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ECONOMIC ANALYSIS OF A PHOTOVOLTAIC INVESTMENT PROJECT

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EXECUTIVE SUMMARY

In Italy, in 2013, on the field of renewable energy production regarding the electric sector, the photovoltaic technology is the second (21%) for contribution following the hydraulic one (44%)[1]. Since its introduction, many aspects of the photovoltaic technology convinced people but it is not already clear if it can be a sustainable future of the production of energy. There are positive aspects such as the low environmental impact and the progressive reduction in costs experienced in the last few years but there are also negative features, such as the pollution generated from the industry of solar panels: PV panels' production involves toxic and flammable substances and chemicals that can involve environmental hazards[2]. Recently, in order to stimulate the investments in this field, several countries applied incentives for the installation of solar panels. This happened in Italy with five subsequent feed-in schemes named "Conto Energia" from 2005 until 2013 that aimed at stimulating the photovoltaic market in order to gain the competitiveness of the photovoltaic source compared to the other systems of energy production.

This work aims at analyzing and valuating a hypothetical investment in the photovoltaic technology applied to a sports center located in the North East of Italy, in the province of Padua. How much is it worth nowadays to invest in the PV technology? People can answer this question in several and discordant ways because there are many endogenous factors that could determine the creation of economic value as well as the destruction of it. Therefore, at the beginning, I will study them in order to depict the general framework. Next, I will evaluate the investment from an economic point of view.

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[1] GSE, "Rapporto statistico – Energia da fonti rinnovabili", 2013.

[2] MCEVOY A., MARKVART T., CASTANER L., 2011. "Practical Handbook of Photovoltaics: Fundamentals and Applications", Academic Press.

CHAPTER 1

This chapter contains a brief description of the photovoltaic technology and its enlargement through the markets all over the world. I will do this first with a global scale, then the European one and finally I will provide the Italian market description. At the end of the chapter there is a paragraph containing the forecasts of the market evolution until 2019. The largest part of this chapter is taken (and obviously adapted to the purposes of my work) from the Global Market Outlook 2015-2019[3], written by the SolarPower Europe association, the new EPIA (European Photovoltaic Industry Association). This association has the purposes of shaping the regulatory environment and improve business opportunities for what regards the photovoltaic sector.

Figure 1- Simulation of mono-silicon photovoltaic panels (Source: "www.pvwatts.nrel.gov")

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[3] SolarPower Europe, "Global Market Outlook for Solar Power 2015-2019", 2014.

1.1 The photovoltaic technology

The primary source of power of a photovoltaic system is the sun. Roughly speaking, photovoltaic (PV) technology consists on the conversion of the solar radiation into electricity. The most common solar cell material is crystalline silicon but newer materials are facing into the market such as thin-film materials like cadmium telluride, copper indium diselenide and amorphous silicon. Recently, companies have announced plans to produce solar cells using polymer plastics and solar absorbing inks printed on aluminum foil.

There is a wide range of PV cell technologies on the market today, using different types of materials, and an even larger number will be available in the future. PV cell technologies are usually classified into three generations, depending on the basic material used and the level of commercial penetration:

- First-generation PV systems, that are fully commercial, use the wafer-based crystalline silicon technology, either mono crystalline or multi-crystalline.

- Second-generation PV systems are based on thin-film PV technologies and generally include three main families: amorphous and micro morph silicon, Cadmium-Telluride and Copper Indium-Selenide and Copper-Indium Gallium-Diselenide.

- Third-generation PV systems include technologies, such as concentrating PV (CPV) and organic PV cells that are still under demonstration or have not yet been widely commercialized, as well as novel concepts under development.[4]

Solar cells could power everything in our life starting from small calculators, passing through commercial buildings and arriving to power satellites in the space.

The photovoltaic effect (Figure 2) is the physical and chemical phenomenon responsible for the conversion from solar light to electric power, a flow of electrons, and it takes place in the photovoltaic cell. This effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current. Alexandre-Edmond

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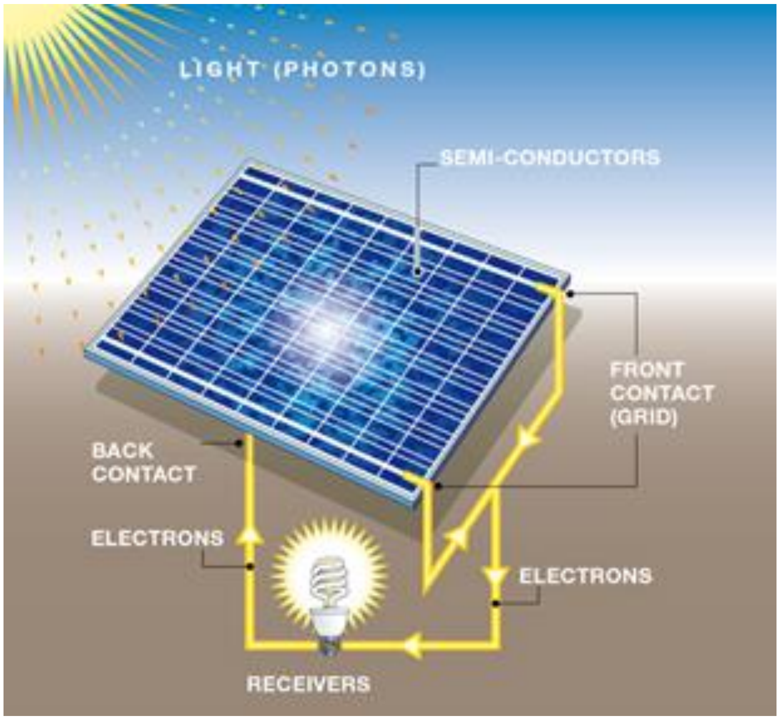
[4] IRENA, June 2012 “Solar Photovoltaics”.

Becquerel first observed the photovoltaic effect in 1839. The first practical application of photovoltaic was to power satellites and other spacecraft, but today the majority of photovoltaic are used for grid connected power generation. The inverter is the device required to convert the direct current to alternate current that is necessary for commercial buildings and houses.

Figure 2 - the PV effect (Source: "solatribune.com")



The conversion efficiency, taking into account the technology progress, is between 12% and 17% for commercial silicon solar cells, while specific laboratory experiments reached 24%. In the next page, I prepared a pie graph representing the share of energy that is really used by the solar cell and the shares that are lost in the conversion process. The most significant part of energy lost is the optical one, regarding the fact that photons with too low (24%) and with too high (32%) energy cannot be players in the photovoltaic effect. The electrical losses (27%) are explained by the fact that not all the energy coming from the sun is directly convertible[5].

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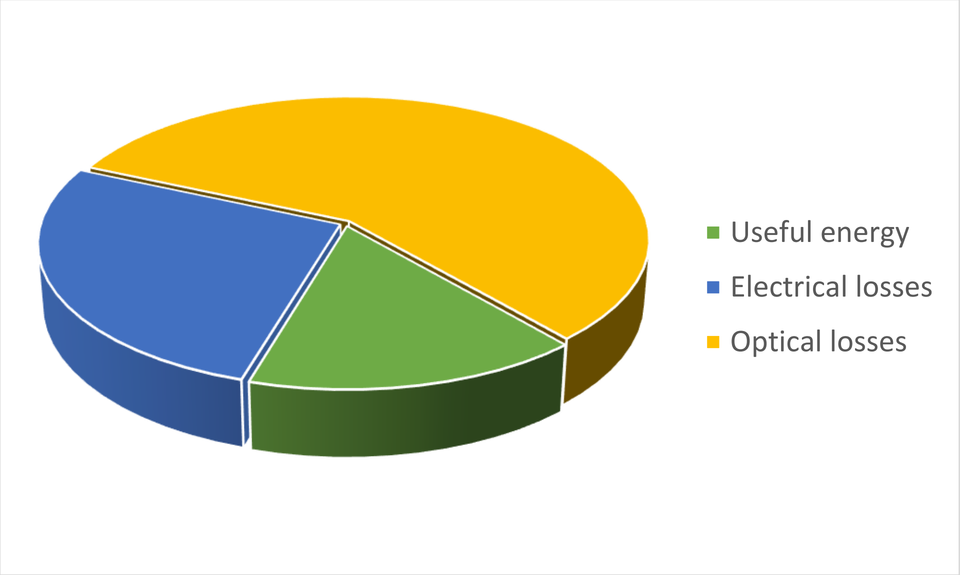
[5] VIVOLI F. P., 2008. "Progettare ed installare un impianto fotovoltaico", ENEA.

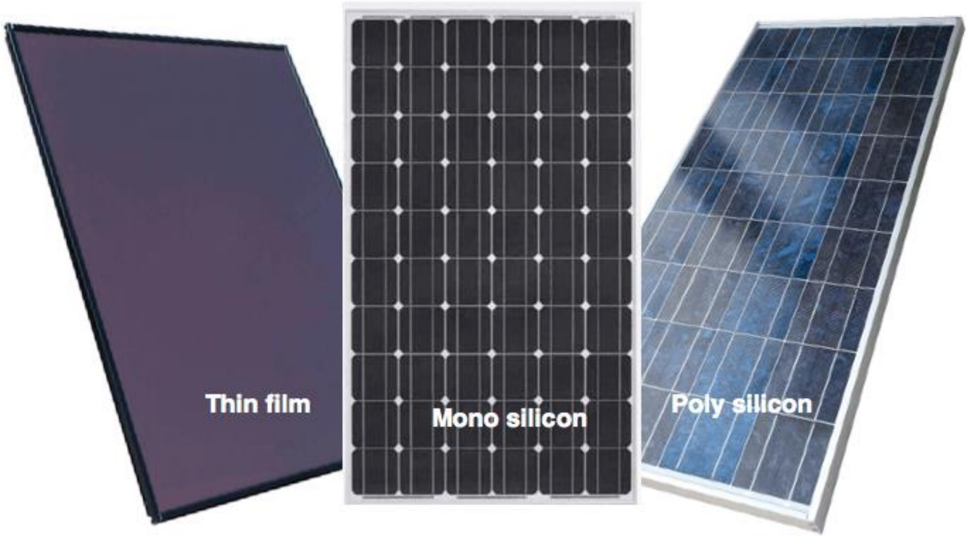
Figure 3 - Solar cells' conversion efficiency (Personal elaboration)



Thanks to the growing request for renewable energy sources, the industry of solar cells and photovoltaic has advanced significantly in recent years. Solar photovoltaic power generation are seen as a clean energy technology that draws upon the planet's most plentiful and widely distributed renewable energy source, the sun.

Cells require protection from the environment and are usually boxed closely behind a glass sheet. When more power than a single cell can deliver is needed, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant, the modules must be arranged in multiples as arrays.

Figure 4 - Different materials used in solar panels' production (Source: www.cleanenergyreviews.info)

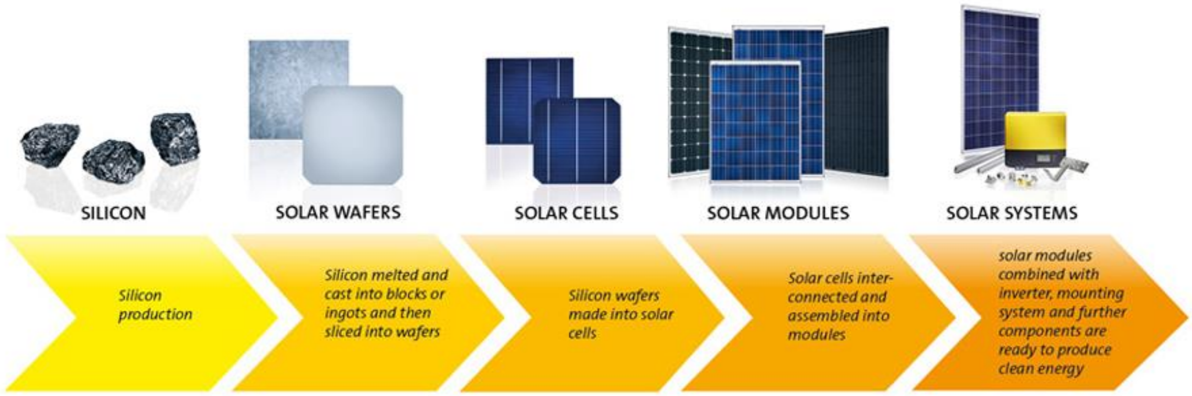


1.2 Photovoltaic value chain

It is interesting, at this point of my work, to track the photovoltaic value chain that is the sequence of passages involved in the production of a PV system. Recently, the photovoltaic industry changed very much because of the reduction of incentives and the improvement of technologies that lead to a decrease in PV systems prices. These changes have effects that not only modify missions and objectives of the several companies involved in this sector, but also adjust the way of producing solar panels, aiming at the most economic procedures to cut costs. The future market developments will depend strongly in the various approaches that the different companies will undertake in response to the fluctuations of the sector.

In Figure 5 is represented the mono or poly silicon photovoltaic module Value Chain that is composed by three working stages (starting from the silicon production, then wafers and solar cells) followed by two assembling steps (solar modules and solar systems).

Figure 5 – Photovoltaic Value Chain
(Source: www.prosun.org)



The first step consists on the silicon production that is the key material for the PV cells fabrication. It is the second most frequent element in the earth's crust and so its availability is almost unlimited. In nature, it occurs exclusively as an oxide, either in the form of silicon dioxide, or as silicon-containing minerals. Thus, sand and quartz mainly consist of silicon dioxide. On an industrial scale, elementary silicon is produced by the reduction of silicon dioxide with carbon in a furnace at temperatures of about 2,000 °C. For the production of solar cells, the raw silicon must be further purified to become solar-grade silicon.

In a second working step, solar wafers are produced from the solar-grade silicon. For this scope, the silicon is melted at a temperature of more than 1,400 °C and cast into blocks or ingots. In the melting process, either the mono-crystalline or the poly-crystalline process can be used. When making mono-crystalline wafers only one single crystal is drawn from the silicon melt. In the poly-crystalline process, the liquid silicon melt solidifies and thousands of small crystals are formed into one block. The blocks are then broken up into columns with a square cross section from which the very thin wafers are cut with wire cutters or by laser.

The machining and coating of their surfaces turns the wafers into solar cells. Now, the cells already possess all the technical properties needed to convert sunlight into electric power. They constitute the basic element of a solar module. A solar cell consists of two layers of silicon. An electrical field is formed at the interfaces of the two layers. Physical processes triggered by incident light cause electrical energy to flow between the metal contacts that have been fixed to these silicon layers. Today, the average degree of efficiency of the solar cells, i.e. their ability to convert solar energy into electrical power, amounts to some 18 percent.

In a last working step, the solar cells are combined into solar modules. Solar power modules are the solar end product and ready for solar power generation. They are framed and encapsulated to be weatherproof. In the modules, the sunlight is converted into electrical energy. A distinction is made between mono-crystalline and poly-crystalline modules. Photovoltaic modules made of mono-crystalline solar cells are more efficient, hence, they are particularly appropriate for small roof areas.

Photovoltaic systems convert the electromagnetic spectrum of sunlight into electrical current. Core elements are the solar cells, which in turn are combined into modules. The photon bombardment by the incident light causes a separation of positive and negative charges. If an electrically conductive connection is established between the charging zones electricity will flow. Depending on the size and type of system, the individual solar modules are connected in line into so-called “strings” or “arrays”. As a result, the voltages of the individual modules are additive. The solar modules are as a rule mounted on a sub-structure that ideally aligns the modules with the sun in such a way that the highest possible or a consistent energy yield is achieved in the course of the year. The sub-structure can also be designed to track the sun in order to optimize the energy yield. By way of an inverter the direct current generated is converted into alternating current and then fed into the national grid, or directly consumed right on the spot.

1.3 The photovoltaic market in the world

In 2014, the solar sector experienced an additional growth reaching a cumulative capacity of 178 GW. Just think that, in 14 years, the installed capacity has been multiplied by a factor of 100. Thanks to the huge price declines achieved in recent years and continued in 2014, solar power is now recognized as a cost-competitive, reliable and sustainable energy source. Moreover, the annual PV market volume has multiplied by 40 times in less than a decade and the global value of the PV sector will probably reach the landmark of 100 billion EUR in 2015. The PV system price declined of 75% in less than 10 years. The achievement of grid parity[6] started to drive those developments but we have to take into account that the competitiveness of this sector depends mainly on how retail electricity tariffs are shaped.

Considering its foreseeable output and its technical reliability, solar PV could be considered a low risk investment for the financial community. However, the perceived risk associated with solar PV is influenced by several external factors that increase the cost of capital for solar PV in all market segments:

- The regulatory risk, especially the possibility of retroactive measures: this risk is by nature unpredictable, since it is linked to political decisions and cannot be easily hedged with existing financial products. It therefore drives the cost of capital higher.

- The operational risk can be reduced with the right combination of components certification and quality installation processes. Meanwhile, the current track record of solar PV installations has not yet convinced the financial community of the stability of solar PV revenues.

Bankability has become a central concept in PV risk management but it cannot replace the use of adequate standardization and certification processes to guarantee both components and installation quality in the long term.

The year 2014 saw several actors returning to profit, in a growing market. From a technology point of view, crystalline silicon-based PV continued to dominate the market, while the share of thin film remained stable, thanks to Cadmium telluride and the boom of the Japanese market for Copper Indium Gallium Selenide. Thanks to the market growth experienced in 2013 and 2014, the utilization rates of manufacturing capacities for solar components went to more reasonable levels and reduced prices. In Europe, the price undertaking for PV modules maintained the prices of some Chinese producers at higher than market levels, while other Asian manufacturers continued to offer cheaper prices. After years of dramatic cost reduction,

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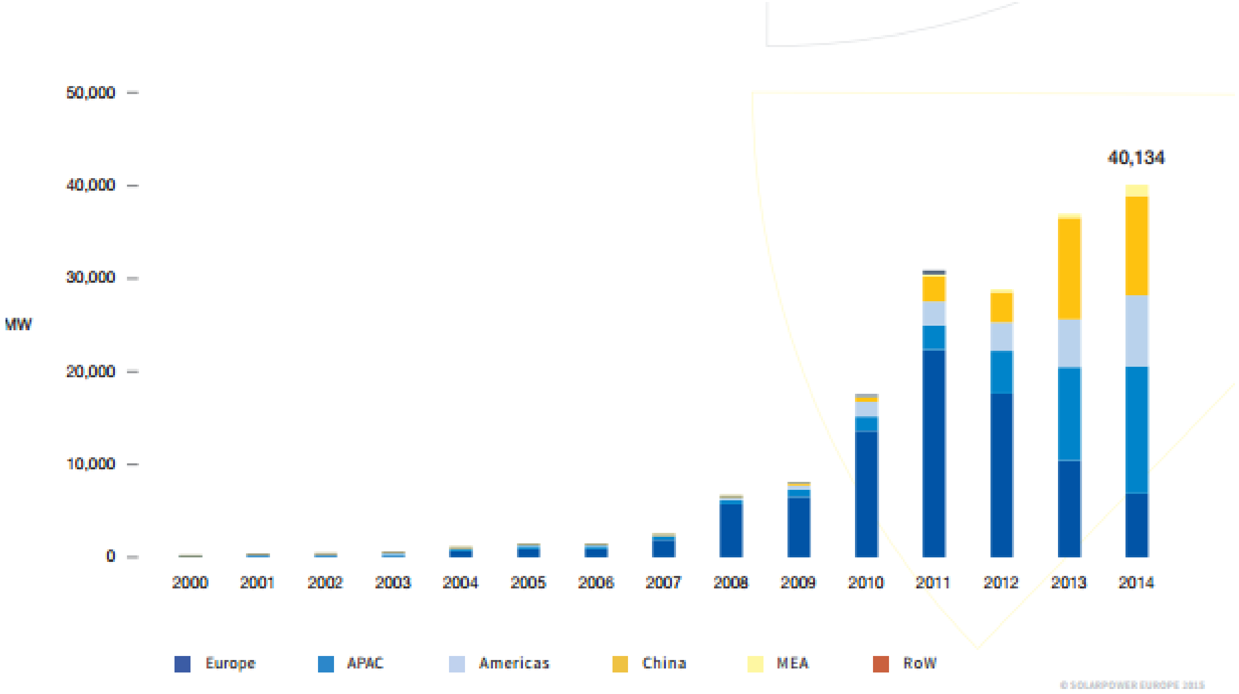
[6] Grid parity occurs when an alternative energy source can generate power at a cost that is less than or equal to the price of purchasing power from the normal electricity grid. Reaching grid parity is considered the point at which an energy source becomes a contender for widespread development without government support.

innovation seems to play a central role again. Several manufacturers have announced orders for innovative equipment to upgrade their current production lines or to put new ones in place. In parallel, new module factories are opening within, or close to, emerging markets while some continued to close in Europe. The market growth has brought production capacities closer to a sustainable utilization rate and therefore, with profitable companies, a new cycle of investment can start in the PV sector. This is reinforced by the expected market growth in several regions. This discussion brings to the fact that, after reaching in 2013 close to 37 GW installed, in 2014 solar PV market reached the 40 GW mark for the first time: this is achieved thanks to both the progresses of the American and Asian markets (see Figure 1). Looking at the graph, we can observe the great development starting from 2008 and that only by 2010, China and other Asian and Pacific countries began to install a significant capacity considering the market scale. Notwithstanding this, Europe is already the dominant player of cumulative installed capacity with more of 88 GW installed at the end of 2014.

Figure 6 - Evolution of solar PV annual installed capacity since 2000. (Source: SolarPower Europe)



1.4 The European scale

In 2014, installations in Europe slowed to the same level of 2009. This can be attributed to a context of transitions in regulation policies in European countries: they are passing from feed-in tariff support towards a more market-based development structure. The European solar PV sector is the first to experience this dynamic. There is also a general aim to integrate progressively solar PV in electricity markets and some countries are experiencing retroactive measures that are influencing the investors' confidence in developing new capacities. Notwithstanding this, Europe represents nowadays an excellent example for the complete incorporation of PV in the energy sector. Looking at the countries, United Kingdom is the leading one, with 2.4 GW installed, followed by Germany (1.9 GW) which was not able to reach its official target of 2.5 GW. France is the third market with nearly 1 GW and then Italy (0.4 GW), which is in a transition period due to the end of the incentives prescribed by its good regulatory framework. The markets driven by net metering[7] evolved in a negative trend in Belgium and Denmark while the market in Netherlands, Portugal and Austria increased.

