Department of Business and Management
Chair of International Management

IPRs strategies & Green Technologies
Concentrated Solar Power (CSP): a sector analysis

SUPERVISOR

Prof. Granieri Massimiliano

CANDIDATE: Serra Giulia
ID: 679321

CO-SUPERVISOR

Prof. Pardolesi Roberto

ACADEMIC YEAR 2016-2017

TABLE OF CONTENTS

Introduction 3

1. An Innovative Green Technology: Concentrated Solar Power 6

1.1 **CSP Technologies** 6

1.1.1 Parabolic Trough Power Plant System 7

1.1.2 Power Tower/Central Receiver Power Plant System 8

1.1.3 Linear Fresnel Power Plant System 9

1.1.4 Solar Dish/Engine Power Plant System 10

1.2 Comparing Heat Transfer Fluids: Molten Salts Vs Oil 11

1.3 Increasing CSP Plants Efficiency: The Energy Storage System 13

2. CSP Market Development 16

2.1 **CSP Industry: Worldwide Overview** 16

2.2 How to evaluate the CSP Market: a Comparative System Approach 19

2.3 **Cost Drivers in Implementing CSP Technologies** 24

2.4 Policy Framework for a Positive Investment Environment 25

3. Intellectual Property Rights and The Green Economy 30

3.1 Patents: Public Documents Providing a wealth of useful Information 30

3.2 IPRs and the Green Economy: the Technology Transfer role 33

3.3 Tagging Sustainable Technology Patents: a New Classification Scheme 36

4. CSP from Research to Market. ENEA Case Study 41

4.1 **CSP Technology: the Italian Experience** 42

4.2 **Parabolic Trough Variant System: The Archimedes Project** 44

4.2.1 Archimedes: the Innovation Process 45

4.2.2 Overcoming Challenges & Results 46

4.2.3 Impact on Italian Players 48

4.3 **Looking Forward: Made in Italy Ongoing Investments** 50

4.4 **Archimede Solar Energy (ASE)** 52

4.4.1 License Agreement and High Innovative Competencies: ASE World Leadership 53

4.4.2 Innovative Solar Receiver Tubes 55

4.5 **A Patent Database Approach: Questel Orbit web-service** 57

Conclusion 62

Glossary 65

Bibliography/ Sitoghraphy 67

INTRODUCTION

One of the biggest challenges facing humanity today is climate change. Since both final energy consumption and world carbon dioxide (CO_2) emissions have doubled in the last 35 years, it is not surprising that the limited fossil fuel resources and the negative impact of greenhouse gases (GHG) emissions command to find solutions for alternative primary energy supply and methods for energy savings. Thus, scientists and engineers are developing new technologies to reduce CO_2 emissions, capture GHG, generate energy from renewable energy resources (RES) and distribute energy more efficiently.

Ambitious Research and Innovation (R&I) targets have been set for renewable technologies showing great potential for cost-reductions, performance improvements and large scale deployment worldwide.

A new concept of Green Economy has emerged. Green economy has been defined as an economic system resulted in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In a green economy, growth in income and employment are driven by public and private investments that can reduce carbon emissions and pollution, enhance energy and resource efficiency and prevent the loss of biodiversity and ecosystem services" (United Nations Environment).

The European Union has established in this green framework, challenging targets for making a transition to a sustainable energy system, including that the EU's electricity supply should achieve essentially zero emission of GHG by 2050. In the light of the Paris Agreement, agreed by nearly 200 countries across the world, we urgently need to revise current EU and national targets to achieve the goal of limiting global temperature increase to 1.5˚C. The EU's 2030 climate and energy goals (e.g. a 40% emission reductions by 2030 compared to the 1990 level), seem not sufficient to get us there: only a stronger emissions target in line with the rapid decarburization of the energy sector and a higher share of renewable energy consumption will make this goal achievable.

Concentrated Solar Power/Solar Thermal Electricity (CSP/STE) technologies represent one of the key factor that would enable Europe to reach its goals. CSP can provide dispatchable electricity (with the provision of an embedded storage capability) and "on demand" heat generation and how it could be a key to achieve 100% renewables share by 2050 in a wise mix with other renewables.

CSP is also a promising option for hybridization and thermal energy storage (TES) integration because it converts sun radiation into thermal energy before generating electrical power. This characteristic simplifies the integration of CSP plants with other thermal energy sources such as fossil fuel or biomass conversion.

In this renewable environment, one of the main misleading issue in evaluating the renewable energy market (especially if we are going to focus on the CSP one) is that the usual key metric for the cost evaluation is the Levelized Cost of Energy (LCOE).

The LCOE metric is not built on the distinction between Value and Cost connected to RES so what we would need to develop is a system approach able to emphasize the value added to the system related to the capabilities of CSP technologies to understand that the value of CSP system is far beyond its generation costs.

To date, CSP counts for about 5% of the global investment in energy infrastructure (158-186 billion Euro invested each year), showing its contributive potential to a “New Green Deal” for the economy. From 2015, the market has started to expand beyond Spain and US and new facilities came up in developing countries.

In this new challenging environment it is important to understand the role of the Intellectual Property Rights (IPRs) and the impact of technology transfer. In fact, as the climate change is the most pressing challenge of our time, we need an intensive mobilization of human and financial resources to alter our patterns of production, consumption and energy use. Enhancing technology transfer has been defined as a key pillar of the global climate change regime. IP is in fact central to business and R&D strategies due to fact that its policy sits at the crossroads between technology, marketing and finance. This is one of the main reasons why companies, associations and other market players are more and more using IP to achieve their goals and to try to maintain a leading edge.

Patents represent an effective way to track the rise of emerging technologies. Thanks to all the information that can be provided, patents statistics can in fact be used to track the dynamics of the innovation process (e.g. co-operation in research, diffusion of technology across industries or countries), the competitive process (the market strategy of businesses) and the globalization patterns.

Also, the new Green Economy is impacting Climate Change Mitigation Technologies (CCMT) focused on controlling, reducing or preventing the anthropogenic GHG emissions, as covered by the Kyoto Protocol.

This document has the aim to demonstrate how patents are an effective intermediate step between R&D (upstream) and innovation (downstream) in the economic process. In this context, European Patent Office (EPO) has produced a policy brief in co-operation with the International Renewable Energy Agency (IRENA) in order to provide evidence on the latest trends in CCMT innovation and dissemination with a focus on renewable energy technologies, showing that patents support their deployment.

To help engineers, scientists, institutions and decision-makers use this wealth of knowledge in their work, the European Patent Office (EPO) has developed a dedicated document tagging scheme (Y02) that enables a continuous and reliable flow of data on selected technologies and their application in the energy field. Patents are the only way to win the global warming race even if many developing countries see patents as a barrier to technology transfer to poorer countries because without patents, without intellectual property rights, it would be very difficult for new technologies even to arise.

Since the Green Economy context is a fast-moving field, patents can either safeguard the pioneering investments and incentive companies to keep going in researching new technologies and generating new ideas which, in the long term, could help to manage the whole climate change problem. Moreover, it is also true that most of developing countries don't have neither the infrastructure nor the capacity to take in high-tech technologies. Thus, patents are not a really obstacle for them because many of low-tech engineering solutions (in which they could be interested) are off-patent.

As a concrete example of this positive effect, one of the most representative Italian CSP has been analyzed and presented. The so called Archimedes program (2001-2010), developed by ENEA in collaboration with ENEL and other Italian manufacturing leading companies, will be not only an example of how to manage the whole innovation process, avoiding the pitfalls of the intermediate stage between basic research and commercialization but also a demonstration of how public applied research is able to entail relevant technology transfer to the productive sector (Casagni et al., 2014). The aim is also to underline the usefulness of the public intervention into the innovation process (i.e. IP system, government support of innovative activities, R&D tax incentives, encouragement of research partnerships).

The activities promoted by ENEA stimulated the attention to the role that Italy could play in the CSP emerging market and it will be demonstrated how technology transfer could be a way to increase the production sector and pursue industrial policy objectives in green technologies.

Also, in analyzing this project, as well as the ongoing activities born later, it is possible to realize that Public intervention has to be the vehicle to overcome the tendency of the private sector to under-invest in R&D pioneers programs.

It will be evident that we should increase our awareness related to these potentialities to avoid the pitfalls of uncertainty regarding public fundings and willingness of policy authorities. It will be also demonstrated that financing the technology transfer is the key successful solution to foster the diffusion of green technologies in our economic system and that patent protection can either guarantee a strong first mover advantage in the fast-growing environment (such as the one of CSP sector) and can also be an incentive to stimulate the investments of new potential players.

To have a concrete feedback from the patents protection perspective and to understand how they can provide reliable information regarding the innovation, the competitive process and the globalization patterns, I have held an internship at ENEA Brussels Office.

This gave me also the chance to meet the ENEA team in Bologna; there, I learnt how "Questel Orbit" patent database is used to track the dynamics in each field of interest. At the end of my internship I met the Archimede Solar Energy team in its head office in Perugia where I had the chance to visit the CSP manufacturing plant and to concretely understand the relation ASE has with ENEA (upstream through license agreements) and with the CSP market (downstream).

1. AN INNOVATIVE GREEN TECHNOLOGY: CONCENTRATED SOLAR POWER

Concentrated Solar Power (CSP) systems are also known as Solar Thermal Electricity system (STE). In 1968, professor Giovanni Francia designed and built in Italy the first operating CSP Plant. At the time, it was able to produce 1MW with superheated steam at 100 bar and 500°C and its configuration has been an example for the new plants operating today.

CSP plants are able to produce heat or generate electricity by using mirrors to concentrate the sun's rays to a temperature typically between 400ºC and 1000ºC. This technology has been developed because, if the aim is producing electricity, when radiation reaches the Earth's surface, it has a density (kW/ m^2) adequate for heating systems but not for an efficient thermodynamic cycle[1]. Through CSP technologies, such density can be increased and, consequently, the incoming solar radiation can be concentrated using mirrors or lenses and then converted into thermal energy. CSP is also a carbon-free source of electricity energy that is best suited to strong irradiated areas: Southern Europe, Northern Africa and the Middle East, South Africa, parts of India, China, Southern USA and Australia.

This technology seems to be the most likely candidate for the conversion of a huge amount of energy because it is dispatchable (if supported by thermal storage capacity) and potentially the most cost-effective renewable electricity technology. It is also a promising option for hybridization and thermal energy storage (TES) integration because it converts sun radiation into thermal energy before generating electrical power. This characteristic simplifies the integration of CSP plants with other thermal energy sources such as fossil fuel or biomass conversion.

1.1 CSP Technologies

CSP technology is based on optical systems gathering the direct solar radiation that is concentrated and sent toward a receiver. It is then converted into high temperature heat that is transferred to a thermodynamic cycle trough a heat carrier fluid.

There are basically two ways through which heat can be transferred from the solar field to the power block: the Indirect Steam Generation (ISG) and the Direct Steam Generation (DSG).

In the first case, a special heat transfer fluid is used in the solar field to collect the thermal energy and to heat up the water of the power block in a heat exchanger. On the other hand, DSG implies exclusively the use of

---

[1] Thermodynamic cycle: a series of thermodynamic processes transferring heat and work, while varying pressure, temperature, and other state variables, eventually returning a system to its initial state.
Cengel, Yunus A.; Boles, Michael A. (2002). Thermodynamics: an engineering approach.

water as heat transfer fluid directly in the solar field. The plant complexity of ISG is higher than the one of DSG: the first needs two working fluids (while DSG only one) and it has the necessity of a steam generator train consisting of a preheater, evaporator and super heater. Given these characteristics, DSG is the commercial option for the electricity generated by CSP plants even if an overall cost reduction has to be achieved to exploit the DSG technology and to advance towards the grid parity[2].

Going forward with technological analysis, there are various CSP arrangements that differ in the mirror shapes, sun-tracking methods and ways to provide useful energy, but they all work under the same principle: driving a heat engine, usually a steam turbine, to generate electricity that can be then fed into the grid. More specifically, considering the geometry and the concentrator's placement with respect to the receiver, four different CSP systems can be identified (all suitable for large power production ready for industrial application): Parabolic Trough, Power Tower/Central Receiver, Linear Fresnel and Solar Dish/Engine.

1.1.1 Parabolic Trough Power Plant System

In the Parabolic Trough System, sunlight is concentrated on absorber tubes placed in the trough's focal line, achieving operating temperatures between 350°C and 550°C.

The troughs are usually designed to track the sun along one axis, predominantly north-south. A heat transfer fluid (HTF), such as synthetic thermal oil or a mixture of molten salts, runs into the absorber tube and transfers the thermal energy to a conventional steam turbine power cycle, generating electricity. In the usual systems, the thermal oil is heated to approximately 400°C by the sun's concentrated rays and then pumped through a series of heat exchangers to produce superheated steam. The steam is converted into electrical energy in a conventional steam turbine generator, which can be either part of a conventional steam cycle or can be integrated into a combined steam and gas turbine cycle.

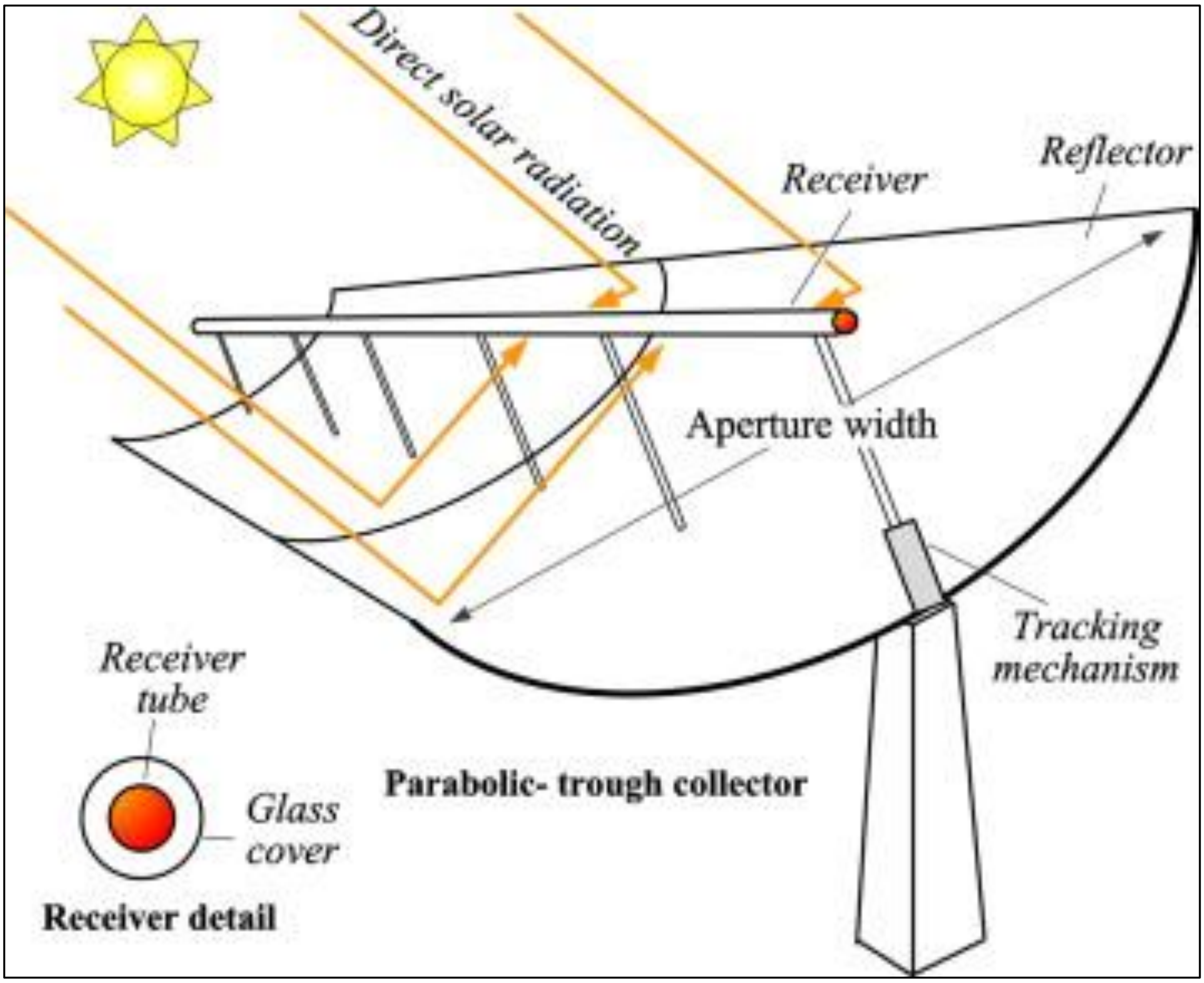
Parabolic Trough plants, then, consist of two parts (Figure 1.1):

- a Solar Field, constituted by reflecting panels concentrating the solar energy. Receiving tubes convert this energy into high-temperature heat which can be stored for some hours;
- a Power Generation Plant where a traditional turbine power generation system produces electricity[3].

[2] Grid parity is when an alternative form of energy generates power at a levelized cost of electricity (LCOE) that's equal to or less than the price of buying power from the electric grid. In other words, it is the point where the cost of the alternative energy becomes equal to or less than electricity from conventional energy forms like fossil fuels.
The Climate Reality Project, *What is grid Parity and Why does it matter?*

[3] Archimede Solar Energy, *Parabolic Trough Plant*

Figure 1.1 *Parabolic Trough Plant – Structure*



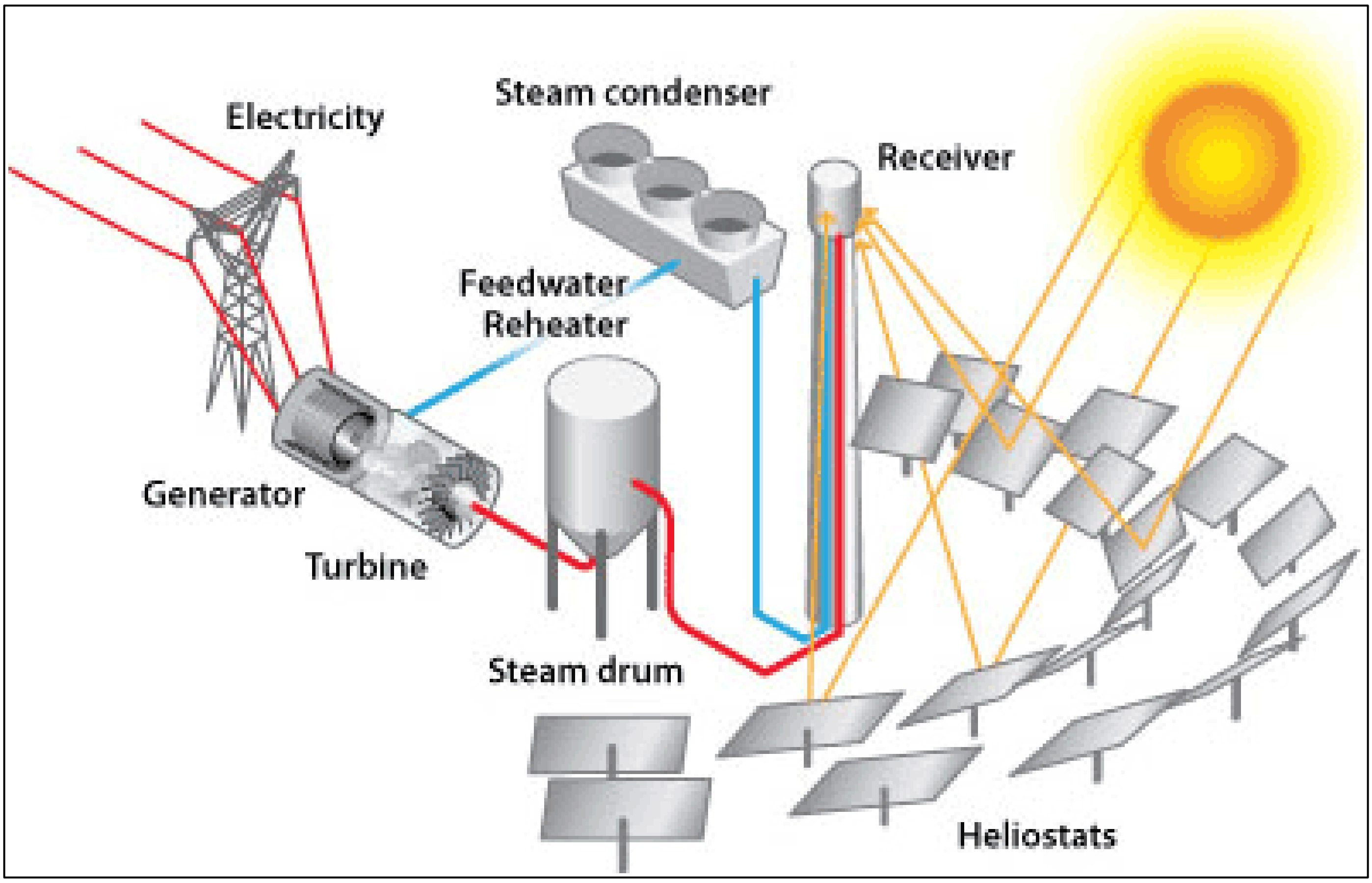
Source*: ScienceDirect*

1.1.2 Power Tower/Central Receiver Power Plant System

In the Power Tower or Central Receiver system, large, flat, heliostat mirrors track the sun focusing its rays onto a receiver. The receiver is located on top of a tall tower in which concentrated sunlight heats a fluid, such as molten salt, until 565°C. Then, the fluid can be either immediately used to generate steam for electricity generation or stored for a later application.

The storage is possible due to the use of molten salts as HTF: they can efficiently retain heat before being converted into electricity even for days. It basically means that electricity can be produced and provided during a high peak of demand, in cloudy days or even after sunset (Figure 1.2).

Figure 1.2 *Power Tower Plant – Structure*



Source: *Energy.gov."Energy Efficiency & Renewable Energy"*

1.1.3 Linear Fresnel Power Plant System

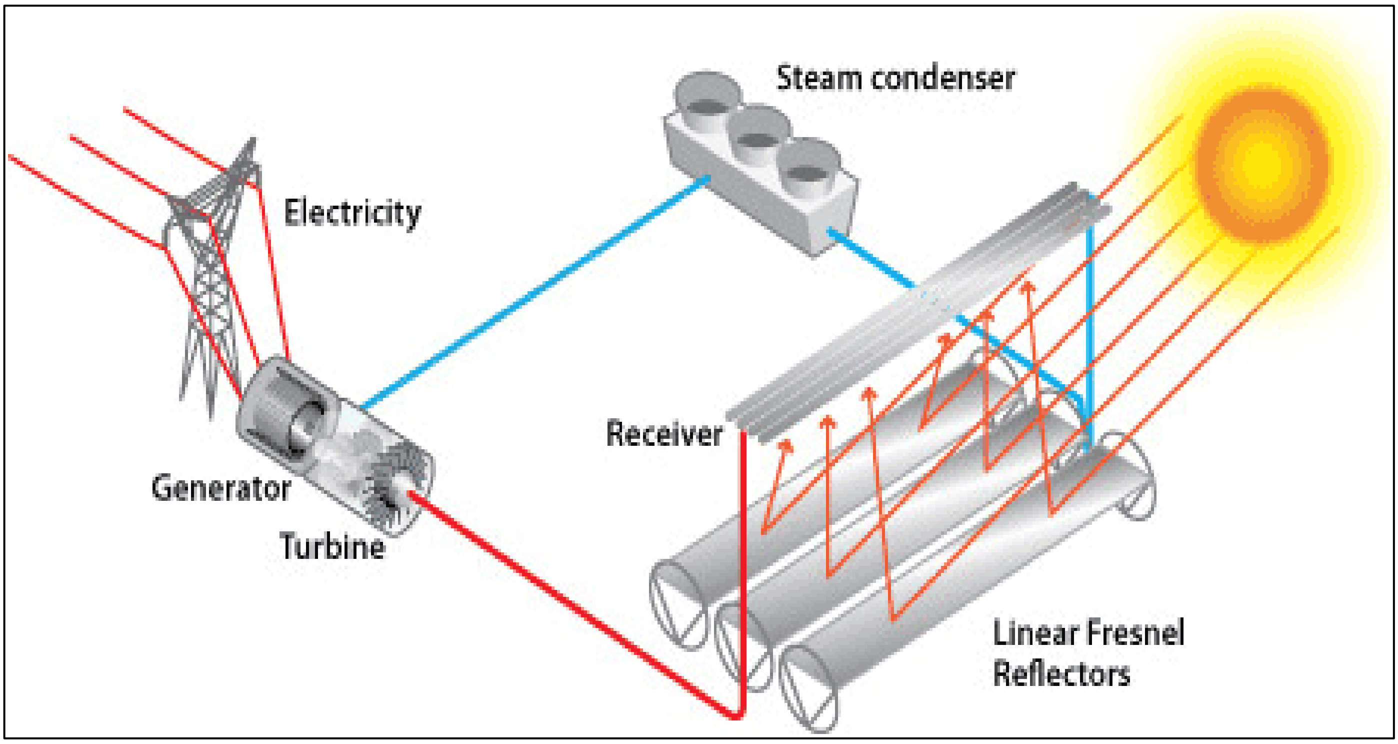
In the Linear Fresnel system, modular and flat mirrors focus the sun's heat onto long, elevated receivers, consisting of a system of boiler tubes through which water flows. The concentrated sunlight boils water in tubes, generating saturated and superheated solar steam that can be used in power generation and industrial steam applications, thereby generating electricity.

Such technology can be modulated according to power plant needs, from 50MW to 500MW (power) and from 10MW to 50MW (boosters and industrial steam). Thus, the technology can be applied in:

- standalone system, where the electricity produced by the steam generated from CSP is used to drive steam turbines;
- booster application, where solar steam generators increase the available steam for natural gas-fired and coal-fired power plants.

