and faster than the patent process but they cannot be awarded to "inventions in biological material or chemical and pharmaceutical substances and processes". The proponent may choose not to require examination and therefore will not pay the associated fee, which is significant. The examination can be postponed until the owner decides to initiate legal diligences.

The applicant can choose to change the protection from a patent to a utility model, or vice-versa, in a year period after the original filling.

1.4.3. Duration

Patens have a 20 years duration, counting from the filling date, whereas utility models only have 6 years which can be extended by two years twice, i.e., the total duration can go up to 10 years.

In the case of the patent or utility model being granted it is necessary for its holder to pay yearly renewal fees which increases in value along the years.

1.4.4. Filling Process

The application is done online, through mail, fax or in person at the INPI by filling an appropriate form and submitting the documents containing the abstract, a main figure, patent description, claims and drawings.

The owner may also apply for a provisional patent, which only requires a description of the invention. This process gives the inventor a priority for the invention but is only valid for 12 months. Within this period it must be converted into a definitive application.

You may request the INPI to conduct a research with the purpose of testing whether invention fulfils the novelty criteria. This search is subject to the payment of a search fee.

1.4.5. Structure of Contents

The patent document will include four sections:

a. Abstract

The abstract must inform the reader about the technical domain of the invention and consists of a summary of the information detailed in the description, claims and drawings and it must not exceed 150 words.

b. Main Figure

This figure should be the most representative of the invention and it will be used for publication in the Intellectual Property Bulletin.

(54) Title: GLASS SEALING OF DYE-SENSITIZED SOLAR CELLS

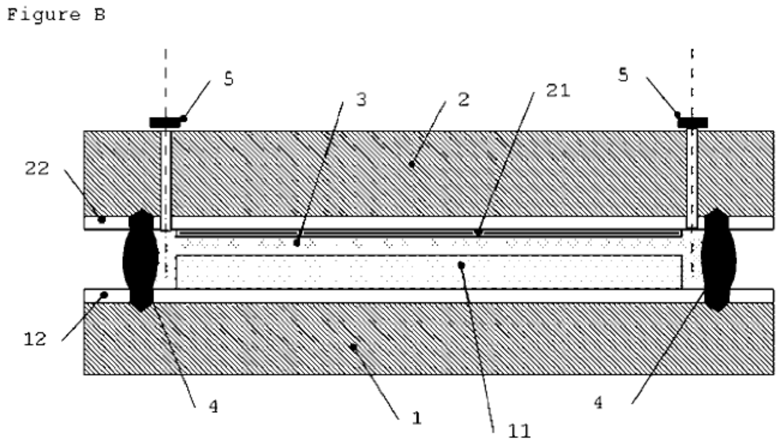

Figure 3 – Main figure of the patent to be valued, *(Magalhães et al. 2009)*

c. Description

This part must cover the following: description of the technical domain which the invention relates to, a detailed overview of the state of the art, a thorough explanation of the invention with reference to the drawings, a case for the industrial application of the invention and a list of references.

Description

Title of Invention: GLASS SEALING OF DYE-SENSITIZED SOLAR CELLS

TECNICHAL DOMAIN

[1] The present invent concerns a DSC (dye-sensitized solar cell) glass-based sealing process by means of a laser beam.

[2] It is described an innovative sealing process that uses a glass precursor of very low melting point (350 ºC to 700 ºC) or low melting point (650 ºC to 990 ºC) and high absorbance on the near infra-red light spectrum region. A laser beam is used to induce the glass fusion, consequently sealing the solar cell.

STATE OF ART

[3] DSCs were invented in 1980 by Skotheim [1]. Despite this fact, only in 1991 Brian O'Regan and Michael Grätzel[2] [3] developed a new fabrication process for DSCs, which allowed to achieve more than 7 % efficiency. Since then, DSCs are considered a low-cost promising alternative amongst a whole set of photovoltaic technologies[2] [3] [4] [5] [6] [7].

[4] DSCs are composed by two glass sheets coated by a transparent conducting oxide (TCO) that act as substrate of the two electrodes: the photoelectrode (PE) and the

Figure 4 – Description extract from the case patent, *(Magalhães et al. 2009)*

d. Claims

The section of the patent presents the several technical characteristics which will be subject to protection (they should be listed as shown in Figure 5). Any claim which depends on another must reference the original claim using an expression such as “according to the previous claims”.

[Claim 4] Sealing process of DSC glass solar cells according to the previous claims, wherein the glass precursor is made of a glass powder or a glass welding paste with a very low melting point between 350 °C and 700 °C.

[Claim 5] Sealing process of DSC glass solar cells according to the previous claims, wherein the glass precursor has a low melting point between 650 °C and 990 °C, and in that it is a paste based on an iron oxide silicate (Fe_2O_3) or a powder glass with the same features, wherein both materials must be opaque in the near infra-red region.

[Claim 6] Sealing process of DSC glass solar cells according to the previous

Figure 5 – Claims section extract from the case patent, (Magalhães et al. 2009)

1.4.6. Geographical Reach

The patent application process through the INPI, if conceded, will only be valid in national territory (or for imports and exports). The same is true for other countries. If the inventor wishes to protect its invention abroad it must follow a similar application process in other countries or apply for a European or International Patent. European patens are valid in the countries which signed the Munich Convention and International Patents are valid in the signatories of the Patent Cooperation Treaty, which includes the majority of the world's countries.

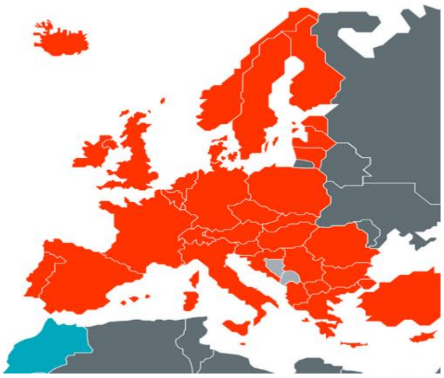

Figure 6 – Members of the European Patent Convention in red and Extension and Validation States[1] in blue and light grey, respectively

[1] Morocco is a validation state and Montenegro and Bosnia-Herzegovina are called extension states. This means that the patent granted by the EPO can be expanded to these countries after the validation, in the case of the validation states, and automatically, in the case of the extension states, contingent on the payment of an extension fee (European Patent Office 2015; Official Journal EPO 2004; Official Journal EPO 2015)

2. Case Description

2.1. Dyesol Presentation

Dyesol is a solar energy company headquartered in Queanbeyan, Australia dedicated to the development and manufacturing of chemicals, components and equipment for the production of Dye Solar Cells (DSC) and more recently Perovskite Solar Cells (PSC).

The DSC technology, which is tightly connected with the company's history, was invented in 1988 by Brian O'Regan and Michael Gratzel while working at the Institute of Physical Chemistry in Lausanne, Switzerland. The result of their work is summarized in the paper "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films" published in an issue of Nature, in which the authors claim to have invented a "photovoltaic cell, created from low-cost medium-purity materials through low-cost processes, which exhibits a commercial realistic energy-conversion efficiency" (Gratzel & O'Regan 1991).

In 1994, a few years after the invention of DSC technology a group of Swiss and Australian research teams engaged in the further development of the technology, establishing for that effect, the first DSC prototype manufacturing facility. Dyesol then acquired the laboratory equipment and intellectual property (Dyesol 2015a).

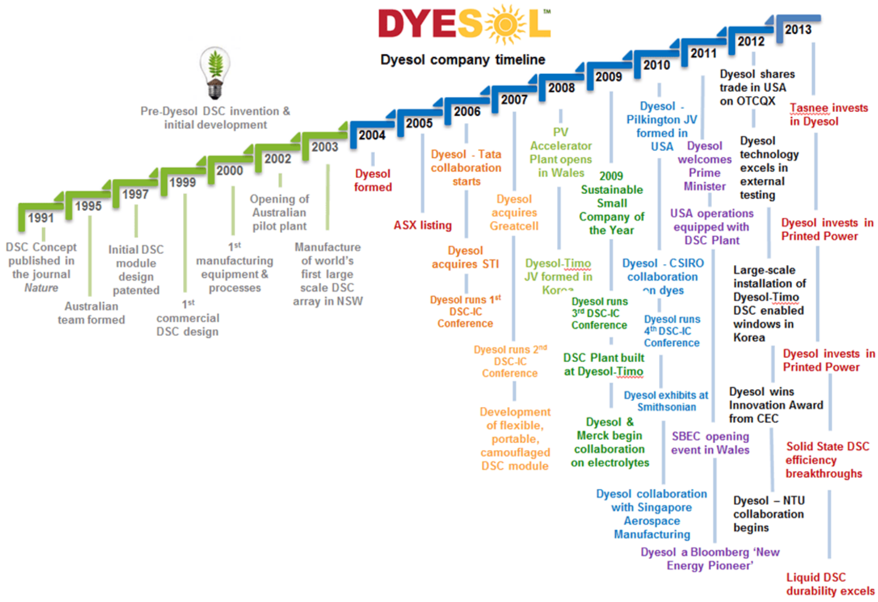

Figure 7 – Dyesol's history timeline

The company was created with the purpose of bringing the DSC technology to commercial use, but in 2015 has shifted its efforts towards the PSC development. Dyesol is listed in the Australian Stock Exchange and in the German Open Market. As of 22nd of May Dyesol shareholder structure was mainly constituted by Institutional Investors JP Morgan and National Industrialization Company[2], and a few individual shareholders including Richard Caldwell, Dyesol's Managing Director. Only about one third of the capital is free float.

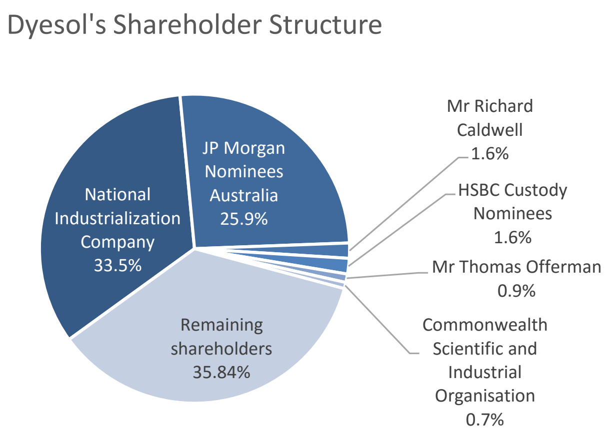

Figure 8 – Dyesol's Shareholder Structure as of 22nd of May

Even now, several years after its inception, Dyesol is mostly a research focused company - more than 70% of its personnel are researchers and engineers. The fact the DSC technology hasn't scaled is reflected in the firm's financial results (Table 1). Being a pre-revenue company its current objective is to produce a PSC solar cell prototype and start its commercialization in 2018.

Table 1 – Consolidated Financial Results of Dyesol (Dyesol Annual Reports 2014)

units: AU$'000	2012	2013	2014
Revenue	1 840	953	709
Loss before income tax benefit	(12 637)	(12 329)	(15 041)
Net income/loss	(8 911)	(8 941)	(12 298)

[2] National Industrialization Company is a Saudi Arabian industrial group which has been funding the company (Vorrath 2015)

2.2. DSC and PSC Technology

The underlying principles of both of these technologies mimic the photosynthesis process used by plants to produce oxygen and glucose (GCell 2015). The anode is a transparent conductive substrate so that sunlight can pass to the cell. Between the anode and the cathode (platinum) there's a porous layer of titanium dioxide nanoparticles, these allow electrons to travel through the cell from the anode to the cathode. These nano-particles are coated with a light absorbing dye which converts the photons from light to electrons. After passing through an external load the chemical electrolyte closes the circuit (Nanotechnology Center for Learning and Teaching 2015) transporting the electrons to the dye molecules.