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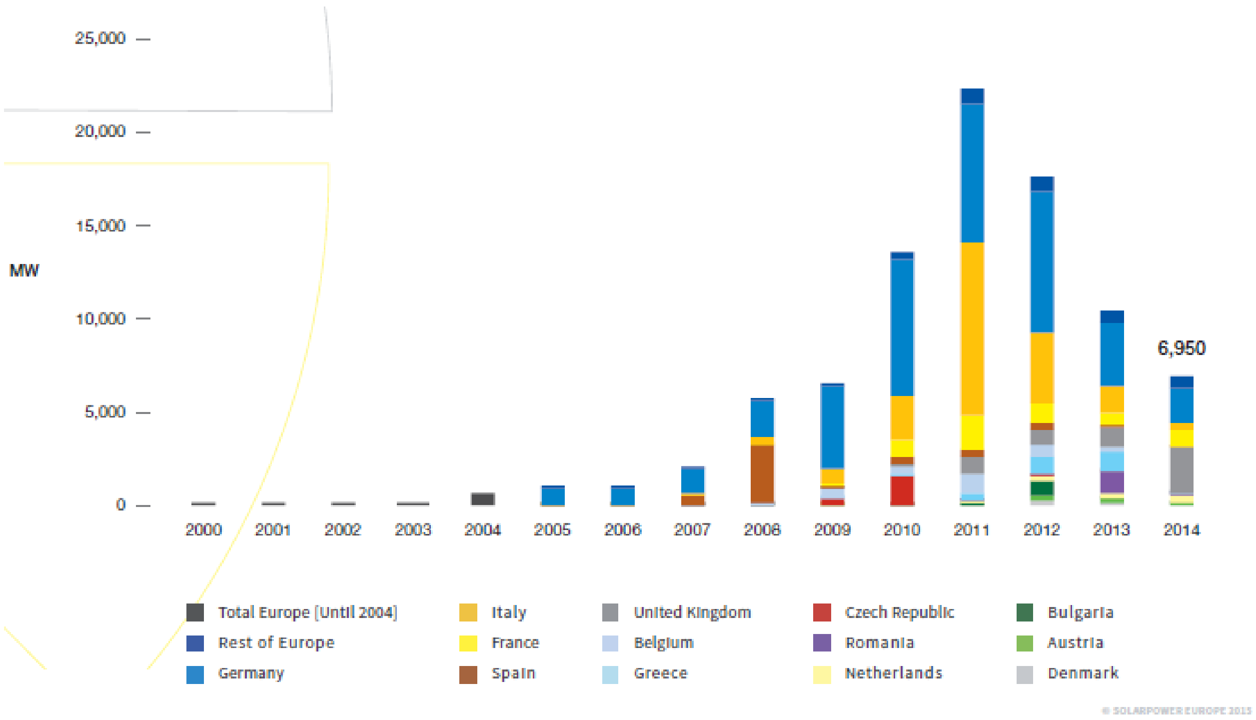
[7] Net metering refers to a service given to an electric consumer that consists on the possibility to sell on the electric market the part of the energy not used and so accumulated during a specific period. In a net metering program, the electric company allows a customer to sell if the electricity the customer generates is more than he is consuming.

Figure 7 - Evolution of European solar PV annual installed capacity (Source: SolarPower Europe)



Spain, that was in 2008 the driver of the global market, suffered from different retroactive measures that caused its disappearing from the European PV map. Like Spain, Bulgaria and Czech Republic, are considered as unreliable countries for the investment in the PV technology. It deserves attention the fact that, with 90 GW of PV capacity in Europe, the 2020 targets defined in 2009 have been reached six years earlier, in 2014.

From what regards the market, Europe remains quite heterogeneous, with different countries presenting different segmentations. Although the market segmentation has no specific definition, considering arbitrarily divided segments can help seeing how the different markets are composed. We can have:

- RESIDENTIAL are systems ≤ 10 kWp. The most frequent form of PV system is the rooftop system on a private property where the existing building carries the sub-structure for the photovoltaic system. At the same time, the inclination of the roof can optimize the alignment of the PV system that would otherwise have to be realized by additional design measures. The operator of the system can sell the power to and feed it into the national grid or alternatively consume it himself. In general, with a 5 kWp photovoltaic system, equal to more or less 40-50 square meters of the roof area, you are able to produce electricity needed for an average household in the EU.

- COMMERCIAL are systems like the previous one but with capacity between 10 and 250 kWp. They are usually applied in bigger houses or in the commercial sector. Again, the power is either fed into the national grid or consumed on the spot.

- INDUSTRIAL are systems ≥ 250 kWp and are usually larger photovoltaic systems that are placed on industrial buildings like. These systems require technology with which they can be optimally aligned with the sun. Usually, the operator of the industrial building consumes the power generated in this way on the spot but sometimes this power is fed into the national grid either.

- UTILITY SCALE are systems with a capacity above 1000 kWp and built on the ground in a free-field site. A system of this type may be a fixed installation in which a sub-structure is used to align the photovoltaic modules at a certain angle to the sun. In addition, there are also the so-called tracker systems that follow the position of the sun. Frequently, utility scale systems are large installations whose output is in the multi-digit megawatt range. Their operators in many cases act as professional utilities. It can also happen that they are used to supply the power to an industrial enterprise. In this case, the latter’s owner and the operator conclude an individual contract on the purchase of the power generated.[8]

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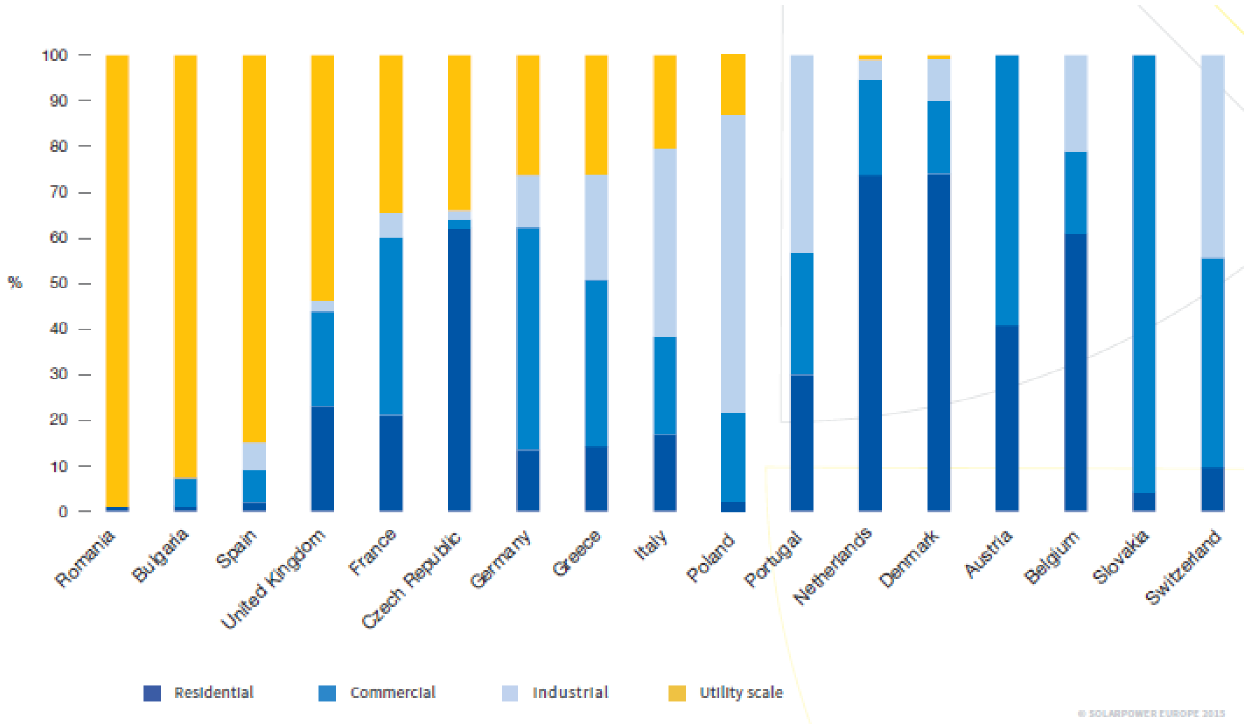
[8] http://www.prosun.org/en/sustainable-eu-solar/eu-solar-industry/solar-value-chain.html.

Figure 8 - European solar PV cumulative capacity segmentation by country in 2014 (Source: SolarPower Europe)



The diversity in the markets' evolution and segmentation strongly depends on the various support policies and the economic framework of the different countries. European institutions are fighting to increase the integration of renewable energy sources into the electricity market and this is contributing the modification of the regulatory frameworks. The guidelines on state aid for environmental protection that entered into application on 1 July 2014 stipulate feed-in premiums and tenders; in this respect, UK, France and Germany in 2016 will use feed-in premiums in addition to a remuneration based on electricity market prices to support the photovoltaic market. Distributed PV is evolving slowly in the direction of auto-consumption. The figure of the prosumer[9] is rising more and more.

Grid financing is a vital issue in several European countries. Indeed, where network tariffs are based on a consumer's acquisition of electricity from the grid, self-consumed electricity, and consequently the prosumer's figure, entails a reduction in grid financing.

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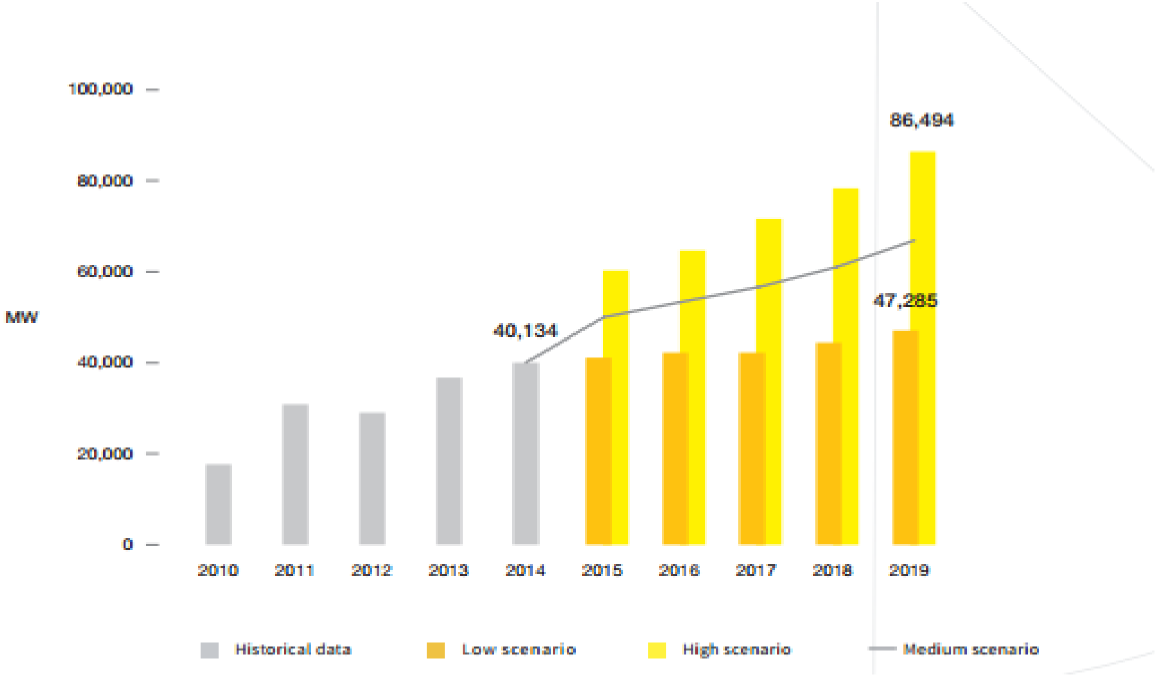
[9] The term "prosumer" is the fusion of the words "producer" and "consumer" and wants to indicate a person who is strongly independent from the market because he/she both produces (using in our case PV technology) and consumes the energy. This figure is rising in nowadays electricity markets.

1.5 Market forecast until 2019

Although the 2014 growth was blurred by the decrease of the European market, 2015 is experiencing a major increase in solar installation numbers globally. Experts' opinions consider mainly two scenarios, the high and the low. The former assumes a favorable environment, followed by strong political motivation while the low scenario assumes rather a pessimistic behavior with no improvements of the investment conditions in most of the markets. A third indicator, the medium scenario, is indicated as the weighted probability defining the most probable market development forecast. The expectations for PV development in China, the US, Europe and a stabilization of the Japanese market could lead to a market above 50 GW in 2015 and 2016, possibly close to 60 GW if all markets react positively. In 2015, the level of installations in China is framing the global growth. After two years below targets, the Chinese government decided to raise the official PV installation target to 17.8 GW in 2015. The probability of seeing this target being achieved remains conditional on many developments, and especially the take-off of distributed solar power. Without unlocking this market segment, China could have difficulties to achieve this ambitious 2015 target despite the impressive 5 GW installed in Q1 2015. The year 2017 could then be a year of market stagnation with the expected end of the ITC tax break regulation in the US and the end of the market boom in Japan. While none of them can be taken for granted, they illustrate the uncertainties on the medium-term PV market development. In the longer term, after 2018, growth should resume based on the expected contribution of dozens of countries attracted by competitive PV, including India and its ambition to develop solar PV. The probability of experiencing an important market growth in 2015 followed by two years of stable installations remains quite high. However a combination of negative policy decisions in key countries, or the difficulties of PV to take off fast enough in emerging markets, could lead to a market stagnation around 40 to 50 GW in the future. This hypothesis is not the most probable but needs to be considered. Depending on the evolution of the solar markets in the coming years, the total installed capacity in 2019 could reach between 396 and 540 GW with the highest probability scenario being around 450 GW. Figure 7 represents the different scenarios assumed. I can observe that, even considering the low scenario, there will be a market growth albeit tiny.

Figure 9 - Different scenarios from 2015 until 2019 (Source: EPIA)



Considering now the forecast for the European market, the year 2014 could represent the slowest year for European solar PV installations. In 2015, UK and Germany are framing the growth while Italy and other countries able to install 1 GW or more in the past years could return to produce at the former levels since new support policies have been introduced in 2014. The market would grow reaching installations between 7 GW (low scenario) and 17 GW (high scenario), five years from now. In 2019, we could reach a cumulative installed capacity equal to 158 GW, an almost 80% increase from now. In the low scenario, the cumulative installed capacity could be of 120 GW. Looking at the countries not included in the European Union, Switzerland is performing very well since solar power is developing and the future looks positive. In Turkey, it appears that the country is not yet acting as well as its potential even if the government announced the objective of reaching 5 GW of installed capacity of solar power by 2023.

Photovoltaic energy is covering the electricity demand in a significant way in 16 out of 28 EU member state while Italy is one of the three countries that is able to cover more than 7% of the demand with solar power. The table in the next page offers a prospect of the principal European countries and a valuation for the political situation, based on governments’ policies and regulations.

Country	Annual installed capacity 2014 (MW)	Cumulative installed capacity 2014(MW)	Political support prospects
Austria	140	767	Good
Belgium	65	3,104	Uncertain
Bulgaria	2	1,022	Bad
Croatia	13	33	Uncertain
Czech Republic	2	2,134	Bad
Denmark	47	608	Good
France	927	5,632	Uncertain
Germany	1,898	38,235	Uncertain
Greece	17	2,596	Uncertain
Italy	385	18,313	Uncertain
Malta	0	23	Uncertain
Netherlands	400	1,042	Good
Poland	27	34	Bad
Portugal	115	414	Uncertain
Romania	72	1,223	Uncertain
Slovakia	0.4	524	Uncertain
Spain	22	5,388	Bad
Switzerland	320	1,046	Good
Turkey	40	58	Good
United Kingdom	2,402	5,230	Good

In conclusion, I can observe that, until the last two or three years, the major part of PV installations growth has been shaped by governmental support policies and financial incentives. Now, it is time to investigate if it could reasonably be the source of energy of the future; it is a challenge for everyone who wants to invest in this sector. With solar PV system prices decreasing at a slower pace than in the past years, the key driver for lower electricity generation costs will be the cost of capital and the way in which the generated energy will be exploited (the auto-consumption).

Now, having described the essential issues of the photovoltaic background, it is time to move to Chapter 2 where I will consider the Italian market and how, the energy production and consumption, is regulated.

CHAPTER 2

In this chapter, I want to focus my attention on the Italian situation and on how the photovoltaic market is developing. Then I will investigate how the past and the present history of the regulation is affecting the photovoltaic framework. In doing this, I will use information and statistics available at www.gse.it, the site controlled by GSE ("Gestore Servizi Elettrici"). This association has the scope of increasing environmental sustainability through the promotion and development of renewable energy sources in Italy.

2.1 The Italian photovoltaic market

The year 2015 has experienced a great deceleration in the PV installations. While, at the end of 2013, in Italy, 18,053 MW of solar panels cumulative capacity results working with a corresponding production of 21,589 GWh, in 2014 only 385 MW have been installed, well below the forecast at the beginning of 2014. This contraction can be explained considering different and interconnected reasons. The remarkable one is end of the period of incentives regulated into the feed-in scheme denominated "Conto Energia" in 2013 and the consequent averseness in investing and producing too much in this field no longer incentivized. Other reasons can be identified in the retroactive measures that reduced feed-in tariffs (the so called "spalma incentivi"[10]) and in the fact that photovoltaic systems got applicable for municipal real estate tax (the so called "IMU"). Many operators refer at these measures as an earthquake that destabilized the credibility of the Italian market. Although these difficulties, I have to remark that Italy has however installed PV for a capacity of almost 400 MW and that, consistently with what I wrote in chapter 1, the International Energy Agency placed Italy as the first country worldwide to produce through photovoltaic 7.9% of the annual electricity demand, followed by Greece and Germany.[11]

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[10] "Spalma Incentivi" is an economic measure enacted by the Italian ministry of Economic Development in 2014, which consists on a retroactive reduction at the PV plants incentives of 20%, in particular addressed to photovoltaic plants with capacity over 200 kW. This proposal caused many discussions in Italy with many associations defining it unfair and unconstitutional.

[11] FABIO SANDRIN, "PV market in Italy: impressions from SolarExpo 2015". www.qualenergia.it.

Figure 10 - Percentage of installed PV plants in Italy at the end of 2013 (Source: GSE)

As we can see from Figure 8, the territorial distribution of solar panel plants in Italy, at the end of 2013, shows that the Northern part of the country has the highest number of installed plants (roughly 54%) while in the Center there is the lowest (17%) and in the South there is 29%. Veneto is the region with the second highest number of installed plants, following Lombardy.

In few years, the market changed from a system based above all in large dimension plants to a more heterogeneous one, composed by a mixture of little, medium and large dimension plants. The detail that is clearly observable is that, unlike the years that benefited from the feed-in tariff schemes, now, the market is driven also by residential (that are the real core of the Italian market) and medium dimensions installations. The residential sector has proven to be the "real hard core" of the Italian market, with more power installed in 2013 than in 2010. In fact, the most critical situation is in the industrial segment. The issue, not considering the difficulty in obtaining credit, is that these systems cannot use the net-metering system called "Scambio sul Posto" (reserved for systems below 200 kW), which allow for the production not consumed to be directly fed into the grid, and so they are profitable only in the case of very high levels of self-consumption. The segment that have resisted best is the one of big plants, above 1 MW, above all thanks to the register lists of IV and V of the feed-in tariff programs "Conto Energia" and the start-up of systems excluded from the registers[12].

The situation for the industrial PV systems (those with capacity bigger than 200 kW) is therefore complex since they cannot enter into the feed-in schemes and so they can become profitable only with a high percentage of auto consumption. I am particularly interested in this case since is exactly the one that I want to examine in the following sections. The energy consumption of the sports facility that I want to study suits for a PV solar system of the industrial category.

2.2 Regulation's evolution

The last decade development that brought Italy in 2011 on the top of the world countries producing energy by photovoltaic panels was mostly due to the regulation feed-in scheme denominated "Conto Energia". This incentive mechanism was introduced in 2003 thanks to the European Directive for renewable energies that wanted to promote an increase in contribution of renewable energy sources to electricity production in the internal market for electricity and to create a basis for a future Community framework. Renewable energy sources are defined as renewable non-fossil energy sources, i.e. wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases (art. 2). On a five-year basis Member States shall adopt and publish a report setting national indicative targets for future consumption of electricity produced from renewable energy sources in terms of a percentage of

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[12] http://www.qualenergia.it/articoli/20140414-italy-1-gw-photovoltaic-market-in-2014-and-beyond, April 2014.

electricity consumption for the next 10 years. It also outlines the measures taken or planned, at national level, to achieve these national indicative targets[13]. “Conto Energia” awarded with premium tariffs the production of energy from the installation of photovoltaic plants for the 20 years following the investment with fixed conditions. Its effects are now still observable since the last edition of that feed-in scheme took place in 2013, but currently PV investments have to be made taking into account different regulatory features that I will examine later. Before doing this, it is however interesting to investigate the main aspects of the five “Conto Energia” versions that took place in the last years.

From 2003 to 2013, the Italian government introduced five different schemes and for every new introduction, the tariff premium gradually reduced and the market reacted in different ways. In particular, those who have invested in 2006 and 2007 in this energy source has caught a rare opportunity, because due to high incentives, for the few systems installed was possible to recover the investment in three or four years with a yield ranging from 30% to 35%. The subsequent decrees reduced the performance, up to 20% in 2010. Finally in 2011, the record year, yields around 15% and the largest number of installations per year worldwide were reached. The market influenced by regulatory uncertainty has released the opinion because it could have been the last chance useful to grasp the benefits of such an extraordinary investment, that can create both positive cash flow and clean energy.

- **The first “Conto Energia”**[14] determined a great change with respect to the past, when the incentive to use the renewable energy power could be obtained only with grants assignments thanks to which the private investor could reduce the initial investment requirement. Entered actually into force on September 2005 this scheme had an unsuspected success exhausting in a very few time the total of 100 MWp installed and financed. The first “Conto Energia” aimed at financing only medium or large size plants since the incentives were directed to installations ranging from 50 to 1000 kWp. In the following Figure 11 and Figure 12, we can see the number and power of PV plants installed that have been divided in three different dimension classes.

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[13] “Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market.” 27/09/2001.