This solar steam enables power plants to increase electricity production at peak periods and reduce plant emissions. Moreover, this application can be exploited to extend plant life for biomass or geothermal facilities (Figure 1.3).

Figure 1.3 *Linear Fresnel Plant – Structure*



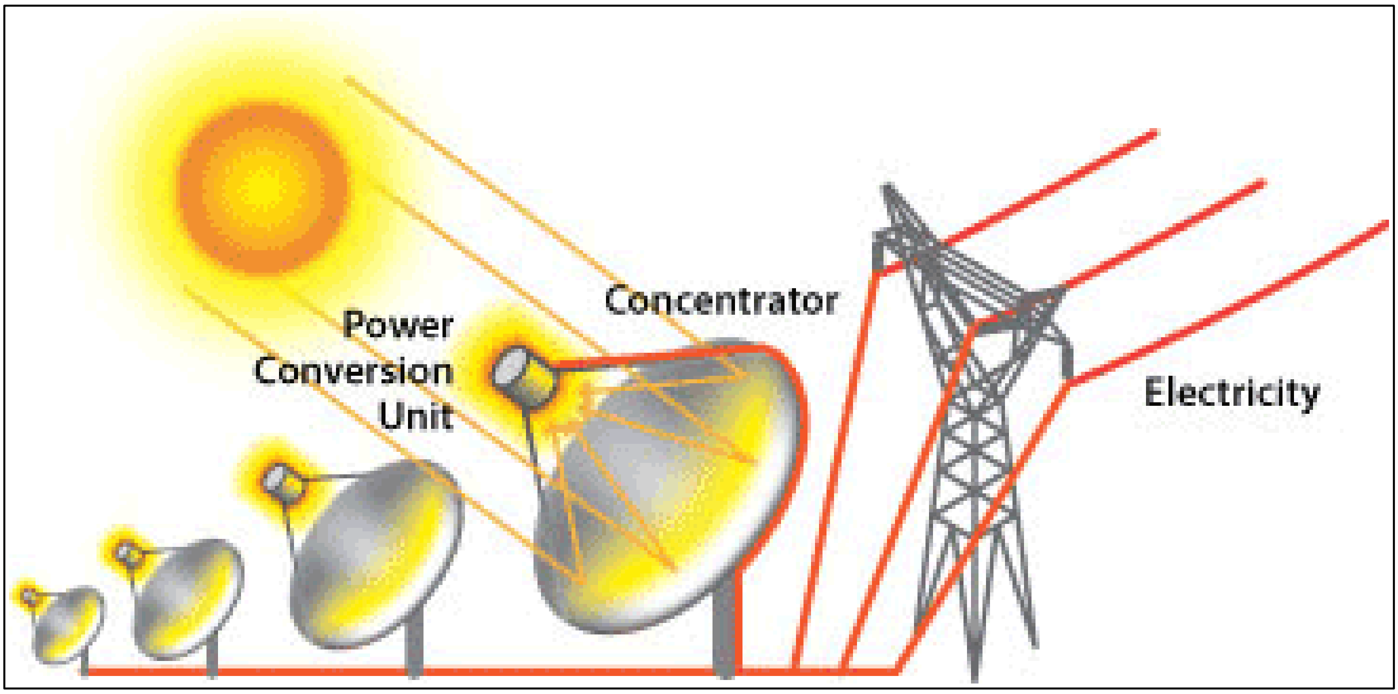
Source: *Energy.gov, "Energy Efficiency & Renewable Energy"*

1.1.4 Solar Dish/Engine Power Plant System

In the Dish/Engine systems, mirrored dishes collect and concentrate sunlight onto a receiver located at the focal point of the dish. Since it is able to track the sun across the sky, the system can capture the maximum amount of solar energy. The receiver is integrated into a high-efficiency "external" combustion engine thanks to thin tubes containing hydrogen or helium gas running along the outside of the engine's four piston cylinders and opening into the cylinders. As concentrated sunlight meets the receiver, it heats the gas in the tubes at very high temperatures, causing its expansion inside the cylinders. Through this process, the expanded gas drives pistons that turn a crankshaft which, in turn, drives an electric generator. The receiver, engine, and generator constitute a unique, integrated assembly located at the focus of the mirrored dish[4].

[4] Solar Energy Development Programmatic EIS, *Concentrating Solar Power Technologies*

Figure 1.4 *Solar Dish/Engine Plant – Structure*



Source*: Energy.gov, "Energy Efficiency & Renewable Energy"*

1.2 Comparing Heat Transfer Fluids: Molten Salts vs Oil

As we mentioned in the technique sheet (par 1.1.1), linear parabolic collectors usually operate using thermal oil as HTF. Given its chemical properties, this kind of fluid is environmentally dangerous, inflammable and it is not able to operate at temperatures above 400ºC: at higher temperatures, the components are subjected to a degradation process and they cannot be used anymore; therefore, the efficiency of the overall steam is reduced. Moreover, due to the aging process, diathermic oil must be replaced every year (even if in small amount) and this leads to a further cost implementation. Also, CSP plant based on the use of thermal oil as HTF, can only operate at daytime, with the availability of direct sunlight.

In order to manage these issues and to mitigate the intermittency of the solar source, intense R&D programs have brought to parabolic trough plant "with variant", introducing a heat storage system based on a mixture of molten salts (60% of sodium nitrate and 40% of potassium nitrate) to extend daily operating hours of CSP plants.

This new application of molten salts started in 2001 with the Italian nuclear physicist and Nobel prize winner Carlo Rubbia, who was at that time the ENEA's president[5]. He invested in an intensive R&D program on molten salt technology in Italy (deeper in next chapters), before moving to CIEMAT[6], in Spain. This is one of the main reason why Spain has been for a long time the world leader in the CSP Industry. Under the guide of

[5]ENEA: Italian National Agency for New Technologies, Energy and Sustainable Economic Development
[6]CIEMAT: Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Carlo Rubbia, ENEA, Consortium Solare XXI and Archimede Solar Energy, the Italian world leader in the production of solar receiver tubes for thermodynamic power plants with parabolic trough collectors, have started to focus on molten salts as an alternative fluid technology[7]. More specifically (deeper in next chapters), they invested in the development of several innovations (protected by patents) focused on improving the pipe's ability to absorb heat and the reflectivity of the parabolic mirrors to maximize the heat transfer to the fluid carrier.

Technically speaking, giving its chemical properties, the molten salts mixture, already widely used as fertilizer and available in large quantities at a lower cost, is able to provide the following advantages:

- it is not inflammable;
- it solidifies in contact with ground;
- it cannot be dispersed when collected;
- it is environmentally safe.

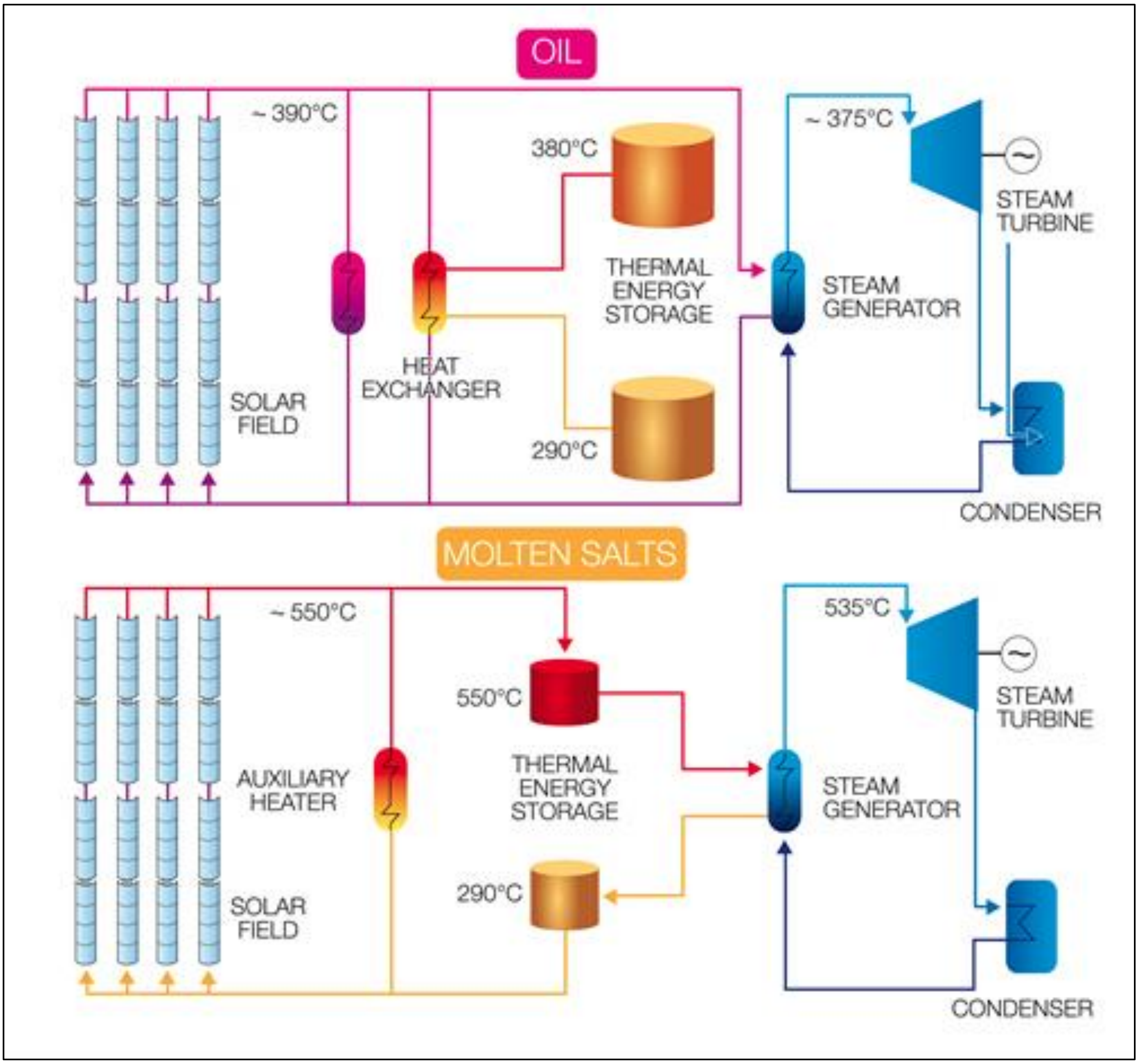
On the other hand, molten salts tend to solidify at around 240°C. It means that they could not be employed for the circulation in the receiver of a linear parabolic concentration system: in the long pipe system, the maximum temperature reachable is around 440ºC, too narrow margin to be sure to avoid the solidification risk. This is precisely the reason why another innovation effort has consisted in finding properly devices and operating procedures able to manage either this risk and the corrosion one given the high temperature reached and make it possible to use molten salts in wide pipe networks.

The advantage is that molten salts can be used either as heat storage and as HTF able to reach temperatures up to 550˚C. Thus, its thermal stability allows a higher power block efficiency. Additionally, its application as HTF can enable a new vision of plant configuration leading to savings at several levels:

- since molten salts are able to operate at higher temperature, the volume needed for the storage system could be reduced by 2/3 leading to, as a result, a size reduction of the storage tanks with an impact of 30% in cost reduction. These savings represent around a 20% plant cost decreasing compared with usual oil plants with storage;
- the higher operating temperature could increase the plant efficiency up to 6%;
- being used both for heat absorption and storage, molten salts allow a simplified design of a plant (avoiding the need for oil-to-salt heat exchange, the storage system’s heat exchanger becomes useless);
- compared to traditional plants, a smaller thermal storage could fully compensate the intermittency of the solar energy.
- Finally, unlike oil, molten salts are environmentally friendly, non-flammable, stable fluid and they not cause the degradation of receiving tubes (Figure 1.5).

[7] Archimede Solar Energy, *Molten Salt vs Oil*

Figure 1.5 *Molten salts vs. Oil*



Source: *Archimede Solar Energy*

1.3 Increasing CSP Plants Efficiency: The Energy Storage System

Renewable energy technologies exploit primary energy sources continuously replenished within natural planetary cycles on a human timescale (i.e. sun, biomass, sea waves). RES are also characterized by low (or null) GHG emissions and among all these resources, solar energy (together with wind) is the most widespread and abundant primary energy source.

However, most of RES are also uncontrollable, making unpredictable the electrical power generation coming from their utilization. It means that matching energy production with energy demand can be laborious. To manage this issue, an efficient energy system is needed to generate electrical power able to avoid shortages.
In this context, we can identify two main systems able to fill this gap:

- energy storage systems able to accumulate energy during lower demand or surplus production periods;
- hybrid power plants able to balance strengths and weaknesses of each technology using two or more primary energy sources.

If we think to combine both systems, it would be possible to control the energy supply while exploiting renewable sources as much as possible.
More specifically, dispatchability capabilities related to energy and ancillary services are strictly connected with the size of the so called Thermal Energy Storage (TES) systems, already at the commercial stage.
Applied to CSP technologies, TES can improve the performance of CSP systems making them able to delay electricity generation to subsequent days. Thus, an overall energy efficiency can be achieved with a growing annual capacity factor and a decreasing of operations and maintenance costs.
The added value of TES is its capacity to timing the electricity production to periods when high marginal cost units would typically be generating (i.e. periods where demand changes require start-up and operation of high ramp-rate fossil generators).
Consequently, CSP integrated with TES can either avoid the least efficient generators and avoid costly power plant starts. Together with the ability to guarantee the firmness of supply, these characteristics represent a potential advantage for CSP systems, especially in a scenario with an increasing need for energy reserves.

Given all these high innovative arrangements, it is evident that CSP has an inexhaustible energy source, proven technology performance and, most fundamental, it is environmentally safe. Thanks to its technology, CSP can significantly contribute to the world energy supply for the following several reasons:

- it is able to provide dispatchable power, helping the grid operator to reliably match supply and demand as well as to maintain the grid stability regulating the power production. Even if the added value of this capability is context-specific, it generally increases as the proportion of electricity generated by variable renewable sources increases;
- it can be easily integrated with thermos electric power stations so that the same thermal cycle and relating machinery can be used;
- it can be integrated in hybrid systems to better implement RES available;
- It can produce energy in remoted deserted areas that can be then moved to countries facing supply lack (given the water scarcity in desert regions, CSP technologies could be able to go one step forward by a dry cooling or CSP desalination cogeneration technologies).

With an implementation of CSP deployment program, the exploitation of this technology could strongly contribute to the reduction of global CO_2 emissions (by reaching a market volume of around 30 GW per year,

CSP technology could avoid the need for new fossil fuel power plants).
Moreover, given the CSP dispatchability capabilities, the system would enable a further reduction in emissions by allowing increased penetration of intermittent renewable energy technologies in a reliable and affordable way. Incorporating TES in CSP plants enables them to provide dispatchable electricity and to help achieving reliable operation of an electricity system as the proportion of electricity provided by variable renewable sources, such as wind and photovoltaics, increases. Finally, since this technology is suitable for hybridization, it is possible to site CSP plants in reduced irradiation zones hence far from arid or desert regions and closer to urban and agricultural areas.

The solar energy source is in fact characterized by daily intermittence due to the day and night cycles and periods with lower irradiation like wintertime or cloudy days. Therefore, the integration of TES systems and the use of a different renewable primary energy source like biomass able to boost the plant generation could provide the solution to the restrictions of solar energy. Consequently, better utilization of a solar resource, greater security of energy supply and reduced overall cost can be reached by hybrid CSP and biomass power plants equipped with TES.

2. CSP MARKET DEVELOPMENT

In the end of 2008 the annual market volume for CSP hit the equivalent of one billion US dollar mark. By the end of 2015, the sector concluded nearly a decade of strong growth. Whilst the installed capacity of CSP in 2006 was only 0.5 GW, it has increased by a factor of 10 to almost 5 GW today.

The CSP sector is now on a steady development pathway towards double digit GW capacity within the next 5 years, establishing a solid base for future growth. Especially for the firm supply of dispatchable power, for water purification and desalination purposes and for industrial process heat needs, CSP technologies are in high demand and offer specific technical advantages.

We are delighted to see CSP on a solid growth pathway and poised to establish itself as a third big player in the new “sustainable power generation industry”. With the potential for cost curves to decline significantly, CSP has the potential to become economically viable in sunny regions across the world. To be more concrete, in the last 10 years, CSP has expanded rapidly becoming a reliable energy generation solution: to date, CSP counts for about 5% of the global investment in energy infrastructure (of €158-186 billion invested each year), showing its contributive potential to a “New Green Deal” for the economy.

With advanced industry development and high levels of energy efficiency, it has also been estimated that it could meet up to 6% of the world’s power needs by 2030 and up to 12% of the world’s projected power needs in 2050, providing approximately 4.500 TWh[8].

New projects mostly located in South Africa, India, Middle East and Morocco are planned to be able to add at least 300 MW. Additionally, as electricity cannot be stored in the grid, power generation must be necessarily equal to or following the demand curve of consumption and there are several ways to achieve flexibility in the system such as: storage of surplus energy, demand-side management, interconnection with neighboring systems and dispatchability of the generation units.

According to the International Energy Agency (IEA) technology Roadmap, CSP will be the largest source of electricity in the Sunbelt countries, especially in the Middle East and in Africa. Additionally, the joint Report “STE’s Global outlook 2016” published by Estela, Greenpeace and SolarPaces concluded that CSP is the key to achieve a 100% renewable share by 2050 in a wise mix with other renewables.

2.1 CSP Industry: Worldwide Overview

2015 represented a challenging year for CSP technology due to the market deceleration after a global operating capacity increasing from 420 MW to around 4.8 GW at the end of the year. At the beginning of 2016, new projects were under construction and new plants are expected to become operative in 2017.

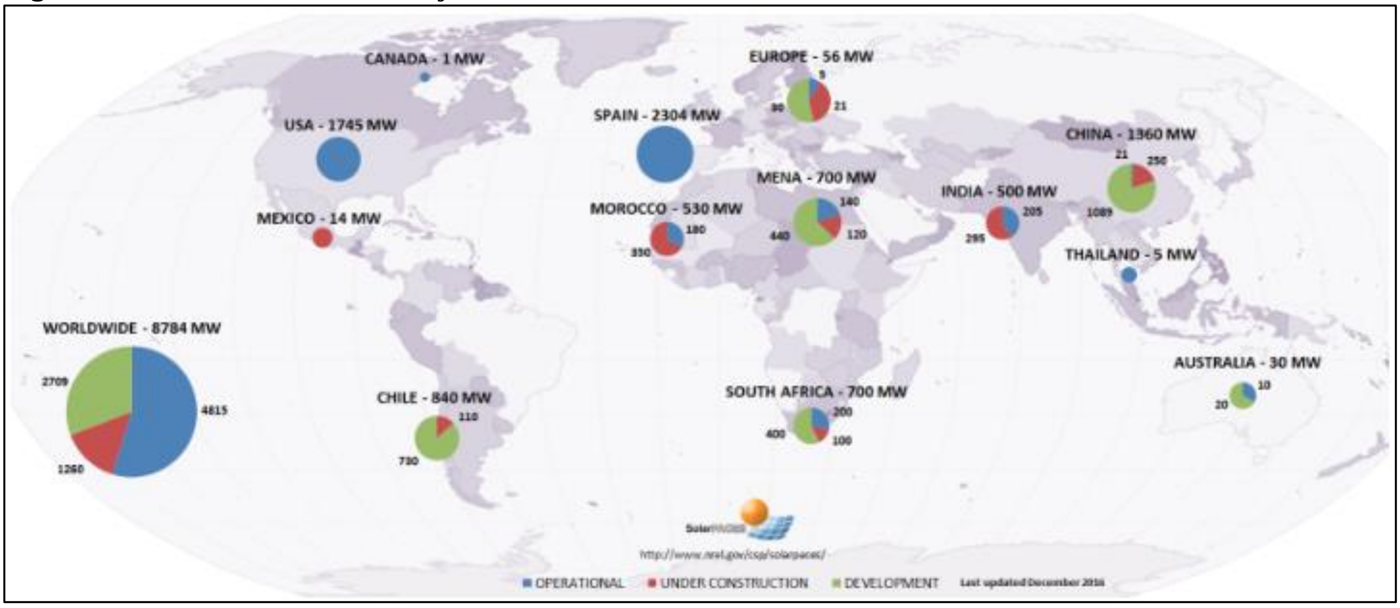
From 2015, the market has started to expand beyond Spain and US (which still cover around 90% of CSP

[8] Green Peace, Estela, Solar Paces. *Global Outlook 2016.*

global installed capacity). In fact, by the end of the year, new facilities came up in Australia, Chile, China, India, Israel, Mexico, Saudi Arabia and South Africa. More specifically, Morocco and South Africa have passed the US in added capacity and Morocco has become the first developing country to top the global CSP market (Figure 2.1).

Nowadays, CSP market is "technologically" balanced between parabolic trough and tower systems, while Fresnel and parabolic dish/engine systems are less diffused. Additionally, starting from 2015, all new CSP systems are projected to incorporate TES capacity to increase the flexibility and the dispatchability of the plants.

Figure 2.1 *Worldwide CSP Projects*



Source: *SolarPaces*

Going deeper, in 2015, South Africa operated its first commercial CSP system, with the 100 MW KaXu Solar One facility and the 50 MW Bokpoort facility. In 2016 an added 50 MW brought its total installed capacity to 200 MW.

The US followed with the added 110 MW of Crescent Dunes facility at the end of 2015, having already more than 1.7 GW in operation. However, no other additional CSP facility was programmed to be built in 2016, due to the fact that funding moved to the PV growing market and to the gas sector (due to its lower price).

Spain is still the global leader in CSP installed capacity (2.3 GW) even if no other new CSP facility was installed/developed/planned neither in 2015 nor in 2016.

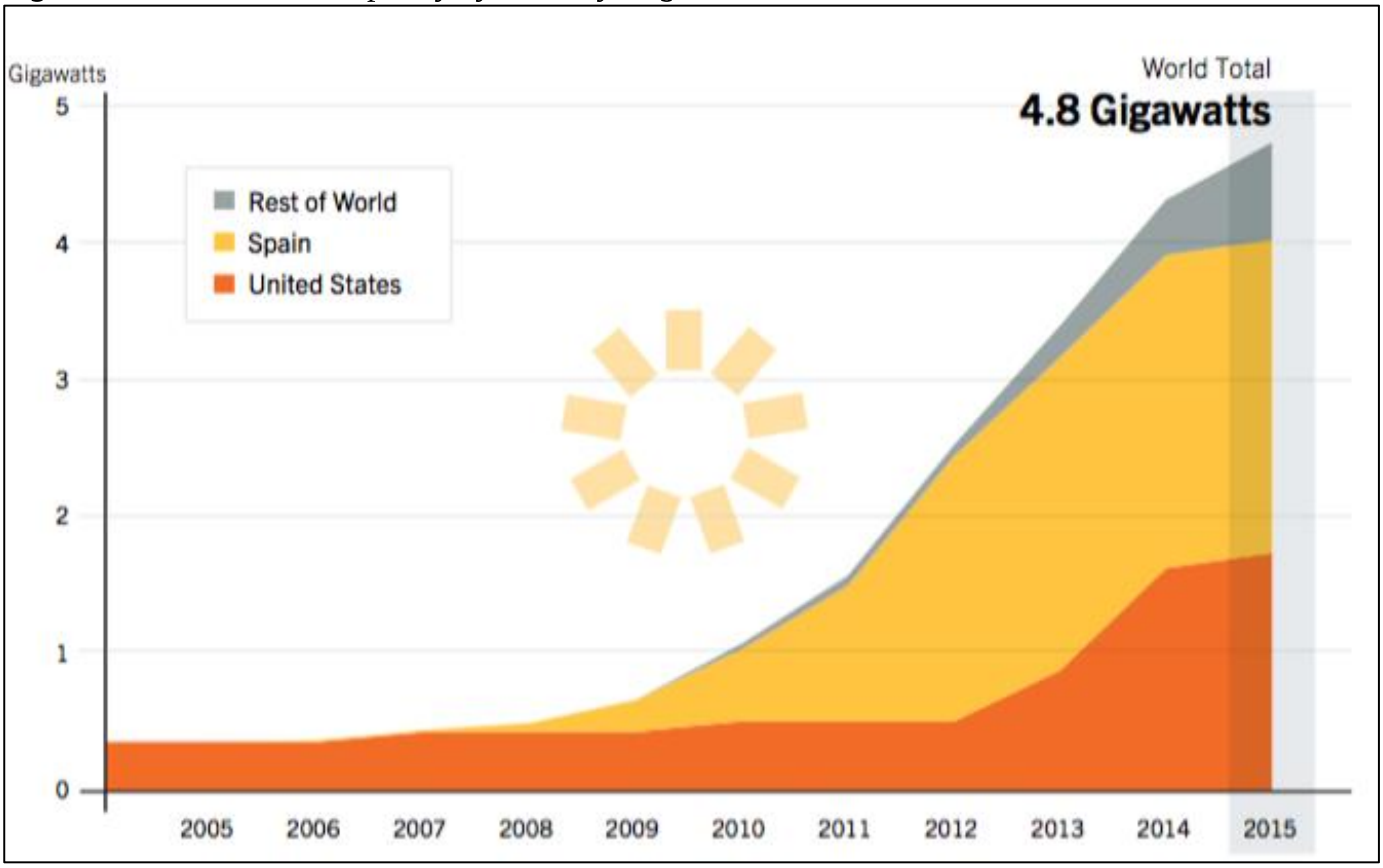
Morocco brought the 160 MW Noor I plant online. Noor I is part of the 500 MW multi-stage Noor-Ouarzazate CSP complex, which is expected to be fully operational by 2018.

Regarding the North African market, CSP installations are planned to grow in other countries of the region. More specifically, at the beginning of 2016, Egypt announced 14 prequalified bidders (including numerous MENA based developers) for a 50 MW facility. In 2015, Algeria announced the aim to develop CSP installation up to 2 GW by 2030.