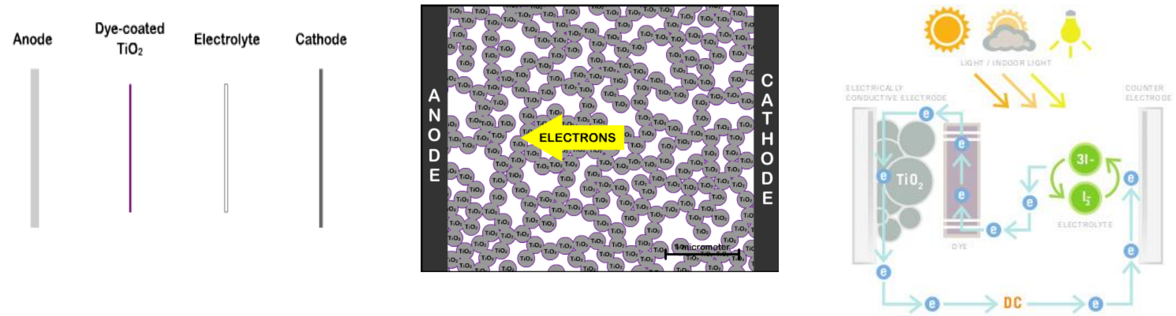

Figure 9 – Main components of a DSC (left), excited electrons from the dye traveling through the TiO2 "highways" from the cathode to the anode (middle), full circuit (right)

Dyesol produces several technologies which incorporate this principle. There are variants of these technology depending on the materials used to harvest the light (might be a dye or perovskite) or the element utilized as the hole transport material which fills the space between the metal titanium dioxide.

All of this apparatus and sealing gaskets are sandwiched into and encapsulated using several methods. The patent under analysis, as we will see later provides a solutions to seal all of these elements.

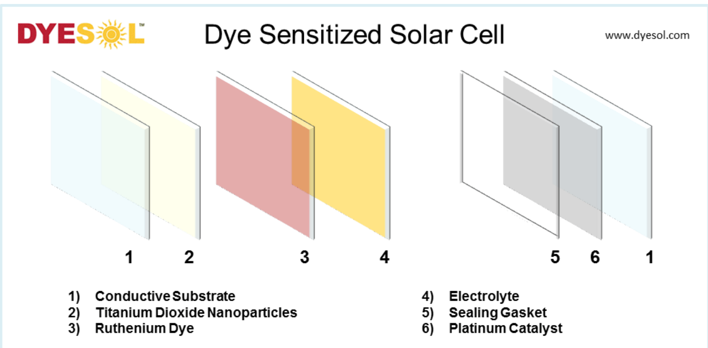

Figure 10 – Layers of a DSC

In a conventional solar cell, using silicon, this material would act as both the source of electrons converted from light's photons and the electric field. In a DSC these functions are divided into its several components.

2.3. Advantages and Disadvantages of DSC and PSC

a. Performance

Dyesol claims that these technologies work well even under difficult conditions (cloud days, hazy days, polluted skies, etc.), and perform better than competing technologies such as silicon. According to Professor Adélio Mendes, the head of the team which developed the patent, the PSC has already achieved a 20% efficiency.

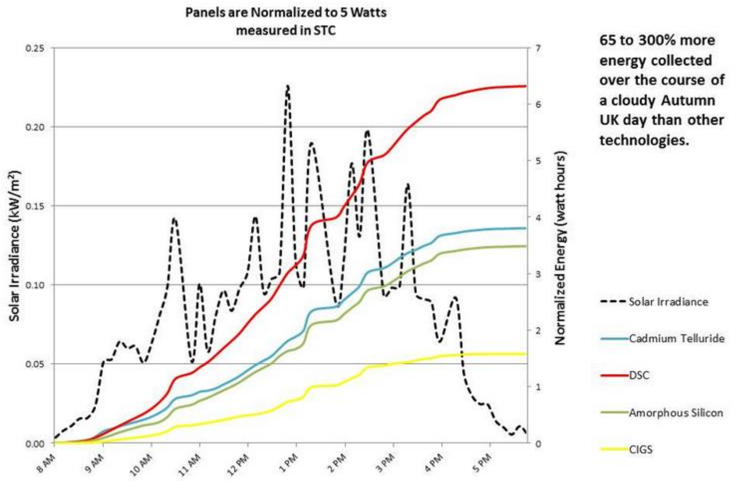

Figure 11 – DSC performance compared with competing technologies (Dyesol 2015a)

There are however problems with stability at low temperatures: the electrolyte may freeze stopping power production and potentially damaging the cell.

b. Low environmental impact and Low Embodied Energy

The nano-materials such as the titanium dioxide contained in these cells can be processed at lower temperatures which mean that they save energy and minimized environmental impact. Dyesol also claims that none of the materials used in DSC are toxic, in contrast with competing technologies which incorporate toxic materials such as cadmium and selenium. Despite of this fact DSC and PSC also contains volatile organic compounds in its electrolyte which are hazardous to the environment and human health (Ecole Polytechnique Fédérale de Lausanne 2008) and therefore must be well sealed, making the sealing process critical. This latter fact is one of the major drawbacks of this technology.

c. Low Cost Manufacturing

Conventional solar cells use silicon. The production of silicon requires significant amounts of energy and is hard to manufacture. Additionally, the high demand for silicon coming from its applications in the semiconductor electronics industry push up the price of this material despite its abundance in nature (Padilla 2015).

Additionally conventional technologies require materials with a high degree of purity and very stringent manufacturing environments which implies high costs. On the other hand, DSC and PSC production uses cheap processes such as printing, lamination, coating requiring only some control over humidity and atmospheric dust.

However, these technologies still haven't found replacement for the several expensive elements that it uses such as the platinum (catalyst), ruthenium (dye) and the conducting glass.

d. Flexible Applications and Scalability

DSC technology is very flexible in terms of the elements that can be used as substrates; it can be glass, metal or polymeric substrates. Another advantage is being bifacial, i.e., it can convert light coming from any of the sides of the panel. Dyesol also claims that the manufacturing process are easy to scale.

e. Aesthetics

The main advantaged when compared with traditional technologies is its aesthetics: as seen in Figure 12 DSC or PSC can be applied as a normal construction material. A window from DSC can produce electricity and protect from the intense sunlight while provide good noise insulation.

Figure 12 – DSC applied as a house window (Dyesol 2015a)

f. Plentiful supply of raw materials

Most of the DSC chemicals: carbon, oxygen, nitrogen, titanium, silicon and iron (for glass and metal substrates) are common in nature. Nevertheless platinum and ruthenium, although used in small quantities, are not as plentiful. For 1.5 GW of installed power of DSC about 2 tonnes of ruthenium would be used. This corresponds to about 6%-7% of its annual production.

The advantage of DSC is it uses very thin layers of photoactive material – when added up the dye layer has a thickness 50 to100 times thinner than a human hair.

2.4. The Patent: Glass Sealing of Dye-Sensitized Solar Cells

The patent under analysis describes a glass sealing process using a laser beam. This new invention created by a team led by Professor Adélio Mendes Magalhães in collaboration with EFACEC provides a sealing solution that assures that the internal components of the cell do not come into contact with the atmosphere which would cause it to loose efficiency and result in harmful effects to the environment and human health. This technology although originally designed for DSC cells can and will be adapted to PSC (Larangeiro 2015).

2.4.1. State of the art

Currently the DSC's several layers seen in Figure 10 are sealed making use of polymeric resins under certain conditions of heat and pressure – about 100 ºC and 0.2 bar – for about 40 minutes (Magalhães et al. 2009). This temperature and time limits the future performance of the cell.

An alternative to this method may be metallic solders, but this technique does not provide stable temperatures, and is clear that this method is not adequate.

For DSC where only the photo electrode (the first layer that light goes through) is made of transparent glass a resin can be applied and fused with a laser beam, but this limits the cell's active area.

A recent technology makes use of fritted glass (a porous glass produced from sintering glass particles). Despite its stable properties the fusion of this material demands a high temperatures. According to (Magalhães et al. 2009) this means that the dye coloration step has to be performed after the sealing process. Another disadvantage is the fact that these materials often contain lead which contaminate the catalyst.

2.4.2. Invention

An adequate method for DSC sealing should, as the patent authors point out: stable at working conditions (solar radiance and outdoor environment), inert to the chemical components of the cell, impermeable to air, moisture, and other atmospheric components, an electric insulator and low cost (for it to be economically viable).

This novel method involves creating a small furrow across the perimeter of the photo electrode where a glass string is deposited and then fused using a laser beam. The glass paste can have a very low or low fusion point and the laser beam should emit a radiation to which the glass string is opaque so it can heat it after crossing the photo electrode.

2.4.3. Claims

The patent claims the invention of a sealing process for DSC glass solar cells in which a glass precursor cord is applied to the external perimeter of the photo electrode, both electrodes are pre-heated to the maximum allowable temperature, and following these steps these sheets are welded together by using a laser beam.

2.5. The History of Solar Cells

The photovoltaic effect was first discovered in 1839 by French scientist Edmond Becquerel who, while experimenting with an electrolytic cell, noticed that the electricity generation surged when the system was exposed to light. Years later, in 1873, Willoughby Smith discovered the photoconductivity of selenium, a semiconductor material. W.G. Adams and R.E. Day, followed, in 1876, when experimenting with the same material, concluded in the study named *The Action of Light on* Selenium that *"the action of sunlight on selenium produces a very singular effect when a current from a battery is passing through it; in all cases it seems to assist the battery-current in whatever direction it is passing, so that the resistance of the selenium appears to be diminished,; and yet, when there is no battery-current, sunlight causes a current from platinum to selenium at the junction on which it falls"* (Adams & Day 1876). Succeeding the discovery to these properties in Selenium, Charles Fritts, developed the first solar cell in 1883 (Fritts 1883), at the time the device had an efficiency of only 1%.

The theoretical explanation to these phenomenon only came at the beginning of the XX century when Albert Eisenstein described the photoelectric effect suggesting that, despite agreeing with the wave theory of light, *"the energy of a light ray (…) consists of a finite number of energy quanta"* (Einstein 1905) - photons.

The first solar module was built by Bell Laboratories in 1955, at the time designed to be used to power telecommunications systems. In the previous year three Bell Labs researchers had developed the first solar cell capable of converting a noteworthy amount of power using silicon. This first cell generated about 10 W in a bright day.

The PV technology was licensed to a company named National Fabricated Products for the purpose of commercializing it, but such efforts proved to be unsuccessful. This company ended up being acquired in 1956 by Hoffman Electronics which applied to technology for use in satellites. Two years later Vanguard I was launched becoming the first satellite powered by solar cells. In the years that followed solar cells were applied only exclusively in space applications.