[14] Italy introduced this support scheme in 2005 (Ministerial Decree of 28 July 2005)

Figure 11 - Number of PV plants installed in Italy after the first feed-in scheme (Source: GSE)

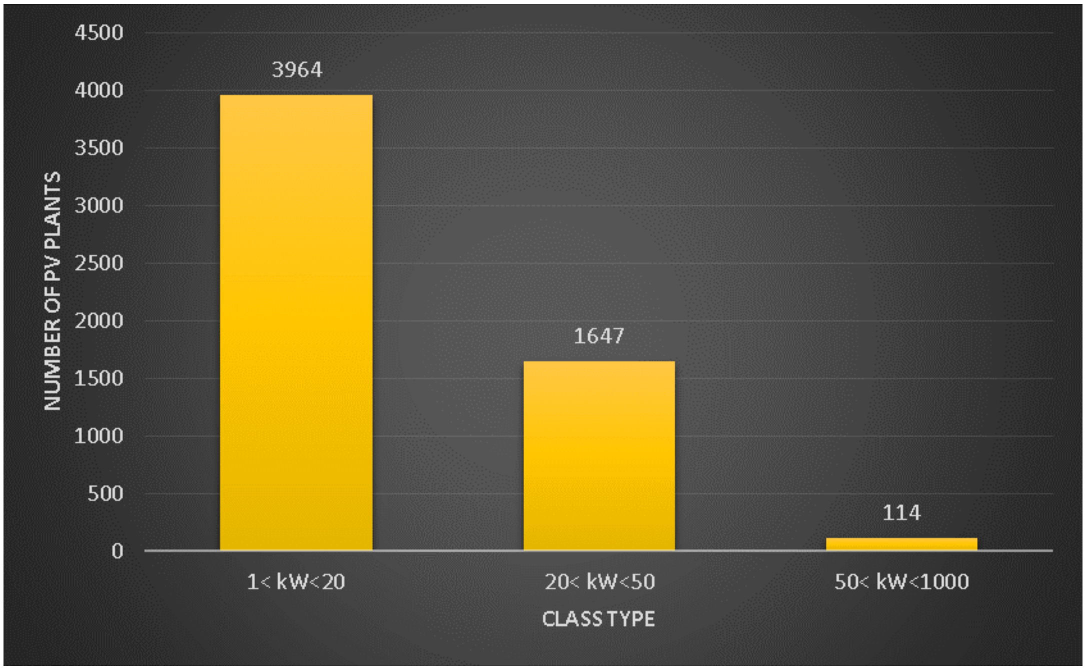
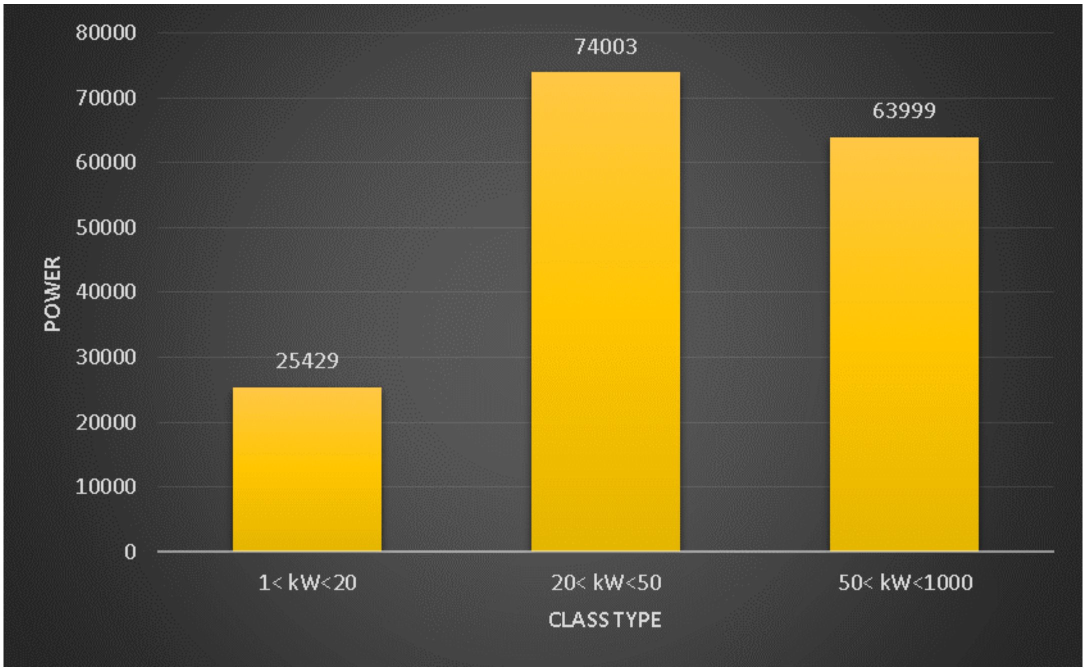


Figure 12 - Power of PV plants installed in Italy after the first feed-in scheme (Source: GSE)



- **The second feed-in scheme** became functioning after the ministerial decree of February 19, 2007 and imposed new criteria for PV plants installation until December 31, 2010. It was maybe the scheme that most stimulated the Italian photovoltaic market since its first application. Its main feature was that the premium tariff would have covered the whole energy produced and not only the energy produced and then consumed on site. This was already present in the previous scheme but only for people holding VAT number. Furthermore, there had been a simplification of bureaucratic procedures through a diversification based on the size of the photovoltaic plant. The maximum power threshold for the incentives to be applicable was 1200 MW. There was even a premium applicable to PV plants that used energy efficiently and the scheme's working period was prorogated until June 30, 2011 amplifying its relevance for an additional year.
- **The third "Conto Energia"**[15] introduced a new distinction of PV plants in order to better define the power classes that could receive the appropriate tariffs in relation to the plant type. This scheme took into consideration the significant cost reduction of plants and materials for the photovoltaic industry and consequently stabilized a progressive incentives reduction. The third scheme applied to plants with a capacity greater than 1 kW that begun operations on January 1, 2011. The three types of installation of the older scheme (integrated, partially integrated and not integrated) were reclassified as on "building" or "other plants". They also added three other categories: "building integrated PV plants with innovative features", "concentrating plants" and "technologically innovative plants".
- **The fourth feed-in scheme**[16] applied to plants with a capacity of at least 1 kW, commissioned between 1 June 2011 and 31 December 2016. Until the end of 2012, a specific tariff (feed-in premium tariff) was paid for the electricity generated by photovoltaic plants. The tariff covered a period of 20 years, starting from the plant commissioning date. This tariff consisted of two components: the premium and the price paid for the electricity produced. Starting from the first half of 2013 and on, the tariff was made up of both the incentives and the value of the electricity fed into the

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[15] Ministerial Decree 6August 2010.

[16] Ministerial Decree of 5 May 2011, published in the "Gazzetta Ufficiale" of 12 May 2011.

grid. A specific tariff was applied to the self-consumed electricity. The fourth feed-in scheme set an about 23,000 MW target of PV capacity to be installed at national level. Under the scheme, feed-in tariffs were planned to be progressively reduced over time, in order to balance the level of public support with the costs of technologies, giving stability and certainty to the market. Moreover, limits to the total costs of the scheme had been set.

- **The fifth and last "Conto Energia"**[17] redefines the rules on support for solar photovoltaic power generation. The new rules entered into force on 27 Aug. 2012, i. e. 45 calendar days after the publication of the relevant Decision adopted by AEEG[18]. Under AEEG's decision, which was based on GSE's data, the indicative yearly cumulative cost of incentives had reached € 6 billion. The feed-in scheme ceased to have effect 30 calendar days after reaching an indicative cumulative cost of incentives of € 6.7 billion per year. Based on the data reported by GSE through its Photovoltaic counter, AEEG will determine the cessation of the scheme. Unlike the previous support schemes, this feed-in scheme granted an all-inclusive feed-in tariff to the share of net electricity injected into the grid and a premium tariff to the share of net electricity consumed on site. The electricity generated by plants with a nominal capacity of above one MW will remain available to the producer. The monthly hourly zonal prices were posted on the website of GME. For example, if a plant generates electricity for self-consumption, the applicable tariff will be given by the sum of the all-inclusive tariff for the share of net generation injected into the grid and of the premium tariff for the share of net generation consumed on site. As established by the Ministerial Decree of 5 Jul. 2012, the values of the two tariffs (all-inclusive and premium) will progressively decrease in the half-years of application of the fifth feed-in scheme, beginning on 27 Aug. 2012. The tariff will be the one applicable upon the date of commissioning of the plant and will be paid over a period of 20 years beginning thereon.

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[17] Ministerial Decree of 5 July 2012 published in "Gazzetta Ufficiale" no. 159 of 10 July 2012.

[18] AEEG stands for "Autorità per l'energia elettrica e il gas", the Italian electricity and gas regulator.

Figure 13 - Number of PV plants installed in Italy after the fifth feed in scheme (Source: GSE)

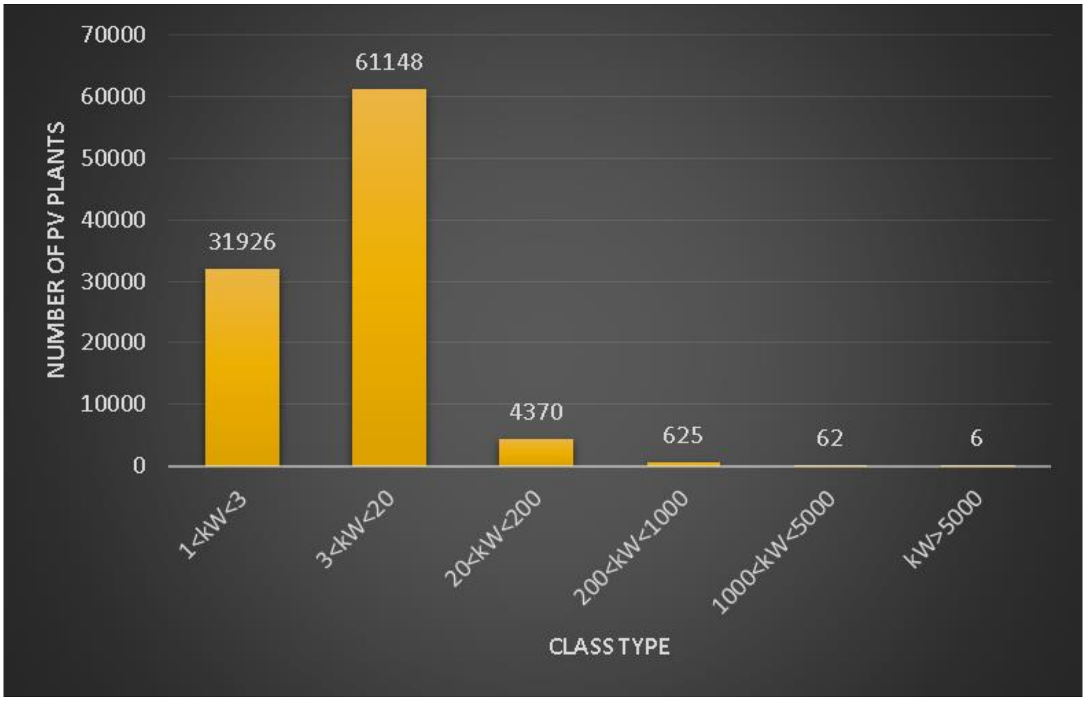
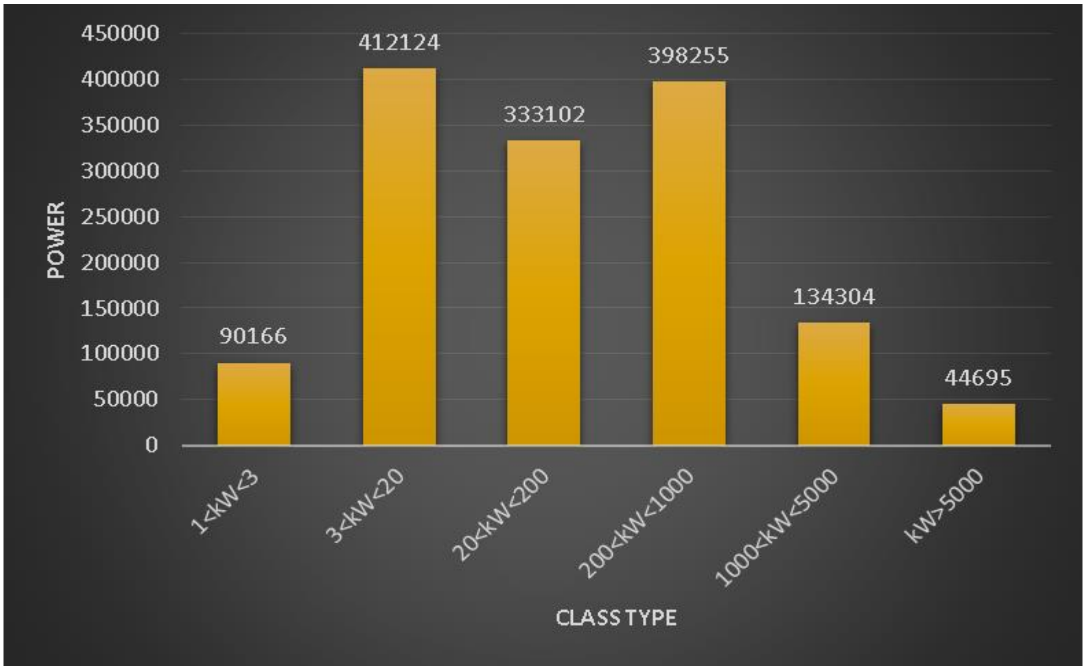


Figure 14 - Power of PV plants installed in Italy after the fifth feed in scheme (Source: GSE)



2.3 The different procedures of energy exploitation

As several times pointed out, starting from June 2013 it was not yet possible to take advantage of the Italian regulation feed-in schemes for new PV installations. Therefore it is now crucial to understand which are the nowadays possibilities in the photovoltaic framework; there are different regulated support schemes that can be used to exploit the energy produced. Additionally, in recent times SEU systems are spreading, even if there is still a bit of confusion on them.

2.3.1 Net metering

Net metering, in Italy known as “Scambio sul posto”, is a billing mechanism that credits solar energy system owners for the electricity they add to the grid. It is not an energy sale, it is rather a valorization of it since net metering permits to use the national grid as a temporary storage for the energy produced but not consumed in such a way to exploit it later. For example, if an industrial customer has a PV system on the plant rooftop, it may generate more electricity than the plant uses during daylight hours. If the plant is net-metered, the electricity meter will run backwards to provide a credit against what electricity is consumed at night or other periods where the plant’s electricity use exceeds the system's output. Customers are only billed for their net energy usage. On average, only 20-40% of a solar energy system’s output ever goes into the grid[19]. GSE pays a contribution to the customer based on injections and withdrawals of electricity in a given calendar year and on their respective market values. Under AEEG’s Decision ARG/elt 74/08, GSE has the role of managing net metering and paying the related contribution, which covers part of the charges incurred by the customer for withdrawing electricity from the grid. GSE determines the contribution taking into account: the characteristics of the plant, the contractual conditions between the customer and his/her supplier and the data that grid operators and suppliers are required to periodically report to GSE.
Net metering can be used by:

- Renewable energy source (RES) plants with capacity up to 20 kW;

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[19] http://www.seia.org/policy/distributed-solar/net-metering.

- Alternative energy plants that became working from 31/12/2007 from 20 kW and up to 200 kW;
- Cogenerated plants with capacity up to 200 kW.

The net metering process is articulated as follows:

1. The plant's owner inject the energy produced but not consumed into the grid managed by GSE that sells it to the market;
2. The plant's owner purchase the necessary energy from ENEL and at the end of the year GSE returns the amount paid, the so called "quota energia";
3. The value of the injected energy is computed based on the average hourly zonal price;
4. The so called "quota servizi" is computed, amount that reimburses the plant's owner from the grid service costs;
5. At the end of the year, the difference from the injected energy and the "quota energia" will represent the credit that can be used on the following three years; if the difference is negative, the debit will be charged on the electric bill;
6. The amount gained by the plant's owner is the sum of "quota energia" and "quota servizi".

2.3.2 Purchase and re-sale arrangements

The second support scheme that I am going to examine are purchase and re-sale arrangements, the so-called "Ritiro Dedicato" in the Italian regulation. In this case, the producers can sell the electricity generated and to be injected into the grid to GSE instead of selling it through bilateral contracts or directly on the Italian Power Exchange market, the IPEX.

As the energy is sold, the GSE will remunerate it according to a previously specified price for the quantity of retired kWh. Into this agreement, GSE will always purchase and resell the electricity at the zonal price or at a minimum guaranteed price. Furthermore, on behalf of the producer, it will transfer the fees for the use of the grid, such as dispatch and transmission, to the distributors. The eligible parties for this type of arrangements are:

- plants having a nominal apparent power of less than 10 MVA[20]: renewable energy source (RES) plants or hybrid plants (only for the amount of energy produced by the renewable energy source);
- plants of any capacity that entirely exploit renewable energy power (wind, solar, geothermal, waves, tides, hydro);
- plants with a nominal apparent power of less than 10 MVA: non-RES plants or hybrid plants for the portion of electricity generated from non-RES;
- plants having a nominal apparent power greater than or equal to 10 MVA: plants using RES other than wind, solar, geothermal, waves, tides and hydro (run-of-river only), provided that they are owned by a self-producer[21].

The price applied to the electricity purchased and injected into the grid is known as the "average zonal price" that is the average monthly price per hourly band which is set on IPEX for the market area to which the plant is connected.

Producers with small-sized plants (with a nominal electrical capacity of up to 1 MW) benefit from “guaranteed minimum prices” for the first 2 million kWh per year and they may get more if the hourly zonal prices prove to be more advantageous. The guaranteed minimum prices are updated annually by AEEG. At the end of each year, GSE makes adjustments for plants in respect of which the revenue associated with the hourly zonal prices will be higher than the one resulting from the application of the minimum guaranteed prices.

Taking into account the prices given by GSE, for the year 2015, this price is of 39.0 euros per MWh for retired capacities up to 1,500,000 kWh per year.

2.3.3 The energy sale to the electric market

The third way it is possible to exploit the energy produced is by selling it through the electric market. Bersani decree[22], starting from 1999, liberalized all the activities of electricity producing, importing, exporting, purchasing and selling. The distribution was the activity subject to the

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[20] The volt-ampere is the unit used for the apparent power in an electrical circuit. Volt-amperes are useful only in the context of alternating current circuits like the one that will be under investigation. Therefore, MVA is equal to one million of VA.

[21] As defined in article 2, par. 2, Legislative Decree 79/99.

[22] D. Lgs. N. 9 16/03/1999.

license while activities such as transmission and dispatching were attributed in monopoly to TERNA (the transmission system operator) and GME (the electricity market operator, that organizes the market for dispatching services), respectively. The liberalized activities were the generation, the import, the export, the supply and metering of electricity and this increased the competition of the market. The main operators and institutions in the Italian electric market are the one depicted in Figure 13, considering that AGCM stands for the Italian antitrust authority.

Figure 15 - Operators in the electric market

(Source: "http://www.industrie.gov.tn")

The IPEX is an essential tool that permits the creation of a competitive market in Italy and has the aim of encouraging the transparency of equilibrium prices allowing producers and customers to buy and sell energy in a more profitable approach. This market operates as a normal exchange market where the operators trade among each other and where there are several actors including GSE, traders, financial institutions, major energy producers, wholesalers and investors.

There are several requirements that an IPEX participant must accomplish to have the permission to trade, such as ability and integrity. The ability requirements refer to the participant's adequate experience and expertise in the use of telematics systems and related security systems, or if there are available employees or assistants with such experience and competence. The integrity requirements oblige that the producer has not been convicted for market rigging[23] or privacy violation or computer fraud[24]. Those in possession of such requirements should present to the Energy Markets Operator (GME) an application form, sign a membership contract and pay to GME:

- an access fee 7,500 €;
- a yearly fixed fee of € 10,000;
- a fee for each MWh traded.

The above-mentioned models of the application and the membership contract are available on GME's website. Within fifteen days of receiving the request, GME will carry out the necessary checks on the documentation and requirements, and then will communicate acceptance or rejection of the request. Only large producers access to the electric market since there are different technical constraints that limit the access to the Italian Power Exchange Market. In addition, there are different challenges that make the electricity market a sophisticated instrument. The main difficulties are the volatility, the demand side non-elasticity, participants' irrationality and the lack of energy storage possibilities that binds the offer.

Operators participating in the market by bidding for the purchase or sale, consisting of a pair of quantity and unit price of energy (MWh € / MWh) and express the willingness to sell (or buy) an amount of energy does not exceed that specified in and offered at a price not lower (or higher) than that specified in the same deal.

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[23] Market rigging refers to the practice of unfairly or illegally controlling the sale or the price of the market products or shares.

[24] Computer fraud is defined as any act using computers, the Internet, Internet devices, and Internet services to defraud people, companies, or government agencies of money, revenue, or Internet access.

2.3.4 Energy sale through bilateral contracts

In alternative to the three methods seen before, the PV plant owner may assign the electricity produced on the so-called over-the-counter market (OTC) and so outside of the regulated market. This mechanism works through the signing of a bilateral contract with an electricity trader; this type of contract ends with the sale price and the fee paid to TERNA for the dispatching service. This type of contract is usually enacted to sell on the market the quantities of energy from photovoltaic plants of large dimensions that are not entirely aimed for self-consumption. Indeed, given that in recent years the size of the new equipment installed is increased, the sale of energy through bilateral contracts has assumed an increasingly important compared to the energy traded on the stock exchange.

2.3.5 The efficient system for users (SEU)[25]

The type of system named SEU has been introduced with the legislative decree 115/08 that obliged the AEEG authority to determine the operating manners for regulating this new and somehow confusing method of exchanging energy. I say confusing since nowadays there is little clarity on how this system can be applied and this causes that every single case has to be considered separately and individually. On December 2013 it was issued the resolution about the "Regulation of networking, measurement, transmission, distribution, dispatching and selling services on simple cases of energy production and consumption", followed by an approval by AEEG. The resolution deals about SSPC (production and consumption simple systems), category that includes SEU. The following Figure 14 better explains the category contained within SSPC, where:

- SAP stands for auto-production systems that includes historical cooperatives, historical consortia and other auto-production systems, ASAP (case in which the auto-production is private and the plant's owner uses at least 70% of his energy);
- ASE stands for other existing systems and are defined in order to assign a qualification to all the systems not classified under the power grid that cannot be identified in any typology described by the regulation;

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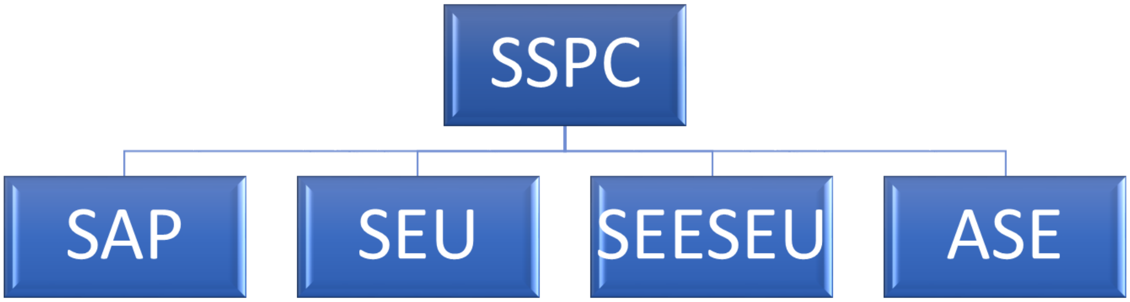
[25] ASSORINNOVABILI, 2014. "Sistemi efficienti di utenza SEU – Guida operativa".

- SEESEU stands for existing systems equivalent to efficient systems for users.

Figure 16 - SSPC outline (Source:"SEU - Guida Operativa, Assorinnovabili")



The SEU category includes systems in which one or more renewable energy production plants, with a total power of no more than 20 MWe[26] and installed in the same site, are directly but privately connected. Through the SEU definition, a new method of energy exploitation has been introduced for the photovoltaic plants.

There are different conditions to respect in order to be applicable to SEU system:

- The presence of a final customer, owner of the connection point and of the consumption unit sited in his own area;
- The presence of a producer, owner of the electrical cabinet and of the authorizations to the realization and functioning of the PV plant;
- The plants must be directly connected with a private connection to the final consumption unit (physical or juridical person) without the obligation of other parties connection.

Respecting these conditions gives the right to own the SEU qualification and gives admission to the following exemptions:

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[26] In MWe, the "e" stands for electrical Mega Watt, different from "t" (thermal) or "p" (peak).

- Self-consumed electricity will not be subject to transmission, dispatching or distribution fees; those fees will be applied only to the electricity taken from the grid;
- The relationships between the producer and the final customer inside a SSPC and referring to energy produced and consumed outside the electric grid are not subject to authority regulation and therefore can be privately negotiated.