The Chinese CSP target is to install from 5 to 10 GW by 2020 achievable through a strong R&D and development programs.

In Latin America, CSP/PV hybrid plant installation (incorporating 100 MW) has been a starting point for the CSP technology development especially in Chile[9].

Figure 2.2 *CSP Global Capacity by Country/Region, 2005-2015*



Source: *REN21, Renewables 2016, Global Status Report.*

Thus, it is evident that developing markets represent a huge potential for CSP development. Additionally, given its characteristics, CSP is receiving increased policy support in countries with limited oil and gas reserves, constrained power networks, or strong industrialization and job creation programs.

We can understand the increased installed capacity in new emerging markets if we consider the stagnation of the Spanish one, as well as the slowdown of the US one. In fact, to manage these issues, CSP players started to create new partnership and to invest in new potential markets. Among these players, we can identify as construction, operation and/or manufacturing leader companies the following: Abengoa and Saudia Arabia's ACWA Power, Rioglass Solar (Belgium), Acciona, ACS Cobra (Spain), Sener and TSK (Spain), Brightsource (US), GE (US) and Solar Reserve (US).

Nowadays, developers are focusing on investing in plants with installed capacity up to 100 MW. Additionally, as we said before, almost all new CSP plants are being developed with TES systems leading to an increasing

[9] REN2. *Renewables 2016, Global Status Report.*

of the global storage capacity. In this context, the US Crescent Dunes facility represented a major step forward: with 10 hours of storage, the plant is able to generate power at any time for half of the year. Finally, after the installation of the first 160 MW CSP plant (Noor I), Morocco is implementing a 200 MW CSP Parabolic Trough plant (Noor II) and in its third phase (Noor III) the aim is to finance the construction of a 150 MW CSP plant with TES (Figure 2.3). This innovative facility is going to be the one of the pioneers in using this technology and it will be the first equipped with a dry cooling system. It is also a first reference project for the vision of producing solar power in the desert regions in the Middle East and North Africa (MENA) on a large scale basis. A photovoltaic plant of a capacity between 50 and 70 MW (Noor IV) on the same site will complete the complex, to be finished by 2016[10].

Figura 2.3 *Noor II CSP Plant (Morocco)*

Source: *LesEco.ma*

2.2 How to evaluate the CSP Market: a Comparative System Approach

According to the current policies, the market will only be triggered by low costs and/or self-consumption strategies (mostly at the distribution level and in many cases without consideration of the abundancy of the respective resource across Europe and World). One of the main misleading issue in evaluating the renewable energy market (especially if we are going to focus on the CSP one) is that the usual key metric for the cost evaluation is the Levelized Cost of Energy (LCOE).

[10] European Commission, International Cooperation and Development. *Noor III: Tower Plant of the Ouarzazate Solar Complex*

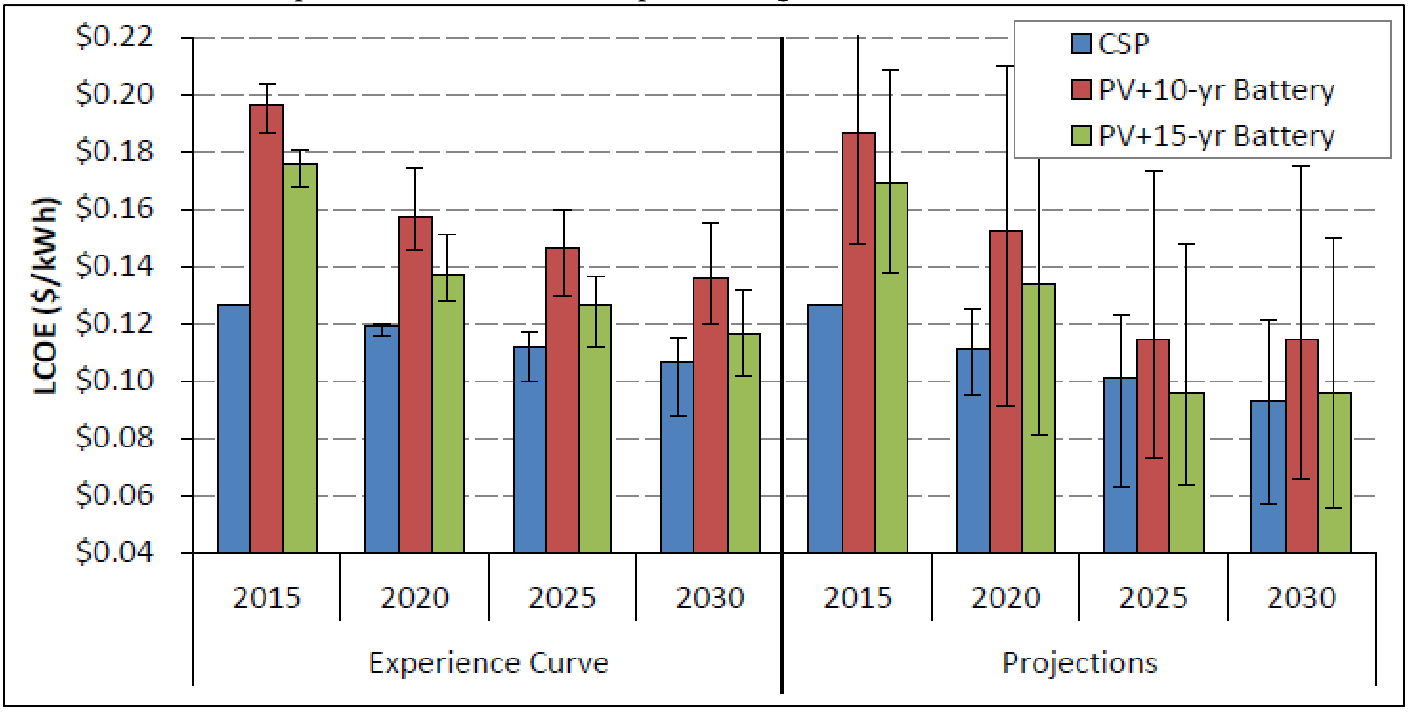
The LCOE metric is not built on the distinction between Value and Cost connected to RES. It means that it does not address the value of flexibility enabling a responsive behavior of plants to the demand, capacity availability, grid stability, energy security, local economic impact as well as the effects on job creation and the impact on trade balance.

Thus, since it is mainly built on pure-cost based auctions, it is not supportive to a far-reaching energy policy-making leading system, planning decisions and support schemes.

What we would need is a system approach able to emphasize the value added to the system related to the capabilities of CSP technologies. According to this approach, the value can be either expressed in operational terms (time-of-day effective operation hours, impact on spinning capacity reserve contribution to ancillary services, induced generation curtailment, etc.) and in terms of added capacity (investments avoided to cover demand in all timeframes on top of the investment of the new plant itself).

If we integrate the system approach with a comparative one, we can estimate and understand the value of CSP technology in relation with other RES such as PV and Wind (Table 2.1).

***Table 2.1** LCOE comparison: CSP versus PV plus storage, 2015–2030*



***Source**: NREL report - Exploring the Potential Competitiveness of Utility-Scale Photovoltaics plus Batteries with Concentrating Solar Power, 2015–2030*

CSP has reached now the cost of 14 c€/kWh with only 5 GW installed capacity in sunny countries while Onshore wind and PV have reached already competitive cost levels: about 6 c€/kWh, with 400 GW of onshore wind and 200 GW of PV installed worldwide[11].

However, when both wind and PV technologies had the same power installed CSP as of today, their c€/kWh were much higher that CSP has today.

[11] Green Peace, Estela, Solar Paces. *Global Outlook 2016.*

Therefore, we can derive that, consequently, at a given corresponding market volume, when we consider the electricity generation costs in its full dimension, what matters should be mainly what we intend for Value: the hidden benefits brought to a system by a given project (instead of considering only the project cost).

This is a relevant evidence of the fact that, in evaluating the CSP system, we should consider the storage flexibility that can be exploited by CSP technologies.

The value can be expressed either as an Operational Value and as a Capacity Value:

- operational value represents the avoided costs of conventional generation at their respective dispatching times along with related ancillary services costs, such as operating reserve requirements. Savings on emission costs are also accounted. Apart from this, another potential value is firm capacity;
- capacity value reflects the ability to avoid the costs of building new conventional generation in response to growing energy demands or plant retirements.[12]

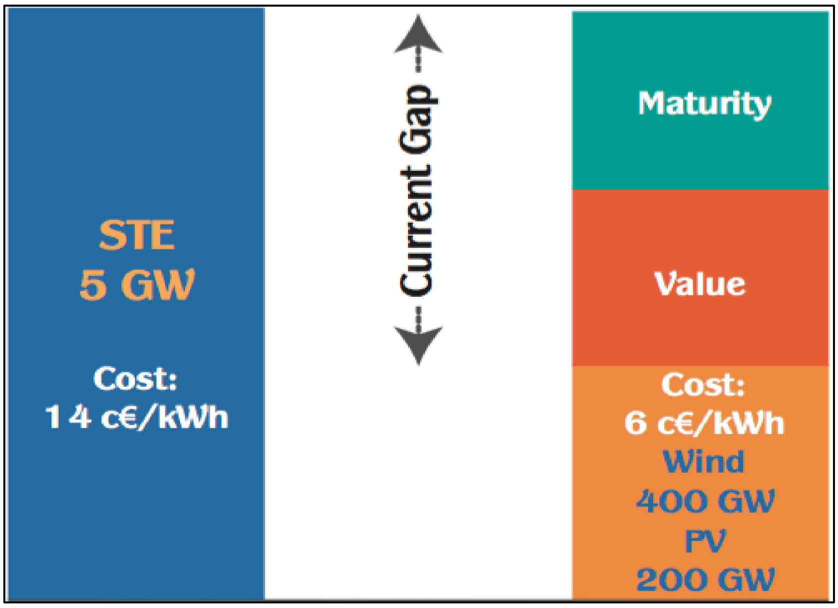
Therefore, this "added-value to the system" can vary depending on the ease for its assessment in the respective countries electrical system:

- countries that are working on double their installed capacities in the next decade will highly value the dispatchability requirement;
- on the other hand, industrialized countries in which an increasing number of old nuclear or coal plants will need to be decommissioned, might be concerned in the dispatchable technology as well.

This comment is a first step to demonstrate that the current price gap between CSP plants and Wind or PV plants could be partially reconsidered and consequently reduced if analyzed in a value-to-the-system perspective. Moreover, the remained gap would be automatically compensated by the growing maturity of CSP market: CSP technologies would not even need to reach the same level of current wind or PV installed capacity to demonstrate its full competitiveness and this is an additional proof of how both the Cost/kW and Cost/kWh are not the best ratios to evaluate its potential (Figure 2.4).

[12] Green Peace, Estela, Solar Paces. *Global Outlook 2016.*

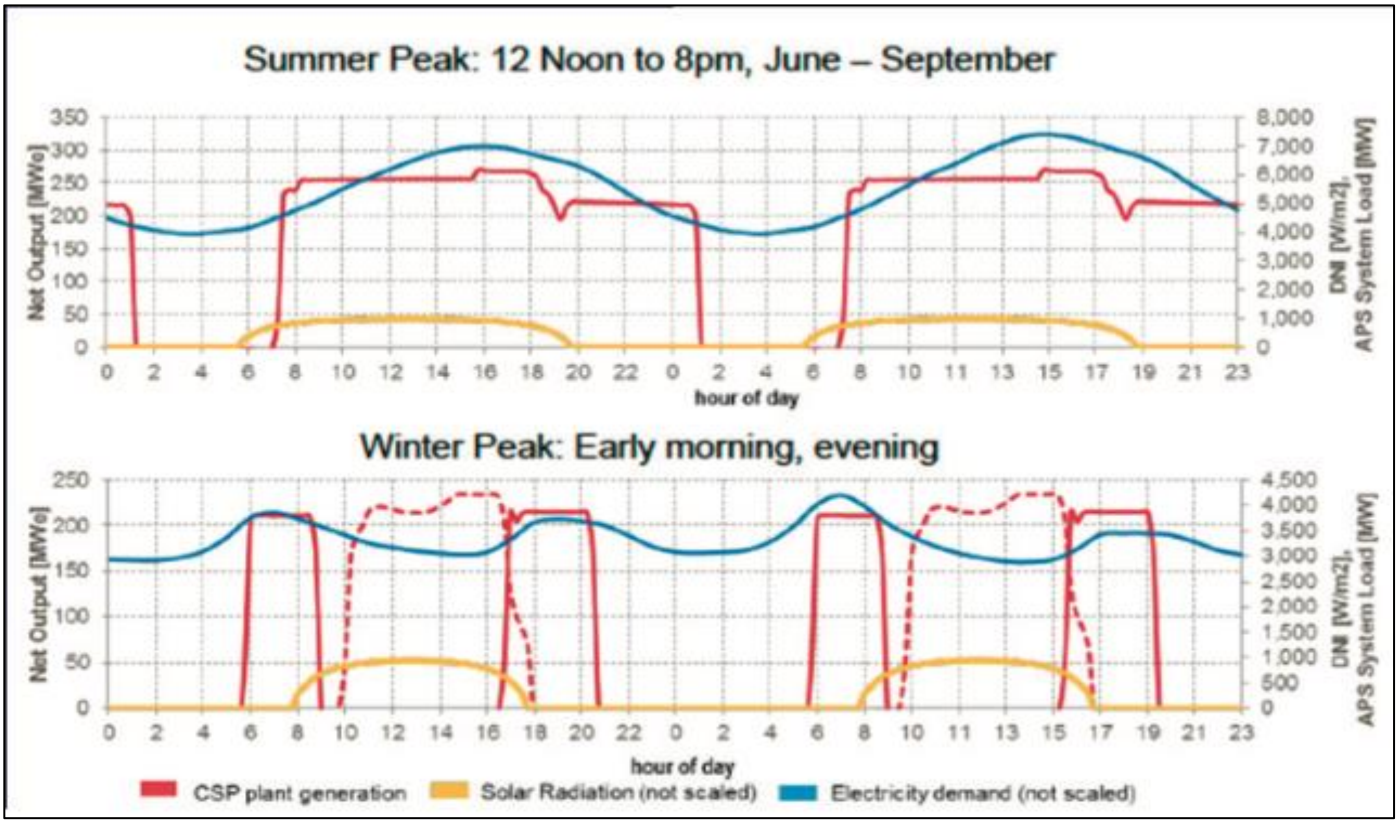
__Figure 2.4__ Current Cost Gap between CSP and Wind & PV



***Source**: Estela, Stela World. The Value of Solar Thermal Electricity. Cost vs Value Approach.*

Thus, we can state that the value of CSP system is far beyond its generation costs. About the added value, we can observe for example how the Solana plant in Arizona is able to meet the demand providing electricity through dispatchability capabilities and, consequently, face the intermittency of the solar energy source (Figure 2.5).

__Figure 2.5__ CSP flexibility: Dispatching Power when most needed



***Source:** Abengoa Solar*

So, we can affirm that CSP plants is able to cover a wide range of needs:

- peaker: with 2-3 hours of storage – designed to quickly provide power (or decrease power) to the grid as needed to balance the intermittency of PV and wind;
- Intermediate: with 5-8 hours of storage – designed to provide power in the early morning and evening as well as during some periods of the day;
- Baseload: with 10-17 hours of storage – designed to provide power 24 h/day.

Thus, CSP can provide firm and dispatchable electricity whenever is needed while PV electricity generation operates better in the middle of the day.

So, we can conclude that, CSP and PV systems can be considered as two complementary technologies: the CSP value could increase as PV could further deploy to be able to exploit early morning/mid-day peaks and beef-up evening.

PV is growing faster, it is a simpler system and apparently costless, but it is not dispatchable and CSP represents a way to deliver power over long hours after daylight.

2.3 Cost Drivers in Implementing CSP Technologies

The next step of our analysis is go deeper in the CSP technology potential evaluating cost factors.

Therefore, before starting, we should remark that, in many countries and regions, electricity is completely or even partially acquired through competitive markets and that nowadays, electricity market is able to offer revenue opportunities for flexible energy systems either by buying and selling energy and by providing ancillary services.

Moreover, given the fact that the electricity price is over time strongly subjected to fluctuation due to the intermittency of RES, the market provides additional incentive for the energy storage.

Focusing on solar power, around half of the generating costs are expected to come from technology developments and the other half from economies of scale and volume production. Also, prices tend to be lower in the early morning and higher in the late afternoon/evening but, through an effective storage system, it could be possible to collect energy at lower prices that can be (re)sell later (energy arbitrage or time-shifting).

It basically means that CSP operations and economics are impacted from at least two significant sources of uncertainty: market prices and solar irradiation, which, as a result impact on profitability.

From a system perspective, CSP system is able to offer significant advantages over PV and Wind especially due to its capability to provide a high reliable system capacity. Starting from this added value, it is possible to identify which are the main cost drivers in implementing a CSP plant.

Since intermittent renewable plants are not usually able to provide firmness-of-supply, we have to consider a cost for additional conventional power needs due to the necessity to integrate intermittent renewable generation sources into grid operation.

Additionally, interconnection costs must be sustained due to any transmission infrastructure and operational measures by Transmission System Operators (TSO) needed to inject the intermittent renewable energy into the high-voltage grids. Such operational measures include capacity allocation on transmission lines and any re-dispatching measures depending on whether a plant can provide ancillary services (e.g. regulation, spinning/non-spinning reserves, and fast ramping up or down) or not.

If we focus on the time-varying price of electricity provided from the energy market and if we consider the impact of the energy storage, the latter would increase the capital costs but, in the meanwhile, it would be able to increase revenues. Additionally, in several cases, revenues increase greatly far more than the cost increases and can be resulted in shorter pay-back periods.

Due to their capabilities, CSP systems may exploit this flexibility asset by transacting energy services on multiple timescales, resulting in a diverse stream of revenues.

More practically it means that the integration of a TES system (better if hybridized with a biomass boiler) could bring the final cost of electricity produced by CSP to 17.36 c€/kWh.

In fact, as reported in a research conducted by the US National Renewable Energy Laboratory (NREL) on California power markets, the main value added of CSP operating with TES is related to its ability to provide

firmness-of-supply. This value is far greater where the penetration of variable renewables is high, or where there is a shortage of baseload capacity. Additionally, CSP with storage has a higher marginal operational value than PV and the relative value may increase slightly with increased PV penetration.
More specifically, the study concluded that, if the aim it to reach a 33%-penetration of renewable energy in California, it is economically equivalent to pay 5 US$ cents/kWh for a new PV plant and 10 US$ cents/kWh for a CSP plant with storage (Table 2.1).

Table 2.2 *The Value of Utility-Scale Solar Technologies in California under two different scenarios.*

Value Component	33% Renewables		40% Renewables	
	STE with Storage Value (USD/MWh)	PV Value (USD/MWh)	STE with Storage Value (USD/MWh)	PV Value (USD/MWh)
Operational	46.6	31.9	46.2	29.8
Capacity	47.9-60.8	15.2-26.3	49.8-63.1	2.4-17.6
Total	94.6-107	47.1-58.2	96.0-109	32.2-47.4

Source: *NREL/TP-6A20-61695, Jorgenson, J., P. Denholm and M. Mehos, 2014 May. Estimating the Value of Utility-Scale Solar Technologies in California under a 40% Renewable Portfolio Standard.*

Again, CSP is a potential technology able to contribute as a third big player in the Green Economy and to implement its cost reduction, a solid deployment program would be needed: strong political decisions could make the difference by establishing a "positive investment environment" based on preferential financing conditions and/or tax investments incentives.

2.4 Policy Framework for a Positive Investment Environment

As we underlined before, nowadays the mix of energy use is at its turning point: it is shifting from conventional fuel sources to renewable energy sources. In 2015, both Wind and PV accounted for 73% of new energy installed capacity, overtaking the conventional power sources, such as fuel oil and coal whose capacity is more decommissioned than installed.
Given the peculiarities of CSP systems, in the last ten years, some national government decisions have boosted CSP, triggering a huge growth in worldwide installations. More specifically, the measure needed to make solar thermal electricity work are:

- financial incentives and national targets: such as a guaranteed sale price for electricity, feed-in-tariffs, renewable portfolio standards or preferential loan programs that apply to solar thermal electricity technologies as well as schemes that put a price on carbon emissions either through cap-and-trade systems or carbon taxes;
- installation of new electricity transfer facilities and market mechanisms between nations and continents through the appropriate infrastructure and political and economic arrangements, so that solar thermal

energy can be moved from the best production sites to areas of high demand;

- Stable, long-term support for research and development to fully exploit the potential for further technology improvements and cost reduction.

Thus, a solid deployment program is needed: strong political decisions could make the difference by the establishment of a "positive investment environment" based on preferential financing conditions and/or tax investments incentives.

Therefore, this could bring to market innovative solutions that will either further reduce costs and increase business opportunities beyond the electricity sector in countries deciding to invest in these technologies. Finally, more benefits can also arise, such as impacting cost reductions due to the location of the plant that can reduce the need for new infrastructure, impacting transmission congestion or the availability of utilities using any surplus capacity for its auxiliary services.

Focusing on the European context, one of the European Industry long term goal is to maintain the global leadership in CSP sector, by achieving significant cost reduction of existing technologies in the short term and working towards the development of the next generation technologies in the longer therm.

More specifically, the agreed strategic targets have been set as follows:

- short term: > 40% cost reduction by 2020 (from 2013) translating into a supply price of < 10 c€/kWh for a radiation of 2050 kWh/m2/year (conditions in Southern Europe).
- longer term: develop the next generation of CSP/STE technology. New cycles (including supercritical ones) with a first demonstrator by 2020, with the aim of achieving additional cost reductions and opening new business opportunities. [13]

The achievement of the targets will be the result of either technological advance and non-technological factors such as economies of scale (resulting from an increase in installed capacity), risk finance for first-of-kind commercial-scale projects (to compensate for the costs of the initially higher commercial risk), the ability to take full advantage of the European “Single Market”, regulation, standardization, skills, etc.

Thus, Europe must lead the development of the next generation of renewable technologies and integrate the energy produced from RES into the energy system in an efficient and cost-effective way.

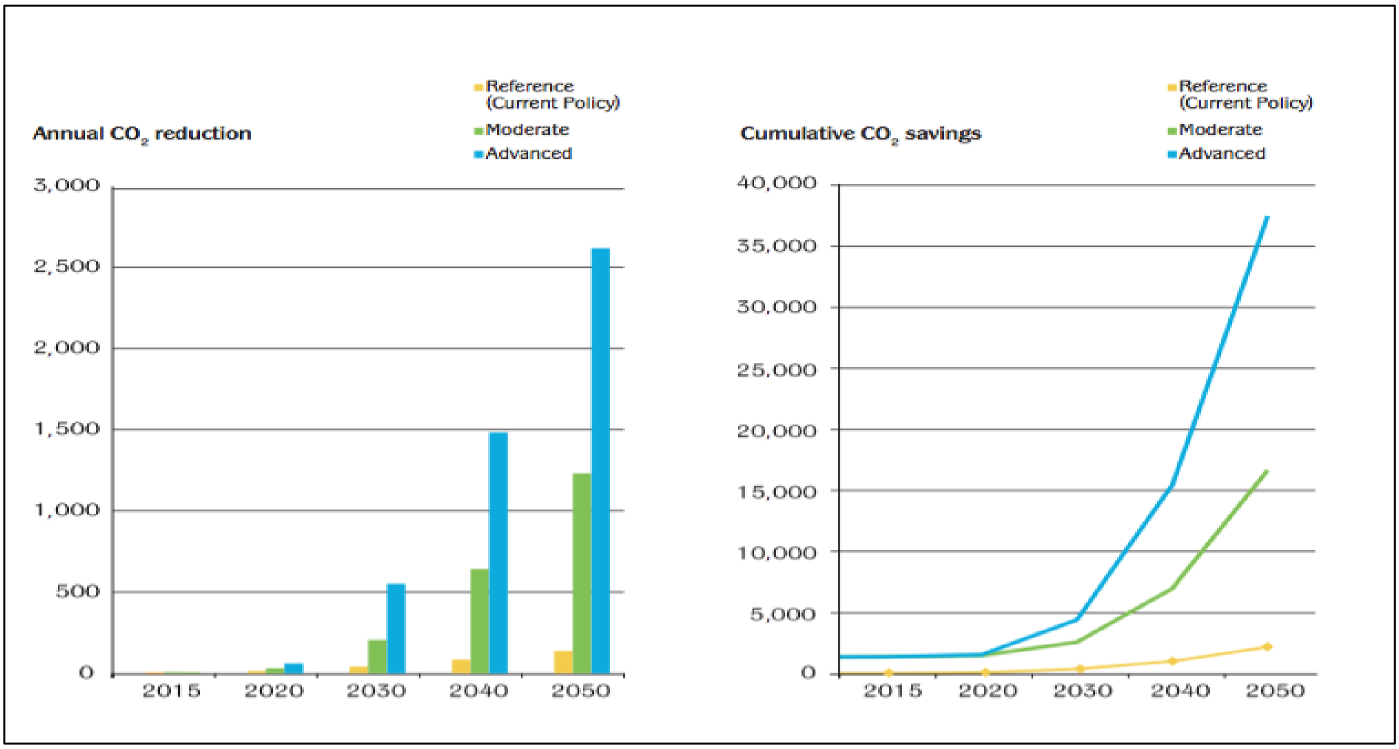
This is the reason why, since 2007, Europe has taken a strategic approach to innovation and has identified priorities that have been delivered through the Strategic Energy Technology Plan (SET Plan). In September 2015, the SET Plan Communication translated the Energy Union Research, Innovation and Competitiveness priorities into 10 Actions[14]. The aim of these targets is to accelerate the decarbonization of the energy systems by making technologies cost-effective and better-performing.