Sharp in Japan, and RTC (subsidiary of Phillips) in France build small production lines in the 1960's manufacturing the first practical silicon photovoltaic modules. But the big leap to the technology only came in the 1970s when the US government started large procurement programmes motived by the 1970's fuel crisis. The 1980's marks the development of others technologies such as thin film – using copper sulphide and cadmium – and dye-sensitized solar cells, the focus of Dyesol research efforts.

2.6. Solar Systems

Most PV systems have a similar form to what is shown in Figure 13. It consists of: a PV module - an array of solar cells -, which converts the light into DC electric current; a blocking diode, which guarantees the one-way flow of power towards the power conditioner; a power conditioner, which makes sure that the current is delivered at the right voltage and maximizes the power output by changing the current and voltage at which the array operates in optimizing those two parameters to atmospheric conditions; and an inverter to convert the DC current to AC to be carried out either to feed the utility grid or used to power local appliances. In residential application the power conditioner device is usually not necessary (Singh 2013). There is an alternative to the use of the inverter using factory integrated micro inverters a technology which was being developed by SolarBridge Technologies acquired by Sun Power in 2014 (SunPower 2014). The systems can be used in a stand-alone model. No connection to the grid would be necessary in that case.

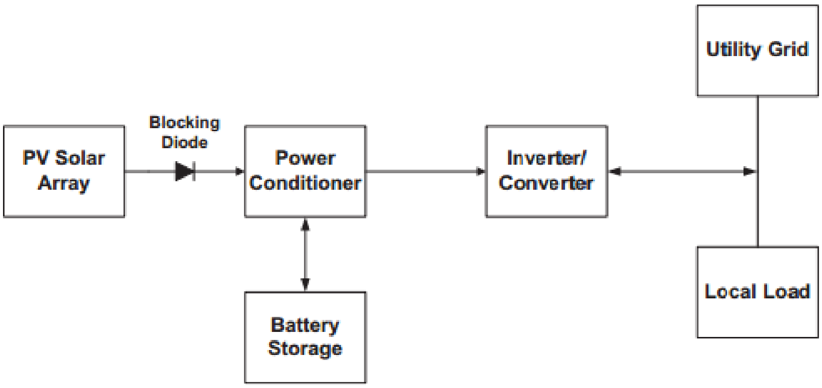

Figure 13 – Block diagram of a typical photovoltaic system (Singh 2013)

2.7. *Competing Technologies*

Despite the numerous advances in photovoltaics technology the most popular PV technology, which accounted for 92% of total production in 2014 (about 44 GWp) is still very much based on the same principles and materials used by Bell Laboratories to develop the first solar cell.

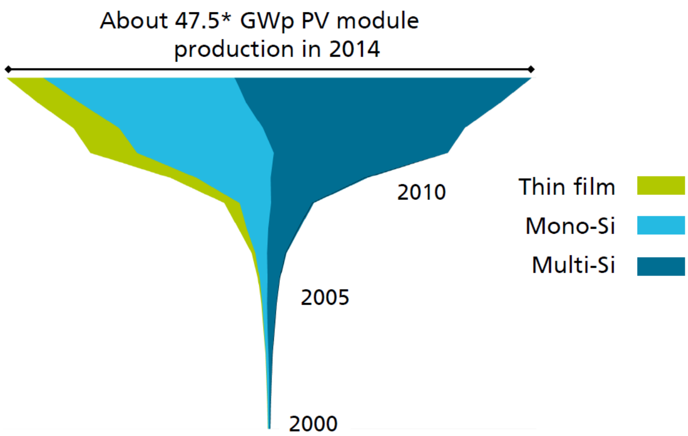

Figure 14 – World Annual PV Production by Technology Worldwide (in GWp)* (Fraunhofer Institute for Solar Energy 2015), *data from Navigant, HIS

All the PV cells contain a photoelectric material which is capable of absorbing the photons from the light and generate free electrons. As mentioned the most commonly used material for this purpose is silicon, but other materials namely cadmium telluride (CdTe), cadmium sulphide (CdS), organic and chemical dyes or perovskite are also used. The structure of the cell and the photoelectric material can also vary. Most PV installation use either thin film or crystalline silicon technology.

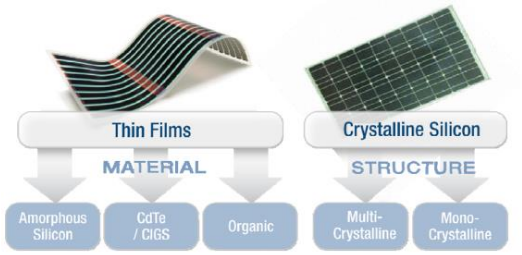

Figure 15 - An Overview of Solar Cell Technology Mike (McGehee 2011)

2.7.1. Crystalline Silicon

Two types of crystalline silicon are used: single or mono crystalline (sc-Si) or multi crystalline silicon (mc-Si). The latter because of its disordered atomic structure produces lower efficiencies but are less degradable (Chu 2011).

Main advantages:

- High efficiency
- High power density
- Silicon has proven to be in the long-term electrically stable and generates a low environmental impact
- Silicon is an abundant resource

Main disadvantages

- Price

2.7.2. Thin-film

The largest thin film producer, First Solar, uses Cadmium telluride (CdTe) which is the dominant thin film technology but other materials such as gallium arsenide (GaAs), indium diselenide ($CdInSe_2$) and titanium dioxide (TiO_2) are also used.

Main advantages:

- Requires less semiconductor material compared to wafer silicon (in the case of silicon the optimum thickness was found to be only 20 µm to 35 µm (Barnett 2001)
- Can be deposited in flexible substrates resulting in a lightweight and bendable module
- High automation and production efficiency

Main disadvantages:

- Existing thin film technology is less efficient than crystalline silicon, thus requiring more space to generate the same power output
- The substrate used to deposit the semiconductor must be low-cost to make it economically viable but it also must have a high mechanical strength and a thermal coefficient of expansion

(TCE) similar to the material used or it can break or deform during handling or when it is being produced (Barnett, et al).

- Despite being the most viable thin film solutions in terms of cost-per-watt Cadmium telluride (CdTe) have a high toxicity and are less abundant than silicon

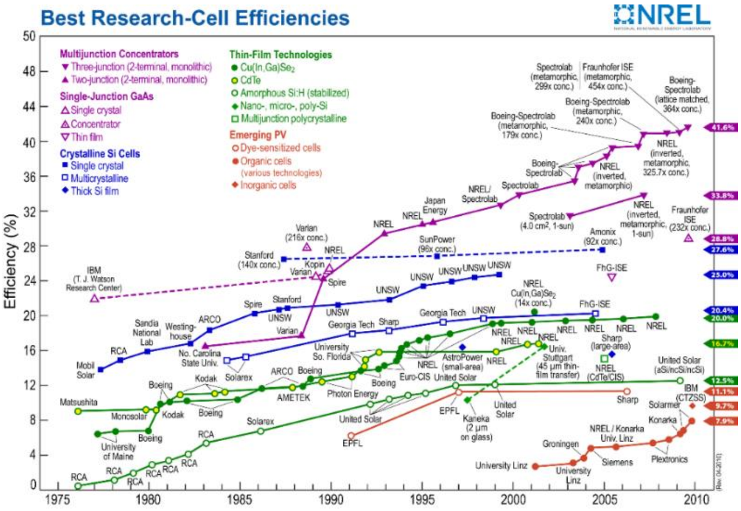

Figure 16 – Solar Cells Efficiencies by technology

The performance of each technology may vary depending on factors such as the temperature, humidity or light spectre, and application – utility scale installation or home rooftop systems. For example CdTE modules are better suited for large scale industrial or commercial application where as traditional crystalline silicon modules are more adequate to home or space constrained applications (Solar 2014).

2.8. Market Brief

The photovoltaics market, in which Dyesol operates in, is a global and fast growing market, and as aforementioned, characterized by a high degree of innovation. Although the solar technology has grown in popularity the same cannot be said for the major industry players, a recent study published by McKinsey (Frankel et al. 2014) highlights this discrepancy mentioning that while the global solar installations have grown at 50 percent a year since 2006, the MAC Global Solar Energy Index, an Exchange Traded Fund (ETF) which tracks the stock performance of Solar companies, has felt by 50 percent from 2011 to 2013. A major driver for both the growth and decreased profitability has been the dropping prices of modules which felt nearly 30 percent a year from 2008 to 2013 (Frankel et al. 2014). Even market player recognize that this industry is characterized by *"intense pricing competition, both at the module and system levels. We believe the solar industry will continue to experience periods of structural imbalance between supply and demand (i.e., where production capacity exceeds global demand), and that such periods will put pressure on pricing"* (Solar 2014).

According to the article solar will continue to grow driven by: its low operating costs, low environmental impact, and the fact that it has no fuel costs and no commodity price risk (the cost of hedging in traditional sources of electricity can meaningfully increase its cost). McKinsey claims that the module cost will keep dropping increasing solar competiveness which may lead it to reach grid parity in several major markets.

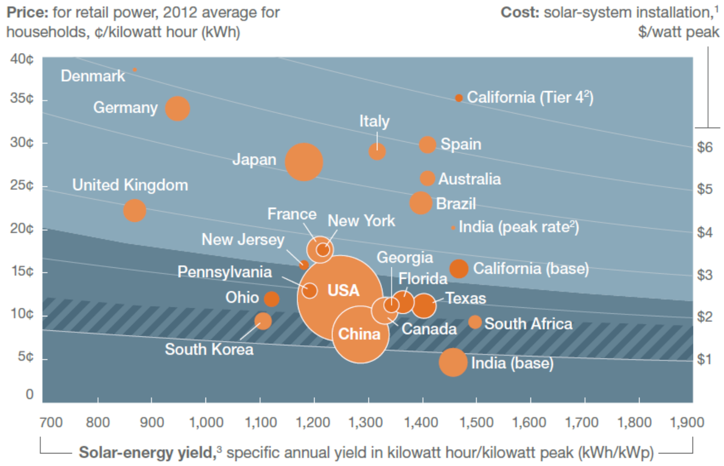

Figure 17 – Distance to grid parity in several markets

2.8.1. Competitive Landscape

2.8.1.1. Large Players

This section provides a short presentation of the dominant players in the solar market.

First Solar

Headquartered in Tempe, Arizona, First Solar develops and manufactures PV solar modules using thin-film semiconductor technology and crystalline silicon modules, it also designs and constructs solar power solutions which incorporate its products, and ancillary equipment such as tracking technology. Additionally First Solar provides maintenance services for solar plant owners. The company is the largest thin-film PV solar module producer and one of the largest worldwide for solar modules in general.

First Solar sees in a key strength in its vertically integrated business model. The company trades in the NASDAQ and was added to the S&P 500 in 2009 being the only solar pure play in that index.

Solar World

Solar World is a German based company with production facilities in Germany and in the United States. The company manufactures multi-crystalline and mono-crystalline modules and associated equipment (inverters, frames, storage systems, etc.). Despite operating the complete production value chain Solar World also sells multi-crystalline and mono-crystalline wafers and cells to other solar companies (annual report 2014). Moreover the company also designs, builds and operates large scale solar plants for investors. Following the drop in prices in 2011 the company went through financial restructuring. Solar

World has on the roof-mounted systems its largest market share as a result of its brand focused strategy. Solar World was the first company to provide a linear guarantee for a period of 25 years. Europe and the Americas are its most relevant markets making up circa 84% of sales in 2014.