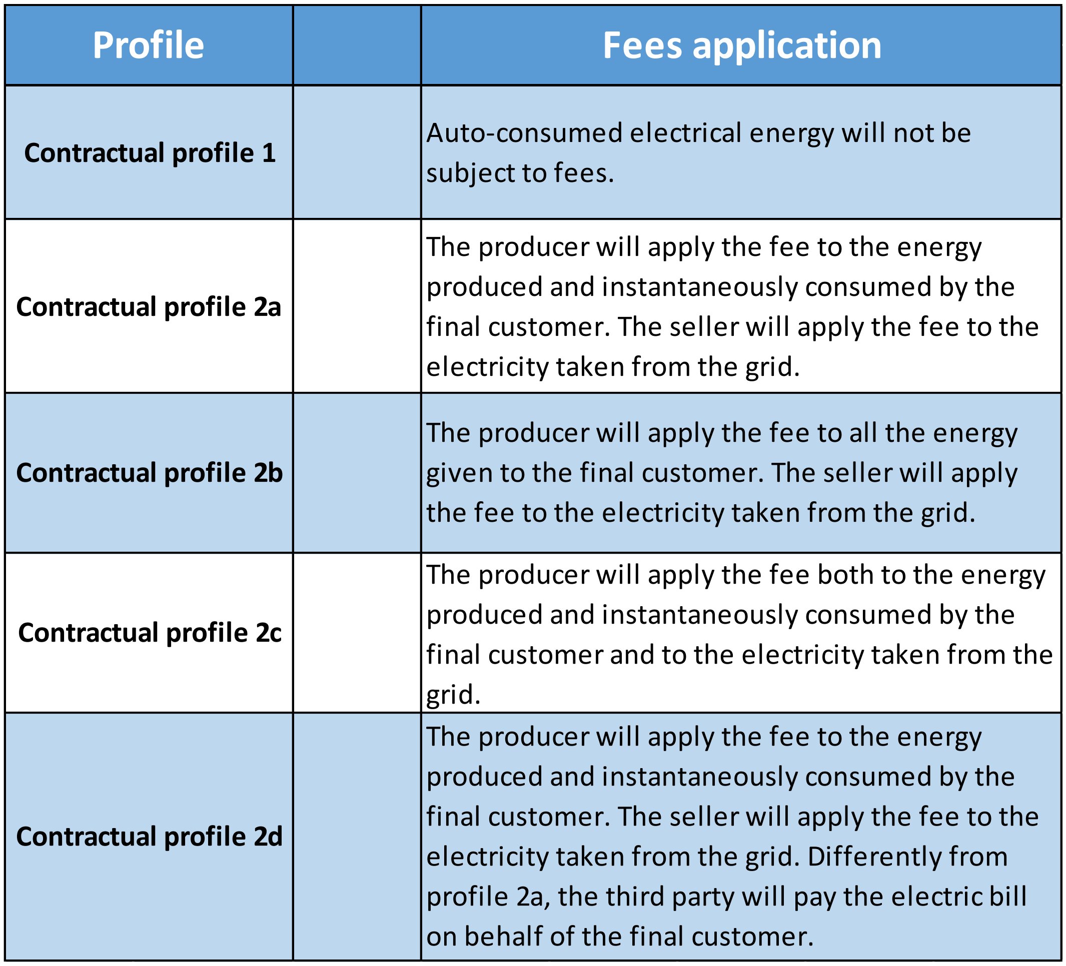
In the SEU systems configurations, five different contractual profiles can be identified:

- Contractual profile 1: the final customer and the producer coincide (the prosumer figure);
- Contractual profile 2a: the two parties don't coincide and decide to manage separately the contracts;
- Contractual profile 2b: the two parties don't coincide and decide that the final customer will manage the contracts;
- Contractual profile 2c: the two parties don't coincide and decide that the producer will manage the contracts;
- Contractual profile 2d: the two parties don't coincide and decide that a third party will manage the contracts.

Figure 17 - Fees applied per monthly consumption (Source: "SEU - Guida Operativa")

Electric energy	Monthly consumption	Fees application
On households		0.0227 euro/kWh
Not on households	less than 200,000 kWh	0.0125 euro/kWh
	between 200,000 kWh and 1,200,000 kWh	0.0075 euro/kWh
	bigger than 1,200,000 kWh	4,820 euro fixed on consumption exceeding the first 200,000 kWh

Figure 18 - Fees applied on the base of the contractual profile (Source:"SEU - Guida Operativa")



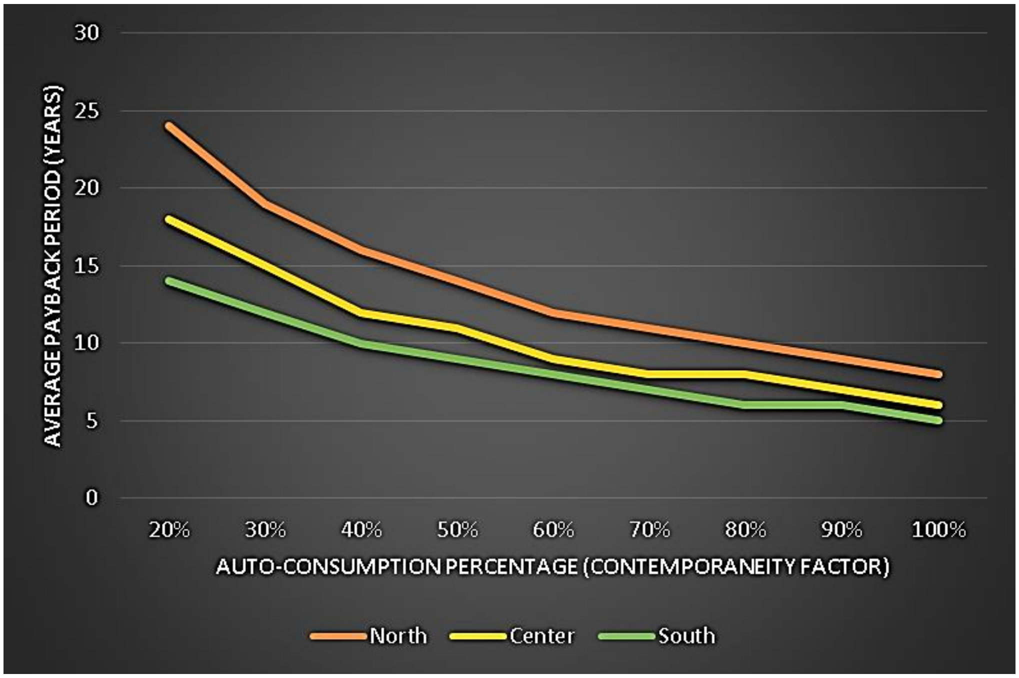
Profile		Fees application
Contractual profile 1		Auto-consumed electrical energy will not be subject to fees.
Contractual profile 2a		The producer will apply the fee to the energy produced and instantaneously consumed by the final customer. The seller will apply the fee to the electricity taken from the grid.
Contractual profile 2b		The producer will apply the fee to all the energy given to the final customer. The seller will apply the fee to the electricity taken from the grid.
Contractual profile 2c		The producer will apply the fee both to the energy produced and instantaneously consumed by the final customer and to the electricity taken from the grid.
Contractual profile 2d		The producer will apply the fee to the energy produced and instantaneously consumed by the final customer. The seller will apply the fee to the electricity taken from the grid. Differently from profile 2a, the third party will pay the electric bill on behalf of the final customer.

As for any type of investment, even in the case of SEU a number of prior analysis is necessary, the outcome of which has a decisive impact on future profitability: making mistakes at this stage can seriously affect the possibility to earn a positive income. In detail, it is worth to consider the economic factor that includes the costs (the initial investment for installing the system and operational management costs incurred during the life of the plant) and the revenues (that are essentially generated from the sale of electricity by the producer to the final customer or those derived from the value of electricity fed into the grid).

The annual electricity forecast that the plant would produce according to the type of installation and the specific location. The greater the production of electricity, the higher the annual revenue of the investor.

The coincidence factor is the ratio between the electricity produced by the plant and instantly consumed by the user and the total output of the plant. When this value increases, the proportion of energy produced that the operator will sell directly to the customer increases. It is interesting to look at the following picture that depicts, for a hypothetic investment in a PV plant of 100 kWp, the average payback period considering the economic factor fixed; the floating variables are the Italian location (North, Center or South) and the hypothetic auto-consumption percentage.

Figure 19 - Average SEU payback period (Source:"SEU Guida Operativa, Assorinnovabili")



The figure displays the results obtained from the assumptions described and certifies that increasing the productive and contemporaneity factors, the payback period falls significantly, reaching values close to five years. In the southern areas of the country, you can have interesting payback periods with an auto-consumption percentage of 65% equal to those that in the northern areas are obtained with the maximum percentage of 100 %.

The considerations depicted above determine the high potential of SEU systems whose application will depend on an accurate analysis of the final customer consumption profile and on the coincidence's maximization with the PV plant production path. Indeed, the greater will be the fraction of auto-consumed energy (that is the contemporaneity factor) with respect to the electric needs, the less will be the energy produced and entered into the grid. This feature will add the benefits for both the producer and the final customer. SEU systems are not immune from risky scenarios such as the delay in payment of the final customer that will sensibly decrease producer's income since it affects the auto-consumption percentage. In conclusion, SEU systems have to be considered when investing in PV plants, hoping that the accumulation system market will develop in Italy since it affects the main variable in this framework: the auto-consumption percentage. In the next chapter, I will evaluate the hypothetic PV plant investment discussing the sports facility's energy consumptions and determining the auto-consumption percentage that can be reached.

CHAPTER 3

In this chapter I will pay attention to the facility under investigation, the sports center ssd Gabbiano srl, sited in via Olmo 12, Campodarsego, in the province of Padua. In particular, I want to examine, given its dimensions, what are the monthly energy consumption in order to better understand the possible photovoltaic plant applicable in such a building. In doing this, I will discuss the auto-consumption hypothesis looking at the average hourly energy consumption in February and May 2014. Then I will calibrate them for the whole 2014 in order to give an idea of the sports facility's hourly energy consumption behavior.

Figure 20 - View of the long course swimming pool with mobile coverage (Source: www.ssgabbiano.com)

3.1 The sports center

The construction, built on the 70s, has been totally renewed in 2005. The renovation included a new bar, the gym, three five-a-side football pitches, additional locker rooms and, of course, swimming pools. Specifically there are three pools; a small one pool and the other are the long course (eight lanes and 50 meters long) and the short course (six lanes and 25 meters long). The long course swimming pool, previously used only during summer since it was outdoor, has been improved with a mobile wood coverage that permits its utilization all the year long. This represented a big innovation since there are not so many long course swimming pools available in winter and autumn in the neighborhoods (the nearest is hundreds of kilometers far).
Certainly, all of these big innovations required a huge investment that also determined a sharp increase in the energy facility's energy consumption. Just think that its dimensions[27] are of 7,957.02 m^2, where only the long course swimming pool and the soccer fields cover 4,593.64 m^2. Here I will present a table that indicates the energy consumption of the sports center in the last years, starting from 2009.

Figure 21 - Monthly energy consumption (kWh) starting from 2009 (personal elaboration)

ENERGY CONSUMPTION	2009	2010	2011	2012	2013	2014
January	36628	49035	94192	87534	84772	108933
February	33934	49548	86568	82072	88325	100535
March	36404	53742	91343	80817	100279	100519
April	34412	46849	71781	78928	88068	92837
May	31360	47657	57831	61339	67121	76350
June	30075	54696	53418	54569	52891	58292
July	32624	58235	54439	53846	55158	58329
August	26626	37565	35968	32260	34453	37298
September	32774	73388	55701	58663	55250	60735
October	54036	87503	65097	72481	89979	83856
November	48148	103561	80700	86340	95826	96530
December	49625	97405	83400	79319	104721	92760
TOTAL CONSUMPTION	**446646**	**759184**	**830438**	**828168**	**916843**	**966974**
AVERAGE CONSUMPTION	**37221**	**63265**	**69203**	**69014**	**76404**	**80581**

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[27] For the data I will use regarding the sports center, I have to thank "ssd Gabbiano srl"'s owners and the administration office.

Looking at the table we can see that the trend of the energy consumed is increasing, starting from January 2009 and arriving at December 2014. The histograms can help more to see this trend and to detect some yearly regularities. From 2009 until 2014, November has been the month in which more energy was consumed while August has been the most economical in these terms, but there is a particular reason for this. Regularly, the sports center remains closed for the two central weeks of August so that it is clear that the energy consumption decreased. I can therefore identify in June the month in which, on average, there had been the greatest energy saving. In general, as it is common, from April to September the sports facility has consumed less than in the rest of the year; this pattern is recognizable also into households since the expenses for heating and lightening are reduced in that period, reflecting into minor energy costs.

Figure 22 - Monthly energy kWh consumptions by year (Personal elaboration)

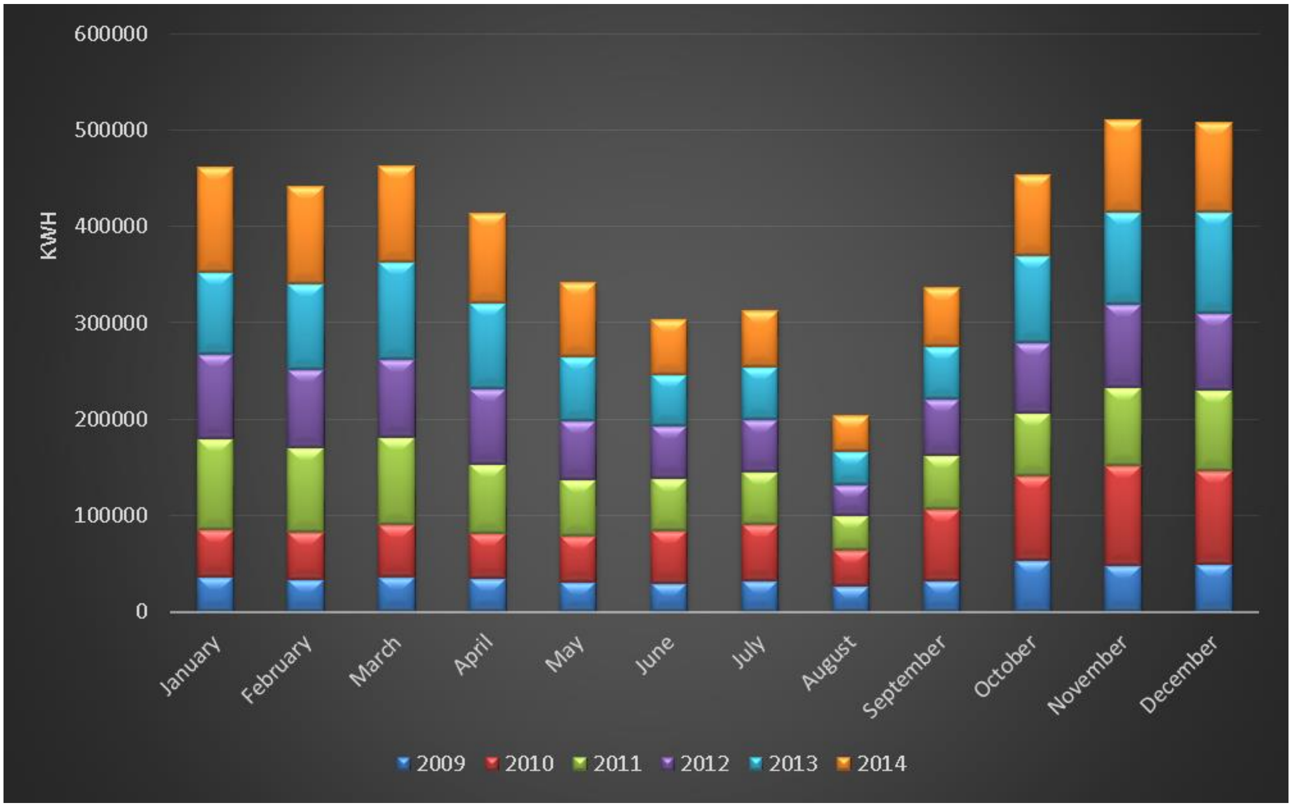
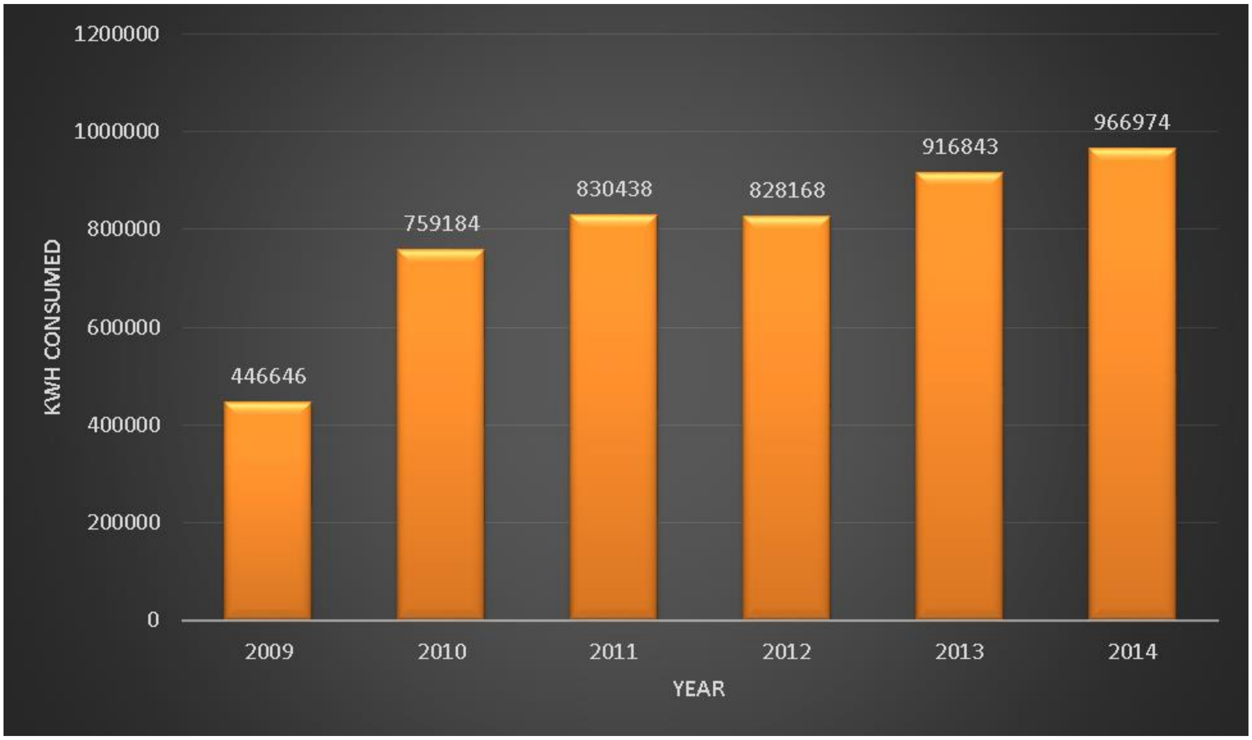


Figure 23 - Energy consumptions by year (Personal elaboration)



From the picture above, I can recognize a sharp energy consumption increase from the year 2009 to the year 2010, and then a more regular growth, except for the year 2012. The huge increase was determined by more electrical demand because the renewed parts of the sports center became functioning.

3.2 The proposed photovoltaic plant

In this section, I want to present the technical features of a photovoltaic plant applicable on the "Gabbiano" sports center, given its annual energy consumption (I will consider 2014 as base year) and given its geographical position (in order to understand and estimate the power of the photovoltaic plant during the year[28]). The online research brought me to an estimate of the cost

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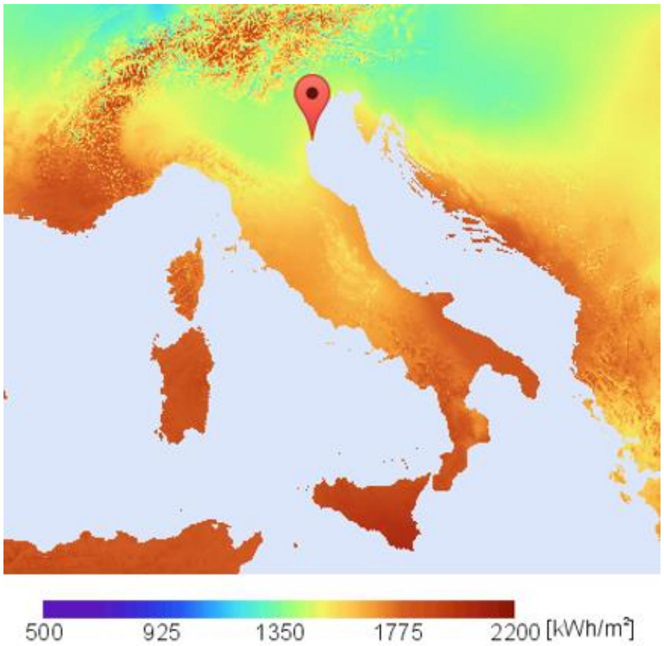
[28] For this purpose, I will use the online website PVGis that is a free solar photovoltaic energy calculator for stand-alone or connected to the grid PV systems and plants, in Europe, Africa and Asia. This application calculates the monthly and yearly potential electricity generation (kWh) of a photovoltaic system with defined modules tilt and orientation.

for the entire plant; the estimate recovered is a simulation of the possible plant manufacturing and therefore many technical aspects, such as the logistics and the real energy production, have not been valued specifically. So, it is necessary to study them before taking any decision. On the other hand it is not on the purposes of this work to select the ideal investment, but I want to write down a technique by which, given a selected asset, I could help in understanding what is convenient to do. Another necessary consideration is that the inputs by which I recovered the photovoltaic plant are the annual energy consumption on 2014 and the geographic position; so, as a starting point, I required a PV plant that, given the Italy's north-east weather, can be able to produce at least 960 MWh of energy during the year. A PV plant of such dimensions, as I discovered from various PV manufacturer, requires additional inquiries since it involves several technical aspects that in general, for example in households PV plant, are not necessary to ponder. In the next figure the Italian yearly global irradiation is shown, considering also the site in which the photovoltaic plant would be installed. In any case I will consider different dimensions, discussing if it could be profitable to select a smaller (and so cheaper) PV plant in order not to waste a big amount of energy in the daily period in which the PV plant will produce more energy than required.

Figure 24 - Yearly total of irradiation on optimally inclined surface in Italy (Source: PVGis)



The investment project under assessment is a hypothetic photovoltaic (with monocrystalline silicon material) plant of 1 MWp that can be built on the sports center parking lot. The plant is optimally oriented and, from the technical point of view, it is composed by the best disposable materials. Therefore, the impact on the economic cost could be reduced by selecting materials of a slightly lower quality. The geographical coordinates useful to calculate the solar irradiation and then the PV plant power during the year and the day are:

- latitude 45° 51’37”;
- longitude 11° 91’35”;
- 18 meters elevation[29].