R&I targets have been set for five renewable technologies with great potential for cost-reductions, performance improvements and large-scale deployment worldwide: off shore wind, the next generation of photovoltaics, concentrated solar power, deep geothermal and ocean.

[13] Key Actions 1 & 2: Concentrating Solar Power/Solar Thermal Electricity (CSP/STE)
[14] The integrated Strategic Technology Plan

More specifically, CSP targets focus on innovation to allow for drastic cost reductions as well as delivery of the next generation of these technologies through performance increase and thermal storage capacity improvement.
Geographically speaking, although Europe is not the best place for CSP plants, it is estimated that CSP would deploy up to 35 GW in Europe by 2030 under an aggressive deployment policy.
To achieve this, the European energy mix should include a certain share of dispatchable renewable generation technologies. Therefore, regarding CSP, contributing a 0.5% share to the EU energy mix, further support and deployment is needed in order to bring the estimated scenarios to life.
Additionally, a strong and positive policy development program is also needed because CSP can not only deliver affordable clean energy, but also create local jobs at various levels such as local / international Engineering, Procurement and Construction (EPC) contractors; strong share of components and equipment and few highly skilled workers. Ernst & Young also emphasized that incentives in CSP industry will be also the key to create a local industry in Middle East and North Africa (MENA) region.
The reported experiences on the Noor plants in Morocco and on the ongoing plants in South Africa confirmed the high expectations on the macroeconomic impacts on developing countries economies.
Going deeper, according to the study conducted by Green Peace with Estela and Solar Paces, the results obtained by assuming an “Advanced Scenario” show that CSP could provide approximately 4500 TWh of solar thermal electricity by 2050, delivering up to 12% of the world’s electricity needs by 2050 and, additionally, when only Sunbelt countries are considered, CSP would save 1.2 billion tons of CO_2 annually by 2050 (Figure 2.6).

Figure 2.6 *Annual and Cumulative CO_2 savings from CSP Scenarios*



Source: *Green Peace, Estela, Solar Paces. Global Outlook 2016.*

So, we can conclude that, in case a future market design would fall short of changing its rationale compared to the current one, it will be up to regulators and system planners to duly assess the value rather than just using the pure marginal cost approach, to make the energy model transition sustainable, efficient and also affordable. We also underlined how CSP coupled with thermal energy storage could improve both economics and technical performance of the system:

- less fossil fuels used for shifting solar power to high-value evening hours;
- significant system cost savings for system control and load-following;
- less variability in power system;
- hedging against solar forecast errors;

Additionally, we were able to extrapolate the added value that CSP installations could provide to the new Green economy:

- CSP dispatchability potential would enable a further reduction in emissions by allowing increased penetration of intermittent renewable energy technologies in a reliable and affordable way;
- CSP would be able to meet both peak and baseload demand and to offer specific technical advantages in terms of water purification and desalination purposes;
- CSP industry would be able to boosting local economies, employing as many as 2.7 million people whose job will be to take up a new role in fighting climate change;
- CSP could create over €16 billion investment in 2020 peaking at €162 billion in 2050;
- CSP could save 32 million tons of CO_2 annually in 2020 and rising to 1.2 billion tons in 2050 (Table 2.3).

Table 2.3 *Market Projections for CSP development between 2015 and 2050 under Reference, Moderate and Advanced Scenarios*

		2015	2020	2030	2040	2050
Investment and employment						
Reference (Current Policy)						
Annual Installation	MW/a	1,171	3,619	5,651	9,500	12,427
Cost	€/kW	4,287	3,485	2,814	2,688	2,674
Investment	€bn/a	1.57	1.34	2.15	4.60	4.53
Employment Job-year		18,904	16,981	29,180	62,545	70,197
Moderate STE Market growth						
Annual Installation	MW/a	1,075	4,834	18,876	36,652	61,654
Cost	€/kW	4,287	3,485	2,814	2,666	2,637
Investment	€bn/a	4.61	16.85	53.13	97.71	162.61
Employment Job-year		16,964	70,051	269,733	574,049	935,995
Advanced STE Market Growth						
Annual Installation	MW/a	797	11,950	49,758	75,455	131,143
Cost	€/kW	4,287	3,485	2,814	2,663	2,577
Investment	€bn/a	3.42	41.65	140.04	169.10	209.76
Employment Job-year		12,985	169,237	712,674	1,072,328	1,443,265

Source: *Green Peace, Estela, Solar Paces. Global Outlook 2016.*

3. INTELLECTUAL PROPERTY RIGHTS AND THE GREEN ECONOMY

Intellectual Property (IP) is central to business and R&D strategies due to fact that its policy sits at the crossroads between technology, marketing and finance. This in one of the main reasons why companies, associations and other market players are always more often using IP to achieve their goals and to try to maintain a leading edge. The new Green Economy is also impacting Climate Change Mitigation Technologies (CCMT) focus on controlling, reducing or preventing the anthropogenic GHG emissions, as covered by the Kyoto Protocol.

This chapter is going to focus on how, in order to help engineers, scientists, institutions and decision-makers use this wealth of knowledge in their work, the European Patent Office (EPO) has developed a dedicated document tagging scheme. The new scheme enables users to find these green technologies in its databases. More specifically, the tagging scheme incorporates both CCMTs and smart grids.

The scheme was devised in close co-operation with expert partners in the field, using technological guidelines produced by the United Nations Framework Convention on Climate Change (UNFCC) and the Intergovernmental Panel on Climate Change (IPCC). The new scheme makes it easier to retrieve relevant information quickly and accurately. It also makes possible to map sustainable technologies, identify trends and facilitate further R&D.

Of the over 90 million patent documents available in the European Patent Office's databases, nowadays over three million are related to CCMT.

3.1 Patents: Public Documents providing a wealth of useful Information

Among the Intellectual Property Rights (IPRs) environment, we are going to focus on Patents. Their statistical properties are determined by their legal characteristics and by their economic implementation. First, a patent is a legal title protecting an invention. More specifically:

"A Patent shall confer on its owner the following exclusive rights:

- where the subject matter of a patent is a product, to prevent third parties not having the owner's consent from the act of: making, using, offering for sale, selling, or importing for these purposes that product;
- where the subject matter of a patent is a process, to prevent third parties not having the owner's consent from the act of using the process, and from the acts of: using, offering for sale, selling, or importing for these purposes at least the product obtained directly by that process.

Patent owners shall also have the right to assign, or transfer by succession, the patent and to conclude licensing contract".[15]

[15] Article 28 of the Trade-Related Intellectual Property Rights [TRIPS] Agreement

And more: “The legal protection conferred by a patent gives its owner the right to exclude others from making, using, selling, offering for sale or importing the patented invention for the term of the patent, which is usually 20 years from the filing date, and in the country/countries concerned by the protection. This set of rights provides the patentee with a competitive advantage. Patents can also be licensed or used to help create or finance a spin-off company. It is therefore possible to derive value from them even if their owner does not have its own manufacturing capability (e.g. universities)[16].”

Patents are obtained after following specific administrative procedures: the inventor has to file an application at a patent office which checks whether the invention fulfils the relevant legal criteria so that the application can be granted or rejected.

Moreover, according to the business strategy preferred, an inventor can choose among different alternative routes to protect its potential competitive advantage: National Route, International Route and Regional Route.

- National route: file an application with a national patent office (generally the national office of the applicant’s country). The first application field worldwide (in any patent office) for a given invention is known as the priority application, to which is associated a priority date. The application is generally published 18 months after is filed (publication date). The time lag between filing and grant or refusal of patents is not fixed; it ranges from two to eight years, with significant differences across patent offices.
- International route: Applicants who wish to protect their invention in more than one country have 12 months form their priority date to file applications in other Convention Countries, and if they do so the protection will apply from the priority date onwards n the countries concerned. PCT route (Patent Cooperation Treaty) procedure, in force since 1978 and is administered by the World Intellectual Property Organization (WIPO), makes it possible to delay national or regional procedures significantly (until the end of the thirtieth month from the priority date) through a unified filing procedure.
- Regional route: Applicants can also submit a patent application to a regional office[17].

Additionally, national patent laws have to comply with international standards, (laid down in the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), an international treaty which is part of the World Trade Organizations (WTO) package signed in 1994).

Then a patent can be challenged by third-parties after it is granted by the Administrative Authorities. This is also possible through the legal system (a national process): in this case, the patent holder has to enforce the disputed patent, alleging third-parties infringement[18].

Thus, patent data are able to provide unique insights about processes and outcomes of inventive activities as well as they can be defined as a complementary source of Science and Technology (S&T) data.

More specifically, patent analysis is a key factor to focus on peculiar innovation dimensions that can be relevant in defining policy framework approaches, entrepreneurship management as well as S&T monitoring.

[16] OECD Patent Statistic Manual
[17] OECD Patent Statistic Manual
[18] WIPO, *Field of Intellectual Property Protection*

Patents represent a mean of protecting inventions developed by firms, institutions or individuals and they can also be defined as a reliable indicator to measure and analyze the invention and innovation field.
In fact, before an invention is able to become an innovation, it has to be developed, manufactured and it has to be potentially marketable.
All these efforts represent information that are able to be collected by patent documents and databases.
Patents are designed to protect inventions and, given the information collected by patent databases, the data statistical exploitation can offer unique perspective of the invention process.
More specifically, patents provide information regarding technological content of the inventions as well as the geographical location of the inventive process. Since the owners and the inventors must be identified in the patent documents, it is also possible to extrapolate the underlying research process if matched with complementary data coming from other sources (such as alliances between firms or between firms and public organizations, the respective role of each firm involved in the process).
Patens are also able to provide information regarding inventor's mobility so that it can be possible to analyze the trend of the diffusion of knowledge.
Thus, patent documents can provide more precise and detailed description of technologies than any other type of literature. One of the reason why is that, if applicants intend to fil a patent application, they must disclose the details about how their invention works. More specifically, when patents are published, everyone can benefit from the information contained and a patent document consists of:

- a first page comprising basic information (e.g. the title of the invention and the name of the inventor);
- a detailed description of the invention (e.g. how it is constructed, how it is used) and what are its benefits compared with what already exists;
- claims containing a clear and concise definition of what the patent legally protects;
- drawings.

Additionally, patent document is able to provide information with the following criteria:

- detailed and accurate: Patents must be written in such a way that a person knowledgeable in the technical field concerned can reproduce the invention.
- cutting-edge: companies usually try to file their patent applications as soon as possible to secure about a competitive advantage through legal protection. Patent applications are normally published 18 months after their first filing date, so they often represent the earliest published information available to the public[19].

Patents are then freely available in a provided on-line database so that they can be used to:

- find out which technology already exists and build on it;
- keep track of what other inventors and companies are doing;
- avoid infringing other people’s patent rights;

[19] EPO, Finding sustainable technologies in Patents

- check out where an invention is patented, and where it is not. [20]

Thus, patents represent especially an effective way to track the rise of emerging technologies.
Thanks to all the information that can be provided, patents statistics can in fact be used to track the dynamics of the innovation process (e.g. co-operation in research, diffusion of technology across industries or countries), the competitive process (the market strategy of businesses) and the globalization patterns. Additionally, patents are usually considered as an intermediate step between R&D (upstream) and innovation (downstream) in the economic process.
On the other hand, patents face a trade-off. On one side, they encourage new inventions ex ante, but they have a cost ex-post: by giving exclusive use to a company, a patent will limit competition and allow higher prices, thereby excluding customers who would have been ready to pay the marginal cost of a good but cannot pay the mark-up charged by the patent owner. This is the key dilemma affecting the patent issue: patents can either improve the dynamic economic efficiency and at the same time be responsible of the detriment of static efficiency (longer and broader patents favor protection, while shorter and narrower ones favor diffusion)[21].
Additionally, we have to consider that patent-based indicators must be analyzed and interpreted with care. First, not all inventions are patented and it is relevant to know especially if we intend to approach a specific field by referring to patent applications. Sometimes secrecy or other mechanisms are preferred to gain the dominance in the market. Additionally, the patent value is decreasing since not all the filed patents having technical and economic value are able to find a concrete market application.
Before going deeper in our analysis, it is interesting to list which is the Taskforce in Patent statistics:
European Patent Office (EPO), the Japan Patent Office (JPO), the United States Patent and Trademark Office (USPTO), the World Intellectual Property Organization (WIPO), Eurostat, and the US National Science Foundation (NSF).

3.2 IPRs and the Green Economy: the Technology Transfer role

As the climate change is the most pressing challenge of our time, we need an unprecedented mobilization of human and financial resources to alter our patterns of production, consumption and energy use. This transition must be achieved through a large-scale technology development. One of the main evidence of the necessity of this fundamental change is that, since 1992 with the United Nations Framework Convention on Climate Change (UNFCCC), enhancing technology transfer has been defined as a key pillar of the global climate change regime.

[20] EPO, Finding sustainable technologies in Patents
[21] OECD Patent Statistic Manual

Nowadays, the current climate change negotiations confirm the need to strengthen this pillar through the establishment of a technology mechanism able to accelerate technology development and transfer.

It means that the challenge is to enhance the environment for innovation, while enabling speedier diffusion of these green technologies to all parts of the world. Moreover, given the urgency of a rapid diffusion especially in the developing countries, a market improvement must be also supported by a licensing encouragement.

We have to take into account that the interests and concerns surrounding technology transfer have been a central theme of several multilateral discussions and agreements (most notably the Uruguay Round of trade negotiations which resulted in the establishment of WTO and TRIPS).

Before moving on, it is important to focus on the concept of Technology Transfer.

The Intergovernmental Panel on Climate Change (IPCC) has stressed that “technology transfer encompasses the diffusion of technologies and technology cooperation between developed countries, developing countries and countries with economies in transition.

The process involves learning to understand, utilize and replicate the technology, including the capacity to choose and adapt to local conditions and integrate it with indigenous technologies”[22].

Moreover, according to the definition given by Keith E. Maskus, the Chief Economist at the U.S.

Department of State, Technology Transfer takes place through:

- market-mediated mechanisms, where some form of formal transaction underlies the technology movement. It mainly includes transactions involving trade in goods and services, foreign direct investment (FDI), joint ventures, licensing, and cross-border movement of personnel;
- non-market mechanisms/ Informal channels. It may comprise legitimate forms of imitation; departure of employees; data in patent applications; and temporary migration.

In this context, the role of Intellectual Property Rights (IPR) is still a controversial issue.

To stimulate the development of climate change mitigation and adaptation technologies, considering also their transfer to developing countries, it would be needed a continuously reliable and updated information about climate change and patents.

Patents are also a reliable measure of knowledge transfer: they provide a detailed description of how the inventions have been made and the prior art.

Patents citations underline also the use of previous inventions in the new one giving the chance to identify the influence of a set of/specific inventions as well as to mark their diffusion in the economy.

It means that citations of other patents can be useful in order to quantify the knowledge transfer across organizations, geographical regions and/or technology fields, as well as knowledge spillovers from specific inventing entities[23].

[22] Intergovernmental Panel on Climate Change (IPCC), 2000
[23] OECD Patent Statistic Manual

These issues have also been presented in negotiations leading to several key multilateral environmental agreements, such as the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC).

To have an overview, polarized views emerged regarding the role that IP should play:

- many developing countries and some non-governmental organizations (NGOs) uphold the use and expansion of the flexibilities on IP available within the WTO TRIPS Agreement, such as compulsory licensing, being convinced that this will help to ensure greater access to climate change technologies;
- on the other hand, many developed countries and business associations claim that only strengthened IP regimes will encourage the innovation, transfer and diffusion of such technologies.

These different perspectives are one of the reason why, in 2009, the United Nations Environment Programme (UNEP), the European Patent Office (EPO) and the International Centre for Trade and Sustainable Development (ICTSD) announced a joint project based on the role of patents in the transfer of climate change mitigation technologies with the aim to provide evidence to support an informed debate. Statistics on patent filings are a powerful indicator of Research, Development and Innovation and they can be a reliable source to undertake accurate analysis.

In 2010, a first study on "Patents and clean energy technologies" (CETs) was published, followed by three EPO-UNEP studies with a regional focus on Africa (2013), Latin America (2014) and Europe (2015).

Nowadays, according to the "Climate Change Mitigation technologies in Europe" report, Europe is one of the world leaders in technical advances developed to contribute in achieving a lower carbon economy.

Regarding this, the EPO has produced a policy brief in co-operation with the International Renewable Energy Agency (IRENA) in order to provide evidence on the latest trends in CCMT innovation and dissemination with a focus on renewable energy technologies, showing that patents support their deployment (EPO 2017).

The main findings have been:

- the number and commercial value of CCMT inventions are growing globally;
- most innovation takes place in the energy sector, with renewables driving the growth;
- the integration of ICTs into renewable energy technologies remains a key challenge;
- climate policy is a main driver of innovation in CCMTs;
- inventive activity in CCMTs is mainly concentrated in a few regions of the world but diversity of inventor countries is growing;
- patents support the deployment of CCMTs.

More specifically, a new classification scheme for technical attributes of technologies (that can be referred to as climate change mitigation) has been established to retrieve patent document covering these technologies.

Under the so called Y02 initiative (deeper in the next paragraph), EPO has now 2.8 million patent documents relating to low carbon inventions, accessible to everybody, free-of-charge, and from anywhere in the world. It is by far the biggest single inventory of low carbon technologies in the world.

To ensure their relevance, the categories were defined with the help of experts in the field, both from within the EPO and with the help of external partners, including the Intergovernmental Panel on Climate Change (IPCC).

3.3 Tagging Sustainable Technology Patents: a New Classification Scheme

Given the large number of patents, the patent offices worldwide use the International Patent Classification (IPC): an alphanumeric symbol identifies each section or sub-section so that examiners can be able to classify patent applications in one or more sections of the IPC. Thus, when a patent document is published, it will have one or more symbol in its front page.

Nowadays, there are approximately 70000 different IPC classification symbols that transcend language. It means that, if they have been correctly classified, it is possible to find documents in languages other than the one used for keyword search. Starting from January 2013, EPO and the United States Patent and trademark Office (USPTO) has started to use the Cooperative Patent Classification System (CPC) as an extension of the IPC, with 250000 classification symbols. CPC replaced the European Classification (ECLA) scheme.

Coming back to the Climate Change Mitigation Challenge, starting from the same features of the patent system to return a structural transparency relating to climate change mitigation technologies, EPO is significantly contributing in facing the climate change challenges by assuming a strong broader responsibility in a societal context (Table 3.1).

Table 3.1 *Sustainable Technologies currently included in the new classification scheme*

Sustainable technologies currently included in the new classification scheme
Climate change mitigation technologies in buildings including the residential sector
Greenhouse gases capture and storage
Climate change mitigation technologies in energy generation, transmission and distribution
Climate change mitigation technologies in the transportation of goods and persons
Smart grid technologies

Source: *EPO, Finding Sustainable Technologies in Patents*

In this context, the new so called Y02 classification scheme has been developed. Y02 scheme is specifically dedicated to climate change mitigation technologies and it enables a continuous and reliable flow of data on selected technologies and their application in the energy field.

To make it more user-friendly, the Y02 scheme includes the following subclasses:

- Y02B tags cover energy-consuming loads and construction elements able to reduce the carbon footprint of a building. There are nine main technical areas, divided into almost 300 different sub-categories in total.
- Y02C tags cover technologies relating to the capture of greenhouse gases (GHG), including the capture and storage of CO2. There are two main technical areas divided into ten sub-categories in total.
- Y02E tags cover energy sources alternatives to fossil fuels. They also cover technologies for using sustainable fossil fuels for energy generation, efficient transmission and distribution. There are seven main technical areas, divided into over 200 sub-categories in total.
- Y02P tags cover climate change mitigation technologies in several energy intensive industries spanning from the chemical and petrochemical to agriculture and agroindustry. The Y02P also includes CCMTs applicable across different sectors, such as technologies relating to the efficient use of energy and enabling technologies with a potential for emissions mitigation, such as smart factories and flexible manufacturing systems. There are eight main technical areas in the Y02P, divided into some 370 sub-categories.
- Y02T tags cover technologies for making transportation less carbon-intensive and more efficient, as well as other ways of reducing greenhouse gas emissions from transportation. There are five main technical areas, divided into more than 250 sub-categories in total.
- Y02W tags cover climate change mitigation technologies related to waste- water treatment and the waste management cycle. The Y02W is divided into three main technical areas further divided in roughly 100 sub-classes.
- Y04S tags cover the full smart grid spectrum, from the remote control of power generators to marketing. They are divided into five sections, which are in turn divided into 90 sub-categories (Table 3.2 and Table 3.3).

There are already over three million documents with Y tags in the EPO’s databases, a number growing as more documents are published (newly published documents are tagged in batches, at least twice a year).

Table 3.2 *Current Sub-group in the Y-section*

Sub-group	Description	Comment
Y02B	Climate change mitigation technologies related to buildings, including housing and appliances or related end-user applications	Integration of renewables in buildings, lighting, HVAC (heating, ventilation and air conditioning), home appliances, elevators and scalators, constructional or architectural elements, ICT, power management
Y02C	Capture, storage, sequestration or disposal of greenhouse gases (GHG).	CO_2 capture and storage, also of other relevant GHG
Y02E	Climate change mitigation technologies in energy generation, transmission and distribution	Renewable energy, efficient combustion, nuclear energy, biofuels, efficient transmission anddistribution, energy storage, hydrogentechnology
Y02P	Climate change mitigation technologies in the production or processing of goods	Metal processing, chemical/petrochemical industry, minerals processing (e.g. cement, lime, glass), agroalimentary industries,
Y02T	Climate change mitigation technologies related to transportation	e-mobility, hybrid cars, efficient internal combustion engines, efficient technologies in railways and air/waterways transport
Y02W	Climate change mitigation technologies related to wastewater treatment or waste management	Wastewater treatment, solid waste mangament, bio packaging
Y04S	Smart grid technologies	Power networks operation, end-user applications management, smart meter ing, electric and hybrid vehicles interoperability, trading and marketing aspects

Source: *EPO, Finding Sustainable Technology in Patents*

Table 3.3 *Breakdown of a specific Energy time according to the new scheme: Solar Energy*

Code Y02E	Description
10/40	Solar thermal energy
10/41	Tower concentrators
10/42	Dish collectors
10/43	Fresnel lenses
10/44	Heat exchange systems
10/45	Trough concentrators
10/46	Solar-thermal plants for electricity generation, e.g. Rankine, Stirling solar-thermal generators
10/47	Mountings or tracking
10/48	Mechanical power, e.g. thermal updraft
10/50	Photovoltaic (PV) energy
10/52	PV systems with concentrators
10/54	Material technologies
10/54B	CuInSe2 material PV cells
10/54D	Dye sensitized solar cells
10/54F	Solar cells from Group II-VI materials
10/54H	Solar cells from Group III-V materials
10/54J	Microcrystalline silicon PV cells
10/54L	Polycrystalline silicon PV cells
10/54N	Amorphous silicon PV cells
10/56	Power conversion electrical/electronic aspects
10/56B	for grid-connected applications
10/56D	concerning power management inside the plant, e.g. battery charging/discharging,economical operation, hybridisation with other energy sources
10/58	M.P.P.T. systems (maximum power point tracking)
10/60	TPV hybrids

Source: *EPO, Finding Sustainable Technology in Patents*

The Y02 symbols can be found using the free esp@cenet service at www.epo.org/espacenet and it works with the same databases as used by EPO examiners. This database is now available as a public patent information

EPO service able to provide continuous, accurate and user-friendly patent information contributing to improve the transparency of the patent system in this critical technology sector.

Thus, according to EPO, patents are the only way to win the global warming race. Therefore, many developing countries see patents as a barrier to technology transfer to poorer countries. “They see patents as an attempt to conceal technological progress, to deny them the benefit of the industrialized world's achievements and not least to make money from inventions that are needed to save the world. But, without patents, without intellectual property rights, it would be very difficult for new technologies even to arise - to say nothing of their transfer to developing countries.[24]”

Since the Green Economy context is a fast-moving field, patents can either safeguard the pioneering investments and incentive companies to keep going in researching new technologies and generating new ideas which, in the long term, could help to manage the whole climate change problem. Moreover, it is also true that most of developing countries don't have neither the infrastructure nor the capacity to take in high-tech technologies. Thus, patents are not a really obstacle for them because many of low-tech engineering solutions (in which they could be interested) are off-patent.

EPO has also decided to establish a technology mechanism within the climate negotiation to make developing countries able to benefit of information on technological process that patents are able to provide. A Climate technology Center and a Network platform are going to be created so that all available technology can be accessed. More specifically, the Center will give advice on what kind of technologies can be used, where they are available and what the best solutions are for each country. The aim is to facilitate the technology transfer to developing countries providing them knowledge and information needed and to establish a financial system in the climate negotiations and in the agreement without compromising the incentive mechanism provided by patent systems. Thanks to this kind of approach, a developing country could have the chance to buy high innovative technology[25].

To sum up, the evidence and existing literature suggest that in the examined sectors, IPRs are one of the key factors influencing the decision to transfer technology to, or to invest in, a particular country. It becomes evident that the effects of IPRs and their strengthening are often dependent on their interrelationship with other factors, such as the size of the domestic market, the structure of factor supply, productive infrastructure and the degree of stability of the macroeconomic environment. Thus, the role of IPRs appears to be sector-specific, impacting the economic evaluation of the development of a fast-growing economy as Green Economy is.

[24] Kosonen E. Without patents it would be very difficult for green technologies even to arise: An interview. EPO
[25] Kosonen E. Without patents it would be very difficult for green technologies even to arise: An interview. EPO

4. CSP FROM RESEARCH TO MARKET. ENEA CASE STUDY

ENEA is the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, founded in 1952 to be a specialized body in the peaceful applications of nuclear energy.

Over time it has been able to reach an international level of excellence by developing competitive skills and know-how focused in the field of plant designing, proof-plant building and new materials application. In 1982, the improvement of these capabilities made ENEA able to extend its research field to RES. Additionally, given the Italian nuclear ban in 1987, RES have become one of its core activities.