Q Cells

Hanwha Q Cells results from the merger of two PV manufacturers: Hanwha SolarOne, a subsidiary of Hanwha, a South Korean industrial conglomerate, and the German based company Q Cells (Green Tech Media 2012).The company is now the largest cell manufacturer in the world with industrial facilities located in China, Malaysia and South Korea. After the restructuring Q-cells divested its stake in companies from its portfolio developing other technologies namely Calyxo GmbH (Calyxo 2012), producer of CdTe panels and Solibro a Swedish company manufacturer of CIGS modules (Financial Times 2012; Olga Papathanasiou 2009).

Sunpower

Sun Power is a California based company majority-owned by Total, the French energy company, who owns 66% of the company. Its stock trades at the NASDAQ stock exchange. The company is known for its high conversion efficiency in its crystalline silicon modules. Sun Power produces solar panels and ancillary equipment (inverters, mounting structures, grid connection equipment, etc.) through authorized dealers and distributors and directly to homeowners, investors and utility companies. Sun Power is fully focused on the development of crystalline silicon technology under a research and collaboration agreement with its main shareholder, Total.

Canadian Solar

Canadian Solar is the third largest solar company in the world by revenue. This Canadian based comply has a vertically integrated value chain with design, development and manufacture of solar wafers, solar cells and modules capabilities and as well and development of utility scale solar installations. The company is more focused on this latter segment, i.e., is oriented more towards the development of complete solutions (EPC and O&M services), solar plants, than solar modules. The company operates three manufacturing facilities: one located in Canada and the other two are located in China. The Americas and Asia-Pacific are also its main markets, representing 60.7% and 31.2% of sales in 2014 (annual report). Because the company's core business consist of large-scale projects this value tends to fluctuate. As an example sales in European markets made up more than half of the company's sales in 2012, the reduction which followed is explained by the elimination of the feed-in tariffs in German and Italy the two largest European markets. After an IPO in 2006 Canadian Solar became a publicly traded company in the NASDAQ.

Sharp

In addition to being a leading LCD and electronic devices manufacturer (projectors, Blu-ray Disc recorders, phones, etc.) Sharp also produces crystalline solar cells, thin-film solar cells and storage batteries through its *Energy Solutions* segment which represented 9.2% of sales in 2014. This Japanese multinational owns several patens on DSC.

SunEdison

Sun Edison originated from a Monsanto former business unit which produced silicon wafers. Today the company has two wholly owned subsidiaries: SunEdison Inc. and TerraForm. The latter is a solar and wind project development company, i.e., designs, builds and operates large-scale wind farms and solar plants which it owns. On the other hand SunEdison Inc. manufactures silicon ingots and wafers in two production facilities: one in Texas and the other in South Korea. Unlike most of its competitors the company outsources the solar and module cells production. This division also develops, finances, and operates large scale projects in wind and solar for external customers (utilities, shopping centres, etc.). Through a distribution and dealer authorized network the company also serves the residential segment. These two subsidiaries and the holding company are publicly traded companies.

Trina Solar

Trina Solar is a Chinese solar company divided into two operating segments: upstream and downstream. Upstream value chain integrates the ingots, wafers, and PV cells and modules production. Its downstream business develops and operates turnkey solar installations to utilities, residential and commercial customers. Its manufacturing facilities are located in China, Malaysia and Thailand but the company runs regional sales offices all over the world. In 2014 sales were evenly spread across the globe with US, Japan, China and Europe representing 28%, 20%, 33%, and 10% (down from 31% in 2013 reflecting the slump in the European market) respectively. The company's shares are traded in the New York Stock Exchange.

2.8.1.2. Smaller players using PSC technology

Oxford Photovoltaics

Oxford PV is an English company originated from the academic work of Oxford Professor Henry Snaith whom together with his team developed a patent portfolio for perovskite technology (Oxford PV 2015). The company was created in 2010 with the objective of developing and commercializing perovskite solar cells and now employs almost 30 scientists. The company claims that its technology will cause a significant change in BIPV systems. In March of 2015 the company announced a successful funding round in which it raised 8 million sterling pounds to accelerate the construction of a marketable perovskite cell. Its investors include universities – Oxford and MIT - and venture capital funds such as Longwall Venture Partners and Parkwalk Advisors (CleanTechnica 2015).

Saule Technologies

Saule Technologies is a Polish company founded in 2014 by researcher Olga Malinkiewicz engaged in the development of perovskite solar cells for BIPV use (Saule Technlogies 2015). The company does not have a commercial product ready yet and is at the moment searching for investor to fund further research. The company obtained funding from state subsidies and Hideo Sawada, a Japanese entrepreneur (Compound Semiconductor 2015).

Weihua Solar

Weihua Solar is a Chinese company dedicated to the advance in perovskite solar technology. Its objective is to develop a commercial solar cell using this technology (Crunchbase 2015; Solar 2015).

Takeaways

- Crystalline silicon is the dominant technology;
- Thin-film and crystalline silicon are the focus of the current R&D efforts of all the main players which opens a space for the new BIPV companies;
- Most solar companies are EPC's and integrate generally commercialize and produce the solar modules;
- PSC competitors seem to be at the same stage of development as Dyesol;
- Research and Development is critical for every one of these companies.

2.9. Testing Standards and Certification

The International Electrotechnical Commission (IEC) establishes several comprehensive testing standards to benchmark both crystalline silicon and non-crystalline silicon devices. The standards created by this organization, widely used in the photovoltaic industry, concern components, processes and test sequences to accurately measure solar panels performance.

Generally the power features announced by solar panel manufacturers use a set norms called STC – Standard Test Conditions. To obtain this rating manufacturers use a flash tester to subject the solar panel to artificial sunlight with an intensity of 1000 watts per square meter at 25ºC and an atmospheric density of 1.5 (Taylor 2010; Standard 2010).

3. Literature Review

The diversity of valuation techniques referenced in the literature reinforces the idea that there is not a "one size fits all" method for determining the value of a patent (Pitkethly 1997).

3.1. An overview

It is possible to organize the wide array of available methods into categories, Langrost et al. (2010) summarizes the methods for IPR valuation dividing these methods into two categories: quantitative approach methods, and qualitative approach methods. While the first approach relies on numerical data to output an economic value of the IPR, the qualitative approach perspective is based on the characteristics and the uses of the intellectual property.

In Flignor & Orozco (2006) and other similar literature quantitate approaches are grouped into four methods:

- Cost-based method;
- Market-based method;
- Income-based method;
- Option-based method.

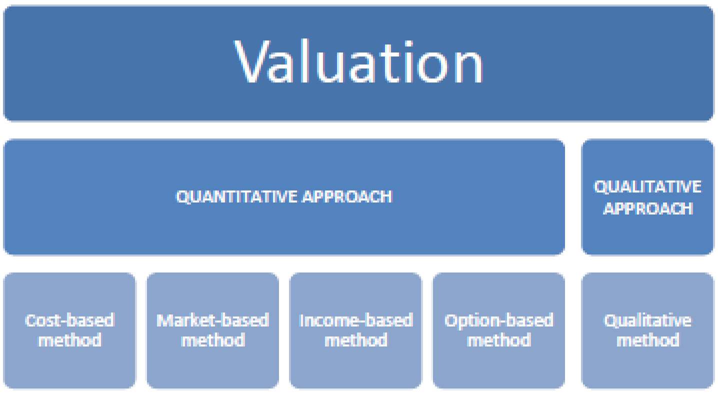

Figure 18 – Categorization of patent IP valuation methods (European IPR Helpdesk 2013)

Alternatively (Arthur Andersen & Co. 1992) categorizes valuation techniques into Cost, Market Value and Economic Value Methods.

A more interesting approach is set forth by Pitkethly (1997) where this author groups several methods by the features each include, i.e., their level of sophistication. Numerous authors including Pitkethly (1997) recognize that, independently of the degree of sophistication it is not possible to account for every factor.

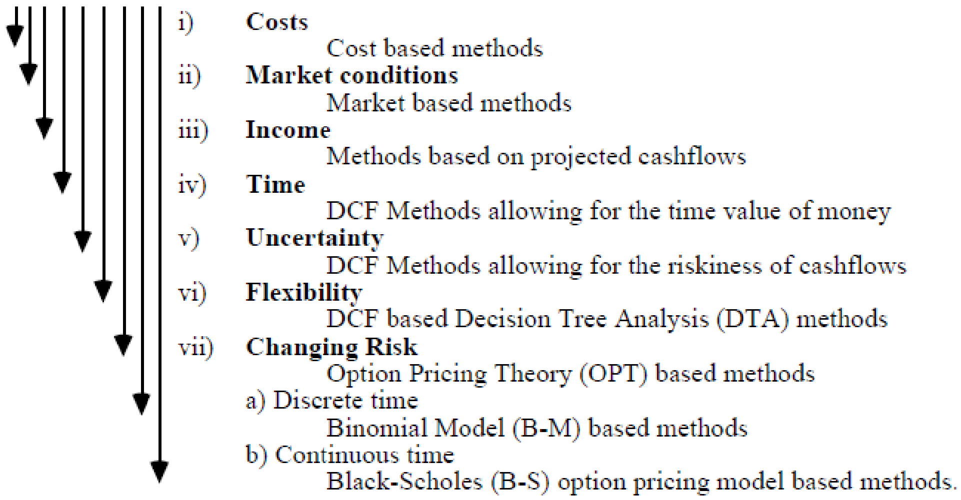

Figure 19 – Valuation Methods sorted by degree of sophistication (Pitkethly 1997)

Acknowledging the importance of this problematic to European companies' competitiveness, several Communitarian organisms have published related with this matter. The European IPR Helpdesk, is an organism managed by the European Commission's Executive Agency for Competitiveness (EACI), produced a Fact Sheet for Intellectual Property Valuation.

3.2. Cost-base Methods

The underlying principle of this method, following a very accounting like perspective, is to associate the economic value of the intellectual property to the resources/costs incorporated in such asset. The cost calculation is performed using either one of the two methods: i) reproduction cost method or ii) the replacement cost method. The latter estimates the costs that one would need to incur to obtain an equivalent IP asset; the reproduction cost method simply performs the summation of all costs of purchase or development of a replica of the IP.

In Drews (2001) the author outlines the limitations of this approach while providing guidelines for its usage. Both of this methods should consider the expenditures costs at today's prices, i.e., inflation adjusted. Two kinds of costs should be accounted for: direct expenditures: materials, labor, etc. and opportunity costs, reflecting the price of being unable to pursue other investment opportunities.

Because it disregards any future benefits from the patent this method holds little value as a decision making tool. However this accrual perspective may be useful to measure the tax impact of transactions involving patents.

3.3. Market-based methods

The market-based valuation method is based on the comparison with other market transaction for similar assets. It can be suitable in the cases where the same IPR right has been involved in a recent commercial transaction (Arthur Andersen & Co. 1992).

In most cases however it is difficult to compare the IPR with other transacted assets given, by definition, its uniqueness. An additional issue raised by (Parr & Smith 1994) is that use of the transaction's underlying IPR may not be optimal limiting the use of its full potential. Licensing agreements for example may constrain the type of application, or the geographical scope of the IPR leading to a suboptimal use of such rights.