The plant is optimally South oriented and presents an inclination of 33 degrees. The solar irradiation of the site has been verified looking at PVGis online application and from this, the monthly photovoltaic power production has been retrieved. The monthly average values of irradiation and production of electricity are shown in the next figure and table. In order to make a more detailed analysis, it would be appropriate to calculate the real irradiation by technicians in charge of the facility’s installation during the site examination.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly produced kWh	45300	67600	96500	102000	116000	114000	126000	117000	98000	72700	48100	43700
Monthly irradiation (kWh/m2)	66.2	100	150	162	190	191	211	196	160	113	72.6	64.1
Daily produced kWh	1460	2420	3110	3400	3760	3810	4060	3780	3270	2340	1600	1410
Daily irradiation (kWh/m2)	2.13	3.59	4.83	5.41	6.14	6.37	6.81	6.32	5.32	3.66	2.42	2.07

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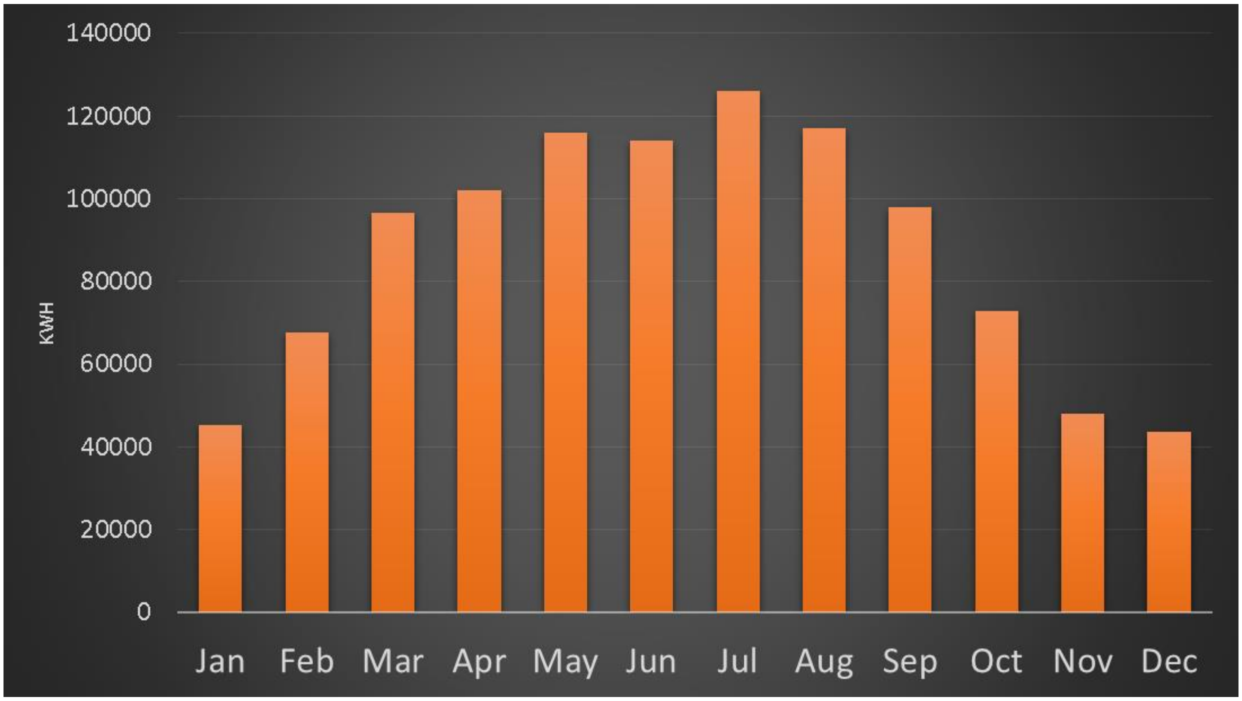
[29] www.mapcoordinates.net/it

Figure 25 - Average monthly electricity production from the given system (Source: PVGis)



The total plant **potential** energy production during the year is of 1,050,000 kWh and all the previous data have been estimated taking into consideration technical system losses of 28.5 % due to:

- Estimated losses due to temperature and low irradiance of 9.8 %;
- Estimated loss due to angular reflectance effects[30] of 2.8 %;
- Other losses (cables, inverter, etc.) of 15.9 %.

All these productivity loss values are usually subjected to a further reduction of 27%, the operating loss. This will enable to determine the estimated annual energy production and in light of this, I can observe that the forecast is very cautious, since it would bring to an underestimation rather than an overestimation of the results. Here I present a table in which the most important

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[30] Among these possible effects, there are shading and albedo that is the incident radiation reflected. The albedo thus indicates the reflecting power of a surface. The albedo is up to 1, when all the incident light is reflected. The albedo minimum is 0, when no fraction of the light is reflected.

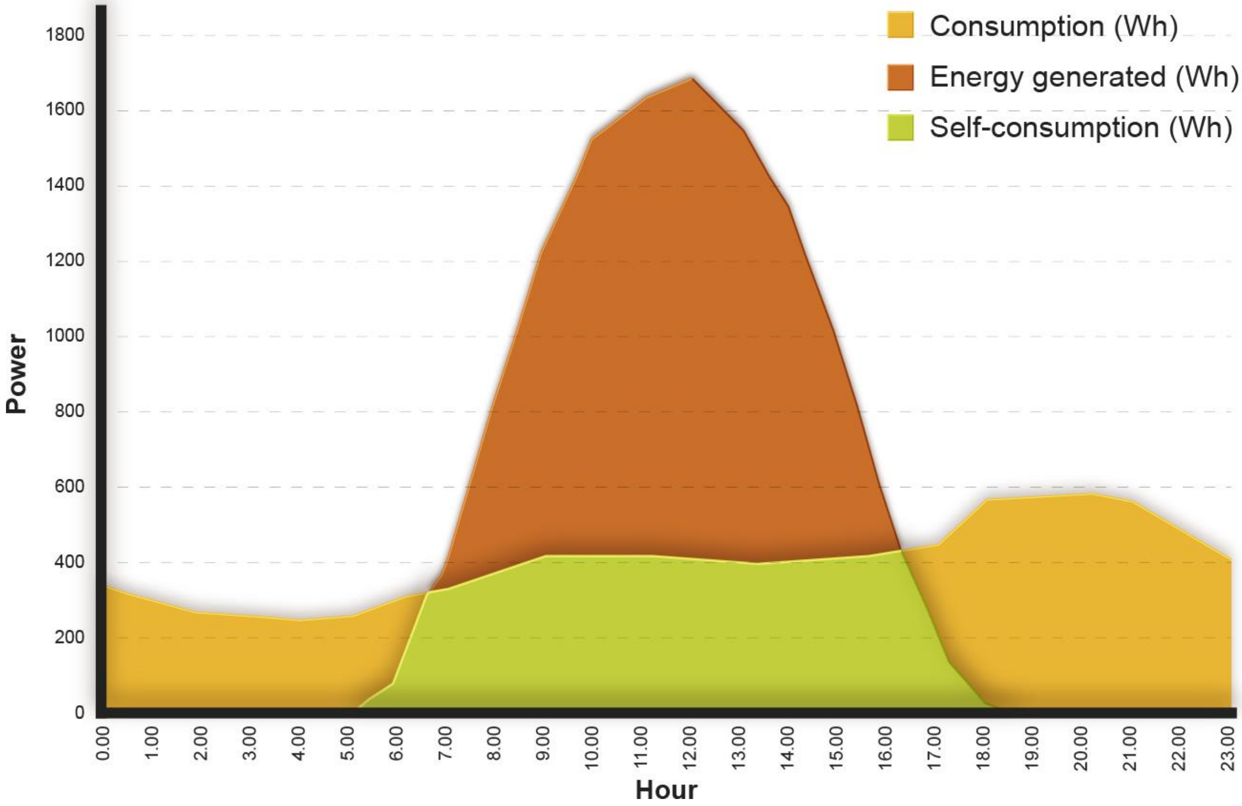
technical characteristics of the PV plant are summarized. The estimated yearly power of this photovoltaic plant is computed taking into consideration the additional reduction of 17.5%, the operating losses. The potential yearly power does not account for this and represents the maximum energy production if no operating losses occur.

General data	
Classification	Ground mounted
Site	Campodarsego, Padua, Italy
Latitude	45.5137
Longitude	11.9135
Elevation	18 meters
Modules' material	Mono-crystalline silicon
Modules' total surface	9,000 m^2
Yearly irradiation	1,680 kWh/m^2
Total power	1 MWp
Modules' number	4,000
Inverter's number	3
Technical losses	28.5%
Potential yearly power	1,050,000 kWh
Estimated yearly power	866,500 kWh

3.3 The self-consumption hypothesis

In the previous chapter, I pointed out that a high auto-consumption percentage can be a good way to properly benefit from a photovoltaic plant. The reason is that the energy auto produced and consumed is not purchased on the electric national grid, determining economic savings with respect to the electric bill. Into industrial buildings, this percentage tends to be higher than in common households because of different energy consumption habits. Indeed, to determine self-consumption, the average consumption of solar energy have to be compared with the amount of energy generated by the PV plants. Consumption depends on how many and what kind of electrical devices are used, strongly correlated with the number of people living in the household and their routines. The amount of generated energy, on the other hand, depends on the power and location of the PV plant as well as weather conditions. For example, the generation and consumption of energy from a 5 kWp solar plant and a four-person household on a typical summer day depicts self-consumption (as a share of the total amount of generated energy) as about 20 to 40 percent[31]. The following figure represents the self-consumption area, the intersection between the energy generated and the energy consumed.

Figure 26 - Example of intersection between energy consumed and energy produced
(Source: "www.sunedisonenergysaverplan")



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[31] http://www.sma.de/en

When dealing with an industrial building this percentage tends to increase since the daily period on households usage of electricity is different from the industrial one. Usually, PV plants installed on industrial buildings present a higher self-consumption (on average, since it depends on many factors, such as the type of PV plant installed or the geographical area). My aim is to identify what this percentage could be on the sports center under analysis.
In order to understand this, I will compare the hourly average energy consumption on 2014 with the estimated energy supply of the PV plant of 1MWp. I will then compute a rate of growth of energy consumption[32] considering that its peak will be in winter months and then create the daily hourly usage of electricity chart for the months in 2014.

3.3.1 Hourly energy consumption time series per month

I will start this analysis comparing the energy consumption in February and May 2014 with the daily estimated energy production of the PV plant described in the previous section. PVGis database also offers the hourly photovoltaic energy production during a particular month. I selected February and May since the data available were not complete and there were not summer months' hourly energy consumption available; I will then construct the other months' time series based on the monthly consumption rate of growth in order to construct the average curve for 2014. These choices brought me at computing, hour by hour, the average energy consumption month by month. Therefore, taking as representative February's and May's time series, I ended up with the two consumption graphs; the time series present similar trends except for the fact that in May energy consumptions were widely smaller, because of, for example:

- Warmer days (and so less energy used for heating);
- More light hours (and so less energy used for lightening).

On February, the curve presents two local maximums, one around 9 a.m. and the other around 6 p.m. Two peaks also characterize the other curve representing May's consumptions but they are wider, since one is around 7 a.m. and the other is around 9 p.m.

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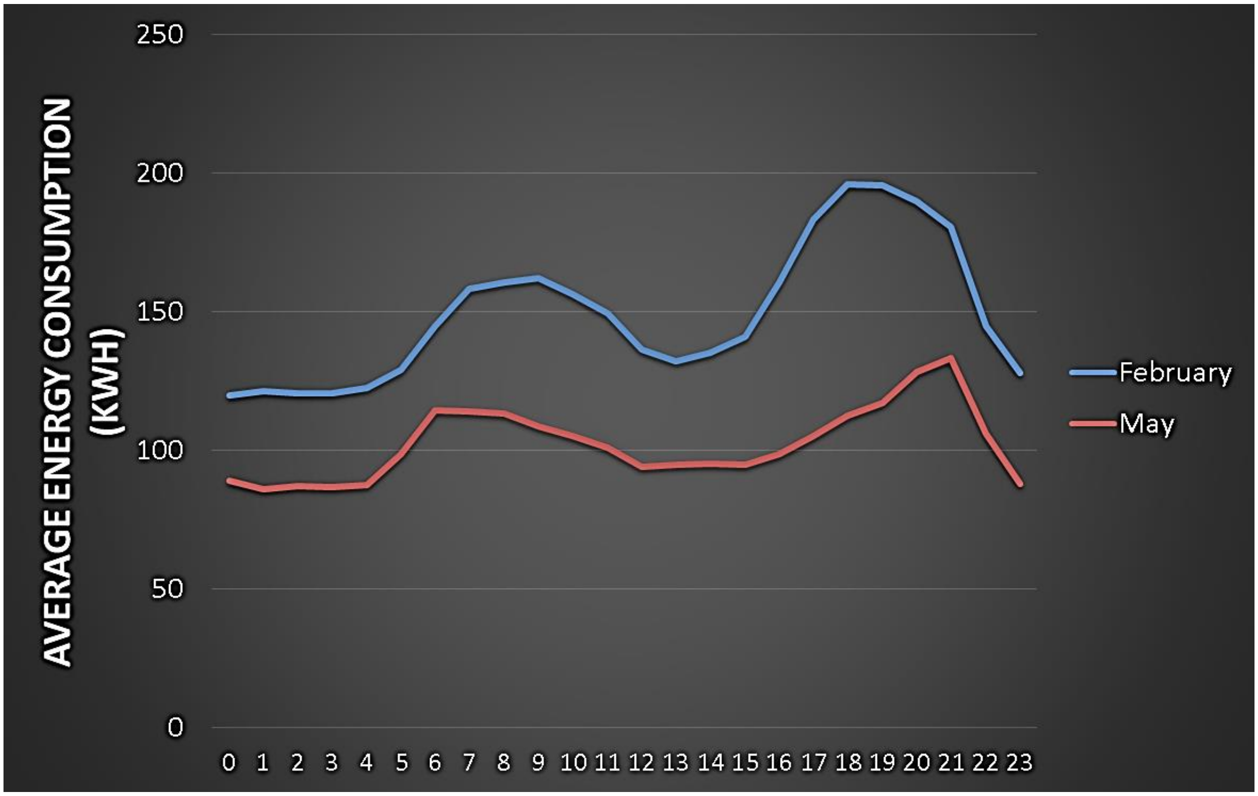
[32] Because of the lack of monthly hourly consumption data, I will use a forecast based on the total monthly consumption growth rate. I gave weights proportional to the effective sports facility schedule, therefore considering holidays and Sundays (in which the plant closed at 1 p.m.).

Figure 27 - 2014 average hourly energy consumption (kWh) (personal elaboration)



Starting from those values, (the disposable consumption dataset gave me 2014 hourly energy consumptions from January until May) I "forecasted" the remaining months of the year remembering that the total monthly energy consumption was available. I computed the energy consumption growth rate per month and using this I calibrated the "assumed" hourly energy consumption for the rest of the months. Of course, the ideal situation would have been to have the entire dataset but it was not the case. The monthly growth rates are depicted in the table below, while the table with the monthly hourly forecasts for all the year 2014 is disposable in the Appendix A.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4%	-8%	0%	-8%	-18%	-24%	0%	-36%	63%	38%	15%	-4%

3.3.2 Self-consumption percentage

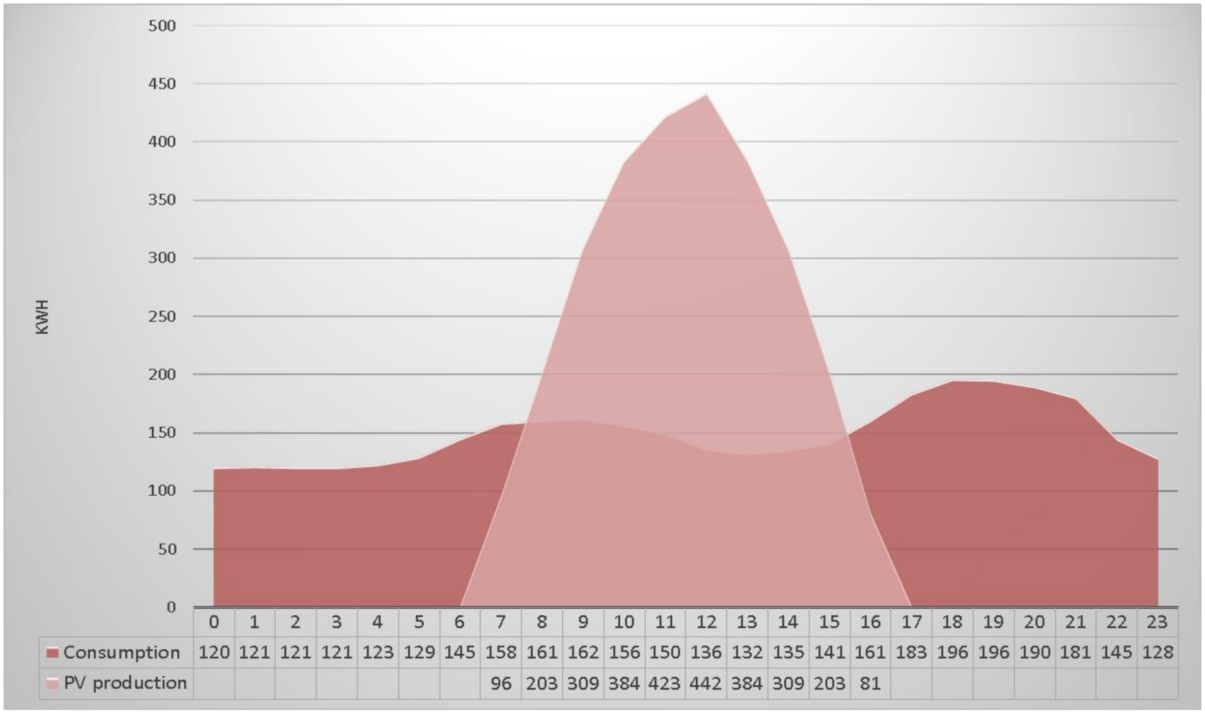
Now it is time to add, separately for the two time series, the forecast of the PV plant energy production and then retrieving the self-consumption percentages. In order to do this I applied the following procedure:

- I retrieved the hourly global irradiance (kWh/m^2) on a fixed plane, for the latitude and the longitude of interest;
- I multiplied the previously found values with the modules' total surface (9,000 m^2) in order to find the hourly potential production of the photovoltaic plant in kWh;
- The hourly potential production has to be reconsidered since the efficiency of solar PV panels is not 100%. Considering that mono-crystalline silicon solar panels have an average efficiency of 15% and that the PV plant installed could have a prudential 27% of operating losses (as assumed in the paragraph 3.2), I retrieved the estimates for the PV plant total energy production.

Now I can intersect the two different hourly curves, the PV plant's production one and the sports center's consumption one, for the single months and find out what could be the assumed percentages of energy self-consumption, that is the share of energy produced and instantaneously consumed with respect to the total energy needs. Here I will develop two explicative months like February and May but next I will construct the average curve of 2014, remembering that in January and from June until September I forecasted the hourly consumption using the rate of growth of the total monthly energy consumed. The formula I applied for the self-consumption computation is:

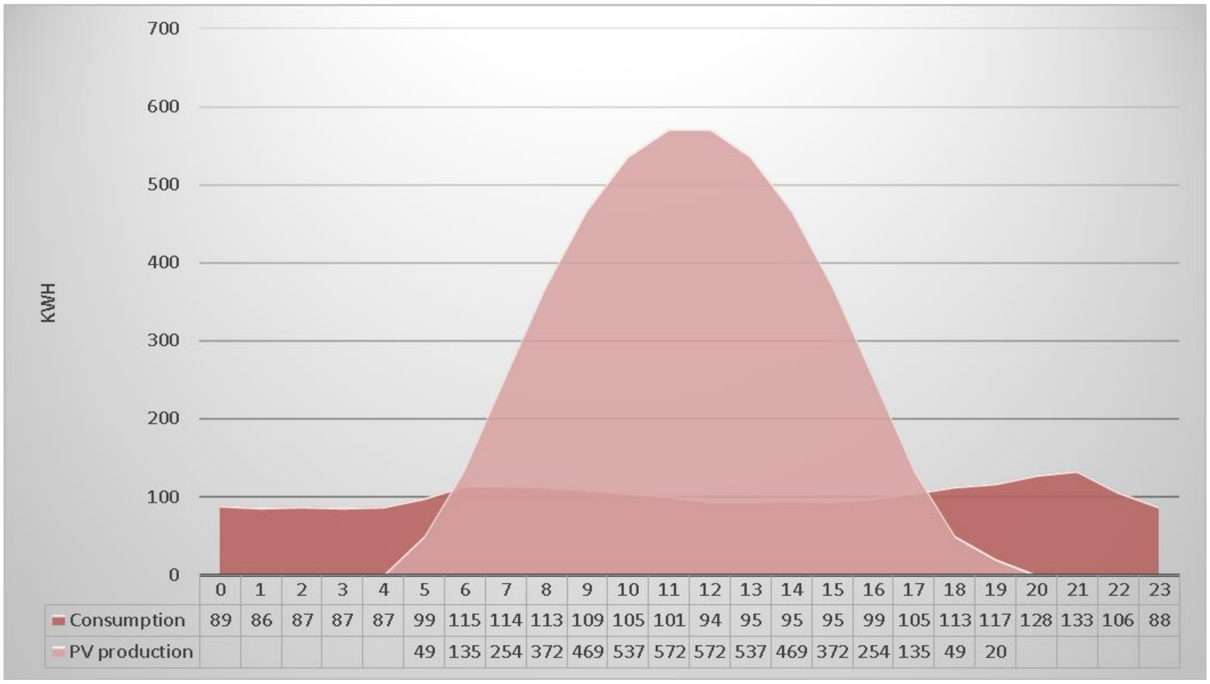
$$Selfconsumption\ percentage = \frac{Self\ consumed\ daily\ energy\ (kWh)}{Total\ daily\ PV\ production\ (kWh)}$$

Figure 28 – February 2014 self-consumption (personal elaboration)



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Consumption	120	121	121	121	123	129	145	158	161	162	156	150	136	132	135	141	161	183	196	196	190	181	145	128
PV production								96	203	309	384	423	442	384	309	203	81							

Figure 29 – May 2014 self-consumption (personal elaboration)

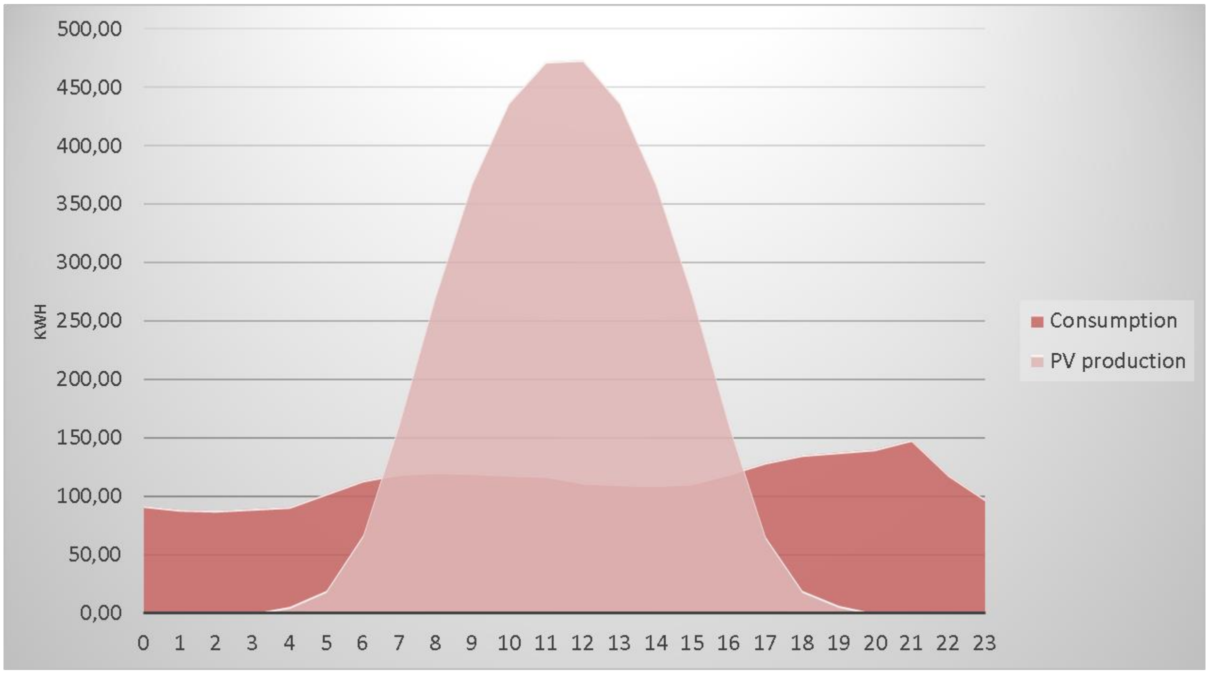


	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Consumption	89	86	87	87	87	99	115	114	113	109	105	101	94	95	95	95	99	105	113	117	128	133	106	88
PV production						49	135	254	372	469	537	572	572	537	469	372	254	135	49	20				

During February, the self-consumption percentage is 56.7% while for May it is 29.7%. I found those values by dividing the total energy self-consumption (i.e. the intersection area) with respect to the total energy production of the PV plant. February presents a higher self-consumption percentage for two main reasons. First, the consumption share that is covered by the PV plant is bigger with respect to May and, second, because the total PV plant energy production is smaller and so there is less energy that remains idle.