Thus, since 2001, ENEA has started to focus on an intensive R&D program aimed at implementing a new concept of CSP "Parabolic Trough Variant" technology in which high temperature (up to 550°C) molten salts (a mixture of potassium nitrate and sodium nitrate) are used either as heat-transfer fluid and heat-storage fluid in replacement of the synthetic oil (up to 390ºC).

In 10 years, the so called "Archimede" ENEA project development passed from the laboratory phase to the industrial-scale demonstration with the contribution of ENEL (the biggest Italian electricity company): a 5 MW plant was realized in Sicily with the aim to give rise to a complete national supply chain.

This program has been not only an example of how to manage the whole innovation process, avoiding the pitfalls of the intermediate stage between basic research and commercialization but also a demonstration of how public applied research is able to entail relevant technology transfer to the productive sector[26].

This experience aimed also to underline the usefulness of the public intervention into the innovation process (i.e. IP system, government support of innovative activities, R&D tax incentives, encouragement of research partnerships): public intervention can be widely recognized as a vehicle to overcome the tendency of the private sector to under-invest in R&D.

We have also to consider that there is a lower awareness regarding the fact that economic activities do not arise only from basic research, but also from the later diffusion of new products, services or processes into the economy. Additionally, this stage of the innovation process is often characterized by the existence of the so called "Valley of Death"[27].

One of the main causes of this gap between basic research and commercialization stage is the uncertainty related to the whole innovation process and to the technical and commercial expertise required by a project moving from pure knowledge to commercialization.

It is crucial to increase the awareness of the necessity of the public intervention in the intermediate stage of the innovation process in a context in which innovation is driving the economic growth.

Thus, as we stated before, since environmental issues are determinant for our future, it is necessary that the Nations adopt urgently different energetic politics compared to the past to implement models of sustainable

[26] Casagni, Coletta, Fontanella, Fratini. (2014). *Concentrating Solar Power (CSP) technology: from Research to Market. A Case Study.*

[27] Valley of death: gap between opportunity discovery and product development

economic development in order to ensure that the future generations have at least a Planet with the same environmental conditions of today.

4.1 CSP Technology: the Italian Experience

Italy can be classified among the pioneers in the CSP field thanks to the contribution given by Giovanni Francia (1911-1980) in the 20th century. He was a mathematician, inventor and visionary engineer who contributed to implement several industries from the 1950s onward. One of its main contribution is related to the field of CSP technologies, that nowadays is still influencing the basic designs of new CSP facilities.

Later on, as a consequence of the oil crisis in 1970s, we can recall the following installations in the Italian territory:

- 1977: fulfilment of the prototypes of solar tower and mirror field in Genova by Ansaldo Engineering company;
- 1981: the installation of Eurelios, the world's first large solar tower plant (1 MW) to be connected to a national electric grid in Sicily, with the engagement of Ansaldo and ENEL, financed also by the European Economic Community funds.

However, in 1985 the Eurelios plant was shutted down. Few years later, the pilot tower concentrator system "La Capanna" (installed in 1983 by ENEA), was disassembled without ever having been used.

Despite this, since 2000s, Europe (Spain first and then Italy) has started to give rise to new CSP development programs with the aim to bring the technology to an industrial maturity stage.

The strong interest in the re-launch of the Italian CSP technology is also strictly connected with the Nobel laureate Carlo Rubbia who was, at that time (2001), the president of ENEA. He was the first to propose to use molten salts as heat transfer fluid in place of diathermic oil in the receiver/boiler of linear parabolic concentrating systems. The worldwide prevailing technology at the time was indeed that of the parabolic trough systems, and with a share greater than 90%, it is still the current dominant technology.

In this challenging context, we have to remark that the growth rate among countries having the same per-capita income is strictly related to their capacity to exploit opportunities arising from new market. Thus, it is necessary to handle the so-called "structural change" of demand and production: a differentiation strategy aimed at catching new demand opportunities from an evolving environment. This kind of strategy in mainly affected by the technology and the market structure of the considered sector. So, given these assumptions the implementation of CSP technologies in Italy could bring the following advantages:

- exploit the CSP clean energy flow if a deeper integration in the Mediterranean area is promoted;
- dress up the role of technology supplier in the growing CSP market.

As we underlined in the previous chapters, several issues (i.e. reducing costs of electricity generation, increasing of the production efficiency, ensuring dispatchability) should be managed in order to improve the marketability of CSP technologies. Since these several issues delimit an obvious trade-off, ENEA has started to work into the following innovation efforts able to identify a successful compromise.

- work on linear parabolic trough variant CSP system;
- use molten salts as HTF;
- develop receiver tubes able to function at high temperature;
- implement the thermal storage energy capacity.

Thus, it has started with the implementation of the innovative Archimedes CSP project in order to demonstrate how it would be possible to have a CSP national supply chain taking into account how the national energy policies will influence this development (Figure 4.1)

Figura 3.1 *Archimedes Plant in Sicily, Italy*

Source: *Inhabitat*

4.2 Parabolic Trough Variant system: The Archimedes Project

Starting from 2001, ENEA has started to focus on an intensive R&D program aimed at implementing a new concept of CSP “Parabolic Trough Variant. More specifically, the R&D program was structured as follows:

- develop and prototype new components for innovative systems;
- fulfill pilot plants for experimental activities supported by special facilities specifically planned and built by ENEA;
- plan the demo CSP plants through joint investments with industrial partners in order to promote a whole national supply chain.

In 2003, ENEA and ENEL signed a Memorandum of Understanding to realize the new Archimedes facility (according to the law n. 388/2000): After a jointly feasibility study, a preliminary plan was elaborated to build a CSP plant integrated to one of the ENEL two groups of a 760 MW gas fired combined cycle power station in Priolo Gargallo (Sicily)[28].

In 2004, it is relevant to underlined also the CSP incentive program established by the Italian Government thanks to a consulting with both ENEA and ENEL. It became actionable with the Ministerial Decree of the 11th April 2008 and with the subsequent changes produced by the Ministerial Decree of the 6th July 2012.

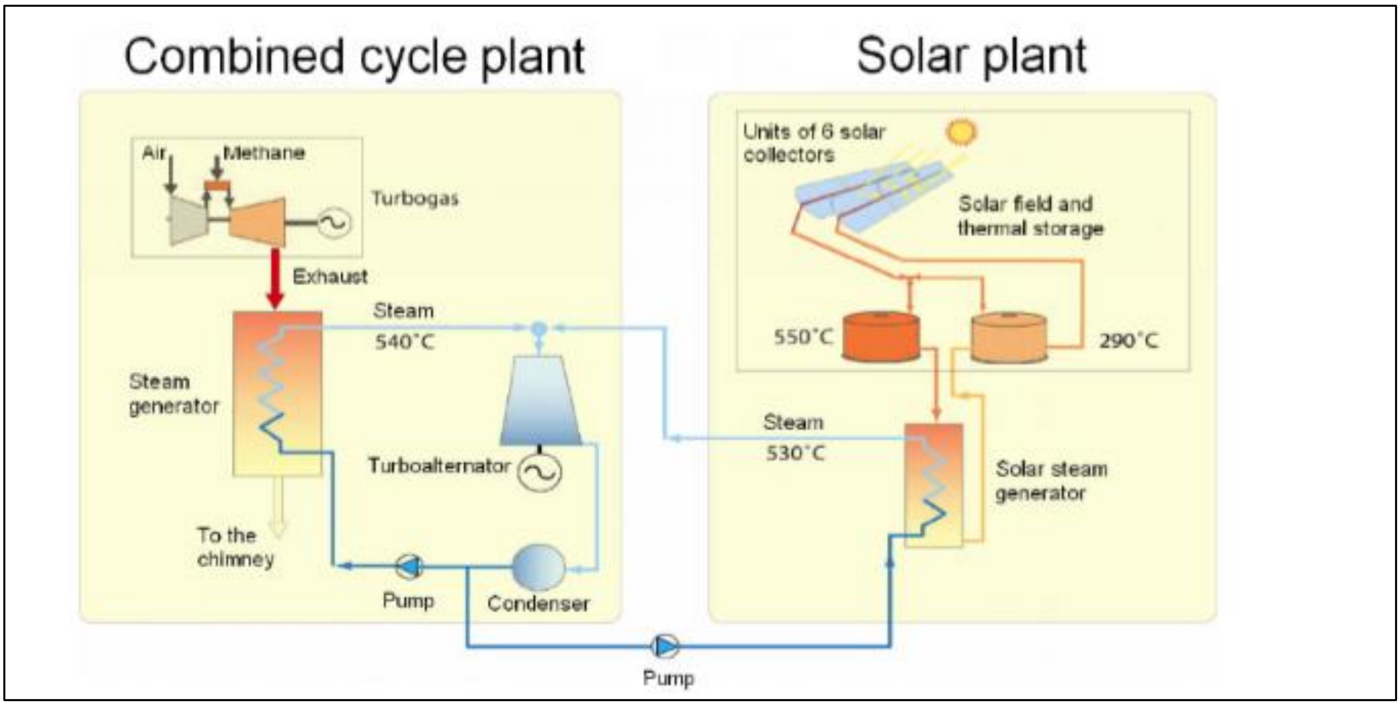
In 2008 ENEL started the construction of the CSP 5MW plant. In this context, all the innovative components were supplied by the Archimede Solar Energy Consortium (association of companies involved in the development of this project to whom ENEA granted the patent licenses relative to achieved innovations).

In 2010, the new plant was turned on. Nowadays, since ENEL is still operating and monitoring the plant, it has the responsibility to disseminate the achieved results.

It is relevant to underline one more time that, according to the project, the steam turbine has been utilized jointly with the thermal cycle to better perform the investment in the innovative components: the solar field, the thermal storage system and the molten salt pipe system. Presently this is the largest system the world with about 6.3 km extension operating with these characteristic (Figure 4.2).

[28] Casagni et al., (2014). *Concentrating Solar Power (CSP) technology: from Research to Market. A Case Study.*

Figure 4.2 *Drawing of the integration of the CSP plant into the combined cycle power station planned in the Archimedes Plant*



Source: *Casagni et al., (2014). Concentrating Solar Power (CSP) technology: from Research to Market. A Case Study.*

The ENEA's CSP project ended in 2010 after the finalization of the Archimedes demonstrating facility. According to the article n. 111 of the law n. 388/2000, each semester ENEA has to report to the Economic Development Department of the Italian Government the progress of the research and experimental activities, the planning and execution of the project and the costs management.

The total project costs incurred from the R&D laboratories to the components test and qualification step in the period 2001-2006 amounted to 39.5 million Euro: 54% of this cost was due to the labor costs and around 56% of the remaining costs was due to the external contracts stipulated with companies and research units involved in the project to realize the experimental facilities and devices. For the fulfilment of the demonstrating power facility were allocated further 27.5 million Euro aimed at financing a share up to 40% of the final cost of the plant. This amount, however, was not spent by the Government, since the whole realization of the demonstrating CSP power plant in Sicily was financed by ENEL, although for a smaller one (5 MW rather than 28 MW)[29].

4.2.1 Archimedes: the Innovation Process

Among the goals of the ENEA's Archimedes experimental project it is possible to identify two main objectives: one of a technical type and the other related to the technological transfer to the Italian industrial

[29] Casagni et al., (2014). *Concentrating Solar Power (CSP) technology: from Research to Market. A Case Study.*

system. Technically speaking, the experimental project was aimed at developing a new generation of more efficient and profitable solar plants realized through:

- the use of a mixture of molten salts as heat transfer fluid;
- the improving of the solar concentrators and the sun-tracking system;
- the improving of the receiver tubes.

At the beginning, the research in the field of the parabolic trough was focused on the performance's improvement and on the manufacturing process of the main components. Additionally, advanced researches were mainly related to the heat transfer fluid and to the thermal energy storage to impact on the efficiency of the system and to reduce the costs. Using molten salts as HTF had the aim to make the system able to store solar heat and, therefore, to mitigate the impact of the intermittency of the energy source.

During the 1990s, molten salts were already tested in US, but in a Solar Tower plant with a short circuit only (Solar Two). Another attempt was later made in Spain (Andasol) but molten salts were used only related to the thermal storage. The peculiarity of the project developed by ENEA concerns the use of molten salts in wide and extended pipe networks. Under these conditions, special devices and operating procedures was developed in order to mitigate the high risk of solidification.

Focusing on the technological standpoint, the project aimed at promoting and implementing the creation of a national supply chain in the emerging and growing CSP industrial sector. Focusing on the technology factor, we can start remembering that it can be hard to spread a kind of knowledge that is largely tacit and implicit in a specific production process. Additionally, a pioneering market (as the CSP market) is always characterized by uncertainty that can be faced only through specific technical and financial endowment not always owned by private entities, especially the smaller ones. On the other side, even if public research institutions are endowed with large technical expertise, they generally lack not only commercial competences but also, especially, available financial capitals.

Given these evident groundworks, the main reasons of the so called "Valley of Death" are identified. A strong collaboration between private and public institutions is needed to have the adequate financial support and strategic direction in order to overcome one of the main barrier connected to the technology transfer process. As we said before, in fact, the technology and innovation transfer is still one of the main effective level that countries like the European ones can implement to manage the opportunities provided by the growing markets.

4.2.2 Overcoming Challenges & Results

According to article n. 111 of the law n. 388 of 2000 (State budget law for the 2001), ENEA has been charged (involving several firms through a selection process) with a R&D program aimed at implement a demo industrial CSP plant able to generate electricity from solar energy source.

Since the main goal was the development of industrial products suitable for large diffusion, the collaboration with industrial partners was encouraged to identify better effective solutions for a mass production. Thus, in 2003, ENEL (the Italian largest power company and one of the European biggest utilities) joined this program by signing a memorandum of understanding. Thanks to this collaboration, it was possible to define either the conditions needed to integrate the developing solar power plant to the already existing combined cycle plants where the demonstrative plant was planned and to draw up the final project.

As we know, even if Linear Parabolic collectors were already a relatively mature technology when the project started, they usually operated (and still) with thermal oil which cannot reach temperature higher than 400ºC due to its thermal stability; this is one of the key factors affecting the plant efficiency. Thus, the effective strategy was identified in finding a balance between thermodynamic efficiency and innovative collector structure designs by taking into account the implementation of the thermal energy storage.

More specifically, the innovating system has been developed using a mixture of molten salts as HTF: 60% of sodium nitrate and 40% of potassium nitrate, melted down at about 238°C, chemically stable up to about 600°C able to guarantee good performances in heat exchange and transport. As a result, the delivery temperature of a solar field rise up to 550°C, increasing the thermodynamic cycle performances for the electric production up to 42/44% (instead of 37/38% allowed using thermal oil).

Furthermore, given their chemical properties, we can recall that molten salts are able to provide the following advantages:

- they are not inflammable;
- they solidify in contact with ground;
- they cannot be dispersed when collected;
- they are environmentally safe (commonly they are used in the agricultural sector as fertilizers).

On the other hand, molten salts begin to solidify at 240°C. It means that they could not be employed for the circulation in the receiver of a linear parabolic concentration system: in the long pipe system the maximum temperature reachable was around 440 ºC, a margin too small to be sure to avoid the solidification.

That is precisely why, another innovation effort consisted in finding properly devices and operating procedures able to make it possible to use molten salts in wide pipe networks, avoiding the solidification risk. Additionally, the project had to find a way to manage the corrosion process to which molten salts are subjected especially when they reach high temperatures. As a result, a new collector structure was designed based on a central bearing pipe and a lateral variable profile support and thin glasses were also used for the reflecting panels.

Regarding the issues related to the receiver tubes, the main challenge was to avoid the thermal loss. So, each metallic tube, corrosion resistant up to 600ºC, was enclosed in a vacuum air gap, with special sealing between glass and metal; then, it was coated with a special film, a new metallic-ceramic compound (CERMET), patented, realized and manufactured at the ENEA's laboratories of Portici (Naples, Italy). This new film is able to efficiently absorb solar radiations emitting low infrared radiation in order to achieve better performances and to enable system stability. Also, as we already pointed out, since molten salts can be used either as HTF and as heat storage, the heat exchanger can be removed and the temperature loss can be avoided. ENEA implemented also an extended energy storage system, aimed at turning an intermittent energy resource in a fully dispatchable one. According to what we analyzed in the Ch 1, TES seems to be the most suitable method to collect and transfer the electricity produced by CSP systems, even from a cost benefit point of view. Moreover, the mixture of molten salts proposed by ENEA is the most convenient choice to store energy among the others available salts with a temperature ranging between 400ºC and 600ºC (Table 4.1).

***Table 4.1** Comparison of Solar Energy Storage System*

	Type of storage	Cost for a 200 MW plant ($/kWh$_e$)	Operation Lifetime (years)	Storage efficiency (%)	Operating temperature (°C)
Molten-salt	HQH	30	30	99	567
Synthetic-Oil	HQH	200	30	95	390
Pumped hydro	ELE	500 to 1600	30	50	N/A
Compressed air	ELE		30	60	N/A
Superconducting	ELE	> 1000	30	90	cryogenic
Battery Storage	ELE	500 to 800	5 to 10	76	N/A

***Source:** Casagni et al., (2014). Concentrating Solar Power (CSP) technology: from Research to Market. A Case Study.*

To conclude, the choice to use molten salts as HTF was the main challenge to face also due to the skepticism of the scientific community: their employment in wide pipe networks, extended for kilometers, had risen greater technical issues with respect to using synthetic oil due to the difference in solidification temperatures and the corrosion risk. However, ENEA developed new innovative devices and service structures to manage all these risks. Finally, on the management side, ENEA had to face the uncertainty related to national funding and policy targets.

As we said at the beginning, the program started thanks to the International reputation of the Nobel laureate Carlo Rubbia. Starting from its innovative vision, ENEA team implemented new capabilities giving origin to effective collaborations between small and medium enterprises (SME) characterized by high quality standards. Additionally, ENEL gave its contribution in building and monitoring the CSP plant supported by public funding which made them able to involve the national manufacturing sector.

4.2.3 Impact on Italian Players

After the Archimedes project and due to the industrial related R&D program, some new players already active in the manufacturing sector, implemented their presence in the CSP market:

- the foundation of Archimede Solar Energy (ASE), a company of the Italian Industrial Group Angelantoni S.p.A. (Massa Martana, Perugia, Italy). ASE is now one of the main international players in manufacturing Receiver Tubes designed to operate at temperatures up to 550°C, also thanks to licenses provided by and developed with ENEA;

- the diversification of the industrial activity of Ronda S.p.A. Group (Vicenza, Italy) with the creation of the Ronda High Tech – CSP Division, specialized in the manufacturing of Solar Collectors. Since 2007 it has an on-going collaboration with the ENEA Research Center Casaccia (Rome, Italy) from which has been developed and concretized the industrialization of the production of large Reflective Panels easy to assemble: they are characterized by high optical performance, new lighter and better performing metal structures panels for the solar industry;
- the widening of the manufacturing supply of Reflex S.p.A. (Treviso, Italy), part of a group of companies including Società Vetraria Biancadese, and producing mirrors since 1958. Reflex entered in a high-tech sector after the development with ENEA researchers with a new generation of ultra-thin mirrors for reflective parabolic panels with an estimated durability over 20 years;
- the development of a new expertise for D.D. s.r.l. (Udine, Italy), a company specialized in the manufacture of steel structures and of the machine final assembly. Since 2003, together with the subsidiary SIFA s.r.l., it collaborates with ENEA for the development of the prototype for a CSP plant since the company plans and supplies mechanical components;
- the deepening of the technology knowledge of Duplomatic Oleodinamica S.p.A. (Milano, Italy), which has realized the sun-tracking collector system, formed by a supporting framework (including shaft and cylinders) and by the hydraulic drive system (including the control panel).

Additionally, one of the main achievement of the program was the capacity to stimulate the interest of private stakeholders for the potential CSP market. More specifically, the technological innovations achieved through the R&D program brought to the establishment of the national Consortium "Solare XXI", formed by four sector leading companies (Archimede Solar Energy for the receiving pipe production, Ronda High Tech for the reflective panels, Duplomatic for the motion control system and Techint for the design of the supporting frameworks and the component integration), with the aim of deeping the research and the implementation of highly technological products, such as the Linear Parabolic Solar Collector with molten salts.

As result, the Italian manufacturing system is able today to produce more than 90% of the components of a standard scale CSP plant.

Additionally, in July 2012, the Italian Minister of Economic Development and the Minister of Environment approved a new decree for new renewable energy mix also aimed at promoting CSP development. Thus, it is expected that CSP plants connected to the grid by 2020 will reach a capacity of 600MW.

4.3 LOOKING FORWARD: MADE IN ITALY ONGOING INVESTMENTS

After the success of the Archimedes project, the industrial research has started to focus on the development of new other potential CSP applications such as Small CSP and Integrated Systems:

- small CSP implies the application of CSP technology in small facilities (around 1MW) to produce heat or combined heat & power (CHP). Since they are characterized by small sized collectors able to reach lower operating temperature, they can be installed on the building roofs/industrial warehouses. The advantage is that these systems can be used either in the industrial sectors to generate process and in the service producing sector for space heat and cooling.
- integrated Systems are referred to CSP plants designed to operate in integration with other RES (especially biomass), in order to produce electric power, process heat, space heating/cooling and desalinated water.

Focusing on a longer term impact in the innovation process, the next step is to have a look on the on-going investment strategies of the Italian leading companies described before.

In 2011, ENEA started the MATS project (Multipurpose Applications by Thermodynamic Solar), with a total investment of 22 million Euro, of which 12.5 million funded by the European Union.

The project has been focused on the innovative CSP technologies developed by ENEA: the use of molten salts has heat transfer fluid, the modularity of the solar field, a storage system with only one tank (instead of two) and the integration of the steam generator inside the storage tank.

This technology, referred as TREBIOS, allows combined heat and power production from solar source integrated with renewable fuels, such as biomass, biogas, industrial residues etc. by means of standardized units that provide high performances and limited cost.

The aim was to produce energy able to be a source in a desalination unit included in the facility installed, as well as for district heating and cooling.Thus, the plant has been programmed for the combined production of electric power (1 MW) and heat (4 MW) to be used for air conditioning and water desalination (250 m3 per day). As we underlined before, the heat storage system is able to implement the firmness-of-supply of the power production managing the intermittency of the solar energy source. The electrical energy production "on demand" is achievable as well as the optimized utilization of captured solar energy by additional loads like desalination. Additionally, the integration with a backup gaseous fuel, coming from biomass or natural gas, is able to provide additional flexibility to the system and consequently, a continuous power production (Table 4.2)

***Table 4.2**: Main features of TREBIOS plant proposed in the MATS Project*

Functions	multi Combined Heat and Power plants
	modular small/medium size
	Integration by biomass
	Integration by fossil fuels
	Operation all over the year
	Operation also in average sunny climates
Significant innovations	Single thermal stratifying storage tank
	Integrated "once-through" steam generator
	Molten salts backup auxiliary heater
Special Units	District heating
	Water desalination unit
Applications	distributed energy in civil sectors
	distributed energy in industrial sectors

***Source:** MATS Project*

The key innovative components (such as molten salts, TES with integrated steam generator, molten salts heater using back up fuel, water desalination units) involved have been first developed and tested individually and then assembled to test the functioning of the overall system.
This collaborative project (2011– 2015) has been coordinated by ENEA with the participation of other research organizations (CEA, France – ISE and Fraunhofer, Germany - ASRT and NREA, Egypt - University of Cranfield, UK) and some industrial companies (Tecnimont KT, Ronda Group, and Archimede Solar Energy, Italy; Orascom Construction Industries and Delft Environment, Egypt)[30].

To conclude, as we stated at the beginning, since one of the main commitment of ENEA was and still is the knowledge transfer to the industrial sector, several Italian industries were involved in its Archimedes project to give their contribute to the system component prototyping and to the solar plant designing/building.
In this context, several of the involved companies have acquired either specialized expertise related to the CSP supply chain and IPRs coming from the results raised from intensive R&D programs: collector and mirror

[30] CORDIS, *MATS Project*

manufacturers like Ronda High Tech, Reflex S.r.l., D.D. S.r.l., and collector tracking equipment like Duplomatic Oleomatica S.p.A. can nowadays benefit of IPRs risen from the ENEA CSP research program and widen their product portfolio.

In this context, Archimede Solar Energy, after being involved in the ENEA Archimedes project, has gained the worldwide patent license in the innovative CSP technology regarding molten salts receivers. Thus, in 2011, invested 60 million Euro in a new manufacturing plant in Massa Martana (Perugia, Italy) giving rise to a fully automated plant area of more than 30000 sqm. with a full capacity of 75000 receivers per year in 2013, and of 140000 receivers per year in 2014 (Figure 4.3).