Other technique included in this category values a “Patented Product” by deducting the value of a company’s several assets to its market value. This implicit valuation is likely to be flawed since it might be accounting for the value of other intangibles. Also this method is only suitable for single-product companies listed in public markets excluding most cases of patent valuation including the one in our problem.

3.4. Income-based method

Income-based methods follow the finance assumption that the intrinsic economic value of a particular asset is equal to the expected cash-flows it will generate in the future. This method is one of the most widely used for investment decision purposes. To apply this technique one must project the cash flows generated by the IPR and discount them at an adequate discount factor thus determining the present value of such asset. The central concern to this method is the process used to produce the cash flow forecasts.

3.4.2. Discounted Cash Flow (DCF)

According to the definition above the net present value of an IP any other asset should be given by the following formula:

Equation 1 – NPV calculation formula

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t}$$

This discount rate reflects the time value of money and the riskiness of the cash flows. Alternatively the cash flows can be adjusted according to their likelihood in which case the cash flows are replaced for an estimated value, in such case the adequate discount factor only incorporates the time value of money Pitkethly (1997).

When it is forecasted that the project will yield perpetual cash inflows a terminal value accounting for those cash flows until infinity must be calculated. Since patents have a limited lifetimes there is usually no need to calculate this value.

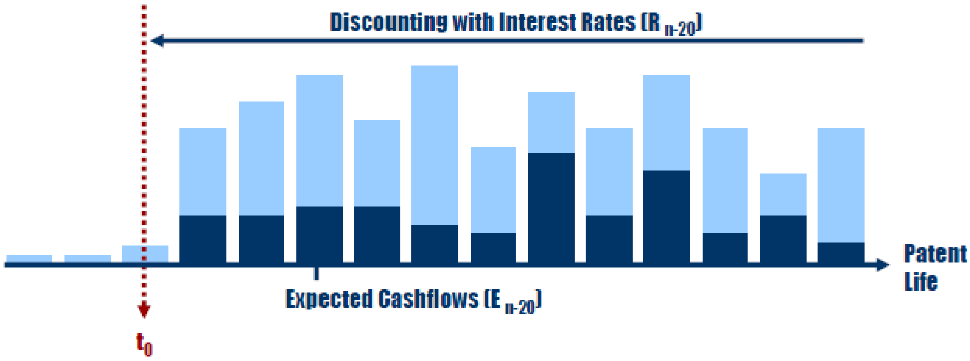

Figure 20 – Diagram of the cash-flows generated by a patent

Following this approach an investment decision, such as the acquisition of a patent, will only be viable if the NPV is greater than zero, i.e., when discounted to present time, the cash inflows outweigh the outflows.

The discount rate that is often used is the Weighted Average Cost of Capital which derives the riskiness of the cash flow from the rate investors – equity and debt holders – demand to fund the company.

Equation 2 – Weighted Average Cost of Capital

$$WACC = \frac{E}{V} r_e + \frac{D}{V} r_d (1 - t)$$

E – Equity Market Value; D – Debt Market Value; V – Enterprise Value, i.e., E + D; r_e – Cost of equity; r_d – Cost of debt; t – tax rate

The cost of equity should be calculated using the Capital Asset Pricing Model. The current cost of debt for Dyesol is difficult to evaluate because the company does not own debt traded in public debt markets. The literature usually provides three solutions for this issue (Damodaran 1999):

- Evaluate the cost of debt from the outstanding debt of other comparable companies
- Perform an estimation of the interest rate based on financial ratios, namely Equity to Debt
- Estimate the cost of debt as being equal to the interest expenses divided by its outstanding debt

Thus not accurately reflecting the cost incurred by the company to raise debt. The second solutions disregards the business profile of the company. Given the low amount of debt relative the company market capitalization the impact of any distortion in the calculation should be meaningless

Equation** 3 **– Cost of equity

$$r_e = r_f + \beta (r_m - r_f)$$

Main Limitations

The DCF model is static, i.e., is based on the assumption that the decision maker has no power to act during all the investment phase. As illustrated by our patent case - although the decision maker in our case might be somehow constrained - that is often not the case. The option-based methods address this limitation.

3.5. *Option-based method*

In order to perform an accurate valuation of a patent one must incorporate in the calculation the value of the options associated with the patent investment. Options such as the possibility of making part of the payment contingent on the additional technology developments featured in this thesis can significantly influence the estimate for the patent price.

For a producer of soybeans or coffee it might be useful to hedge against the price of these commodities, an electric company in its decision making process must decide between a power station capable of using fuel oil or natural gas, a deal structure can feature postponement of payment. All these investments involve options. Generally the literature distinguishes options between financial and real options.

3.5.1. Financial options – Calls and Puts

In the capital markets two standard options are traded: call options and put options. A call option allow its holder the right, and not the obligation, to buy an underlying asset - which might be shares, commodity futures or others – until a pre-determinate date and price designated maturity date and exercise price, respectively. On other hand, a put option gives its owner the right to sell the underlying asset at specified price until its maturity. If the option allows for it to be exercised before the maturity it is known as American call/put, whereas when it can only be exercised at maturity is called a European call/put (Brealey et al. 2013).

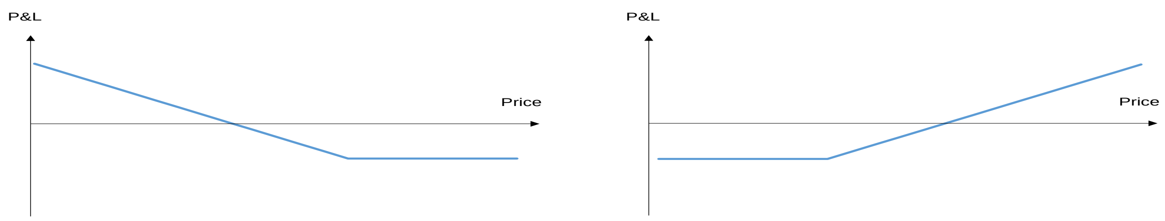

Figure 21 - Variation of the put option (left) and call option (right) payoff with the underlying asset price

3.5.2. Real Options

Although financial options have many applications, for the purpose of the patent valuation, following the limitations of the DCF analysis mentioned above, there is a need to model real options. In real applications there's an infinity of options associated with investments but there is a handful of types of common options (Copeland & Keenan 1998; Kamara 2002) that are used, namely:

a. Option to abandon or terminate

At some point in the investment period there might be an option to abandon the project, following, for examples, changes in the market, the invention of competing technologies, or financing conditions. The exercise of this options makes sense when the NPV of the rest of the investment is negative. This option is especially useful for our case given that the agreement provides Dyesol with the option to cancel the last payments depending on the status of the research.

b. Option to delay

Decision makers may also consider, in the circumstances mentioned for the option to abandon, the option to delay further investments until, for instance, there is lower uncertainty about the project income, without losing the opportunity to continue the project in a later stage. This might be the case of a pharma company that halts a particular drug research to see if a competitors' drug passes clinical trials.

c. Option to expand

In R&D projects it is often the case that a company engages in a project that will not be profitable until a certain stage because it might give it the option to conduct other profitable investments. In this situation the option is value is often called "strategic". In infrastructure investments for example a company may choose to buy land next to its factory minimizing the cost of a potential capacity upgrade.

d. Option to switch or redeploy

Some investment may account for the possibility of switching the asset use at a particular moment in time or in any moment. Manufacturing plants may prepare their assembly lines to produce several types of products for example.

3.6. Qualitative Approach

Rather than using measurable inputs the qualitative approach evaluates a set of different indicators such as the geographic coverage of the IPR, its legal strength, the level of disruption that the new IP brings to a specific sector. The method however has very limited applications and fails to meet our works' objective.

	Method	when/why	advantages	disadvantages
QUANTITATIVE	**cost-based**	✓ Valuation of an asset in the early stages of development ✓ Cases where there is no market revenue data ✓ Accounting and tax purposes	✓ Simplicity ✓ Information gathered easily since most of it is in the accounting sheets	✓ May be difficult to isolate the costs related to the intellectual property assets from the other research costs ✓ The economic benefits associated with the assets are not taken into account
	market-based	✓ Valuation for internal purposes ✓ Valuation for IP transactions ✓ Valuation in litigation situations ✓ Trade mark valuation	✓ Accuracy, since it is close to market reality ✓ Objectivity	✓ May be difficult to gather comparable or similar data, since transactions are often confidential
	Income-based	✓ Valuation for fund raising	✓ Analytic	✓ May be difficult to use in high risk sectors ✓ Subjective assumptions can be made
	Option-based	✓ Valuation of an asset in the early stages of development ✓ Sectors of high uncertainty	✓ Deeper analysis since it takes into account the uncertainty of potential cash-flows	✓ Complexity
QUALITATIVE	**Qualitative method**	✓ Internal management decision making	✓ Simplicity	✓ Subjective

Figure 22 – Summary of the characteristics of the various valuation methods (European IPR Helpdesk 2013)

3.7. Case Studies

In a case showcased by van Triest & Vis (2007), the authors use Monte Carlo simulation to estimate the value of a patent which is considered to be the difference between the Net Present Values (NPV) of the R&D project in two scenarios, one with and other without the patent protection. The input parameters are estimated from historical values or by the company's executive's experience.

Ernst et al. (2010) construct their valuation model based on the assumption that the patent will result in a reduction in operational costs from the viewpoint of the company that holds the patent. The approach consists on a Discounted Cash Flow of the licensing fees less the patent maintenance fees. The licensing fees are calculated based on the savings it can generate for the potential licensees.

Collan & Heikkilä (2011) also models a case of a cost reducing innovation and applies an income-based principal, but models each parameters as a triangular distribution with a best guess, pessimistic and optimistic values. This results in a pay-off distribution for the NPV which can be used to value of a real option. The income from the patent is assumed to come from licensing fees and from a competitive advantage

4. Methodology

The model developed for the valuation is a combined approach of the income and option methods using stochastics variables for the cash flows estimation. The results of the model are computed using Monte Carlo simulation through an Excel add-in called @Risk developed by Palisade.

One of the underlying assumptions for the construction of the valuation model is that the patent, which provides more durability and stability to the solar cells, will improve the product quality, thus having the potential to generate sales. The patent value can be expressed as the difference in the Net Present Values (NPV) between the operating cash flows obtained with and without the patent.

Equation 4 – Patent Value

$$\boldsymbol{Patent\ Value = NPV_{with\ patent} - NPV_{without\ patent}}$$

The difference between the two scenarios are i) the cost to acquire the patent and ii) the additional operating income generate by the surplus of sales. The patent value can be rewritten as:

$$Patent\ Value = PV_{additional\ operating\ income} - PV_{patent\ acquistion\ cost}$$

The Net Present Value of the cost is calculated by discounting each scheduled payment to the present, i.e., when the agreement was sealed, 22 of January of 2015. Dyesol is an Australian company so any cash flow should be denominated in Australian dollars.