Now it is time to compute the assumed self-consumption percentage for the whole year 2014 for a PV plant installed with 1 MWp capacity. To do this I will compare the hourly production averages (taken from PVGis database and computed like described at the beginning of the paragraph).

Figure 30 - Average 2014 self-consumption (personal elaboration)



When dividing the share of self-consumed energy with respect to the total energy produced during the year, I ended up with 36.52%. This percentage seems low and it depends on different reasons. Looking at the intersection area with respect to the total area of the photovoltaic production, I can notice that a huge amount of energy is produced but is not useful. Actually, this is a “coordination” problem: before 04:00 and after 19:00, when energy consumption is still required, the PV plant is not able to produce energy anymore because of the lack of solar irradiance. This is a problem, since many energy is kept idle and this could result in an economic negative Net Present Value if the energy is not sufficiently remunerated into the electric market (here the energy price will play a crucial role). The reason for that lies in the fact that the PV plant has an economic cost depending on its size, and I selected1 MWp power since it is able to cover the total amount of the sports center yearly energy consumption. However, the issue here is that the energy cannot be stored and then consumed when the need arises; it must be instantaneously consumed[33]. Having said that, it is crucial to determine the proper plant size, given the reflections just made. It has no sense to waste the energy produced in excess and so the trading into the electric market could be a valid alternative.

Could an 800-kWp PV plant size be a better choice? What about a 600-kWp or a 1,200-kWp one? The next section will try to provide an answer taking into consideration the auto consumption percentage. I have to remember one important aspect, namely the fact that the self-consumption percentage is an important indicator of the suitability of a PV plant but is not the only one. The economic cost is another key variable and it is significant, for example, to investigate if the price at which the energy is sold to the electric market could be a valid alternative to a plant with a smaller size (and therefore less energy sold to the electric market).

3.3.3 Different size photovoltaic plants

Reasoning as I did above, a photovoltaic plant itself will not be able to cover the total amount of energy needs for the sports center. If the aim is to increase the self-consumption percentage, and so increasing the share of instantaneously consumed energy with respect to the total energy produced, the plant size must be reduced. In this respect, the percentage will increase because of a denominator reduction rather than a numerator upswing. With the same calculations made in the previous section, I want to determine the self-consumption percentage in different sizes photovoltaic plants. Obviously, the energy consumption monthly patterns remain the same; the curve that modifies is the photovoltaic production one. With a PV plant with less power, the

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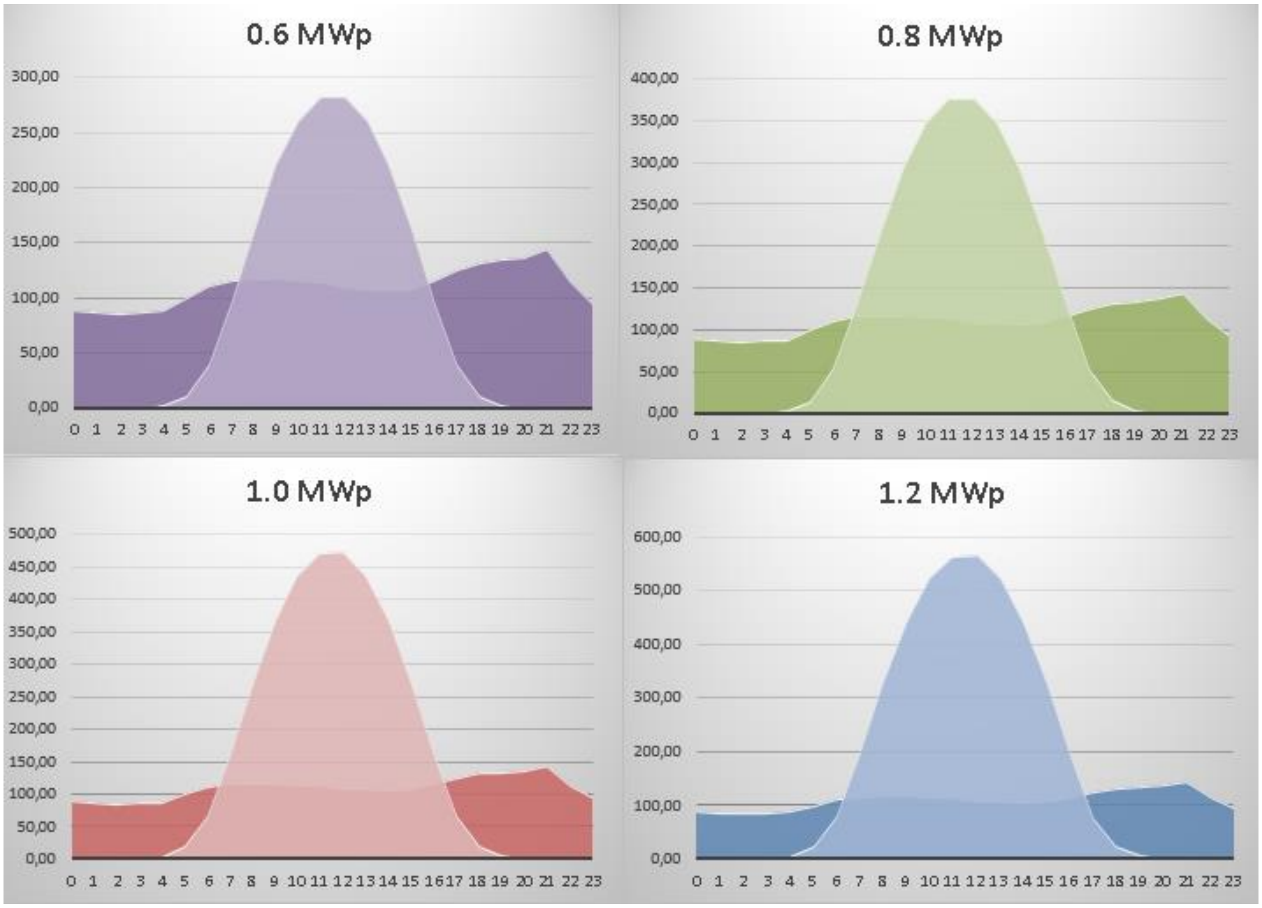
[33] There exists the possibility to use accumulation batteries in order to collect energy and reshape the PV production line in a more suitable way. I will consider this possibility and its costs at the end of Chapter 4.

function will be lower and the total PV production area will decrease, determining the denominator reduction.

The self-consumption percentages obtained considering PV plant of different sizes but with the same materials are (using the formula described in section 3.3.2), on average:

- 1,200 kWp: daily self-consumption/daily PV production= 1,352.52/4,325.04=31.3%
- 1,000 kWp: daily self-consumption/daily PV production= 1,316.31/3,604.2=36.5%
- 800 kWp: daily self-consumption/daily PV production= 1,280.57/2,883.83= 44.4%
- 600 kWp: daily self-consumption/daily PV production= 1,203.78/2,162.52= 55.7%

Figure 31 - Different self-consumption percentages with different PV power and constant energy consumption (personal elaboration)



3.4 Conclusions

Taking as fixed the energy consumption habits and the materials used for the photovoltaic plants hypothetic construction, I retrieved different shares of self-consumed energy. If I want to select the best one, taking the above percentages as criterion for the choice, the 600 kWp plant is the superior one, because of an higher auto-consumption percentage. This will result in a lower economic cost for the plant installation but also in less energy produced. Considering the 1 MWp plant, it is true that there is a huge amount of energy that is not self-consumed. Perhaps, considering other key variables such as scale economies (therefore a tighter economic cost) or different selling prices based on the stipulation of contracts (therefore a higher cash flow if the excess energy is sold), this plant could be considered also convenient.

The baseline scenario will consider the one MWp power plant since it is the one that produces the necessary amount of energy for the sports center under investigation. Next, I will investigate if using different plant sizes will result beneficial. In the last part of the following chapter I will also examine if there is a method for collecting the energy not instantaneously consumed and using it in different moments. I refer to the next chapter for the valuation of the different economic costs and the final decision on the best choice.

CHAPTER 4

Here I will develop the economic investment framework. After having presented the sports center under examination and its energy requirements, in the context of the present Italian regulation framework, it is time to move into the budgeting features of such an investment. I will present the NPV methodology and I will use it in building different scenarios. The different scenarios are constructed by letting change some key investment variables while maintaining others fixed. In such a way, it will be possible to valuate in an appropriate way the investment in order to understand its feasibility and the problems involved within.

4.1 The NPV methodology[34]

Different methods are disposable in order to fairly evaluate any type of investment. Among the most used, there is the Net Present Value methodology (also known as discounted cash flow method). It is a popular capital budgeting technique that permits to account for money time value by discounting it for a proper rate, the WACC rate. It uses the net present value of the investment project as the baseline to decide if the economic decision will be profitable (net present value bigger than zero) or not (negative net present value). The case that I am examining perfectly fits into this framework since cash outflows are represented by money expenditures in order to buy the whole PV plant and maintain it over time (insurance policies, loan interests, amortization, loss of value and productivity over time, etc.), while cash inflows include the gains from the potential energy selling or the amount of money saved with respect to the energy purchasing through the normal electric bill. In this respect, the self-consumption percentage will play a key role, like said in the previous chapter.

Briefly, the NPV formula (for n periods, with $-NCF_0$ indicating the initial investment and NCF_i indicating the net cash flow on period i) can be summarized by the following formula:

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[34] KOLLER T., GOEDHART M., WESSELS D., “Valuation – Measuring and managing the value of companies”, Mc Kinsey & Company, 5th edition.

$$NPV = -NCF_0 + \sum_{i=1}^{n} \frac{NCF_i}{(1+WACC)^i}$$

The NPV methodology is not exempted by flaws since it does not account for the flexibility option. When the project's scope is uncertain, the value of some business decisions such as postponing the investment or developing an existing one can have a significant weight in determining the NPV. In this respect, projects that could have been rejected with NPV should be realized accounting for the flexibility option (only if this possibility is available). In this work I will not consider this option.

In the next section, I will briefly present those elements that are necessary for a budgeting plan. Into my work, I will discuss only the key assumptions of this method and I will not deeply consider every aspects of it since it is not on my purposes.

4.1.1 The Weighted Average Cost of Capital

The discount rate is also an opportunity cost rate. It represents the cost that the decision maker forgoes in investing in this particular field instead of being remunerated from the best available alternative. The WACC is not easy to compute since it entails many economic models and assumptions and because of it is not so easy to find the best alternative in a financial world full of investing possibilities (there is an infinite number of possible alternative solutions)

The WACC is a way of computing the cost of capital invested in a project. It is a discount rate that permits the decomposition of the capital cost components: debt and equity[35]. Each of them are considered for their weight in relation to the total required investment. The following formula summarizes its calculation:

$$WACC = \frac{E}{D+E}(k_e) + \frac{D}{D+E}(k_d)(1-t)$$

The cost of debt is usually recognized as the yield-to-maturity of the long-term national government bonds depurated with the country marginal tax rate; the cost of equity is computed

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[35] This is a simplification since equity is distinct also into preferred equity. Notwithstanding, this, the distinction is not useful in the case I am examining.

using the Capital Asset Pricing Model. This model states that the investor will demand a minimum rate of return equal to the return from a risk-free investment plus a return for bearing additional risk. The extra-risk is known as equity risk premium and is equivalent to the risk premium of the whole market times a multiplier that accounts for the investment sensitivity to the market movements, the so-called beta. The CAPM formula is the following:

$$E(r_e) = r_f + \beta_e[E(r_m) - r_f]$$

The beta β_e is a key CAPM factor that amplifies (if it is bigger than 1), reduces (between 0 and 1) or replicates (equal to 1) the market movements. If the market is in trouble but the beta is close to 0, the expected project returns will not suffer so much from averse price movements while, vice versa, when beta is bigger than one the averse returns will be magnified. Mathematically, the project's beta is calculated with the historical covariance between the project returns and the market returns divided by the market returns' historical variance.

$$\beta_e = \frac{Cov\ (r_m; r_e)}{Var\ (r_m)}$$

There are two types of beta: the levered one and the unlevered one. The unlevered beta is the beta of a company considered as without any debt: computing this type of beta removes the financial effects from financial leverage and depicts the investment risk, depurated by the target companies' value of debt.

In general, in order to measure a consistent WACC, and consequently its key factors, it is necessary to include the opportunity cost of all investors (debt and equity) since the cash flow will be available to all of them, who expect a compensation for the risk they took. The duration of the securities used to estimate the cost of capital must match the duration of the cash flows.

4.2 The major risks associated with a PV investment project

Investing in a PV system is an activity that has a level of risk that is often not adequately considered by the standard evaluation methods. The choice of investing in a PV plant in order to save money with respect to the electric bill is a challenging one since it involves several threats. For example, among the others, it must be considered:

- The end of the feed-in schemes;
- The unpredictability of the energy production since it depends on irradiation and other atmospheric events;
- Trends in energy prices, if plant's owner decide to go to the electric market to sell the energy produced but not instantaneously consumed;
- The location of the plant;
- The type of technology for the solar energy conversion;
- Materials' characteristics.
- Degradation risk[36];
- Hot-spot risk that consists on a localized overheating of a photovoltaic module. It appears when, due to some anomaly, the short circuit current of the affected cell becomes lower than the operating current of the whole, giving rise to reverse biasing, thus dissipating the power generated by other cells in the form of heat. The anomalies that cause hot-spots can be external to the PV module, like shading or dust, or internal, like micro-cracks, defective soldering. In general, when a hot-spot persists over time, it entails both a risk for the PV module's lifetime and a decrease in its operational efficiency[37];
- Mismatching risk, which is a phenomenon regarding PV modules' cell, when a cell in a series connected string produces lower current than the other cells in that string. The current output of the string is limited by the weakest cell in the string.
- Risk of electrical faults to inverters or transformers.

These are only the most common risks that an investor should take into consideration when a PV plant investment project is in mind. In this respect in the baseline scenario, there will be additional risk since what I choose to do is to sell the excess energy to the electric market. The additional risk is the financial one, and depends on the price at which the energy can be sold to the market.

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[36] It will be considered taking into account a 1% yearly depreciation.

[37] MORETON R., LORENZO E., LELOUX J., CARRILLO J.M., 2014. "Dealing in practice with hot-spots", Instituto de Energía Solar – Universidad Politécnica de Madrid, Photovoltaic Systems Group, EUITT, Madrid.

4.3 The 1 MWp PV plant investment scenario

In this section, I will evaluate the investment cost on a 1 MWp size photovoltaic plant, the one that has been depicted and described in the previous Chapter. It is important to remind that, by assumption, I will consider that the energy consumption patterns will remain the same for the whole length of the investment such as the other variables, unless otherwise specified.

4.3.1 The 1 MWp PV plant cost

The total PV plant cost can be split in different parts. For the size under examination, the cost percentages with respect to the total cost are composed by[38]:

- 49 %, PV modules;
- 10%, inverter;
- 12% infrastructure;
- 11% cables and circuit panels;
- 18% project and installation.

In general, the various cost items distribution strongly depends on the power of the system: the smaller the plant will be the greater the weight of the services (installation and design) and the lower the cost of modules; larger plants will imply greater weight on costs by the modules. The most significant cost item in the budget for the construction of a solar system is certainly the purchase cost of the photovoltaic modules; indeed this affect the total expense ranging from 40% to 60% (depending on the power). However, photovoltaic modules are the most enduring components of a PV plant, since many manufacturers claim they are designed and constructed to produce electricity for more than 50 years. The design and the installation together range from 30%, for smaller plants, to approximately 15% for greater power plants. These elements are relevant for efficiency and duration purposes: a plant dimensioned and correctly realized makes it possible to produce a greater amount of energy and, therefore, permits to maintain costs reduction as well as an increase in the internal rate of return of the investment. The remaining cost items are usually below 10%. The support structures of the modules instead vary from 5% to 8% for

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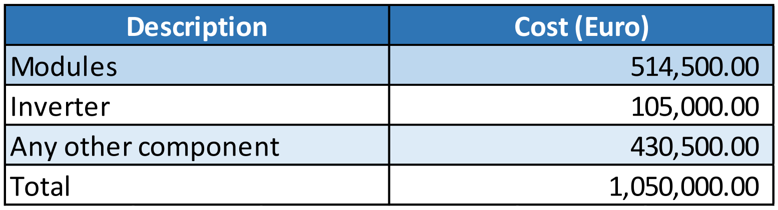
[38] http://www.enerpoint.it/solare/fotovoltaico/costi-fotovoltaico.php

traditional structures depending on the size of the system. Similar numbers were recorded for cables and panels while the inverter and cable costs remain minor items.

However, how much does a 1 MWp PV plant cost? It strongly depends on the seller. Using the information I retrieved[39], I ended up considering that the price of the majority of PV plants in Italy ranges from 1,000 to 1,300 euro/kWp installed. The average price is 1,150 euro/kWp, always considering that for PV plant of higher size there is a proportional price reduction. The market is experiencing continuously falling prices due to technology improvements.

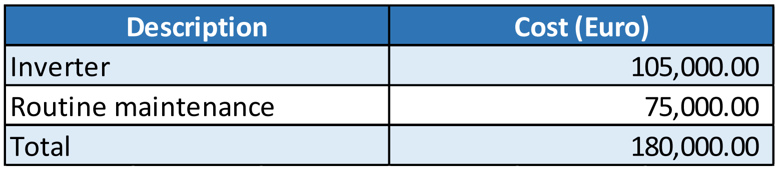
I will consider the lower of them, 1,050 euro/kWp because thanks to the higher plant size and for precautionary purposes, it can exploit the economy of scale with respect to smaller size plants.

The total cost of the plant will therefore be of 1,050,000 euro that are divided as follows:



Description	Cost (Euro)
Modules	514,500.00
Inverter	105,000.00
Any other component	430,500.00
Total	1,050,000.00

The total represents the total costs estimation that is the initial investment cost. Ten years after the investment, additional costs are supposed to display for operative reasons such as the inverter substitution and routine maintenance.



Description	Cost (Euro)
Inverter	105,000.00
Routine maintenance	75,000.00
Total	180,000.00

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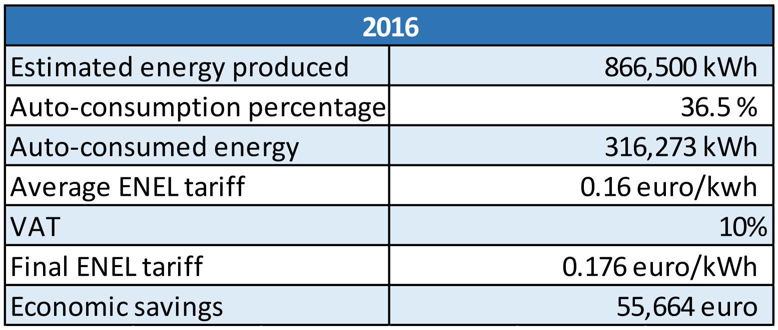
[39] MAYER J., 2015. “Current and Future Cost of Photovoltaics - Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems”, Agora Energiewende.

4.3.2 Revenue analysis

Once having determined the PV plant costs I want now to examine the revenues of this type of investment that are:

- The economic savings for what concerns the self-consumed percentage;
- The revenues deriving from the excess energy sold to the GSE.

The estimated amount of energy produced by the plant is 866,500 kWh and the average 2014 ENEL tariff is 0,176 euro/kWh (considering 10% VAT). The total savings are therefore:



2016	
Estimated energy produced	866,500 kWh
Auto-consumption percentage	36.5 %
Auto-consumed energy	316,273 kWh
Average ENEL tariff	0.16 euro/kwh
VAT	10%
Final ENEL tariff	0.176 euro/kWh
Economic savings	55,664 euro

I can see that, beginning from 2016, a considerable amount of money can be saved yearly. I will now consider how much can be gained in exploiting the energy not self-consumed that, in the case of the PV plant under consideration, are more than a half of the total PV production.

The methodology by which the electricity fed into the grid will be remunerated is "Ritiro Dedicato", the energy exploiting methodology described in Chapter 2.

As regards the selling mechanism through purchase and re-sale agreements, the electricity fed into the grid is extracted by GSE and valued with the average Hourly Zonal Price. However, as part of this analysis, the price of electricity sold to GSE will approximate the average PUN[40] value of the last three years. The next figure represents the last three years monthly PUN values.

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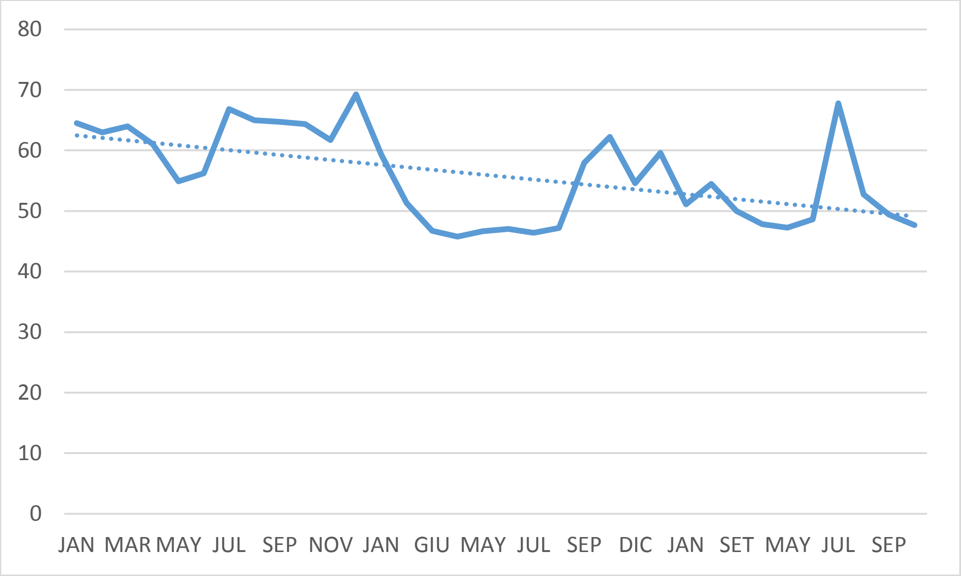
[40] PUN stands for unique national price and is the referring Italian energy price to be purchased on the electric market.

Figure 32 - PUN price (euro/MWh) from January 2013 until October 2015 (Source: GSE)



The average PUN value in the last three years is 0.0558 euro/kWh and this will be the price at which I assume to be able to sell electricity to GSE.
In order to do this, the sale of electricity under “Ritiro Dedicato” consists on the final contribution that GSE pays to the owner of the system on a monthly basis. This contribution will be determined by the difference between:

- contributions due by GSE to the plant’s owner that are:
    - the total injected electricity value;
    - contributions for transport services equal to 0.00356 (€/kWh).
- contributions due by the plant’s owner to GSE that are:
    - transmission fees equal to 0.000256 (€/kWh);
    - administrative fees of 0.5% of the value of the energy injected up to a maximum of 3,500 € / year.
    - Transport and dispatching fees of 11 €/month.