Figure 4.3 *New Manufacturing Plant in Massa Martana (Perugia, Italy)*

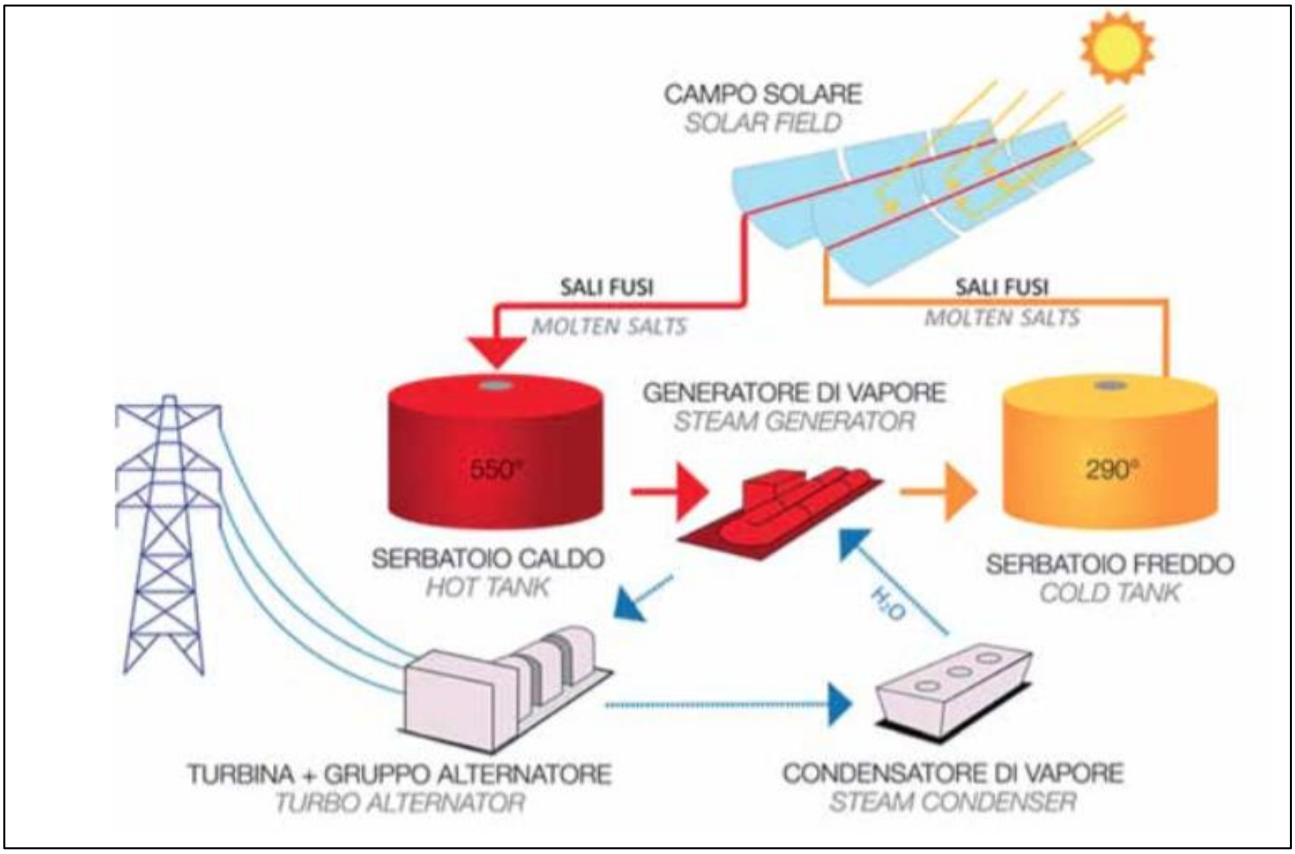
Source*: Archimede Solar Energy*

In September 2012, Chiyoda Corporation(a Japanese company engaged in integrated engineering) entered Archimede Solar Energy's share capital with a 15% stake (today is participated also by the Saudi Arabia Fal Holdings). In 2013, ASE and Chiyoda Corporation invested 6 million Euro to build the first stand-alone Molten Salt Test Loop in the world, close to the ASE manufacturing plant in Massa Martana (Perugia, Italy). Thanks to the Archimedes project ASE has started to implement a national and international program in the CSP market. The six National projects are in Italy (Sardinia, Sicily and Basilicata) while the International ones in China, California, New Mexico and Egypt.

4.4 ARCHIMEDE SOLAR ENERGY (ASE)

After this first analysis, it is evident that Italy has started to implement its R&D centers focusing on the production of energy from RES in order to manage the turning to a green economy. In this Italian environment, ENEA created a fully integrated Italian supply chain operating in the CSP sector. Among all the companies and research units involved in the ENEA project, we are going to analyze the Archimede Solar Energy case. Archimede Solar Energy (ASE), born as a subsidiary of Angelantoni Industrie Group, is nowadays a world leader in the production of solar receiver tubes for CSP plants with Parabolic Troughs or Fresnel Reflectors. With a license agreement with ENEA, obtained after its collaboration in the Archimedes project, ASE started to produce Solar Receiver Tubes operating up to 550ºC with different types of HTF: diathermic oil (for the bigger CSP plants) and molten salts or direct steam generation (for the new innovative plants)[31] (Figure 4.4). As a result, the turbine performance is improved and the configuration of the plant is simplified. ASE represents a successful example on how the technology transfer has been fundamental to let it to achieve an absolute international leadership in the production of high temperature receiver tubes.

Figure 4.4 *CSP Parabolic Trough with Molten Salts technology*



Source: *Archimede Solar Energy, Concentrating Solar Plant*

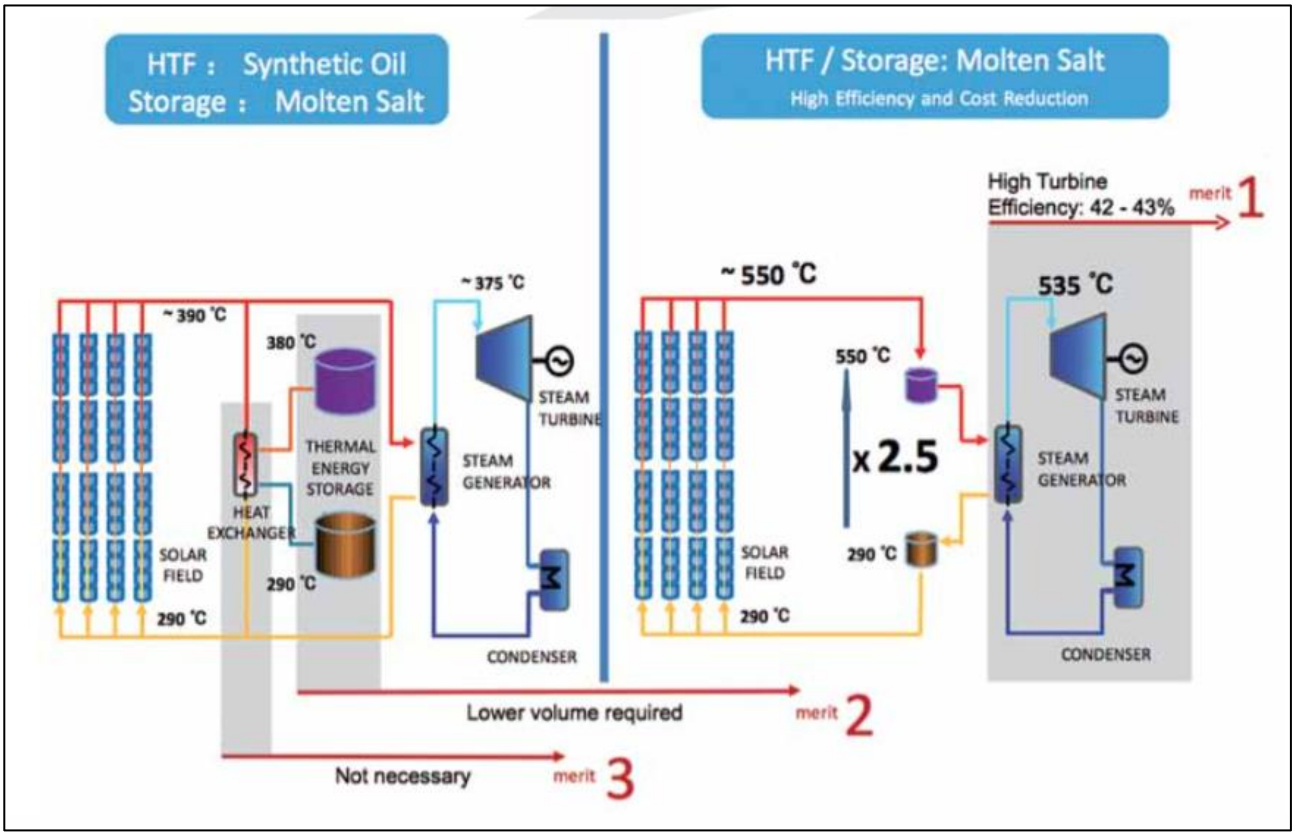
4.4.1 License Agreement and High Innovative Competencies: ASE World Leadership

Using molten salts instead of thermal oil as HTF increases the optimization of the plant and reduce the cost. More specifically, this innovative application has the following advantages (Figure 4.5):

[31] Archimede Solar Energy, *Concentrating Solar Power*

- higher efficiency in the thermodynamic conversion (42/43%) due to the higher temperature steam (535°C);
- the 2/3 reduction of the storage tanks volume by exploiting the entire operating range of the molten salts (up to 550°C) allowing to save at least 30% of the cost of the storage system;
- elimination of the heat exchanger between the solar field and the thermal storage system (the fluid circulating in the solar field is the same also used for the thermal storage).

Figure 4.5 *Comparison between CSP molten salts and oil plants*

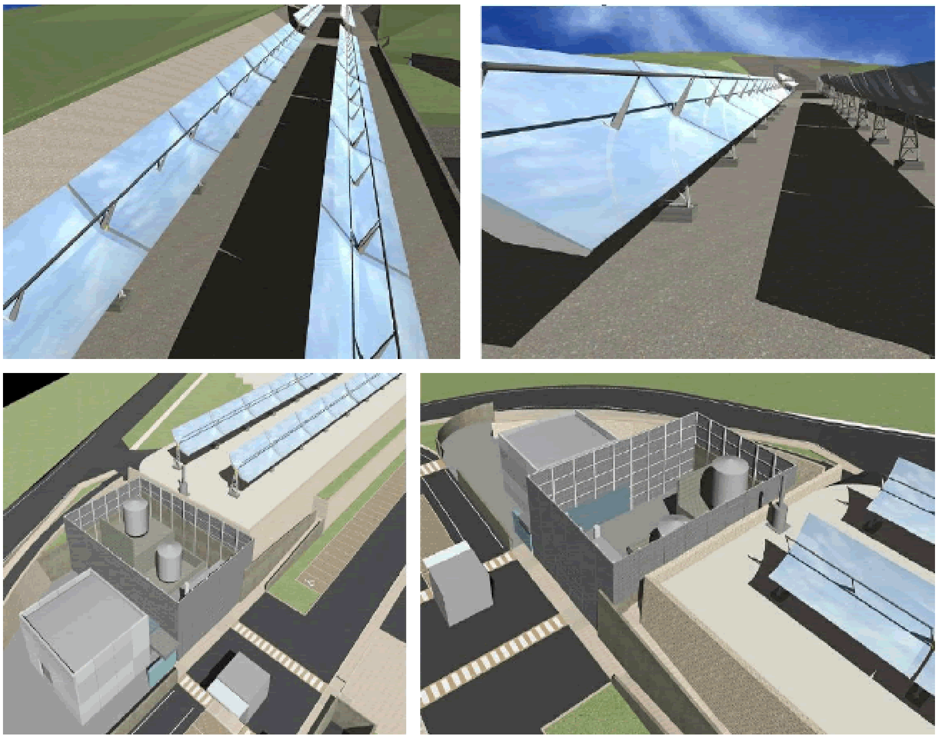


Source: *Archimede Solar Energy, Concentrated Solar Power, the New Frontier of Molten Salt*

Under the license agreement with ENEA, ASE can develop and produce Receiver Tubes having a coating stable up to 580°C and suitable to operate with different types of heat transfer fluid: molten salts, diathermic oil, pressurized water, saturated or overheated steam (DSO). In this context, high quality standards used to manufacture solar receivers ensure the highest optical and thermal performances, as well as stability over time, allowing the maximum efficiency of the operating plant. With the current tubes production capacity of 75000 tubes, equivalent to 150 MW per year, manufactured in the most modern production facility and equipped with the most updated standards, ASE confirms its technological worldwide leadership offering an entirely Made in Italy product[32]. Additionally, thanks to the capabilities achieved during the development of its Demo plant (Figure 4.6), ASE offers also consultancy and engineering services to its customers for the construction of CSP Parabolic Trough plant using molten salts as HTF.

[32] Archimede Solar Energy.

***Figure 4.6**: Archimede Solar Energy Demo Plant*



ASE Demo Plant
(Operational in Summer 2013):

A complete Stand Alone CSP Demo Plant using molten salts with storage system and turbine.

Main Parameters:

- One Loop: 600mt
- (DNI): 1527 kWh/m2
- HTF: (40% KNO3 60% NaNO3)
- Grid Connected: 2010
- NOT: 290 – 550°C
- Number of collectors: 6
- Collecting area [m2]: 3398
- Storage thermal capacity [MWh]: 4.27
- Nominal electric gross power [kW] :350
- Maximum electric gross power [kW] : 420
- Steam turbine: Siemens
- Turbine efficiency at nominal power [%]: 15.61
- Integration heater thermal power [kW]: 500
- Overall FF fraction [%]: 15
- Yearly Net Electricity Production [MWh]: 275
- Power block operating hours [h/y]: 1300

Source: *Archimede Solar Energy, Demo plant*

4.4.2 Innovative Solar Receiver Tubes

Just to have an overview of the innovative technologies developed also thanks to the collaboration with ENEA, it is interesting to understand which are the peculiarities of the Receiver Tubes produced by ASE. The innovative technologies enable ASE to be a worldwide leader in CSP manufacturing and that is why they are patent protected at an international level.

ASE Solar Receiver Tubes are characterized by high complexity in terms of construction technology: they are made by combining various materials such as glass, steel and CERMET (spectrally selective nano-composite coating). With such coatings, it is possible to maximize the absorption of solar radiation while the emissivity is minimized: as a result, it is possible to efficiently convert solar energy into thermal energy.

More specifically, a solar receiver consists of:

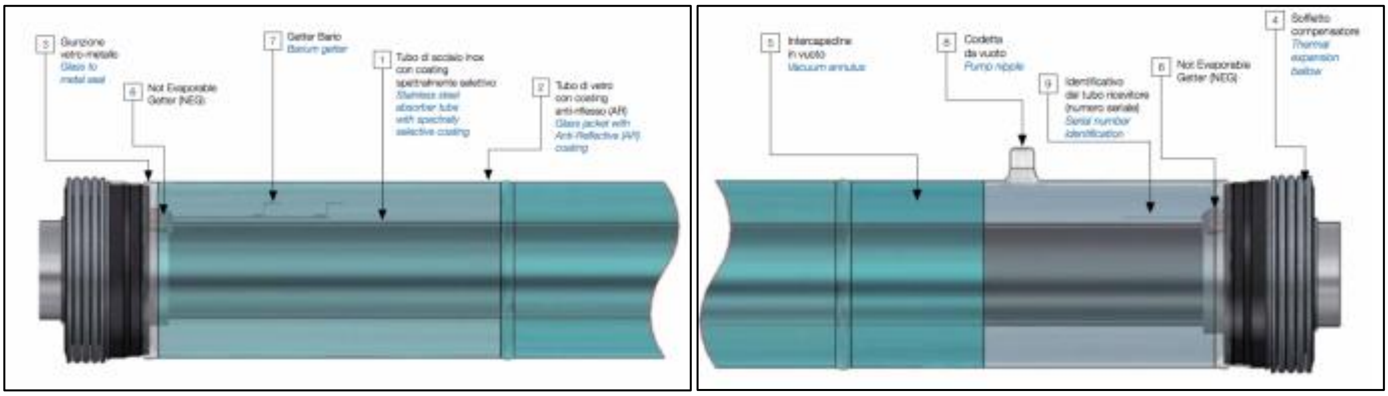
- an inner tube in which the heat transfer fluid flows. Due to the Austenitic stainless factory, the tube is able to contrast the corrosion risk given the chemical properties of the different fluids used;
- an outer surface coated by thin multilateral film, made of a top layer of ceramic material with high anti-reflective power, an intermediate layer of CERMET with a high absorption coefficient for solar radiation and a lower layer of metallic material capable of reflecting infrared radiation[33].

[33] Archimede Solar Energy, *Solar Receiver Tube*

Additionally, in order to avoid convective heat losses and through a high vacuum cavity, the steel tube is enclosed in an outer tube made of borosilicate glass and provided of an anti-reflective coating on the inner and the outer surfaces. Then, to finalize the protective technology, the outer surface is subjected to a hydrophobic treatment, able to increase the resistance of the anti-reflective coating to atmospheric agents.

Finally, two metal bellows are located at the end of the receivers to compensate the differential thermal expansion between glass and steel, ensuring optimum operation of the receiver on the solar collector (Figure 4.7).

***Figura 4.7** Features of ASE Receiver Tube*



***Source:** Archimede Solar Energy, Concentrated Solar Power, the New Frontier of Molten Salt*

The technology just described is so able to optimize the solar radiation absorption and to reduce the thermal losses. Since 2008, it is qualified by external laboratories (ENEA, DLR, CENER, CIEMAT) and texted on field. Thanks to these innovative technology, ASE has today an interesting product portfolio:

- HCEMS: MOLTEN SALTS solar receiver tube: the first worldwide receiver operating up to 550°C using Molten Salts as thermo fluid;
- HCEOI PLUS: OIL solar receiver tube: An incomparable thermal efficiency specifically for medium temperature (up to 400°C) solar plants using diathermic Oil (as well as pressurized water or saturated steam).
- HCESHS: OVERHEATED STEAM solar receiver tube: Unique worldwide receiver operating up to 550°C at 100 bar pressu- re for superheated steam.

In conclusion, given the CSP case study developed between 2001 and 2010, ENEA has been able to stimulate the attention to the role that Italy could hold in the CSP emerging market. Focusing on the national border, the project has represented an example of how, through the public applied research, technology transfer could be a way to increase the production sector and pursue industrial policy objectives and how patent protection can guarantee a strong first mover advantage in the fast growing environment such as the one of CSP sector.

Thus, what really matters is that we should increase our awareness related to these potentialities to avoid the pitfalls of uncertainty regarding public fundings and willingness of policy authorities. Financing the technology transfer could in fact be a successful solution to handle the threatening slowdown of our economic system.

4.5 A Patent Database Approach: Questel Orbit web-service

To have a concrete feedback from the patents protection perspective and to understand how they can provide reliable information regarding the innovation, the competitive process and the globalization patterns, I have held an internship at ENEA Brussels Office.
This gave me also the chance to meet the ENEA team in Bologna; there, I learnt how "Questel Orbit" patent database is used to track the dynamics in each field of interest. At the end of my internship I met the Archimede Solar Energy team in its head office in Perugia where I had the chance to visit the CSP manufacturing plant and to concretely understand the relation ASE has with ENEA (upstream through license agreements) and with the CSP market (downstream).

Focusing on Questel Orbit, it has to be said that it is service oriented to IP, aimed to provide web-based solution useful to implement productivity of different users and it is present in more than 30 countries. Thanks to how it is structures, the database covers the entire innovation lifecycle (from the idea to the final outcome) and it provides solutions in term of business development, R&D, legal financial and licensing departments.
Going forward, Questel's product Orbit.com (used by ENEA) is a web-based Patent & Design search software with own patent family structure (FAMPAT) providing unique features through which implement the research in the platform. The reliability of this web-based service is that the family structure FAMPAT is a duplicate-free invention based family records that combines the family rule of the EPO with additional rules that take into account Patent Cooperation Treaty (PCT) application links, links between US provisional applications and US published patent: in this way, it is possible the platform provides a service able to show the impact of patent law in some countries that are not visible in the EPO family.
It includes all major classification systems such as International Patent Classification (IPC), Cooperative Patent Classification (CPC), Japanese classification-F-Terms, FI-Terms, US classification with additional Technology Domain Field (based on IPC) and by the characteristic to be the only software where it is possible to search by Legal state (Alive or Dead) and Legal status (Revoked, Lapsed, Term Right Extension, Opposition etc.) [34].
Orbit.com also provide bibliographic patent collection almost from 100 IP office with full text collection from more than 22 Authorities with high quality Human assisted language translations.

[34]Patracode, Empowering your intellect. *Orbit IP Business Intelligence* (2016)

To understand how patent data analysis can be used as a complementary source of S&T data, I have tried to extrapolate reliable data regarding CSP technologies, supported by Gateano Coletta, researcher at ENEA in Bologna.

To implement our analysis, we had to keep in mind that, even if the CSP plant is a whole integrated installation, the chain is characterized by a high grade of fragmentation: CSP facility is made by several components coming from different manufacturing sectors.

Consequently, we have implemented a strategy according to which we searched for patents segments related to innovative technologies fundamental to manufacture CSP plants: receiver tubes and solar collector mirrors.

Another issue we considered in this analysis is that, as we know, the patentee entity is not necessarily also the player exploiting that technology in the market. However, as we will see, the results obtained from our research are consistent with analysis done in this document and it helped us to understand how the CSP market is evolving.

Our first research was related to the Receiver Tubes. We tried to build a code made by key words as much reliable as possible, to avoid results overlapping and closely related to CSP sector:

(((RECEIVER TUBE?) OR (ABSORBER W (PIPE? OR TUBE?)) OR (COLLECTOR TUBE?)) AND ((PARABOLIC TROUGH) OR (PARABOLIC MIRROR?)))/TI/AB/IW/OBJ/ADB/ICLM

Through the same procedure, we built the research related to Solar Collector/Mirrors:

(((((REFLECT+ OR MIRROR) AND ELEMENT) OR ((THIN OR FLAT OR CURVED) AND MIRROR)) AND ((PARABOLIC TROUGH) OR (SOLAR COLLECTOR) OR (SOLAR HEAT COLLECTOR) OR (SOLAR FIELD?) OR (CONCENTRATING SOLAR AND (POWER OR PLANT)))) NOT (PHOTO OR LIGHT))/TI/AB/IW/OBJ/ADB/ICLM.

Even if we have structured the researches proceeding following a segmentation according to the main components of CSP plants, the results have been analyzed after having being crossed and assembled to each other. In this way we were able to return a comprehensive and consistent overview of the evolution of new technology development in CSP sector.

To better compare the obtained results with the market development analysis done in the previous chapters, the conclusive data are showed using graphs.

The evidences provided by our researches are coherent with the findings analyzed before:

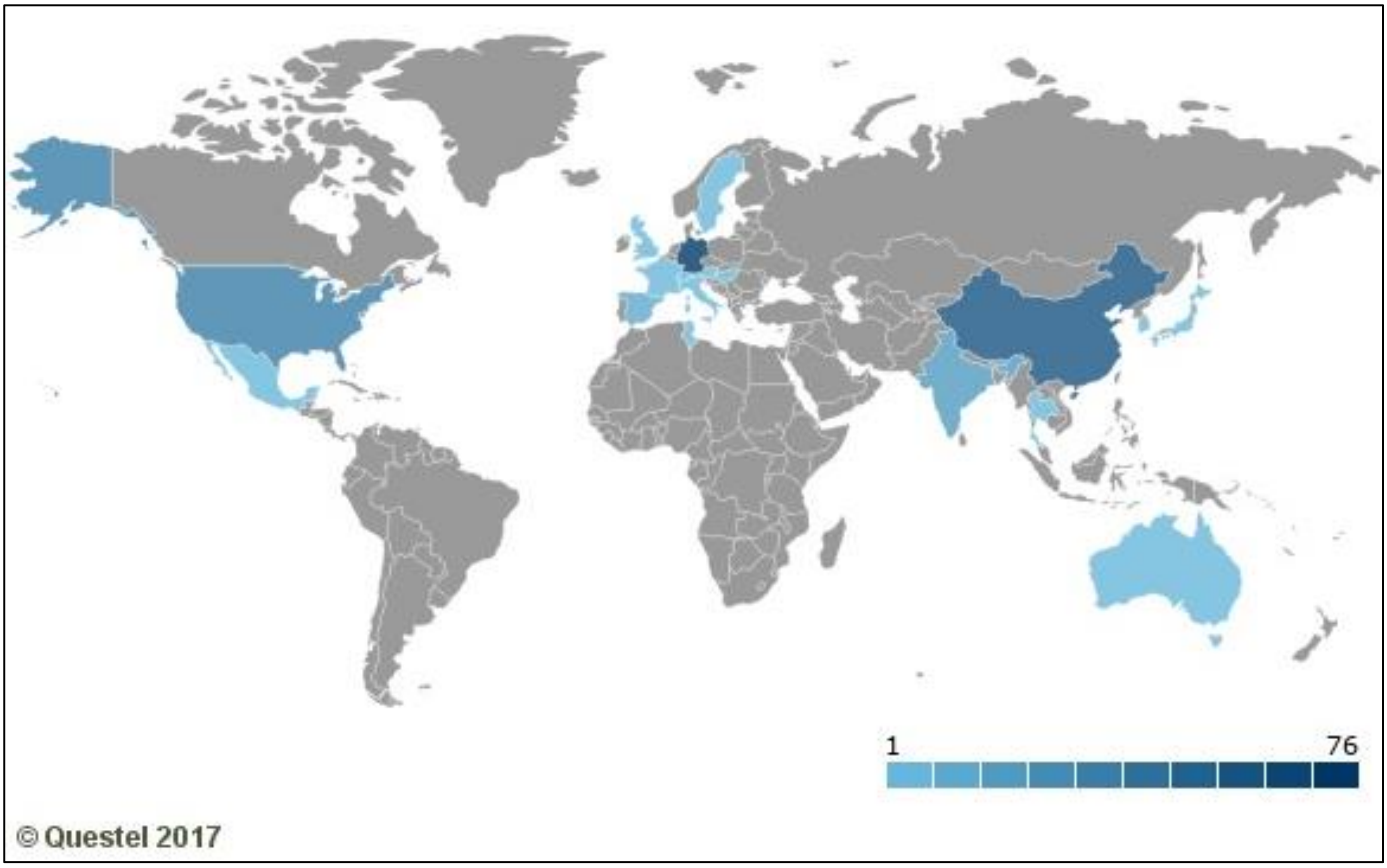
- 2015 represented a challenging year for CSP technology due to the market deceleration; during 2016, the patent applications in the field of interest are much lower with respect to 2015 (Table 4.3 and Table 4.4);
- the market has started to expand beyond Europe and US. From a patent perspective, new technologies have been developed in countries such as Australia, China, India, Mexico and Thailand (Figure 4.8 and Figure 4.9);
- developing markets represent a huge potential for CSP development: the fact that CSP is receiving

increased policy support in countries with limited oil and gas reserves, constrained power networks, or strong industrialization and job creation programs is demonstrated by the growing concentration of new technologies patented in new emerging markets.