Equation 5 – PV of patent acquisition cost

$$PV_{patent\ acquisition\ cost} = \sum_{t=0}^{m} \frac{payment_t \times AUD, EUR\ exchange\ rate}{(1+r)^t}$$

The cash flows generated by the patent correspond to the added sales, subtracted by the associated costs (costs of goods sold, general and administrative expenses, etc.) and the patent renewal fees, plus the tax shield given by the reduction in the taxable income from the depreciation cost. Because the available market forecasts are provided in us dollars the cash flow map was developed in that currency so the final cash flow in each period t must converted.

Equation 6 - PV of the income

$$PV_{additional\ operating\ income} = \sum_{t=0}^{n} \frac{(\Delta Sales_n - \Delta Costs_n + Tax\ Shield_n - Patent\ Renewal\ Fees\ _n) \times AUD, USD\ exchange\ rate}{(1+r)^t}$$

Since Dyesol is a pre-revenue company the traditional organic growth assumption could not be used. Instead Dyesol's revenues will be estimated from the BIPV market size. The market size shoud be obtained from market forecasts. Two other assumptions are used to calculate the surplus of sales: the PSC share in the BIPV market, to calculate Dyesol's sales, and the percentage of additional sales. The first has a very high dregree of uncertainty because PSC is not even commercially available. To account for this uncertainty different scenarios for this parameter should be tested. The latter assumption could be estimated from available customer surveys. The cost can be projected by using the average EBITDA margin in a peer group. The tax shield is given by:

Equation 7 – Tax shield

$$tax\ shield = depreciation(1-t)$$

The depreciation in each period is given by the patent book value in the beginning of the year divided by the remaing years of the patent. Renewal fees should be estimated based on the number of countries and classes covered.

Since there is a great amount of uncertainty in the problem the management option to delay the commercialization of the technology postponing the € 2.8 million royalty payment should have a noteworthy value. The case study draws a significant resemblance with Aswath Damodaran's Biogen example (Aswath Damodaran 2001). In his case study the company in question is trying to value the option to delay the development of a patented drug called Avonex which is already patented. The method estimates the present value of the cash flows from the sale of the product to be the strike of an American call option and the development costs as being the exercise price. Similarly, our case situation can be modeled by a call option of value C with a strike price equal to net present value of the operating income cash flows (S) generated from 2018 to 2029 and an exercise price equal to the royalty that has to be paid (E). Instead of using the industry average, since the model incorporates the uncertainty related with the project, it is more appropriate to use the variance (σ) from our models' Monte Carlo simulations than using industry averages. The yield used to incorporate the dividends when applied to stocks in this case represents the delay cost from not using the patent while its life is being reduced.

Equation 8 – Black-Scholes-Merton formula, Call Option value

$$C = Se^{-yt}N(d_1) - Ke^{r_f}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r_f - y + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}} \qquad d_2 = d_1 - \sigma\sqrt{t} \qquad y = \frac{1}{t}$$

Considering the additional value of holding the option to delay the commercialization of the technology the patent value should be updated to:

Equation 9 – Patent value with option to delay

$$Patent\ Value = PV_{additional\ operating\ income} - PV_{patent\ acquistion\ cost} + Value\ of\ Option\ to\ Delay$$

The calculation will result in a value or a set of reasonable values for the patent which must be compared to our market price. The market price will be given the increase in the market capitalization of Dyesol after the acquisition announcement.

5. Case Study

5.1. Cash flows estimation

5.1.1. Surplus sales

The market size of the BIPV market in 2018 - the estimated date for product release - is forecasted to be $ 2,100 million (Figure 24). From the period of 2018 to 2021 the market size growth was considered to be normally distributed around a mean equal to the growth forecasted for each year by *NanoMarkets*. The cash flow map with inputs are presented in Tables 10, 11, and 12, in the Appendix. The standard deviation attributed to this distribution was assumed to be equal to the one observed in the Solar PV Manufacturing market from 2003 to 2013 (Cleanedge 2013). For the remaining 8 years of the model horizon the growth also followed a normal distribution around the average growth in the forecast with the same deviation from the mean as before.

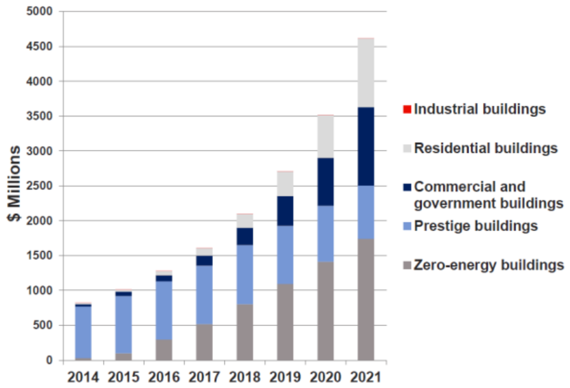

Figure 23 – BIPV market size forecast **(NanoMarkets 2014)**

The PSC share of the BIPV market is the most difficult parameter to estimate since there are no publicly available predictions for it. As a result several growth scenarios where established all starting from a 1% market share in 2018 and growing linearly until 2029. The ending market share for scenarios A, B and C are, respectively: 10%, 15% and 20%.

Following the market analysis carried out four main PSC players were identified: Dyesol, Oxford Photovoltaics, Saule Technologies, and Weihua Solar. The model assumption was that the sales would be evenly distributed between the four, i.e., Dyesol would achieve a 25% market share.

Customer surveys (Chen et al. 2013; National Renewable Energy Laboratory 2014) highlight the importance of durability and power warranty of solar systems. Study of the National Renewal Energy Laboratory shows that around 22% of customer named reliability as the reason why not to acquire a solar system. Dyesol mentioned the importance of the patent in the road to commercialization, and since the cell durability and stability is one of the major product this value is expected to be significant. To incorporate the uncertainty of this parameter the percent increase in sales was presumed to have a triangular distribution with a best guess value of 10%, pessimistic value of 5% and optimistic value of 15%.

5.1.2. Costs

For the purpose of estimating the margin on the additional sales a sample of the EBITDA margins for a peer group were gathered (Table 14). The group includes the 9 largest solar companies in the world by revenue. Through the *@Risk* software the author was able to fit the trailing twelve month EBITDA margin sample date to a uniform probability distribution with a maximum value of 19.1% and minimum value of -14.6% (Figure 25).

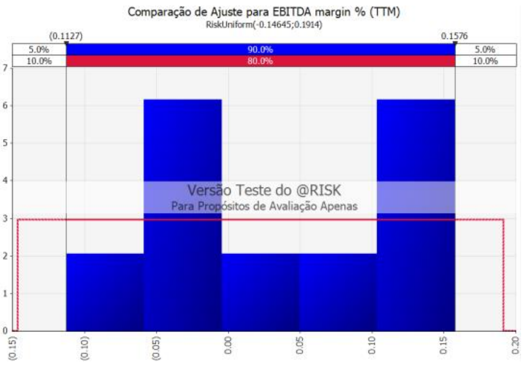

Figure 24 – Probability distribution for the EBITDA margin

After the expected payment of the royalty in 2018 the patent will be transferred to Dyesol which shall be responsible for the payment of its renewal fees. Using the fee calculator tool provided by the World Intellectual Property Organization maintenance fees were estimated to be CHF 17,945 (World Intellectual Property Organization 2015).

5.1.3. Depreciation tax shield

The reduction in the taxable income due to the depreciation of the patent acquisition costs are shown in Tables 10, 11 and 12. At the end of 2029, 20 years after the patent filling date, the book value of the patent is fully depreciated.

5.1.4. Currency conversion

The revenues and costs forecasts denominated in us dollars and the acquisition costs paid in euros, are converted to Australian dollars at a constant exchange rate throughout the period. The renewal fees estimated in CHF were converted to USD and then assumed to be constant. This means that the model does not incorporate exchange fluctuations. The EUR/AUD and AUD/USD used refer to the values in at the date of the press release, 22 of January of 2015 (Table 2).

Table 2 – Exchange rates considered in the model, closing quotes at 22 of January of 2015 (Bloomberg)

Exchange rates	
EUR / AUD	1.415
AUD / USD	0.802
USD / CHF	0.872

5.2. *Cost of capital*

This section is dedicated to the calculation of the WACC to which the cash flows derived from the patent are discounted.

5.2.1. Current WACC

The risk free rate is considered to be 2.61% which corresponds to the 10 year Australian government bond yield. Dyesol's beta is calculated by performing a regression of the monthly returns of Dyesol with the reference stock index for Australian stocks the ASX 200.

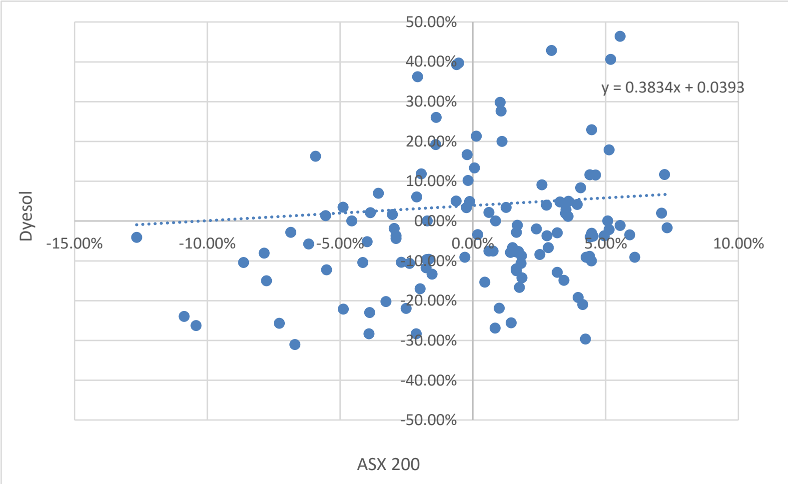

Figure 25 – Regression of the returns of Dyesol and the ASX 200

The market risk premium was computed to be 1.0%, resulting in a cost of equity of 3.59% as shown below.

$$r_e = 2.61\% + 0.38(5.17\% - 2.61\%) = 3.59\%$$

At the market closing of 31 of August 2015 the company's shares were trading at 0.215 Australian dollars giving it at market capitalization of AUD 73 million, considering the 339 033 259 shares outstanding last reported by the company at June 30 of 2015.

$$WACC = 0.99 \times 3.59\% + 0.01 \times 8.8\%(1 - 30\%) = 3.62\%$$

The different perspectives on the calculation of the discount rate suggest that this should the sensitivity of this parameter should be tested. The low cost of capital considering the company risk profile and negative operating results reflect the importance of its strategic shareholders which continue to fund the company despite the stock performance.

5.2.2. Future WACC

For the estimation of the future WACC an adjustment was performed to the beta and capital ratios to correspond to the peer group's (Table 4). The new WACC was calculated using the average values in the peer group. The resulting WACC was 7.89%.

Table 3 – Average beta, equity to capital and debt to capital ratios for the peer group, Morningstar

Company	Beta	E/C	D/C
First Solar	2.41	0.9	0.1
SunPower Corp	3.44	0.2	0.8
Canadian Solar	4.26	0.7	0.3
SunEdison	4.84	0.2	0.8
Trina Solar	1.45	0.8	0.2
Yingli	1.63	n.a.	n.a.
SMA	1.05	1.0	0.0
Solarworld	2.99	0.4	0.6
LDK Solar	0.42	n.a.	n.a.
Average	**2.50**	**0.61**	**0.39**

5.3. Patent acquisition cost

The schedule for the payments as presented in table 13 of the Appendix. When discounted the cash flows of the payments amount to AUD 6,436,624.