The following table summarizes the components that determine the revenues resulting from this type of contract.

Amount to be given by GSE	
Average PUN by 2013 (euro/kWh)	0.0558 euro/kWh
Transport services	0.00356 euro/kWh
Amount to pay to GSE	
Transmission fees	0.000256 euro/kWh
Administrative fees	0.5%
Transport and dispatching fees	11 euro/month

2016	
Amount to be given by GSE	
Injected energy	550,227 kWh
Injected energy value	30,702.87 euro
Transport services	1,958.81 euro
Total	**32,661.68 euro**
Amount to pay to GSE	
Transmission fees	140.86 euro
Administrative fees	2,751.14 euro
Transport and dispatching fees	132 euro
Total	**3,024 euro**
Net cash flow from energy injection = 29,637.68 euro	

4.3.3 WACC computation

Now that I have computed the investment cash flows, it is time to retrieve the proper discount rate, the WACC. Therefore, it is now important to determine all of its key elements. As an assumption, I will compute the Net Present Value for a period of twenty years and so the WACC components must reflect this. I set the debt weight as 70% of the total capital required and therefore equity will have a 30% weight in my analysis.

The relevant variables to the discount rate computation have been estimated as follows:

- unlevered beta of 0.65 calculated with the expected returns covariance of the product between the PUN and the FTSE-MIB and the expected returns from the stock market (FTSE - MIB) all divided by the variance of expected returns of the market[41];
- risk-free rate relative to a 20 years Italian Government Bond (BTP) that is equal to 2.220%[42];
- market risk premium of 5.4%[43] ;
- marginal taxes of 31.40%[44].

WACC computation summary	
Risk-free rate	2.22%
Unlevered beta	0.65
Market risk premium	5.4%
Cost of equity	5.73%
Equity weight	30%
Cost of debt	7.0%
Marginal taxes	31.4%
Net cost of debt	4.81%
Debt weight	70%
WACC rate	**5.09%**

4.3.4 Amortization schedule

In order to realize the PV plant under evaluation it will need to invest the sum of € 1.05 million

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[41] MILANI E., “Lo sviluppo del fotovoltaico in Italia: valutazione di progetti di investimento e analisi della rischiosità”, 2012.

[42] “www.bloomberg.com”

[43] FERNANDEZ P., PIZARRO A.O.., ACIN I.F.., “Market Risk Premium used in 41 countries in 2015”, 2015.

[44] 27.5% IRES (company revenues tax) plus 3.9% IRAP (regional tax on production activities).

This sum will be financed in the following ways:

- € 315,000 (30%), through liquidity and equity capital. In this case I assume that the sports center will invest a consistent part of its own equity.
- € 735,000 (70%) collected through banks in the form of debt capital; this funding will take the form of loan with a mortgage having 20 years duration and a 7.00% yearly interest rate.

2016 BALANCE SHEET			
Assets		**Liabilities**	
(A) Receivables	0	315,000	**Net equity (A)**
		315,000	Share capital (A.I)
(B) Total fixed assets	1,050,000	735,000	**Total payables (D)**
(B.II) Tangible fixed assets	1,050,000	0	Short term debt(D>>>)
		735,000	Long term debt (D>>>)
Total balance sheet assets	**1,050,000**	**1,050,000**	**Total balance sheet liabilities**

These values, with the exception of the share capital, will reduce over time. Indeed the debt will decrease for the repayment of the principal, while the value of the plant will be amortized over time with a yearly depreciation rate (1 %) calculated on the useful life of the plant, estimated at 30 years; the amortization will be 35,000 euro per year, net of the interest cost. In addition, on the tenth year of the investment extraordinary costs will incur for routine maintenance and inverters substitution, amounting to 180,000 €.

4.3.5 NPV calculation

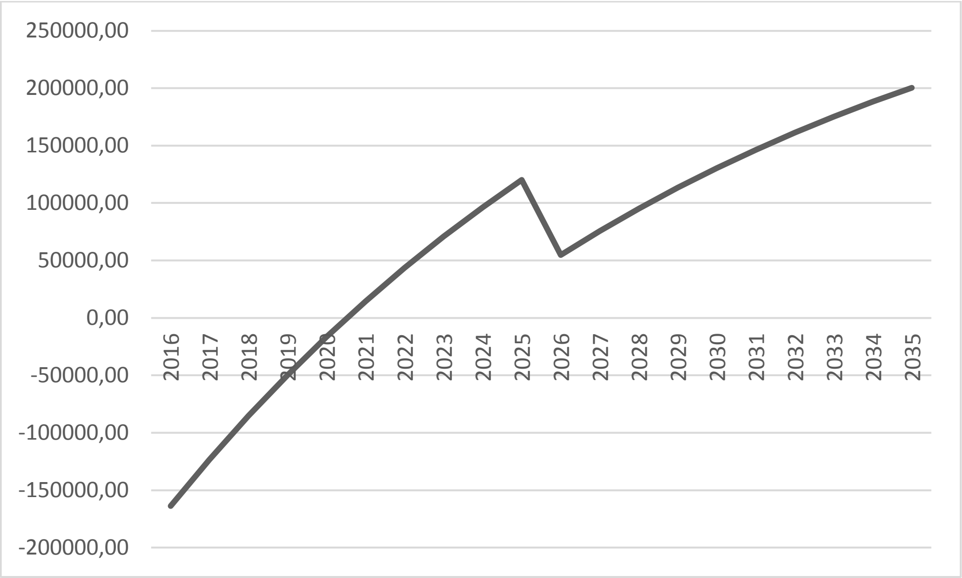
Here I present the NPV calculation, starting from 2016 and arriving to 2036, remembering that the proposed WACC rate is 5.09%. I want also remember that, after 2035 (and maybe with additional maintenance costs), the plant is supposed to have another ten years of functioning.

	2016	2017	2018	2019	2020	2021

Investment (-)	315000,00					
Energy sold revenues	29637,68	29341,30	29047,89	28757,41	28469,84	28185,14
Electric bill savings	55664,00	55107,36	54556,29	54010,72	53470,62	52935,91
Mortgage repayment (-)	39322,50	39322,50	39322,50	39322,50	39322,50	39322,50
Net Cash Flow	-269020,82	45126,16	44281,68	43445,63	42617,95	41798,55
Actualized NCF	-269020,82	42940,49	40096,02	37433,63	34941,94	32610,26
NPV	-269020,82	-226080,33	-185984,31	-148550,67	-113608,73	-80998,48
2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
				180000,00		
27903,29	27624,25	27348,01	27074,53	26803,79	26535,75	26270,39
52406,55	51882,49	51363,66	50850,02	50341,52	49838,11	49339,73
39322,50	39322,50	39322,50	39322,50	39322,50	39322,50	39322,50
40987,34	40184,24	39389,17	38602,06	-142177,19	37051,36	36287,62
30428,56	28387,43	26478,03	24692,09	-86539,82	21459,96	19999,62
-50569,92	-22182,49	4295,54	28987,63	-57552,19	-36092,23	-16092,61
2029	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
26007,69	25747,61	25490,13	25235,23	24982,88	24733,05	24485,72
48846,33	48357,87	47874,29	47395,55	46921,59	46452,37	45987,85
39322,50	39322,50	39322,50	39322,50	39322,50	39322,50	39322,50
35531,52	34782,98	34041,92	33308,28	32581,97	31862,93	31151,07
18634,41	17358,30	16165,65	15051,16	14009,86	13037,09	12128,48
2541,80	19900,10	36065,75	51116,91	65126,77	78163,85	**90292,34**

The NPV methodology results are strongly positive and from the results this appears to be a profitable investment. The NPV of the project is 90,292,34 euro. This type of investment presents to be a suitable one. In 2020 the actualized cash flows of the project turns positive as the picture below describes.

Figure 33 - 1MWp plant investment NPV (personal elaboration)



The problem here stands in the plant's size since a substantial amount of energy is not instantaneously consumed and has to be sold to GSE at no so convenient price. Furthermore, when there is a peak performance for the PV plant (August), the sports facility decreases its consumption (because it remains closed for two weeks). When, instead, the PV plant has less power (winter months in general) the energy consumption reaches its peak. The issue here is a timing problem, a mismatch between the energy production and the energy consumption. This makes me arise the question: can this investment be improved?
I will try to follow the path of reaching the highest possible percentage of auto-consumption. Consequently, it is convenient to discover what happens selecting a power plant of a smaller size but remembering that it will be able to produce less energy and so to cover an inferior part of the sports center energy consumption.

4.4 The 0.6 MWp PV plant investment

For the total cost of the PV plant installation, I will consider a slightly higher price with respect to the 1 MWp PV plant since its dimensions don't permit the scale economies useful on the previous investment. The PV plant is supposed to be built using the same material and in the same place of the previous one. The cost of this plant is 1,150 euro/kWp, reflecting a total cost of 690,000 euro divided as follows:

Description	Cost (Euro)
Modules	338,100.00
Inverter	69,000.00
Any other component	282,900.00
Total	690,000.00

The tenth year after the initial investment, routine maintenance and inverter substitution costs will arise for a total amount of 144,000 euro.

I assume a yearly plant depreciation of 1% caused, as in the previous case by the material deterioration and other endurance problems.

The revenues will depend on the total PV energy production. Using the PVGis database I found that the annual estimated energy produced is 563,225 kWh. The economic savings with respect to the electric bill are:

2016	
Estimated energy produced	563,225 kWh
Auto-consumption percentage	55.7 %
Auto-consumed energy	313,716 kWh
Average ENEL tariff	0.16 euro/kwh
VAT	10%
Final ENEL tariff	0.176 euro/kWh
Economic savings	55,214.02 euro

The revenues deriving from the energy sale to the GSE are instead:

2016	
Amount to be given by GSE	
Injected energy	249,508 kWh
Injected energy value	13,922.64 euro

Transport services	888.25 euro
Total	**14,810.89 euro**
Amount to pay to GSE	
Transmission fees	63.87 euro
Administrative fees	1,274.54 euro
Transport and dispatching fees	132 euro
Total	**1,443.41 euro**
Net cash flow from energy injection = 13,367.48 euro	

The WACC rate remains the same while, considering that in order to realize the PV plant under evaluation it will need to invest the sum of € 690,000 I choose to finance this sum, as in the previous case, as follows:

- € 207,000 (30%), through liquidity and equity capital. In this case I assume that the sports center will invest a consistent part of the disposable equity.
- € 483,000 (70%) collected through banks in the form of debt capital; this funding will take the form of loan with a mortgage having 20 years duration and a 7.00% yearly interest rate.

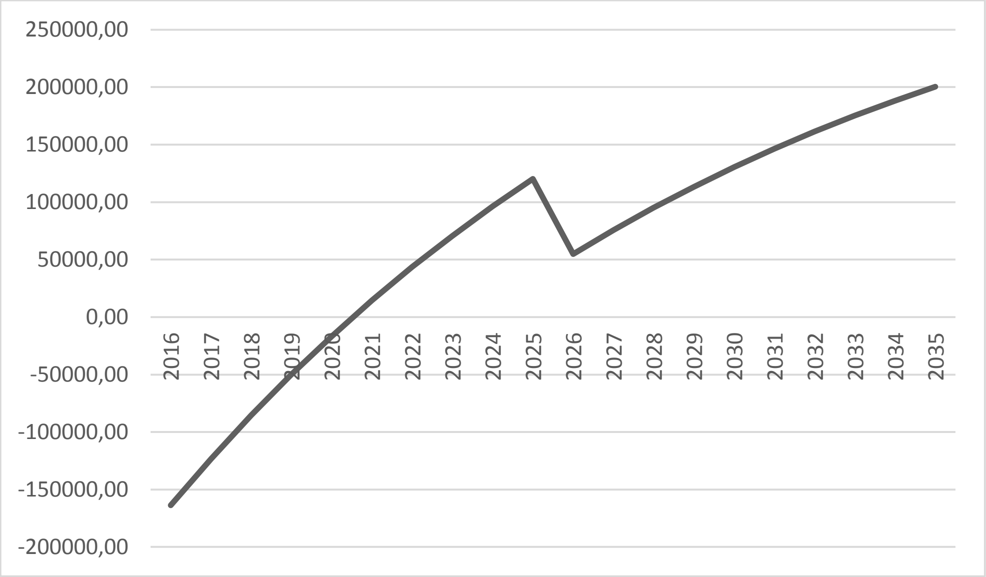
2016 BALANCE SHEET			
Assets		**Liabilities**	
(A) Receivables	0	207,000	**Net equity (A)**
		207,000	Share capital (A.I)
(B) Total fixed assets	690,000	483,000	**Total payables (D)**
(B.II) Tangible fixed assets	690,000	0	Short term debt(D>>>)
		483,000	Long term debt (D>>>)
Total balance sheet assets	**690,000**	**690,000**	**Total balance sheet liabilities**

Now I can move to the NPV calculation, remembering that the cash flows are actualized using the same discount rate as the previous investment.

	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Investment (-)	207000,00					
Energy sold revenues	13874,03	13735,29	13597,94	13461,96	13327,34	13194,06
Electric bill savings	55214,20	54662,06	54115,44	53574,28	53038,54	52508,15
Mortgage repayment (-)	25840,50	25840,50	25840,50	25840,50	25840,50	25840,50
Net Cash Flow	-163752,27	42556,85	41872,87	41195,74	40525,38	39861,72
Actualized NCF	-163752,27	40495,62	37914,91	35495,08	33226,26	31099,19
NPV	-163752,27	-123256,65	-85341,74	-49846,66	-16620,40	14478,79
2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
				144000,00		
13062,12	12931,50	12802,19	12674,17	12547,42	12421,95	12297,73
51983,07	51463,24	50948,61	50439,12	49934,73	49435,39	48941,03
25840,50	25840,50	25840,50	25840,50	25840,50	25840,50	25840,50
39204,70	38554,25	37910,30	37272,79	-107358,34	36016,84	35398,26
29105,14	27235,95	25483,91	23841,82	-65346,43	20860,77	19509,46
43583,93	70819,88	96303,79	120145,61	54799,17	75659,94	95169,40
2029	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
12174,75	12053,01	11932,48	11813,15	11695,02	11578,07	11462,29
48451,62	47967,11	47487,43	47012,56	46542,43	46077,01	45616,24
25840,50	25840,50	25840,50	25840,50	25840,50	25840,50	25840,50
34785,87	34179,61	33579,41	32985,21	32396,95	31814,58	31238,03
18243,36	17057,20	15946,02	14905,17	13930,30	13017,31	12162,34
113412,76	130469,95	146415,97	161321,14	175251,44	188268,75	**200431,09**

By increasing the self-consumption percentage, and decreasing the PV plant cost in order to produce a moderate quantity of energy the NPV is high and amounts to 200,431.09 euro. The value of this type of investment has doubled the previous case NPV. The sixth year from the initial investment will experience positive cash flows.

Figure 34 - 0.6 MWp NPV investment (personal elaboration)



Summarizing the obtained results, it comes down that they had been satisfying since both NPV are strongly positive and it seems that they could be improved again.

One of the best way to improve these investments is trying to enlarge the self-consumption intersection area in order to have more benefits from the point of view of the economic returns. This is confirmed by the fact that the electric bill economic savings are highly remunerated over time with respect to the energy fraction that I have to sell. It is worth now to implement a strategy that permits to increase the share of self-consumed energy. I will do this in the next sections providing two different hypothetic choices, resulting in two alternative scenarios:

I. The sports center's owner could decide not to close anymore the plant in August in order to better exploit the new PV plant installation. In this way, August energy consumption will be in line with the other summer months, thus increasing the yearly average auto consumption percentage.

II. The sports center’s owner could decide to invest an additional amount of money in order to purchase and install a battery storage accumulation system, useful in order to exploit the PV plant energy produced also during nights and mornings.

4.5 First alternative scenario: “Full August” case

Looking at section 3.1, Figure 22, it is suddenly distinguishable that August is the month in which the energy consumption falls dramatically. This can be viewed, in general, as a positive characteristic since less energy consumption means more energy hoarded and, therefore, economic savings. However, this reasoning cannot apply in the case I am examining since investing in a photovoltaic system means self-providing the energy requirements all the year long. This is even more important when the energy that is not exploited is exactly the one that is produced in huge quantity, as it happens in August. The aim of this part of my work is considering whether this type of scenario will increase the quality of the investments evaluated before.

In order to consider August’s full consumption, I have to almost double its total energy consumption value. Remember that the August hourly energy consumption are not real values but they had been estimated using the monthly rate of growth of consumption (see Appendix A). Instead of having -36% growth rate with respect to July the new growth rate is -2.4%. The table below summarizes the new daily energy patterns of August.

AUGUST	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
Baseline cons	40,2	38,0	36,9	37,5	38,0	45,2	49,5	50,8	52,6	53,8	55,2	56,8	55,4	55,3	54,5	55,0	57,5	60,0	59,6	59,3	61,9	70,4	56,1	43,6	1243,2
PV production					0,0	19,8	66,9	147,2	229,0	298,5	348,1	373,7	373,7	348,1	298,5	229,0	147	66,9	16,7	0,0					2963,2
Excess energy							17,4	96,4	176,4	244,7	292,9	316,9	318,3	292,7	244,0	174,0	89,6	6,9							2270,1
New scenario consumption	61,4	58,0	56,4	57,2	57,9	68,9	75,6	77,6	80,2	82,1	84,2	86,7	84,6	84,5	83,2	83,9	87,8	91,6	91,0	90,6	94,4	107,5	85,6	66,5	1897,5
New excess energy								69,6	148,7	216,4	263,9	287,0	289,1	263,6	215,3	145,1	59,4								1957,9

This new energy consumption pattern also affects the average hourly energy consumption, increasing it, and consequently enlarging the self-consumption percentage. The total yearly consumption will then cross the 1 million kWh threshold. Reminding that I am considering the smaller size plant (600 kWp) since it was the one that gave me the best economic results, the new achieved self-consumption percentage is 62.3% (a remarkable increase with respect to the previous 55.7%, see section 3.3.2). I can now examine how the NPV will change with these new conditions.

The resulting new auto-consumed fraction of the total PV production is 350,889.18 kWh and this implies that the economic savings for the year 2016 would be 61,756.49 euro. With respect to GSE:

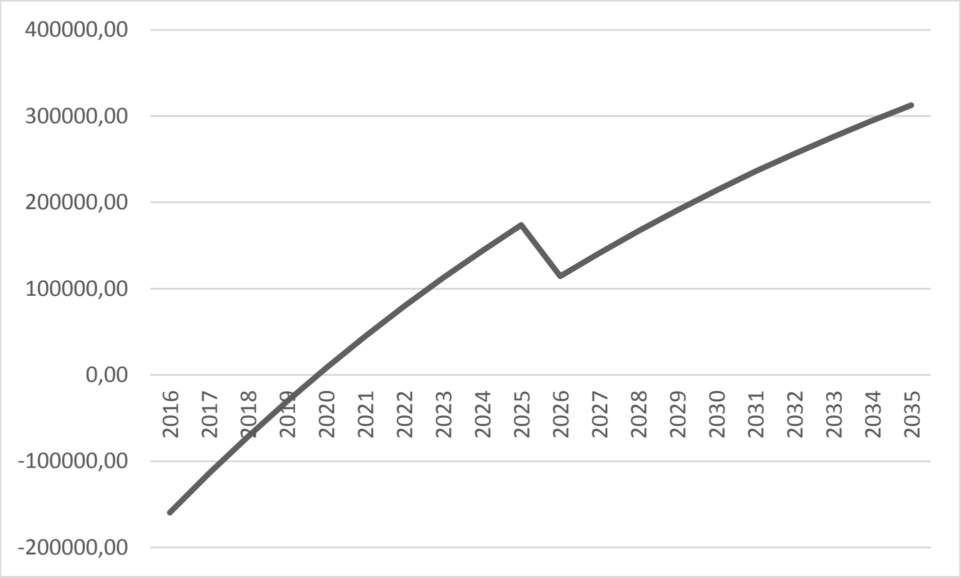
2016	
Amount to be given by GSE	
Injected energy	212,335.82 kWh
Injected energy value	11,848.42 euro
Transport services	755.92 euro
Total	**12,604.26 euro**
Amount to pay to GSE	
Transmission fees	54.36 euro
Administrative fees	1,061.68 euro
Transport and dispatching fees	132 euro
Total	**816.95 euro**
Net cash flow from energy injection = 11,667.40 euro	

The capital structure and the loan will remain the same of the 0.6 MWp size PV plant.

Into this type of investment, the NPV amounts to 312,482.40 euro reaching the first ranking among the investments considered up to this point. In Appendix B the NPV calculation is detailed.

It confirms that increasing the self-consumption percentage is one the best ways to appropriately benefit from a photovoltaic investment. In the next section, I will explore the second alternative scenario pursuing the path aimed at the maximum increase of the self-consumption percentage.

Figure 35 - First alternative scenario NPV (personal elaboration)



4.6 Second alternative scenario: "the storage"[45] case

Many manufacturers claim that any photovoltaic investment aims at creating clean energy, but it is not enough since it is necessary to make an optimal use of this energy. It is possible to do this, for example, using a storage system made by solar batteries. Photovoltaic systems are already saving several million tons of carbon dioxide all over the world but, as pointed out in the previous sections, the excess energy given to GSE is not appropriately enhanced. The nowadays largest savings are achieved by the sum of all photovoltaic systems but until recent times, solar energy for power consumption could only be used during the day; on the morning and during afternoon the PV produced energy cannot be rescued. The issue here was that the selling price of the energy is very low, resulting detrimental to NPV calculations. Many owners of a photovoltaic system therefore sought out a storage solution. It consists on a photovoltaic battery storage unit that can supply self-produced solar power in low-light conditions. The system either provides the solar energy directly from the photovoltaic system or it also extracts power from the storage unit of the solar batteries.

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[45] NAUMANN M., 2015. "Lithium-ion Battery Cost Analysis in PV-household Application".

This is a revolutionary idea that, depending on its costs, will provide a perfect methodology for who wants to reshape in a more efficient way the PV production function allowing to use it when the plant has no solar irradiance.

In brief, is installing storage batteries with the photovoltaic technology the solution to improve savings with respect to the electric bill? How to choose the most suitable battery? Before trying to understand this, it is convenient to see more specifically how the photovoltaic system works with energy storage. The accumulation system is connected to the photovoltaic plant, on one hand, and (as appropriate) to the external power grid, on the other. Through a control unit the system governs the energy flows according to the user needs. Through a charge regulator, instead, the system regulates the batteries' charging avoiding dangerous overloads. The whole, of course, must be dimensioned in proportion to the plant, to the batteries and the power or amount of electrical consumption. The clean electricity produced by photovoltaic is transferred on different routes in priority order:

- directly to users for immediate consumption;
- to the storage batteries, for deferred self-consumption;
- to ENEL (only if required by the project and only when the batteries are fully charged), for the development through the mechanism of the spot exchange.

What it is now important to understand is if and how the batteries are sufficiently good to guarantee the greatest savings in the electric bill and if their costs could be amortized in a timely manner.

The more suitable type of batteries for my purposes are the Lithium batteries. For these it is considered the 80 % exploitation rate that is, for 4.5 kWh we will need an accumulation of almost 5.7 kWh. This type of battery is more expensive but provides a longer life and greater efficiency than the other types. They typically last 10 or 12 years against the five years of Lead batteries.