In conclusion, it is true that we expected to see CSP on a solid growth pathway and poised to establish itself as a third big player in the new “sustainable power generation industry”. At the same time, it is evident how statistics on patent filings are a powerful indicator of Research, Development and Innovation since they are a reliable source to undertake accurate analysis.

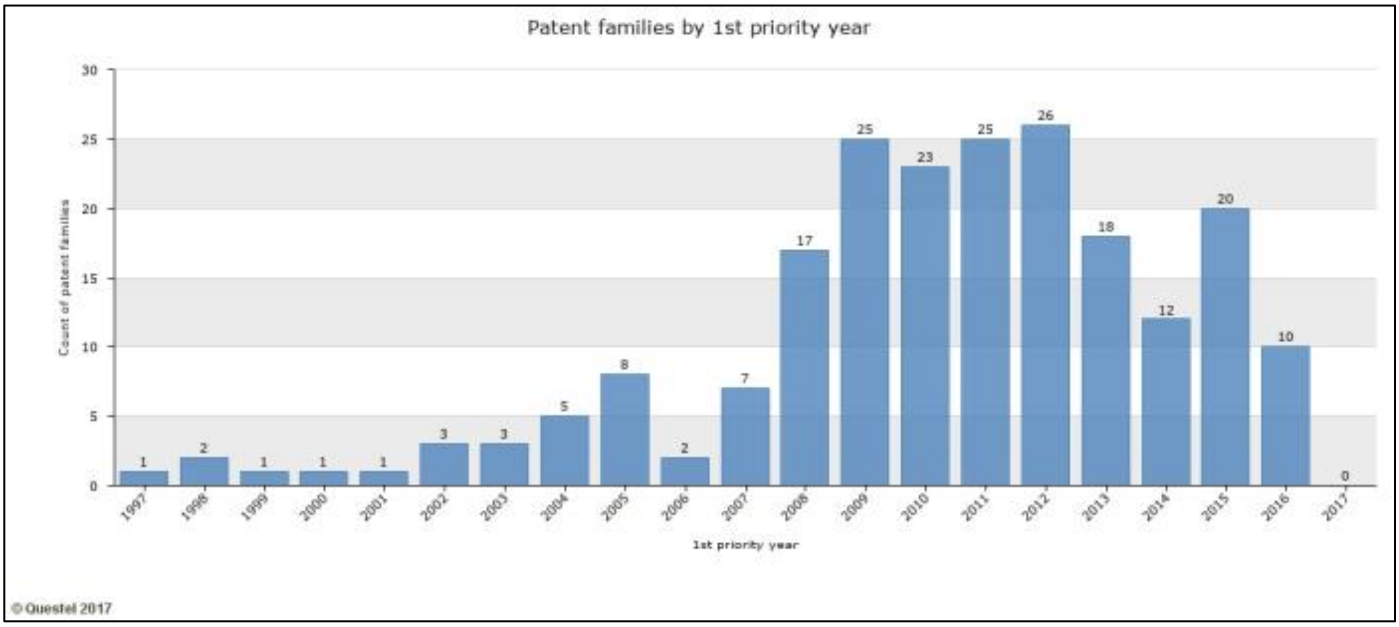
This patent approach also showed that is important to implement a patent protection system to stimulate the development of a fast-growing market (such as the CSP one). New potential and existing players need to have legal guarantees to significantly invest in a risky sector.

__Figure 4.8__ Receiver Tubes: World map Distribution of Patent families by Priority Countries



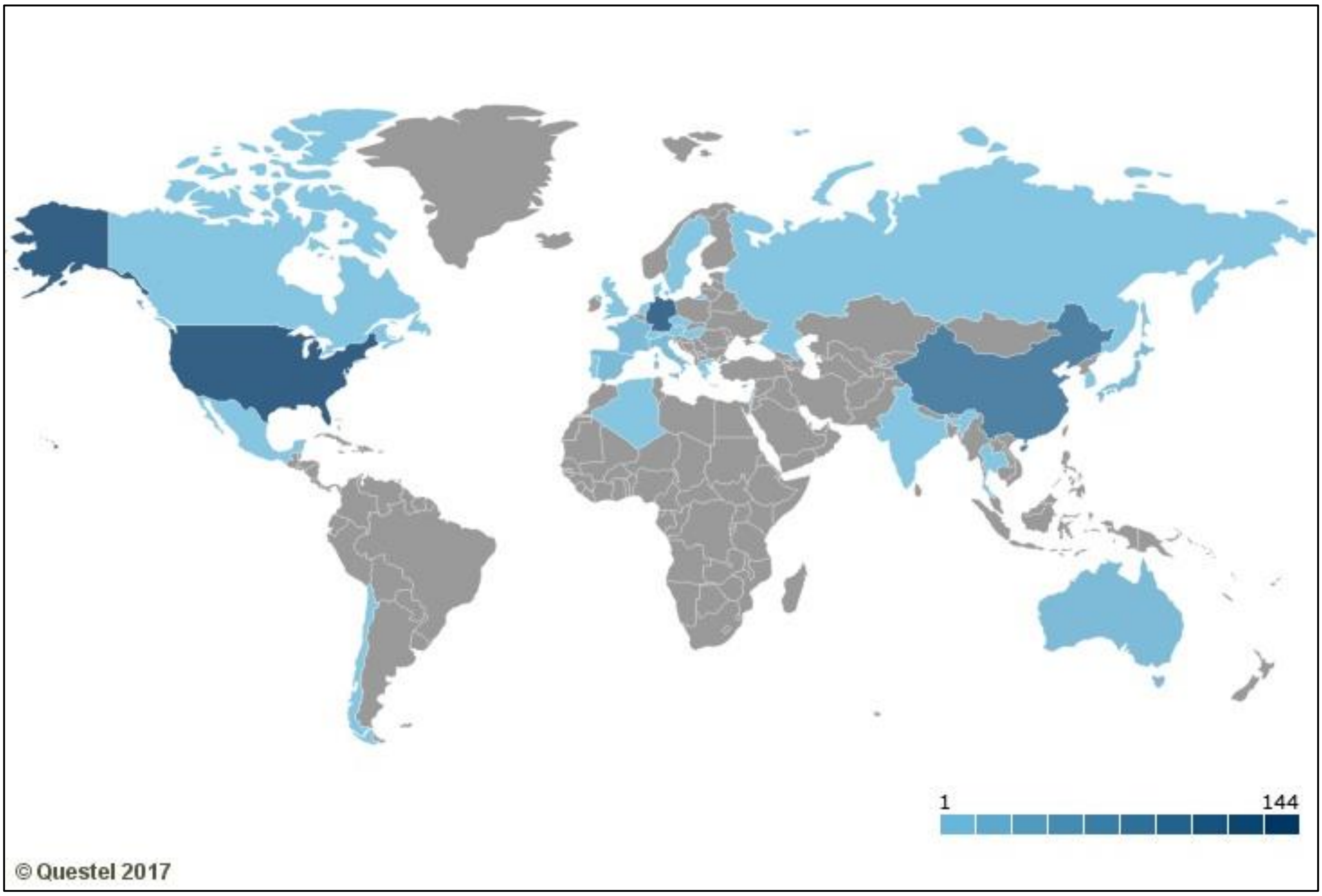
Source: *Questel 2017*

__Table 4.3__ Receiver Tubes: Distribution of Patent Families by 1st Priority Year



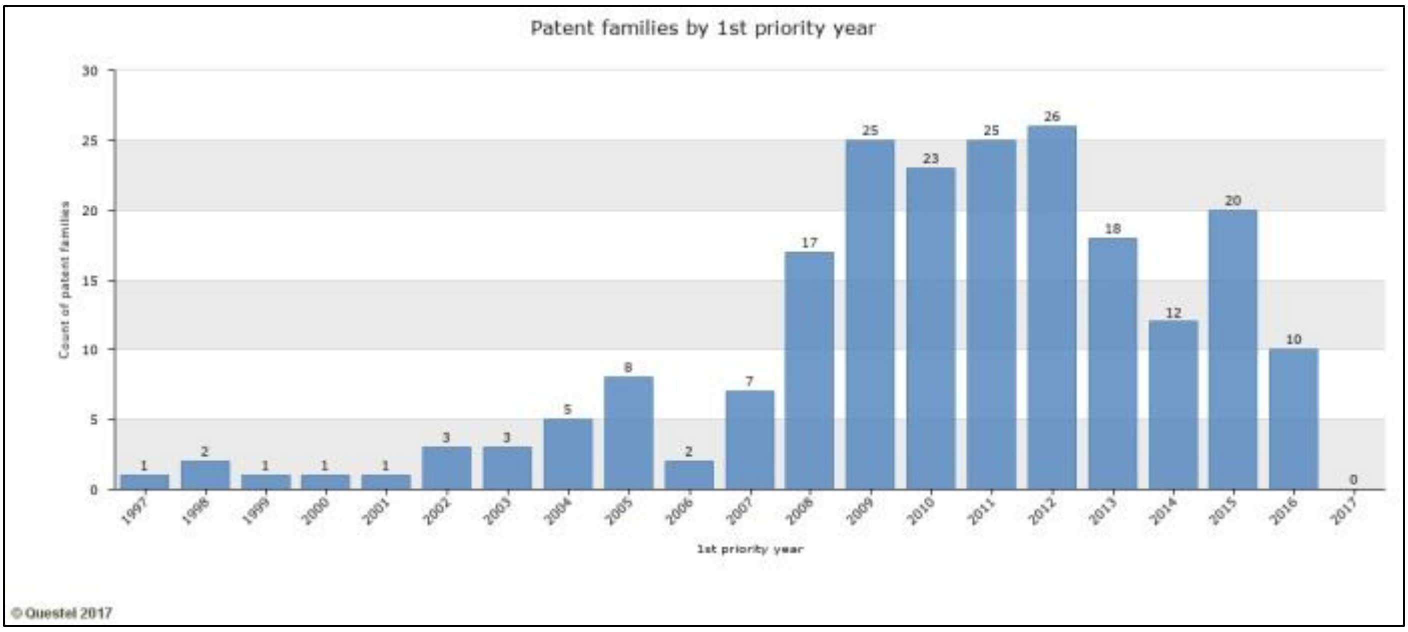
Source*: Questel 2017*

Figure 4.9 *Solar Collectors, Mirrors World Map Distribution of Patent families by Priority Countries*



Source*: Questel 2017*

Table 4.4 *Solar Collectors/Mirrors: Distribution of Patent Families by 1st Priority Year*



Source*: Questel 2017*

CONCLUSION

Nowadays the mix of energy use is at its turning point: it is shifting from conventional fuel sources to renewable energy sources. In this context CSP technology is the potential candidate able to contribute as a third big player in the Green Economy. We are delighted to see CSP on a solid growth pathway and poised to establish itself as a third big player in the new “sustainable power generation industry”: with advanced industry development and high levels of energy efficiency, it has also been estimated that it could meet up to 6% of the world’s power needs by 2030 and up to 12% of the world’s projected power needs in 2050, providing approximately 4.500 TWh.

In this analysis, it has been underlined the added value that CSP installations could provide to the new Green economy:

- CSP dispatchability potential would enable a further reduction in emissions by allowing increased penetration of intermittent renewable energy technologies in a reliable and affordable way;
- CSP would be able to meet both peak and baseload demand and to offer specific technical advantages in terms of water purification and desalination purposes;
- CSP industry would be able to boosting local economies, employing as many as 2.7 million people whose job will be to take up a new role in fighting climate change;
- CSP could create over €16 billion investment in 2020 peaking at €162 billion in 2050;
- CSP could save 32 million tons of CO_2 annually in 2020 and rising to 1.2 billion tons in 2050

On the other hand, to implement its cost reduction, a solid deployment program would be needed: strong political decisions could make the difference by establish a "positive investment environment" based on preferential financing conditions and/or tax investments incentive.

Thus, it is evident that CSP has an inexhaustible energy source, proven technology performance and it is environmentally safe. Thanks to its technology, CSP can significantly contribute to the world energy supply for the following several reasons:

- it is able to provide dispatchable power, helping the grid operator to reliably match supply and demand as well as to maintain the grid stability regulating the power production. Even if the added value of this capability is context-specific, it generally increases as the proportion of electricity generated by variable renewable sources increases;
- it can be easily integrated with thermos electric power stations so that the same thermal cycle and relating machinery can be used;
- it can be integrated in hybrid systems to better implement RES available;
- It can produce energy in remoted deserted areas that can be then moved to countries facing supply lack (given the water scarcity in desert regions, CSP technologies could be able to go one step forward by a dry cooling or CSP desalination cogeneration technologies).

With an implementation of CSP deployment program, the exploitation of this technology could strongly contribute to the reduction of global CO_2 emissions (by reaching a market volume of around 30 GW per year, CSP technology could avoid the need for new fossil fuel power plants).

This document aims to demonstrate how patents are an effective intermediate step between R&D (upstream) and innovation (downstream) in the economic process. In fact, since the Green Economy context is a fast-moving field, patents can either safeguard the pioneering investments and incentive companies to keep going in researching new technologies and generating new ideas which, in the long term, could help to manage the whole climate change problem.
Regarding this, EPO has produced a policy brief in co-operation with the International Renewable Energy Agency (IRENA) providing evidence on the latest trends in CCMT innovation and dissemination with a focus on renewable energy technologies, showing that patents support their deployment.
Patents are the only way to win the global warming race even if many developing countries see patents as a barrier to technology transfer to poorer countries because without patents, without intellectual property rights, it would be very difficult for new technologies even to arise. The evidence and existing literature suggest that in the examined green economy sectors, IPRs are one of the key factor positively influencing the evolution from R&D (upstream) to innovation (downstream) in the economic process.

As a concrete example of this positive effect, the Archimedes CSP project developed by ENEA, in collaboration with Italian industrial partners, has been analyzed and presented.
One of the main achievement of the program was the capacity to stimulate the interest of private stakeholders for the potential CSP market. Consequently, some new players already active in the manufacturing sector, implemented their presence in the CSP market.
Since one of the main commitment of ENEA was and still is the knowledge transfer to the industrial sector, several Italian industries, after being involved in Archimedes project, have acquired either specialized expertise related to the CSP supply chain and IPRs coming from the results raised from intensive R&D programs
Thanks to this mechanism, the Italian manufacturing system is able today to produce more than 90% of the components of a standard scale CSP plant and in July 2012, the Italian Minister of Economic Development and the Minister of Environment approved a new decree for new renewable energy mix also aimed at promoting CSP development showing its growing interest in the implementation of green technologies.

Then, focusing on Archimede Solar Energy, starting from a license agreement with ENEA regarding the use of molten salts as HTF, it produces today Solar Receiver Tubes operating up to 550ºC with different types of HTF: diathermic oil (for the bigger CSP plants) and molten salts or direct steam generation (for the new innovative plants). Until now, ASE has been able to made the most modern production facility ever built, becoming a worldwide technological leader thanks to a product entirely Made in Italy.

In conclusion, given the CSP study developed between 2001 and 2010, ENEA has been able to stimulate the attention to the role that Italy could play in the CSP emerging market. Focusing on the national border, the project has represented an example of how, through the public applied research, technology transfer could be a way to increase the production sector and pursue industrial policy objectives. Public intervention can in fact be widely recognized as a vehicle to overcome the tendency of the private sector to under-invest in R&D pioneers programs. Thus, we should increase our awareness related to these potentialities to avoid the pitfalls of uncertainty regarding public fundings and willingness of policy authorities. Financing the technology transfer could in fact be a successful solution to foster the diffusion of green technologies in our economic system. Additionally, patent protection can either guarantee a strong first mover advantage in the fast-growing environment such as the one of CSP sector and can also be an incentive to stimulate the investments of new potential players.

To sum up, the evidence and existing literature suggest that in the examined sectors, IPRs are one of the key factor influencing positively the evolution from R&D (upstream) to innovation (downstream) in the economic process.

GLOSSARY

CCMT: Climate Change Mitigation Technologies

CETs: Clean Energy Technologies

CHP: Combined Heat and Power

CIEMAT: Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CSP: Concentrated Solar Power

DSG: Direct Steam Generation

ENEA: Italian National Agency for New Technologies, Energies and Sustainable Economic Development

EPO: European Patent Office

ESTELA: European Solar Thermal Electricity Association

GHG: Green House Gases

HTF: Heat Transfer Fluid

IEA: International Energy Agency

IP: Intellectual Property

IPC: International Patent Classification

IPCC: Intergovernmental Panel on Climate Change

IPRs: Intellectual Property Rights

IRENA: International Renewable Energy Agency

ISG: Indirect Steam Generation

JPO: Japan Patent Office

MENA: Middle East and North Africa

MW: Mega Watt

NGO: Non-Governmental Organization

NREL: US National Renewable Energy Laboratory

PCT: Patent Cooperation Treaty

PV: Photovoltaic

R&D: Research and Development

R&I: Research and Innovation

RES: Renewable Energy Sources

S&T: Science and Technology

SET PLAN: Strategic Energy Technology Plan

STE: Solar thermal Electricity

TES: Thermal Energy Storage

TRIPS: Trade-Related Aspects of Intellectual Property Rights

TRIPS: Trade-Related Intellectual Property Rights

UNEP: United Nations Environment Programme

UNFCC: United Nations Framework Convention on Climate Change

USTPO: United States Patent and trademark Office

WIPO: World Intellectual Property Organization

WIPO: World Intellectual Property Organization

NSF: US National Science Foundation

BIBLIOGRAPHY

Archimede Solarenergy. (2016). “Concentrated Solar Power (CSP) The new frontier of molten salts”.

Battistelli, B. (2015). “Climate change mitigation and the role of patents”. *EPO*. Dec. http://blog.epo.org/patents/climate-change-mitigation-and-the-role-of-patents/

Belfer Centre for Science and International Affair. (2011). “The Energy Technology Innovation Policy Research Group Transforming the Energy Economy: Options for Accelerating the Commercialization of Advanced Energy Technologies”.

Braun, Frauke G., Liz Hooper, R.Wand, P. Zloczysti (2010). “Innovation in Concentrating Solar Power Technologies: A Study Drawing on Patent Data.” *Discussion Paper, DIW Berlin, German Institute for Economic Research.*

Business Insights. (2011). “The Future of Concentrating Solar Power Technologies Technology developments, key costs and the future outlook”. Feb.

Casagni, M., Coletta, G., Fontanella, A. & Fratini, D. (2014). “Concentrating Solar Power (CSP) Technology: from Research to Market. A Case Study. *ENEA – Italian National Agency for New Technologies.* Feb.

Crescenzi, T., Falchetta, M., Fontanella, A., Metelli, E., Miliozzi, A., Spinelli, F., Sipione, L. (2016). “Opportunità di Applicazione delle Tecnologie Solari Termodinamiche in Italia”. *ENEA.* ISBN: 978-88-8286-335-7

Delegation of the European Union to China and Mongolia (2015). “*China-EU Institute for Clean and Renewable Energy”*. May.

Dowling, A. W., Zheng, T., Zavala., V.M. (2017). “Economic Assessment of Concentrated Solar Power Technologies: A Review.” *Renewable and Sustainable Energy Reviews 72*.

European Commission, Office for Official Publications of the European Communities. (2007). “Concentrating Solar Power. From Research to Implementation”. http://www.eurosfaire.prd.fr/7pc/doc/1290173080_solar_power_ko7707256en.pdf

ENEA. (2009). “ENEA activities on thermodynamic solar plant (CSP)”. Feb.

ENEA. (2010). “A new approach to concentrating solar plant (CSP)”. https://www.kyotoclub.org/docs/roma160709_convKC_Vignolini_sm.pdf

European Commission. (2015). “STAGE –STE Project Meeting with Industrial Partners”.

European Commission. (2016). “Integrated STE Plan Progress in 2016”

European Commission. (2016). “Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy”. *2nd Periodic Report.* Feb.

European Commission. (2016). “SET-Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Solar Thermal Electricity (CSP/STE)”. Jan.

European Commission. (2017). “Financing energy efficiency: Lessons from successful Horizon 2020 projects and other initiatives across Europe”. March.

European Commission. (2016). “Transforming the European Energy System through Innovation. Integrated Strategic Energy Technology (SET) Plan Progress in 2016”. https://ec.europa.eu/energy/sites/ener/files/documents/set-plan_progress_2016.pdf

European Patent Office. (2016). “Finding sustainable technologies in patents”. https://www.epo.org/news-issues/issues/classification/classification.html

European Patent Office. (2015). **“**Climate change mitigation technologies in Europe - evidence from patent and economic data”. http://www.epo.org/news-issues/technology/sustainable-technologies/clean-energy/europe.html

European Solar Thermal Electricity Association and World Solar Thermal Electricity Association. “The Value of Solar Thermal Electricity Cost Vs Value Approach”.

European Solar Thermal Electricity Association. (2013). “Solar Industrial Initiative for STE – Implementation plan 2013-2015”.

Falchetta M. (2006). “Il Programma ENEA sull’Energia Solare a Concentrazione ad alta temperatura”. *ENEA.*

Fontanella, A., Crescenzi, T., Di Mario, F., Fabrizi, F., Mazzei, D. (2011). “Quaderno Solare Termodinamico”. *ENEA*. July. www.enea.it/it/comunicare-la-ricerca/documenti/quaderni.../solaretermodinamico.pdf

Gasparatos A., Doll, C.N.H., Esteban, M., Ahmed, A., Olang, T.A. (2017) “Renewable Energy and Biodiversity: Implications for Transitioning to a Green Economy.” *Renewable and Sustainable Energy Reviews 70*.

Giglio A., Lanzini, A., Leone, P., Rodriguez Garcia, M.M., Moya, E.Z. (2017). “Direct Steam generation in Parabolic through Collectors: A Review about the Technology and Thermo-Economic Analysis of a Hybrid System.” *Renewable and Sustainable Energy Reviews 74*.

GIURI. (2017). “Interim Evaluation of Horizon 2020 and Future FP9, Contribution to Debate”. March.

Granieri, M. (2014). “Intellectual Property for Managers. Law, Practice and Strategy”. *Luiss University Press*. ISBN: 978-88-6105-187-4.

Green Peace, Estela, Solar Paces. (2016). “Solar Thermal Electricity. Global Outlook 2016”. http://m.greenpeace.org/international/Global/international/publications/climate/2016/Solar-Thermal-Electricity-Global-Outlook-2016.pdf

Jorgenson, J., Denholm, P., & Mehos, M. (2014). *Estimating the value of utility-scale solar technologies in California under a 40% renewable portfolio standard* (No. NREL/TP-6A20-61685). National Renewable Energy Laboratory (NREL), Golden, CO..

Kosonen E. Without patents it would be very difficult for green technologies even to arise: An interview. *EPO* https://www.epo.org/news-issues/technology/sustainable-technologies/clean-energy/patents-clean-energy/green-technologies.html

Mansur, S., Jenkins, J. (2011). “Bridging the Clean Energy. Valley of Death Helping American Entrepreneurs Meet the Nation’s Energy Innovation Imperative.” *Breakthrough Institute.*

March E., OMPI, Oficina del Director General. (2009). “Hot Property – IP Strategies in the Solar Tech Sector.”
http://www.wipo.int/wipo_magazine/en/2009/02/article_0008.html

OECD. (2009). “OECD Patent Statistics Manual”. ISBN 978-92-64-05412-7

QUESTEL IP Business Intelligence. (2017). “ORBIT QUICK START”.

Raiser, K., Naims, H., Bruhn, T. (2017). “Corporatization on the Climate? Innovation, Intellectual Property Rights, and Patents for the Climate Change Mitigation.” *Energy research & Social Science 27*:1-8.

REN21, Renewable Energy Policy Framework for The 21st Century**.** (2016). *Renewables 2016, Global Status Report.*
http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

Rubini L., Habib, G., Lavra, M. (2011). “Tecnologie solari a concentrazione – Produzione di calore a media temperatura.” *ENEA.*

Scambieuropei. “Guida di Scambieuropei alle Borse di Studio”.

SunShot, US Department of Energy. (2014). “Concentrating Solar Power”.

SET-Plan CSP/STE Implementation WG – Document for Second Meeting. “Definition of ‘first-of-a-kind’/ first demonstration projects to reach the CSP/STE Targets”.

Spanish Delegation to the SET Plan. (2016). “Implementation of CSP Targets. State of Play”.

UN Environment. “What is an Inclusive Green Economy?”
https://www.unep.org/greeneconomy/what-inclusive-green-economy

UNEP, EPO, ICTSD. (2010). “Patents and Clean Energy: Bridging the Gap Between Evidence and Policy: Final Report”. *Geneva, Munich: United Nations Environment Programme (UNEP) Economics and Trade Branch, European Patent Office (EPO), International Centre for Trade and Sustainable Development (ICTSD).*

UNEP, EPO. (2015). “Climate Change Mitigation Technologies in Europe. Evidence from Patent and Economic Data”.
www.epo.org/climate-europe

WIPO. (2011). “Patent Landscape Report on Solar Cooking”.
www.wipo.int/publications/en/details.jsp?id=233

World Bank. (2011). “Middle East and North Africa Region Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects”. Jan.

Zuccarello, D. (2011). “L’analisi della tecnologia solare-termodinamico e la sua potenziale diffusione in ambito nazionale: Il programma CSP ENEA”.

(2016). “WG on implementation measures to achieve the SET-Plan targets on CSP/STE
Minutes of the First Teleconference - Priority technology actions to reach the targets”. May.