5.4. Value of the option to delay

Applying equation 8 to the problems parameters (Table 5) the value of the options according the Black-Scholes-Merton model for each model are AUD 1,776,090 for scenario A, AUD 2,462,504 for scenario B and AUD 3,116,555 for scenario C. The large option value compared to the underlying asset reflects the significant uncertainty embedded in the model.

Table 4 – Black-Scholes-Merton input parameters

Black-Scholes-Merton input parameters			
Scenario	**A**	**B**	**C**
Underlying Asset Value (*S*), aud	4 859 120	6 699 519	8 539 918
Exercise Price €, aud	3 522 542	3 522 542	3 522 542
Time to expiration (*t*), years	11	11	11
Risk-free rate (r_f)	2.61%	2.61%	2.61%
Variance (σ^2)	283%	407%	474%
Annualized dividend yield (*y*)	9%	9%	9%

Table 5 – Summary of the computed option values for each scenario

Value of the option to delay			
Scenario	**A**	**B**	**C**
d1	2.72	3.33	2.66
N(d1)	1.00	1.00	1.00
d2	-2.86	-3.35	-2.59
N(d2)	0.00	0.00	0.00
Value of the option to delay (aud)	**1 776 090**	**2 462 504**	**3 116 555**

5.5. Project Value

The Net Present Value of the project, given by subtracting the present value of the acquisition costs to the present value of the operating income cash flows plus the value of the option to delay, has a mean of AUD 245,699 for scenario A, AUD 2,772,513 for scenario B and 5,266,962 in scenario C. The result of 2000 trials for each scenario can be seen in the histograms (Figures 26, 27 and 28). The results have a significant dispersion expressed by substantial standard deviations (Table 7).

Table 6 – Summary of the results

Project Net Present Value (mean values, AUD)			
Scenario	**A**	**B**	**C**
PV Operating Income	4 906 233	6 746 632	8 587 031
PV Acquistion Cost	6 436 624	6 436 624	6 436 624
Value of the option to delay	1 776 090	2 462 504	3 116 555
Net Present Value	**245 699**	**2 772 513**	**5 266 962**

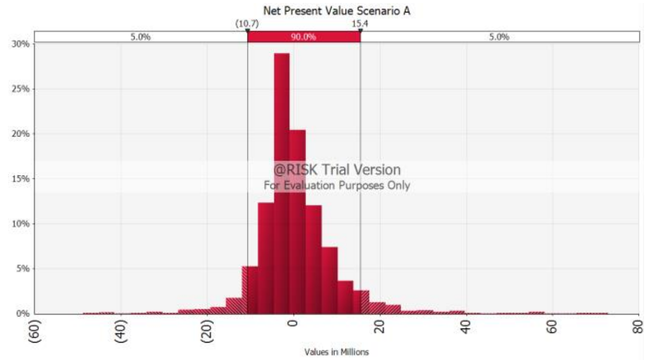

Figure 26 - Histogram for the NPV in scenario C

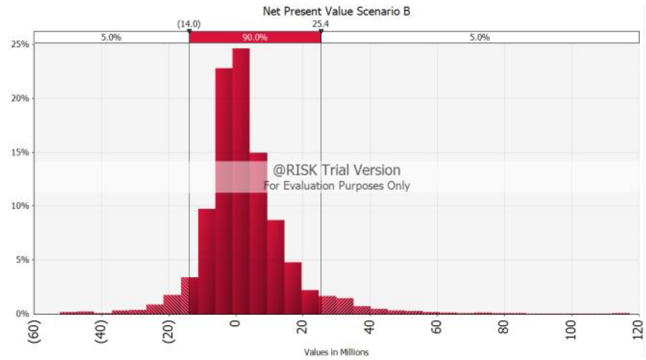

Figure 27 - Histogram for the NPV in scenario B

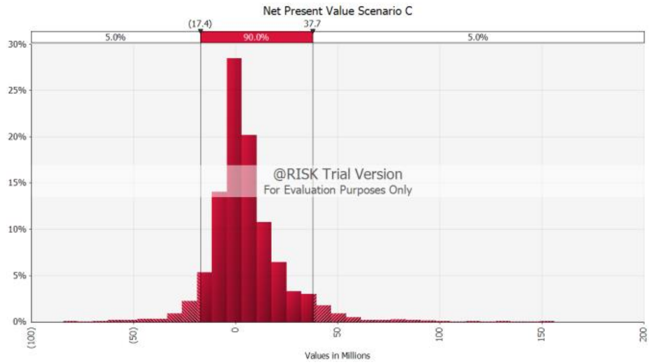

Figure 28 – Histogram for the NPV in scenario A

Table 7 – Standard deviations of the NPV

Simulations Standard Deviations (AUD)			
Scenario	**A**	**B**	**C**
Standard deviation	8 303 073	12 436 211	17 528 404
Iterations	2 000	2 000	2 000

5.6. Market value

Given that there were not any relevant news for Dyesol in the day of the press release informing about the agreement it can be assumed that the patent price implied by the market is given by the market capitalization difference between the open and the closing price of the following day market session.

Equation 10 - Patent Market Value

$$Patent\ Market\ Value = Dyesol\ Market\ Cap_{close} - Dyesol\ Market\ Cap_{open}$$

$$Patent\ Market\ Value = number\ of\ shares \times (share\ price_{close} - share\ price_{open})$$

$$Patent\ Market\ Value = 339{,}033{,}459 \times (0.205 - 0.200) = AUD\ 1{,}695{,}167$$

The calculated market value is superior to scenario A's Net Present Value, but lower than the most optimistic scenarios B and C. This value should however be taken with some caution since Dyesol has a small market capitalization and only about a third of its capital is free float.

5.7. Sensitivity Analysis

The most critical parameters as measured by the impact in the mean Net Present Value are the EBITDA margin and BIPV market growth, for any of the scenarios. The EBITDA margin becomes increasingly important in time due to the sales increase while the BIPV market growth causes more impact earlier because its effect is multiplied by the growth in the following years.

Table 8 – Ranking of the inputs to which the NPV is more sensitive to

Rank	Input
1	EBITDA Margin / 2029
2	EBITDA Margin / 2028
3	EBITDA Margin / 2027
4	EBITDA Margin / 2026
5	EBITDA Margin / 2025
6	BIPV Market growth / 2021
7	BIPV Market growth / 2020
8	EBITDA Margin / 2024
9	BIPV Market growth / 2022
10	EBITDA Margin / 2023
11	BIPV Market growth / 2023
12	BIPV Market growth / 2026
13	BIPV Market growth / 2019
14	BIPV Market growth / 2024

The EBITDA margin sensitivity is especially problematic since from all the parameters included in the model it is the one which can vary the most. A value of 15% for the EBITDA margin would be admissible which would represent a 585% increase to the average of this parameter. It is not likely that any other input could realistically suffer such increase. Table 9 compares the impact of a 20% increase and decrease in the inputs with the least and the most impact on NPV, the EBITDA margin of 2019 and 2029 respectively. A small 20% drop or increase, about 0.5 percentage points, in 2029's result in a circa 80% impact on NPV.

Table 9 - Sensitivity analysis

	Variation in input	Variation in NPV
EBITDA margin 2029	20.0%	80.3%
	-20.0%	-80.3%
EBITDA margin 2019	20.0%	1.2%
	-20.0%	-1.2%

6. Conclusions

The application of a Discounted Cash Flow model using stochastic variables together with a real options approach resulted in valuation values in the same order of magnitude of the stock market valuation but still substantially different (86%, -64% and -211% compared to the mean values of scenario A, B and C). Such difference was expected given the uncertainty and sensitivity of the model.

This valuation method, in contrast with a simple income based approach, allows the incorporation of uncertainty and managerial flexibility to the model. However, given the underlying uncertainty of the case study the model is very sensitive to variations in its input parameters which negatively affects the confidence level with which the NPV outcomes can be interpreted.

This work also highlights many of the difficulties of patent valuation mentioned in the literature namely in the cash flow estimation for a technology that is novel and will be used in a market which has not matured. Many parameters used in the model are derived from the traditional solar industry, which bears the most similarity to the BIPV market, but is struggling to be profitable.

Another difficult task using this approach is to balance the model complexity and its adequacy to reality: if one tries to incorporate every possible parameter in the model it will be difficult to use it as a management tool and take any conclusion, on the other hand, if it is too simplistic the predictions may not be the most accurate. In this case factors such as working capital investment, economies of scale from additional sales, the possibility of entrance of new players or competing technologies in the market, for example, were disregarded because it would be difficult to provide a good estimate for them.

The aforementioned conclusions suggests that in scenarios with a very high degree of uncertainty a more practical approach might be more suitable. However, when applied to more stable markets, in industries with higher predictability this approach should produce good results.

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Appendix

Income cash flows – scenario A

Table 10 - Income cash flows (Scenario A)

Scenario A															*units: usd unless indicated otherwise*
Year	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*
BIPV Market Size				2 100 000 000	2 700 000 000	3 500 000 000	4 500 000 000	5 760 144 558	7 373 170 073	9 437 894 548	12 080 808 205	15 463 822 585	19 794 189 668	25 337 198 643	32 432 428 195
BIPV Market growth					*28.6%*	*29.6%*	*28.6%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*
Mean (NanoMarkets Forecast)					*28.6%*	29.6%	28.6%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
Standard Deviation					27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%
PSC market size				21 000 000	49 090 909	92 272 727	155 454 545	246 115 267	375 361 386	557 693 769	812 708 916	1 166 815 704	1 655 514 045	2 326 415 512	3 243 242 819
PSC market share				1.0%	1.8%	2.6%	3.5%	4.3%	5.1%	5.9%	6.7%	7.5%	8.4%	9.2%	10.0%
Scenario A				1.0%	1.8%	2.6%	3.5%	4.3%	5.1%	5.9%	6.7%	7.5%	8.4%	9.2%	10.0%
Scenario B				1.0%	2.3%	3.5%	4.8%	6.1%	7.4%	8.6%	9.9%	11.2%	12.5%	13.7%	15.0%
Scenario C				1.0%	2.7%	4.5%	6.2%	7.9%	9.6%	11.4%	13.1%	14.8%	16.5%	18.3%	20.0%
Market share among PSC players				25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Dyesol sales forecast				5 250 000	12 272 727	23 068 182	38 863 636	61 528 817	93 840 346	139 423 442	203 177 229	291 703 926	413 878 511	581 603 878	810 810 705
Incremental revenues from patent				**525 000**	**1 227 273**	**2 306 818**	**3 886 364**	**6 152 882**	**9 384 035**	**13 942 344**	**20 317 723**	**29 170 393**	**41 387 851**	**58 160 388**	**81 081 070**
Sales increase from patent				10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Best Guess				10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Pessimistic				5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Optimistic				15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Patent maintenance fees				**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**
Additional costs				**513 201**	**1 199 690**	**2 254 972**	**3 799 018**	**6 014 596**	**9 173 128**	**13 628 990**	**19 861 082**	**28 514 788**	**40 457 659**	**56 853 233**	**79 258 773**
EBITDA Margin				2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%
a				-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%
b				19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Depreciation Tax shield	**7 143**	**6 633**	**21 921**	**43 171**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**
Patent accrual value at end of the year	309 524	949 915	1 726 845	4 737 108	4 306 461	3 875 815	3 445 169	3 014 523	2 583 877	2 153 231	1 722 585	1 291 938	861 292	430 646	0
Addition	333 333	662 500	850 000	3 154 167											
Depreciation	-23 810	-22 109	-73 070	-143 904	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646
Cash flows (USD)	**7 143**	**6 633**	**21 921**	**34 391**	**136 198**	**160 460**	**195 961**	**246 901**	**319 521**	**421 969**	**565 256**	**764 219**	**1 038 807**	**1 415 769**	**1 930 912**
AUD/USD	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Cash flows (AUD)	**8 906**	**8 270**	**27 333**	**42 882**	**169 823**	**200 075**	**244 340**	**307 856**	**398 405**	**526 146**	**704 807**	**952 892**	**1 295 270**	**1 765 299**	**2 407 621**
Discounted cash flow	**9 910**	**8 880**	**28 323**	**42 882**	**157 410**	**171 897**	**194 584**	**227 247**	**272 591**	**333 680**	**414 317**	**519 210**	**654 180**	**826 404**	**1 044 719**
Discount rate	3.6%	3.6%	3.6%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%