4.6.1 Energy storage systems in Italy

In Italy, the battery's cost is still high and the regulation for the moment is not following the development of the storage systems. Nevertheless today, the storage systems are already used by a lot of people and companies to increase the share of consumption, saving electricity and therefore reducing the dependence on the electric grid. Obviously, a key element is the cost of these batteries.

The cost of the batteries, also thanks to the development of electric mobility, are presumed to fall by 50% in the next 3 or 4 years. Meanwhile, it seems that there are already interesting and affordable solutions on the market that are able to bypass the current regulatory uncertainty. Albasolar, for example, offers photovoltaic systems with storage. Systems in which the solar panels recharge the batteries, but could not feed in instantaneously the excess energy. Until the battery is fully charged, the user can use its energy. When the battery charge is low, the system quits from the batteries and connects to the network.

4.6.2 Batteries' price and valuation

Li-ion systems of energy accumulation costs currently range between 350 and 700 euro/kWh[46] and costs should continue to fall on the back of growing supply from mega battery factories like Tesla, Alevo, Sharp, LG and Panasonic. Technological innovation and economies of scale backed by big balance sheets are helping leading Li-technology battery manufacturers to widen their competitive advantage and lower costs. Li-ion battery system prices have already dropped 33% in the last five years.

In this context, I want to examine how much an investment in this technology could help in reaching higher capital efficiencies. For this purpose, I will evaluate this possibility with respect to the 0.6 MWp size PV plant, since it was the one with the best NPV. In doing this additional analysis, I have to remember the main important Lithium batteries characteristics:

- Their expected lifetime utility is around 10 years long, so during a 20-years investment they must be replaced;
- Their average costs varies between 350 and 700 euros per kWh capacity, and it is expected to drop significantly in the next five years;
- Their efficiency is about 80%.

Looking at Figure 31 in section 3.3.2, it depicts, on the top-left side the annual 2014 average hourly PV production with respect to the sports center consumption habits. The total share of

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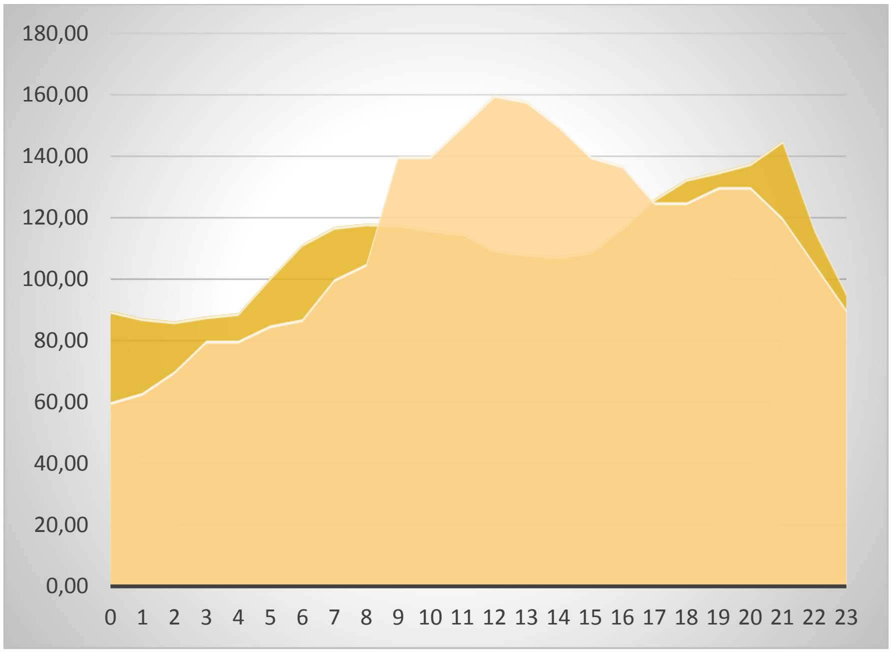
[46] http://analysis.energystorageupdate.com/lithium-ion-costs-fall-50-within-five-years

instantaneously consumed energy is 313,716 kWh while the energy that had to be paid into the electric bill was the remaining 536,958 kWh equal to 1,471 kWh per day

By investing 360,000 euro (the remaining part by which the investment made into the 1 MWp is matched) I can retrieve a set of batteries that could approximately store 1,000 kWh per day, amount that can be used to consume the generated electricity during the afternoon, in the evenings and nights, therefore increasing the self-consumption percentage. This will enact a different "consumption over PV production" curve.

Figure 36 - Reshaped PV production curve with storage batteries (personal elaboration)

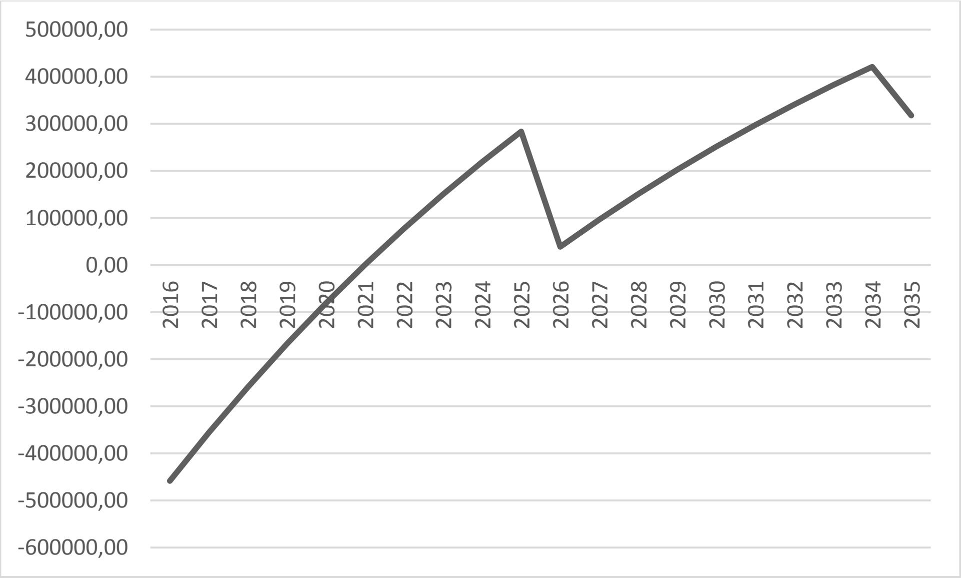


This enabled to reach the huge self-consumption average percentage of 87.3%; anyone can note this looking at the intersection area enlarging. Now it is time to move on and consider the NPV approach for this new type of investment. Will the storage scenario outperform the "August full consumption" one?

The amount of total yearly energy auto-consumed, considering the 80% batteries potential is 598,231 kWh and this will result in higher economic savings with respect to the electric bill.

Now the investment cost and the balance sheet of the project are equal to those considered for the 0.6 MWp PV plant; the difference now is in the proportion of energy consumed with respect to the energy that has to be purchased plus another one. On the tenth year of the investment, in addition to the routine maintenance cost, there will be the need to replace those batteries. Even if their price is supposed to significantly drop over the years, I will prudentially consider its current cost twice (360,000 euro equity financed expenditure paid twice, in 2026 and in 2035). In Appendix C the NPV calculation is detailed since its computation path follows the same procedure of the other examined cases.

Figure 37 - Storage alternative scenario investment NPV (personal elaboration)



The NPV (317,767.15 euro) is slightly higher than the previous scenario's one. It is worth to consider, however, that the storage batteries present a higher investment requirement (that is supposed to be financed with equity) and that it is considered twice. The electric bill savings permit a huge benefit in this case since they represent economic savings equal to 78,790.14 euro per year (on average and considering the PV plant depreciation). This is the main driver and it is determined by the self-consumption percentage. In the table below, before ending this chapter, I want to rank the four examined projects on the base of their NPV.

	SCENARIO	NPV
1	**Storage**	**317767,15**
2	**Full August**	**312482,40**
3	**0.6 MWp**	**200431,09**
4	**1 MWp**	**90232,34**

I want to point out that the storage case is supposed to be the better also for the fact that, starting from 2035, the photovoltaic plant will produce electricity for the following ten years. The major part of this electricity will be stored and auto-consumed determining huge positive cash flows.

CONCLUSIONS

This study had the main goal of investigating a methodology for efficiently valuating a photovoltaic investment project. Like all the other types of investments, it has its risks and must promise positive net present values in order to be undertaken. After having explored the global and the Italian market, having passed through the Italian regulatory system, I tried to evaluate an investment of this type into a sports center. My proposal was to investigate if it could convenient for a sports center, with relatively high-energy consumptions, to undertake the not so easy decision to invest a consistent amount of money in a PV plant.

Nowadays, with the end (for what concerns Italy) of the feed-in schemes (that had the merits since 2000 of pushing the Italian PV market on the top of the global markets) it is crucial to understand what could be the ideal cases in which a positive cash flow could be reached. It is important to notice that the Italian market is also boosted by the fact that Italy, and in particular the South, is sited in an ideal geographical position for PV investment because of an higher irradiance with respect to the other European countries. When doing my investigation, I encountered several issue and characteristics but the main driver at, this time, is above all the self-consumption percentage.

This important energy investment feature, explains the way in which a photovoltaic plant (or any other type of energy production plant) is exploited. This means that, given that my photovoltaic system produces 100, how much of that amount I will be able to self-consume? This is a very important question since it involves two different aspects. The first is the fact that the auto-consumed energy determines the biggest savings in terms of energy cost. In Chapter 4 (and in Appendix B and C) the NPV calculation is detailed and it is noteworthy that the higher the electric bill savings, the higher the net present value. The other positive cash flow is represented by the energy selling to the energy provider GSE, through “Ritiro Dedicato” system. The problem of this system is that the energy not exploited by an industry (or in this case by a sports center), the excess energy, is not properly remunerated with respect to the first positive cash flow, the electric bill savings. Again, the higher the self-consumption percentage, the more electric bill savings with respect to the energy sold to GSE. The challenge here is to try to self-exploit the highest possible energy quantity.

Looking at Chapter 4, I can summarize that the highest economic results would be reached by the "storage case" were the self-consumption percentage amounted at 87.3%. This percentage determined a huge saving with respect to the other cases that are ranging from 36.5% (the lowest NPV, even if positive, from the 1 MWp size) to 62.3% (the second higher NPV in the August full consumption hypothesis). However, why is this variable so important?

The answer is very simple, since, until 2013, any photovoltaic investment was remunerated by appropriate incentives for the energy not auto-consumed but injected into the grid. The Italian market, after 2013, had to search for other ways of exploiting the excess energy since the end of the incentives enacted by the government made it necessary. So nowadays, the key element to properly take advantage of a photovoltaic investment is to auto-consume the highest possible share of the total energy produced by the plant.

The modules' material, the geographical position, the ideal modules' inclination, the atmospheric events, the cost of capital and other, are all determinant elements that are very important for the photovoltaic energy production. If, for example, I had made this analysis, instead of in the North of Italy, in the South, the solar irradiance would have been higher and so the PV production. This could have brought me to the same results of a North 1 MWp photovoltaic plant with a smaller size one, reflecting in a reduced amount of the original investment. Technology will also continue to play a crucial role in the future with the usual efficiency enhancements and the consequent costs cutting.

This work helps at indicating that, **with all the other relevant variables fixed**, reaching a high self-consumption percentage will be the main driver for a profitable long term (from 30 to 50 years) investment. Many sector experts confirm this. Finally a want to point out that the investment is positive not only from an economic point of view. Even if toxic substances in the production of PV modules should be considered, in general a PV plant permits the production of clean energy and so pollution reduction. This is a positive aspect for all the community.

APPENDIX A

The table below shows, from January until May, the real monthly hourly energy consumption for 2014 of the sports center. The other data has been forecasted using the growth rate of monthly energy consumption and are indicated in bold font.

MONTHLY CONSUMPTION TABLE

H	January	February	March	April	May	June
0	**115.17**	120.00	112.16	113.77	89.26	62.90
1	**116.44**	121.32	116.50	109.50	86.23	59.37
2	**115.72**	120.57	113.10	115.13	87.26	57.73
3	**115.82**	120.68	122.10	118.67	87.00	58.57
4	**117.68**	122.61	122.33	120.77	87.45	59.33
5	**123.85**	129.04	133.87	130.13	98.74	70.57
6	**139.00**	144.82	134.33	156.97	114.55	77.43
7	**151.85**	158.21	157.67	156.53	114.23	79.43
8	**154.35**	160.82	145.30	156.53	113.45	82.17
9	**155.66**	162.18	141.83	142.23	108.71	84.07
10	**150.14**	156.43	131.70	128.70	105.13	86.23
11	**143.66**	149.68	122.33	120.40	101.16	88.77
12	**130.84**	136.32	117.13	111.53	94.13	86.63
13	**126.93**	132.25	113.87	106.67	94.97	86.50
14	**129.81**	135.25	111.40	105.07	95.32	85.20
15	**135.29**	140.96	112.87	105.10	94.81	85.90
16	**154.08**	160.54	121.53	115.17	98.84	89.93
17	**175.88**	183.25	141.83	122.90	105.35	93.80
18	**188.32**	196.21	177.83	136.00	112.77	93.20
19	**187.84**	195.71	189.33	153.90	117.29	92.73
20	**182.32**	189.96	180.33	162.27	128.26	96.70
21	**173.48**	180.75	170.77	160.27	133.48	110.03

22	**139.07**	144.89	135.67	133.53	106.13	87.60
23	**123.02**	128.18	119.27	113.73	88.00	68.13

July	**August**	**September**	**October**	**November**	**December**	**AVERAGE**
62.94	**40.25**	**65.54**	**90.48**	**104.16**	**100.09**	89.73
59.40	**37.99**	**61.85**	**85.40**	**98.31**	**94.47**	87.23
57.77	**36.94**	**60.15**	**83.05**	**95.60**	**91.87**	86.24
58.60	**37.47**	**61.02**	**84.25**	**96.98**	**93.20**	87.86
59.37	**37.96**	**61.82**	**85.35**	**98.25**	**94.42**	88.95
70.61	**45.15**	**73.52**	**101.51**	**116.86**	**112.29**	100.51
77.48	**49.55**	**80.68**	**111.39**	**128.23**	**123.22**	111.47
79.48	**50.83**	**82.76**	**114.27**	**131.54**	**126.40**	116.93
82.22	**52.57**	**85.61**	**118.20**	**136.07**	**130.75**	118.17
84.12	**53.79**	**87.59**	**120.93**	**139.21**	**133.78**	117.84
86.29	**55.18**	**89.85**	**124.05**	**142.80**	**137.22**	116.14
88.82	**56.80**	**92.49**	**127.70**	**147.00**	**141.25**	115.00
86.69	**55.43**	**90.26**	**124.63**	**143.46**	**137.86**	109.58
86.55	**55.35**	**90.13**	**124.43**	**143.24**	**137.65**	108.21
85.25	**54.52**	**88.77**	**122.56**	**141.09**	**135.58**	107.49
85.95	**54.96**	**89.50**	**123.57**	**142.25**	**136.69**	108.99
89.99	**57.54**	**93.70**	**129.37**	**148.93**	**143.11**	116.89
93.86	**60.02**	**97.73**	**134.94**	**155.33**	**149.26**	126.18
93.26	**59.63**	**97.11**	**134.07**	**154.34**	**148.31**	132.59
92.79	**59.34**	**96.62**	**133.40**	**153.56**	**147.57**	135.01
96.76	**61.87**	**100.75**	**139.11**	**160.13**	**153.88**	137.70
110.10	**70.40**	**114.64**	**158.29**	**182.21**	**175.10**	144.96
87.66	**56.05**	**91.27**	**126.02**	**145.06**	**139.40**	116.03
68.18	**43.59**	**70.99**	**98.01**	**112.83**	**108.42**	95.20

APPENDIX B

NPV calculation for the first alternative scenario.

	2016	2017	2018	2019	2020	2021
Investment (-)	207000.00					
Energy sold revenues	11667.40	11550.73	11435.22	11320.87	11207.66	11095.59
Electric bill savings	61756.49	61756.49	61756.49	61756.49	61756.49	61756.49
Mortgage repayment (-)	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50
Net Cash Flow	-159416.61	47466.72	47351.21	47236.86	47123.65	47011.58
Actualized NCF	-159416.61	45167.69	42875.41	40700.23	38636.11	36677.34
NPV	-159416.61	-114248.92	-71373.50	-30673.28	7962.83	44640.17

	2022	2023	2024	2025	2026	2027	2028
Investment (-)					144000.00		
Energy sold revenues	10984.63	10874.78	10766.04	10658.38	10551.79	10446.27	10341.81
Electric bill savings	61756.49	61756.49	61756.49	61756.49	61756.49	61756.49	61756.49
Mortgage repayment (-)	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50
Net Cash Flow	46900.62	46790.77	46682.03	46574.37	-97532.22	46362.26	46257.80
Actualized NCF	34818.51	33054.49	31380.41	29791.64	-59365.51	26852.78	25494.60
NPV	79458.69	112513.18	143893.59	173685.23	114319.72	141172.50	166667.11

	2029	2030	2031	2032	2033	2034	2035
Investment (-)							
Energy sold revenues	10238.39	10136.01	10034.65	9934.30	9834.96	9736.61	9639.24
Electric bill savings	61756.49	61756.49	61756.49	61756.49	61756.49	61756.49	61756.49
Mortgage repayment (-)	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50
Net Cash Flow	46154.38	46052.00	45950.64	45850.29	45750.95	45652.60	45555.23
Actualized NCF	24205.54	22982.06	21820.80	20718.57	19672.36	18679.29	17736.66
NPV	190872.65	213854.72	235675.52	256394.09	276066.45	294745.74	**312482.40**

APPENDIX C

NPV calculation for the second alternative scenario.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Investment (-)	567000.00										504000.00									360000.00
Energy sold revenues	3738.06	3700.68	3663.67	3627.04	3590.77	3554.86	3519.31	3484.12	3449.28	3414.78	3380.63	3346.83	3313.36	3280.23	3247.42	3214.95	3182.80	3150.97	3119.46	3088.27
Electric bill savings	86538.32	85672.94	84816.21	83968.05	83128.36	82297.08	81474.11	80659.37	79852.78	79054.25	78263.71	77481.07	76706.26	75939.20	75179.80	74428.01	73683.73	72946.89	72217.42	71495.24
Mortgage repayment (-)	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50	25840.50
Net Cash Flow	-458359.24	107812.76	106993.03	106181.51	105378.10	104582.72	103795.30	103015.75	102244.00	101479.97	-403276.43	99974.74	99233.40	98499.47	97772.88	97053.56	96341.42	95636.42	94938.46	-265752.52
Actualized NCF	-458359.24	102590.88	96879.69	91488.12	86398.22	81593.02	77056.51	72773.61	68730.06	64912.42	-245464.63	57904.85	54691.67	51657.79	48793.16	46088.29	43534.22	41122.51	38845.18	-103469.17
NPV	-458359.24	-355768.36	-258888.67	-167400.55	-81002.33	590.69	77647.20	150420.80	219150.86	284063.28	38598.65	96503.50	151195.17	202852.96	251646.11	297734.40	341268.62	382391.13	421236.31	**317767.15**

BIBLIOGRAPHY & SITOGRAPHY

Below I list the documents I used into this work.

[1] AEEG, 2012, “Ritiro dedicato dell’energia elettrica”, Delibera n°280/07.

[2] AGENZIA DELLE ENTRATE, 19 luglio 2007. “Disciplina fiscale degli incentivi per gli impianti fotovoltaici”. Rome.

[3] ASSORINNOVABILI, 2014. “Sistemi Efficienti di Utenza (SEU). Guida Operativa”.

[4] AWERBUCH S., 2000. “Investing in photovoltaics: risk, accounting and the value of new technology”. Energy Policy.

[5] BERK. J., DEMARZO. P., 2008. “Finanza Aziendale” First Edition 2008. Milan, Pearson.

[6] BORELLO A., 2009. “Il business plan, dalla valutazione dell’investimento alla misura-zione dell’attività d’impresa”. Fourth Edition, McGaw-Hill.

[7] CIANCI S., 2015. "Analisi dei rischi ed analisi di redditività per la produzione di energia da fonti rinnovabili: biogas, biometano e fotovoltaico".

[8] DAMODARAN A., 1999. "Estimating Risk Parameters". Stern school of business.

[9] EPIA, 2012." Connecting the Sun: Solar photovoltaics on the road to large-scale grid integration".

[10] FACCIA D., LUCCHESE E., MIOTTO M., SIMONETTO S. e TURA G., 2012. "Analisi di un progetto fotovoltaico". University of Padua.

[11] GESTORE MERCATI ENERGETICI, 2015. "Relazione annuale 2014".

[12] GESTORE MERCATI ENERGETICI, 2011. "Vademecum Borsa Elettrica 2011".

[13] GESTORE DEI SERVIZI ELETTRICI, 2011. "Lo scambio sul posto ed il ritiro dedicato dell'energia elettrica".

[14] GESTORE SERVIZI ELETTRICI, 2014. "Rapporto statistico 2013", solare fotovoltaico.

[15] GESTORE SERVIZI ELETTRICI, 7 agosto 2012. "Regole applicative per l'iscrizione ai registri e per l'accesso alle tariffe incentivanti, DM 5 luglio 2012", (Fifth feed-in scheme).

[16] GESTORE SERVIZI ELETTRICI, 2011." Regole applicative per il riconoscimento delle tariffe incentivanti previste dal DM 5 maggio 2011".

[17] IRENA, June 2012. "Solar Photovoltaics".

[18] KOLLER T., GOEDHART M. e WESSELS D., 2010. "Valuation: measuring and managing the value of companies". Fifth edition. Hoboken:John Wiley & Sons, Inc.

[19] MAYER J., 2015. "Current and Future Cost of Photovoltaics - Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems", Agora Energiewende.

[20] MCEVOY A., MARKVART T., CASTANER L., 2011. "Practical Handbook of Photovoltaics: Fundamentals and Applications", Academic Press.

[21] MILANI E., 2012. *“Lo sviluppo del fotovoltaico in Italia: valutazione di progetti di investimento e analisi della rischiosità”.*

[22] MORETON R., LORENZO E., LELOUX J., CARRILLO J.M., 2014. “Dealing in practice with hot-spots”, Instituto de Energía Solar – Universidad Politécnica de Madrid, Photovoltaic Systems Group, EUITT, Madrid.

[23] NAUMANN M., 2015. “Lithium-ion Battery Cost Analysis in PV-household Application”.

[24] QUALENERGIA, May 2012. “Rinnovabili ed efficienza, *mobilitazione e organizzazione”*. Rome, Legambiente.

[25] SMA Solar Technology AG, 2014. “Performance Ratio: fattore di *qualità per l’impianto fotovoltaico”.*

[26] SOLARPOWER EUROPE, 2014, “Global market outlook for Solar Power 2015-*2019”.*

[27] VIVOLI F. P., 2008. “Progettare ed installare un impianto fotovoltaico”, ENEA.

Below I list the sites I used into this work.

[1] https://aida.bvdep.com

[2] http://analysis.energystorageupdate.com

[3] http://www.bloomberg.com

[4] http://www.enerpoint.it

[5] http://www.grimel.it

[6] http://www.gse.it/

[7] http://www.mercatoelettrico.org

[8] http://www.photon-online.it/

[9] http://www.prosun.org/en/sustainable-eu-solar/

[10] http://www.pv-magazine.com

[11] http://www.qualenergia.it

[12] http://www.seia.org

[13] http://www.solarbuzz.com/