SITOGRAPHY

Archimede Solar Energy
(www.solarexxi.com)

Concentrating Solar Power Projects
https://www.nrel.gov/csp/solarpaces/index.cfm

CSP Projects Around the World
http://www.solarpaces.org/csp-technologies/csp-projects-around-the-world/

ENEA
http://www.enea.it/en

ENERGY.GOV: Office of Energy efficiency & Renewable Energy
https://energy.gov/eere/sunshot/sunshot-initiative-goals

EPO: EPO publishes new policy brief on climate technologies and enhances cooperation with IRENA
https://www.epo.org/news-issues/news/2017/20170703.html

Greenpeace International: The Energy [R]evolution.
http://www.greenpeace.org/international/en/campaigns/climate-change/energyrevolution/

Investigating the industrial needs in the CSP research
https://www.eera-set.eu/wp-content/uploads/STAGE-STE-survey_2016_11_24-Birmigham.pdf

Leading countries in installed concentrated solar power (CSP) as of 2014 (in megawatts)
https://www.statista.com/statistics/494169/global-installed-concentrated-solar-power-csp-capacity-by-key-country/

MATS Project: Multipurpose application by Thermodynamic Solar
http://www.mats.enea.it/obiettivi.asp

Multipurpose Applications by Thermodynamic Solar
http://cordis.europa.eu/project/rcn/100479_en.html

NREL: National Renewable Energy Laboratory
https://www.nrel.gov/csp/

Patracode, Empowering your intellect. Orbit IP Business Intelligence (2016)
https://www.patracode.com/questel-orbit-ip-business-intelligence/

STAGE-STE, EERA, European Commission. “Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy”. *Project Periodic Report.*
http://cordis.europa.eu/project/rcn/111484_en.html

The Climate Reality Project: What is grid Parity and Why does it matter?
https://www.climaterealityproject.org/blog/what-grid-parity-and-why-does-it-matter

Why We’ll Need CSP’s Solar Thermal Energy Next (2017):
http://www.solarpaces.org/why-need-csp-solar-thermal-energy-next/

EXECUTIVE SUMMARY

One of the biggest challenges facing humanity today is climate change. Since both final energy consumption and world carbon dioxide (CO_2) emissions have doubled in the last 35 years, it is not surprising that the limited fossil fuel resources and the negative impact of greenhouse gases (GHG) emissions command to find solutions for alternative primary energy supply and methods for energy savings. Thus, scientists and engineers are developing new technologies to reduce CO_2 emissions, capture GHG, generate energy from renewable energy resources (RES) and distribute energy more efficiently. Ambitious Research and Innovation (R&I) targets have been set for renewable technologies showing great potential for cost-reductions, performance improvements and large scale deployment worldwide. This challenge make us to think about how "going green" is not only an obligation toward future generations, but it is also a key factor to boosting development in a world where, as International Energy Agency (IEA) stated, a quarter of the population has no electricity.

In this context, a new concept of Green Economy has emerged. Green economy has been defined as an economic system resulted in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In a green economy, growth in income and employment are driven by public and private investments that can reduce carbon emissions and pollution, enhance energy and resource efficiency and prevent the loss of biodiversity and ecosystem services" (United Nations Environment).

In this green framework, the European Union has established challenging targets for making a transition to a sustainable energy system, including that the EU's electricity supply should achieve essentially zero emission of GHG by 2050. In the light of the Paris Agreement, agreed by nearly 200 countries across the world, we urgently need to revise current EU and national targets to achieve the goal of limiting global temperature increase to 1.5˚C. The EU's 2030 climate and energy goals (e.g. a 40% emission reductions by 2030 compared to the 1990 level), seem not sufficient to get us there: only a stronger emissions target in line with the rapid decarburization of the energy sector and a higher share of renewable energy consumption will make this goal achievable.

Concentrated Solar Power/Solar Thermal Electricity (CSP/STE) technologies represent one of the key factor that would enable Europe to reach its goals. CSP can provide dispatchable electricity (with the provision of an embedded storage capability), "on demand" heat generation and it could be a key to achieve 100% renewables share by 2050 in a wise mix with other renewables. The solar thermal technology is not the same as photovoltaic (PV). Solar thermal electric energy generation concentrates the sun light to a temperature typically between 400ºC and 1000ºC to produce heat that is used to run a heat engine, which turns a generator to make electricity. On the other hand, PV directly converts the sun's light into electricity. Thus, while solar panels are effective only during daylight hours, CSP technologies can be integrated with an energy storage system to store heat during the day and convert it into electricity at night. Therefore, solar thermal is attractive for large-scale energy production and can improve the economics and the dispatchability of solar electricity.

As the other RES, solar power is an intermittent energy source, making unpredictable the electrical power generation coming from its utilization. It means that matching energy production with energy demand can be laborious. To manage this issue, an efficient energy system is needed to generate electrical power able to avoid shortages. Two main systems can be identified to fill this gap:

- energy storage systems able to accumulate energy during lower demand or surplus production periods;
- hybrid power plants able to balance strengths and weaknesses of each technology using two or more primary energy sources.

If we think to combine both systems, it would be possible to control the energy supply while exploiting renewable sources as much as possible.

Thus, CSP technology seems to be the most likely candidate for the conversion of a huge amount of energy: if supported by thermal storage capacity, it is dispatchable and potentially the most cost-effective renewable electricity technology. It is also a promising option for hybridization and thermal energy storage (TES) integration because it converts sun radiation into thermal energy before generating electrical power. This characteristic simplifies the integration of CSP plants with other thermal energy sources such as fossil fuel or biomass conversion.

One of the main misleading issues in evaluating the renewable energy market (especially if we are going to focus on the CSP one) is that the usual key metric for the cost evaluation is the Levelized Cost of Energy (LCOE). The LCOE metric is not built on the distinction between Value and Cost connected to RES. It means that it does not address the value of flexibility enabling a responsive behavior of plants to the demand, capacity availability, grid stability, energy security, local economic impact as well as the effects on job creation and the impact on trade balance. Thus, since it is mainly built on pure-cost based auctions, it is not supportive to a far-reaching energy policy-making leading system, planning decisions and support schemes; what we would need is a system approach able to emphasize the value added to the system related to the capabilities of CSP technologies. According with this approach, the value can be either expressed in operational terms (time-of-day effective operation hours, impact on spinning capacity reserve contribution to ancillary services, induced generation curtailment, etc.) and in terms of added capacity (investments avoided to cover demand in all timeframes on top of the investment of the new plant itself).

If we integrate the system approach with a comparative one, we can estimate and understand the value of CSP technology in relation with other RES (e.g. PV and Wind). What emerged from this analysis is that when both Wind and PV technologies had the same power installed as CSP has today, their c€/kWh were much higher. Furthermore, it has been highlighted that at a given corresponding market volume, when we consider the electricity generation costs, we have to consider what we intend for Value (defined as either operational value and capacity value): the hidden benefits brought to a system by a given project (instead of considering only the project cost). This is a relevant evidence of the fact that, comparing the RES costs, we should consider

also the added value that storage flexibility can bring when a storage system is integrated in the CSP Technology.
The value of CSP system is far beyond its generation costs: the current price gap between CSP plants and Wind or PV plants could be partially reconsidered and consequently reduced if analyzed in a value-to-the-system perspective and the remained gap would be automatically compensated by the growing maturity of CSP market.
According to a research conducted by the US National Renewable Energy Laboratory (NREL) on California power markets, the main value added of CSP operating with TES is related to its ability to provide firmness-of-supply. Moreover, the research shows that CSP with storage has a higher marginal operational value than PV and the relative value may increase slightly with increased PV penetration. The study concluded that, it is economically equivalent to pay 5 US$ cents/kWh for a new PV plant and 10 US$ cents/kWh for a CSP plant with storage.
Since CSP can provide firm and dispatchable electricity whenever is needed while PV electricity generation operates better in the middle of the day, the two systems can be considered as two complementary technologies: the CSP value could increase as PV could further deploy to be able to exploit early morning/mid-day peaks and beef-up evening. PV is growing faster, it is a simpler system and apparently costless, but it is not dispatchable and CSP represents a way to deliver power over long hours after daylight.
We can conclude that, in case a future market design would fall short of changing its rationale compared to the current one, it will be up to regulators and system planners to duly assess the value rather than just using the pure marginal cost approach, to make the energy model transition sustainable, efficient and affordable.

To sum up, CSP coupled with TES could improve both economics and technical performance of the system:

- less fossil fuels used for shifting solar power to high-value evening hours;
- significant system cost savings for system control and load-following;
- less variability in power system;
- hedging against solar forecast errors;

Additionally, CSP installations could provide added value to the new Green Economy:

- CSP dispatchability potential would enable a further reduction in emissions by allowing increased penetration of intermittent renewable energy technologies in a reliable and affordable way;
- CSP would be able to meet both peak and baseload demand and to offer specific technical advantages in terms of water purification and desalination purposes;
- CSP industry would be able to boosting local economies, employing as many as 2.7 million people whose job will be to take up a new role in fighting climate change;
- CSP could create over €16 billion investment in 2020 peaking at €162 billion in 2050;
- CSP could save 32 million tons of CO_2 annually in 2020 and rising to 1.2 billion tons in 2050

The shift from conventional fuel sources to renewable energy sources is demonstrated by the evidence that in 2015 both Wind and PV accounted for 73% of new energy installed capacity, overtaking the conventional power sources, such as fuel oil and coal whose capacity is more decommissioned than installed.

2015 represented a challenging year for CSP technology due to the market deceleration after a global operating capacity increasing from 420 MW to around 4.8 GW at the end of the year. At the beginning of 2016, new projects were under construction and new plants are expected to become operative in 2017.

From the data analysis CSP results to be on a solid growth pathway and poised to establish itself as a third big player in the new "sustainable power generation industry". To date, CSP counts for about 5% of the global investment in energy infrastructure (of 158-186 billion Euro invested each year), showing its contributive potential to a "New Green Deal" for the economy. With advanced industry development and high levels of energy efficiency, it has also been estimated that it could meet up to 6% of the world's power needs by 2030 and up to 12% of the world's projected power needs in 2050, providing approximately 4.500 TWh (Green Peace, Estela, Solar Paces, 2016). Additionally, starting from 2015, all new CSP systems are projected to incorporate TES capacity to increase the flexibility and the dispatchability of the plants.

From 2015, the market has started to expand beyond Spain and US (which still cover around 90% of CSP global installed capacity). By the end of the year, new facilities came up in Australia, Chile, China, India, Israel, Mexico, Saudi Arabia and South Africa. More specifically, Morocco and South Africa have passed the US in added capacity and Morocco has become the first developing country to top the global CSP market.

It is evident that developing markets represent a huge potential for CSP development. Additionally, given its characteristics, CSP is receiving increased policy support in countries with limited oil and gas reserves, constrained power networks, or strong industrialization and job creation programs.

Even if Spain is still the global leader in CSP installed capacity (2.3 GW), no other new CSP facility was installed/developed/planned neither in 2015 nor in 2016. This is one of the reason why (together with the slowdown of the US CSP market) new emerging markets are facing a strong increase in the CSP installed capacity: CSP players started to create new partnership and to invest in new potential markets.

In this new environment it is important to understand the role of the Intellectual Property Rights (IPRs) and the impact of technology transfer.

In fact, as the climate change is the most pressing challenge of our time, we need a significant mobilization of human and financial resources to alter our patterns of production, consumption and energy use. Enhancing technology transfer has been defined as a key pillar of the global climate change regime. Nowadays, the current climate change negotiations confirm the need to strengthen this pillar through the establishment of a technology mechanism able to accelerate technology development and transfer. A market change as the one mentioned above must be also supported by a licensing encouragement.

In this context, polarized views emerged regarding the role that Intellectual Property (IP) should play:

- many developing countries and some non-governmental organizations (NGOs) uphold the use and expansion of the flexibilities on IP available within the WTO TRIPS Agreement, such as compulsory licensing, being convinced that this will help to ensure greater access to climate change technologies;
- on the other hand, many developed countries and business associations claim that only strengthened IP regimes will encourage the innovation, transfer and diffusion of such technologies.

IP is in fact central to business and R&D strategies, due to the fact that its policy sits at the crossroads between technology, marketing and finance. This is one of the main reason why companies, associations and other market players are more and more using IP to achieve their goals and to try to maintain a leading edge.

Patents represent an effective way to track the rise of emerging technologies. Thanks to all the information that can be provided, patents statistics can in fact be used to track the dynamics of the innovation process (e.g. co-operation in research, diffusion of technology across industries or countries), the competitive process (the market strategy of businesses) and the globalization patterns.

On the other hand, patents face a trade-off. On one side, they encourage new inventions ex ante, but they have a cost ex-post: by giving exclusive use to a company, a patent will limit competition and allow higher prices, thereby excluding customers who would have been ready to pay the marginal cost of a good but cannot pay the mark-up charged by the patent owner. This is the key dilemma affecting the patent issue: patents can improve the dynamic economic efficiency and, at the same time, be responsible of the detriment of static efficiency: a longer and broader patent protection favors rent appropriation, while a shorter and narrower one favors diffusion. (OECD Patent Statistic Manual, 2009).

The new Green Economy is impacting Climate Change Mitigation Technologies (CCMT) by focusing on controlling, reducing or preventing the anthropogenic GHG emissions, as covered by the Kyoto Protocol. Since patents are usually considered as an intermediate step between R&D (upstream) and innovation (downstream) in the economic process, EPO has produced a policy brief in co-operation with the International Renewable Energy Agency (IRENA) in order to provide evidence on the latest trends in CCMT innovation and dissemination with a focus on renewable energy technologies, showing that patents support their deployment. To help engineers, scientists, institutions and decision-makers use this wealth of knowledge in their work, the European Patent Office (EPO) has developed a dedicated document tagging scheme. More specifically, the tagging scheme incorporates both CCMTs and smart grids. The scheme was devised in close co-operation with expert partners in the field, using technological guidelines produced by the United Nations Framework Convention on Climate Change (UNFCC) and the Intergovernmental Panel on Climate Change (IPCC). The new scheme makes it easier to retrieve relevant information quickly and accurately. It also makes possible to map sustainable technologies, identify trends and facilitate further R&D. Out of the over 90 million patent documents available in the European Patent Office's databases, nowadays over 3 million are related to CCMT.

The new so called Y02 classification scheme is specifically dedicated to climate change mitigation technologies and it enables a continuous and reliable flow of data on selected technologies and their application in the energy field. There are already over 3 million documents with Y tags in the EPO's databases, a number growing as more documents are published (newly published documents are tagged in batches, at least twice a year). These documents are accessible to everybody, free-of-charge, and come from anywhere in the world. It is by far the biggest single inventory of low carbon technologies in the world. To ensure their relevance, the categories were defined with the help of experts in the field, both from within the EPO and with the help of external partners, including the Intergovernmental Panel on Climate Change (IPCC).

Patents are the only way to win the global warming race even if many developing countries see patents as a barrier to technology transfer to poorer countries. "They see patents as an attempt to conceal technological progress, to deny them the benefit of the industrialized world's achievements and not least to make money from inventions that are needed to save the world. But, without patents, without intellectual property rights, it would be very difficult for new technologies even to arise." (Kosonen E., European Union Expert)

Since the Green Economy context is a fast-moving field, patents can either safeguard the pioneering investments and incentivize companies to keep going in researching new technologies and generating new ideas which, in the long term, could help to manage the whole climate change problem. Moreover, it is also true that most of developing countries don't have neither the infrastructure nor the capacity to take in high-tech technologies. Thus, patents are not a real obstacle for them because many of low-tech engineering solutions (in which they could be interested) are off-patent.

EPO has also thought to establish a technology mechanism within the climate negotiation to make developing countries able to benefit from information on technological process that patents can provide. A Climate Technology Center and a Network platform should be created so that all available technologies can be accessed. The Center could give advice on what kind of technologies can be used, where they are available and what are the best solutions for each country. The aim is to facilitate the technology transfer to developing countries providing them knowledge and information needed and to establish a financial system in the climate negotiations and in the agreement without compromising the incentive mechanism provided by patent systems. Thanks to this kind of approach, a developing country could have the chance to buy high innovative technologies.

To sum up, the evidence and existing literature suggest that in the examined sectors, IPRs are one of the key factor influencing positively the evolution from R&D (upstream) to innovation (downstream) in the economic process. As a concrete example of this positive effect, the Archimedes CSP project developed by ENEA, in collaboration with Italian industrial partners, has been analyzed and presented.

Italy can be classified among the pioneers in the CSP field thanks to the contribution given by Giovanni Francia (1911-1980) in the 20th century. He was a mathematician, inventor and visionary engineer who

contributed in implementing several industries from the 1950s onward. One of its main contributions is related to the field of CSP technologies, that nowadays is still influencing the basic designs of new CSP facilities.
The strong interest in the re-launch of the Italian CSP technology is also strictly connected with the Nobel laureate Carlo Rubbia who was, at that time (2001), the president of ENEA (the Italian National Agency for New Technologies, Energy and Sustainable Economic Development). He was the first to propose to use molten salts as heat transfer fluid (HTF) in place of diathermic oil in the receiver/boiler of Linear Parabolic concentrating systems. The worldwide prevailing technology at the time was indeed that of the Parabolic Trough Systems, and with a share greater than 90%, it is still the current dominant technology.

ENEA was founded in 1952 to be a specialized body in the peaceful applications of nuclear energy. Since 2001, ENEA has started to focus on an intensive R&D program aimed at implementing a new concept of CSP “Parabolic Trough Variant" technology in which high temperature (up to 550°C) molten salts (a mixture of potassium nitrate and sodium nitrate) are used either as heat-transfer fluid and heat-storage fluid in replacement of the synthetic oil (up to 390ºC).
The so called Archimedes program (2001-2010) has been not only an example of how to manage the whole innovation process, avoiding the pitfalls of the intermediate stage between basic research and commercialization but it has also been a demonstration of how public applied research is able to trigger relevant technology transfer to the productive sector (Casagni et al., 2014). This experience aimed also to underline the usefulness of the public intervention into the innovation process (i.e. IP system, government support of innovative activities, R&D tax incentives, encouragement of research partnerships): public intervention can be widely recognized as a vehicle to overcome the tendency of the private sector to under-invest in R&D. We have also to consider that there is a lower awareness regarding the fact that economic activities do not arise only from basic research, but also from the later diffusion of new products, services or processes into the economy.
This stage of the innovation process is often characterized by the existence of the so called "Valley of Death". One of the main causes of this gap between basic research and commercialization stage is the uncertainty related to the whole innovation process and to the technical and commercial expertise required by a project moving from pure knowledge to commercialization.

According to article n. 111 of the law n. 388 of 2000 (State budget law for the 2001), ENEA has been charged (involving several firms through a selection process) with an R&D program aimed at implement a CSP industrial plant able to generate electricity from solar energy source.
Since the main goal was the development of industrial products suitable for large diffusion, the collaboration with industrial partners was encouraged to identify better effective solutions for a mass production. Thus, in 2003, ENEL (the Italian largest power company and one of the European biggest utilities) joined this program by signing a memorandum of understanding. Thanks to this collaboration, it was possible to define the

conditions needed to integrate the developing solar power plant to the already existing combined cycle plants where the demonstrative plant was planned and to draw up the final project.
One of the main achievements of the program was the capacity to stimulate the interest of private stakeholders for the potential CSP market.
As a consequence, some new players already active in the manufacturing sector, strenghten their presence in the CSP market. In this context, it is important to recall the foundation of Archimede Solar Energy (ASE), a company of the Italian Industrial Group Angelantoni S.p.A. (Massa Martana, Perugia, Italy). ASE is now one of the main international players in manufacturing Receiver Tubes designed to operate at temperatures up to 550°C, also thanks to the license agreement on technologies provided by and developed with ENEA.

The technological innovations achieved through the R&D program brought to the establishment of the national Consortium "Solare XXI", formed by four sector leading companies (Archimede Solar Energy for the receiving pipe production, Ronda High Tech for the reflective panels, Duplomatic for the motion control system and Techint for the design of the supporting frameworks and the component integration), with the aim of deepening the research and the implementation of highly technological products, such as the Linear Parabolic Solar Collector with molten salts.
As result, the Italian manufacturing system is able today to produce more than 90% of the components of a standard scale CSP plant. Moreover, in July 2012, the Italian Minister of Economic Development and the Minister of Environment approved a new decree for new renewable energy mix also aimed at promoting CSP development. It is expected that CSP plants connected to the grid by 2020 will reach a capacity of 600 MW.

After the success of the Archimedes project, the industrial research has started to focus on the development of new other potential CSP applications such as Small CSP and Integrated Systems. Additionally, focusing on a longer term impact in the innovation process, it is also interesting to have a look on the on-going investment strategies of the Italian leading companies involved in the Archimedes project.
In 2011, ENEA started the MATS project (Multipurpose Applications by Thermodynamic Solar), with a total investment of 22 million Euro, of which 12.5 million funded by the European Union. Among the innovative CSP technologies developed by ENEA it is important to mention: the use of molten salts as HTF; the modularity of the solar field; a storage system with only one tank (instead of two); the integration of the steam generator inside the storage tank.
The project aim was to produce energy able to be a source in a desalination unit included in the facility installed, as well as for district heating and cooling. Additionally, the installed heat storage system is able to implement the firmness-of-supply of the power production managing the intermittency of the solar energy source. The electrical energy production "on demand" is achievable as well as the optimized utilization of captured solar energy by additional loads like desalination. Finally, the integration with a backup gaseous fuel,

coming from biomass or natural gas, is able to provide additional flexibility to the system and consequently, a continuous power production

All these key innovative components (such as molten salts, TES with integrated steam generator, molten salts heater using back up fuel, water desalination units) have been first developed and tested individually and then assembled to test the functioning of the overall system.

Since one of the main commitment of ENEA was and still is the knowledge transfer to the industrial sector, several Italian industries, after being involved in Archimedes project, have acquired either specialized expertise related to the CSP supply chain and IPRs coming from the results raised from intensive R&D programs: collector and mirror manufacturers like Ronda High Tech, Reflex S.r.l., D.D. S.r.l., and collector tracking equipment like Duplomatic Oleomatica S.p.A. can nowadays benefit from IPRs stemming from the ENEA CSP research program and widen their product portfolio.

In this context, ASE, one of the manufacturing company involved in the project, has gained the worldwide patent license in the innovative CSP technology regarding molten salts receivers.

Born as a subsidiary of Angelantoni Industrie Group, ASE is nowadays a world leader in the production of solar receiver tubes for CSP plants with Parabolic Troughs or Fresnel Reflectors.

Starting from a license agreement with ENEA regarding the use of molten salts as HTF, ASE started to produce Solar Receiver Tubes operating up to 550ºC with different types of HTF: diathermic oil (for the bigger CSP plants) and molten salts or direct steam generation (for the new innovative plants).

In conclusion, given the CSP study developed between 2001 and 2010, ENEA has been able to stimulate the attention to the role that Italy could play in the CSP emerging market. Focusing on the national border, the project has represented an example of how, through the public applied research, technology transfer could be a way to increase the production sector and pursue industrial policy objectives. Public intervention can in fact be widely recognized as a vehicle to overcome the tendency of the private sector to under-invest in R&D pioneers programs. Thus, it is of pivotal importance to raise the awareness related to these potentialities to avoid the pitfalls of uncertainty regarding public funding and willingness of policy authorities. Financing the technology transfer could in fact be a successful solution to foster the diffusion of green technologies in our economic system.

It is evident that patent protection can either guarantee a strong first mover advantage in the fast-growing environment such as the one of CSP sector and can also be an incentive to stimulate the investments of new potential players.

To have a concrete feedback from a patent protection perspective and to understand how they can provide reliable information regarding the innovation, the competitive process and the globalization patterns, I have held an internship at ENEA Brussels Office.

This gave me also the chance to meet the ENEA team in Bologna; there, I learnt how "Questel Orbit" patent database is used to track the development dynamics in each field of interest. To understand how patent data analysis can be used as a complementary source of Science and Technology (S&T) data, I have tried to extrapolate reliable data regarding CSP technologies, supported by Gateano Coletta, researcher at ENEA in Bologna.

At the end of my internship I met the Archimede Solar Energy team in its head office in Perugia where I had the chance to visit the CSP manufacturing plant and to concretely understand how the relation ASE has with ENEA (upstream through license agreements) and with the CSP market (downstream) brought it to be a manufacturing leader worldwide.

To implement the analysis, it has to be kept in mind that, even if the CSP plant is a whole integrated installation, the value chain is characterized by a high grade of fragmentation: CSP facility is made by several components coming from different manufacturing sectors and players.

Consequently, we have implemented a strategy according to which we searched for patents segments related to innovative technologies fundamental to manufacture CSP plants: receiver tubes and solar collector mirrors. Another issue we considered in this analysis is that the patentee entity is not necessarily also the player exploiting the technology in the market.

Even if we have structured the researches proceeding following a segmentation according to the main components of CSP plants, the results have been analyzed after having being crossed and consistently combined. In this way we were able to return a comprehensive and consistent overview of the evolution of new technology development in CSP sector.

The results obtained from our research are consistent with the market analysis presented in the first part of the present document and it helped us to understand how the CSP market is evolving. The evidence gained through our researches are coherent with the findings analyzed before:

- 2015 represented a challenging year for CSP technology due to the market deceleration; during 2016, the patent applications in the field of interest are much less with respect to 2015;
- the market has started to expand beyond Europe and US. From a patent perspective, new technologies have been developed in countries such as Australia, China, India, Mexico and Thailand;
- developing markets represent a huge potential for CSP development: the fact that CSP is receiving increased policy support in countries with limited oil and gas reserves, constrained power networks, or strong industrialization and job creation programs is demonstrated by the growing concentration of new technologies patented in new emerging markets.

It is true that we expected to see CSP to be on a solid growth pathway aiming at establishing itself as a third big player in the new “sustainable power generation industry”. At the same time, it is evident how statistics on patent filings are a powerful indicator of Research, Development and Innovation since they are a reliable source to undertake accurate analysis.

This patent approach also showed that is important to implement a patent protection system to stimulate the development of a fast-growing market (such as the CSP one). New potential and existing players need to have legal guarantees to significantly invest in a risky sector.