Income cash flows – scenario B

Table 11 - Income cash flows (Scenario B)

Scenario B															units: usd unless indicated otherwise
Year	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*
BIPV Market Size				2 100 000 000	2 700 000 000	3 500 000 000	4 500 000 000	5 760 144 558	7 373 170 073	9 437 894 548	12 080 808 205	15 463 822 585	19 794 189 668	25 337 198 643	32 432 428 195
BIPV Market growth					*28.6%*	*29.6%*	*28.6%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*
Mean (NanoMarkets Forecast)					*28.6%*	29.6%	28.6%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
Standard Deviation					27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%
PSC market size				21 000 000	61 363 636	124 090 909	216 818 182	350 845 169	542 933 433	815 090 893	1 197 098 268	1 729 136 525	2 465 276 350	3 478 106 359	4 864 864 229
PSC market share				1.0%	2.3%	3.5%	4.8%	6.1%	7.4%	8.6%	9.9%	11.2%	12.5%	13.7%	15.0%
Scenario A				1.0%	1.8%	2.6%	3.5%	4.3%	5.1%	5.9%	6.7%	7.5%	8.4%	9.2%	10.0%
Scenario B				1.0%	2.3%	3.5%	4.8%	6.1%	7.4%	8.6%	9.9%	11.2%	12.5%	13.7%	15.0%
Scenario C				1.0%	2.7%	4.5%	6.2%	7.9%	9.6%	11.4%	13.1%	14.8%	16.5%	18.3%	20.0%
Market share among PSC players				25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Dyesol sales forecast				5 250 000	15 340 909	31 022 727	54 204 545	87 711 292	135 733 358	203 772 723	299 274 567	432 284 131	616 319 087	869 526 590	1 216 216 057
Incremental revenues from patent				**525 000**	**1 534 091**	**3 102 273**	**5 420 455**	**8 771 129**	**13 573 336**	**20 377 272**	**29 927 457**	**43 228 413**	**61 631 909**	**86 952 659**	**121 621 606**
Sales increase from patent				10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Best Guess				10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Pessimistic				5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Optimistic				15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Patent maintenance fees				**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**
Additional costs				**513 201**	**1 499 612**	**3 032 549**	**5 298 630**	**8 573 998**	**13 268 275**	**19 919 293**	**29 254 837**	**42 256 855**	**60 246 732**	**84 998 398**	**118 888 160**
EBITDA Margin				2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%
a				-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%
b				19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Depreciation Tax shield	**7 143**	**6 633**	**21 921**	**43 171**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**
Patent accrual value at end of the year	309 524	949 915	1 726 845	4 737 108	4 306 461	3 875 815	3 445 169	3 014 523	2 583 877	2 153 231	1 722 585	1 291 938	861 292	430 646	0
Addition	333 333	662 500	850 000	3 154 167											
Depreciation	-23 810	-22 109	-73 070	-143 904	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646
Cash flows (USD)	**7 143**	**6 633**	**21 921**	**34 391**	**143 093**	**178 338**	**230 439**	**305 746**	**413 675**	**566 594**	**781 234**	**1 080 173**	**1 493 792**	**2 062 876**	**2 842 060**
AUD/USD	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Cash flows (AUD)	**8 906**	**8 270**	**27 333**	**42 882**	**178 421**	**222 367**	**287 331**	**381 229**	**515 805**	**706 476**	**974 108**	**1 346 849**	**1 862 583**	**2 572 164**	**3 543 716**
Discounted cash flow	**9 910**	**8 880**	**28 323**	**42 882**	**165 380**	**191 049**	**228 820**	**281 408**	**352 917**	**448 045**	**572 623**	**733 869**	**940 703**	**1 204 128**	**1 537 695**
Discount rate	3.6%	3.6%	3.6%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%

Income cash flows – scenario C

Table 12 - Income cash flows (Scenario C)

Scenario C															units: usd unless indicated otherwise
Year	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*
BIPV Market Size				2 100 000 000	2 700 000 000	3 500 000 000	4 500 000 000	5 760 144 558	7 373 170 073	9 437 894 548	12 080 808 205	15 463 822 585	19 794 189 668	25 337 198 643	32 432 428 195
BIPV Market growth					*28.6%*	*29.6%*	*28.6%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*	*28.0%*
Mean (NanoMarkets Forecast)					*28.6%*	29.6%	28.6%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
Standard Deviation					27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%	27.8%
PSC market size				21 000 000	73 636 364	155 909 091	278 181 818	455 575 070	710 505 480	1 072 488 017	1 581 487 620	2 291 457 347	3 275 038 654	4 629 797 207	6 486 485 639
PSC market share				1.0%	2.7%	4.5%	6.2%	7.9%	9.6%	11.4%	13.1%	14.8%	16.5%	18.3%	20.0%
Scenario A				1.0%	1.8%	2.6%	3.5%	4.3%	5.1%	5.9%	6.7%	7.5%	8.4%	9.2%	10.0%
Scenario B				1.0%	2.3%	3.5%	4.8%	6.1%	7.4%	8.6%	9.9%	11.2%	12.5%	13.7%	15.0%
Scenario C				1.0%	2.7%	4.5%	6.2%	7.9%	9.6%	11.4%	13.1%	14.8%	16.5%	18.3%	20.0%
Market share among PSC players				25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Dyesol sales forecast				5 250 000	18 409 091	38 977 273	69 545 455	113 893 767	177 626 370	268 122 004	395 371 905	572 864 337	818 759 664	1 157 449 302	1 621 621 410
Incremental revenues from patent				**525 000**	**1 840 909**	**3 897 727**	**6 954 545**	**11 389 377**	**17 762 637**	**26 812 200**	**39 537 190**	**57 286 434**	**81 875 966**	**115 744 930**	**162 162 141**
Sales increase from patent				10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Best Guess				10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Pessimistic				5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Optimistic				15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Patent maintenance fees				**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**	**20 579**
Additional costs				**513 201**	**1 799 535**	**3 810 126**	**6 798 242**	**11 133 400**	**17 363 422**	**26 209 596**	**38 648 592**	**55 998 921**	**80 035 804**	**113 143 563**	**158 517 547**
EBITDA Margin				2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%
a				-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%
b				19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Depreciation Tax shield	**7 143**	**6 633**	**21 921**	**43 171**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**	**129 194**
Patent accrual value at end of the year	309 524	949 915	1 726 845	4 737 108	4 306 461	3 875 815	3 445 169	3 014 523	2 583 877	2 153 231	1 722 585	1 291 938	861 292	430 646	0
Addition	333 333	662 500	850 000	3 154 167											
Depreciation	-23 810	-22 109	-73 070	-143 904	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646	-430 646
Cash flows (USD)	**7 143**	**6 633**	**21 921**	**34 391**	**149 989**	**196 216**	**264 918**	**364 591**	**507 830**	**711 219**	**997 213**	**1 396 127**	**1 948 777**	**2 709 982**	**3 753 209**
AUD/USD	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Cash flows (AUD)	**8 906**	**8 270**	**27 333**	**42 882**	**187 019**	**244 659**	**330 322**	**454 602**	**633 204**	**886 807**	**1 243 408**	**1 740 807**	**2 429 897**	**3 379 030**	**4 679 812**
Discounted cash flow	**9 910**	**8 880**	**28 323**	**42 882**	**173 350**	**210 201**	**263 057**	**335 568**	**433 242**	**562 410**	**730 929**	**948 527**	**1 227 226**	**1 581 853**	**2 030 672**
Discount rate	3.6%	3.6%	3.6%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%

Payment cash flows

Table 13 - Payment schedule

Stage	*Payments to adapt technology to PSC*														
Instalment n.º	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
	31/03/2015	30/04/2015	31/05/2015	30/06/2015	31/07/2015	31/08/2015	30/09/2015	31/10/2015	30/11/2015	31/12/2015	31/01/2016	29/02/2016	31/03/2016	30/04/2016	31/05/2016
Payments	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333	33 333
Discounted Payments	33 333	33 233	33 133	33 033	32 934	32 835	32 736	32 637	32 539	32 441	32 343	32 246	32 149	32 052	31 956
EUR/AUD	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Discounted Payments (AUD)	47 167	47 025	46 883	46 742	46 601	46 461	46 321	46 182	46 043	45 904	45 766	45 628	45 491	45 354	45 218
PV Payments (Price)	**6 436 624**														

Stage	*Payment contingent on achieving technical specifications*											
Instalment n.º	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*
	30/06/2016	31/07/2016	31/08/2016	30/09/2016	31/10/2016	30/11/2016	31/12/2016	31/01/2017	28/02/2017	31/03/2017	30/04/2017	31/05/2017
Payments	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833
Discounted Payments	67 702	67 498	67 295	67 092	66 890	66 689	66 488	66 288	66 089	65 890	65 691	65 494
EUR/AUD	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Discounted Payments (AUD)	95 798	95 510	95 222	94 936	94 650	94 365	94 081	93 798	93 515	93 234	92 953	92 673

Stage												
Instalment n.º	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*
	30/06/2017	31/07/2017	31/08/2017	30/09/2017	31/10/2017	30/11/2017	31/12/2017	31/01/2018	28/02/2018	31/03/2018	30/04/2018	31/05/2018
Payments	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833	70 833
Discounted Payments	65 296	65 100	64 904	64 709	64 514	64 320	64 126	63 933	63 741	63 549	63 357	63 167
EUR/AUD	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Discounted Payments (AUD)	92 394	92 116	91 839	91 563	91 287	91 012	90 738	90 465	90 193	89 921	89 651	89 381

Stage	*Royalty payment contingent on commercialization*
Instalment n.º	*39*
	31/12/2018
Payments	2 800 000
Discounted Payments	2 489 429
EUR/AUD	1.42
Discounted Payments (AUD)	3 522 542

Table 14 – EBITDA margins in the peer group

Company	EBITDA margin % (TTM)
First Solar	2%
SunPower Corp	10%
Canadian Solar	16%
SunEdison	-2%
Trina Solar	11%
Yingli	9%
SMA	-3%
Solarworld	-11%
LDK Solar	-1%