Evaluation of the Appropriateness of Photovoltaic (PV) Panels for Sustainable Building in North Cyprus

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ABSTRACT

Over the past several years, many paces have been taken to increase energy efficiency in buildings, due to inadequate energy sources. The integration of photovoltaic (PV) panel in buildings is still in its preliminary stage. However, has advanced and new components have been effectively applied in architecture to solve energy issues. Currently, the use of PV panels has been adopted by several developing countries and is integrated as a cover material in roof, facade, chimneys, skylights, shading system and even atrium of buildings. PV technologies are advancing and still expensive. However, increases the overall environmental effects caused by human activities and evidently decrease the emissions from electricity use in buildings led to use PV panels as one of components of renewable energy to be sustainable. In addition, PV Panels also serves as means of reducing electricity consumption in buildings. Against this backdrop, the study will highlights the basic fundamentals of PV panels including the different types of PV modules for building, construction methods, orientation of PV panels on buildings, classification and feature of PV panels, and climatic conditions of PV panels. In this study, qualitative research method was used to address the appropriateness, cost, economical aspect, and current approaches of PV panels in both international level and North Cyprus. The research will also stress on the overall productivity and sustainability characteristic of PV panels as it correlates with building sectors. Suggestion and recommendation to this effect will be given at the concluding part of this research to guide any research student who wishes to integrate PV panels in building sector.

Keywords: Energy efficiency, Photovoltaic panels, Sustainable building

ÖZ

Son yıllarda yetersiz enerji kaynaklarından dolayı binalardaki enerji verimliliğinin arttırılması için önemli adımlar atılmıştır. PV panellerinin binalara monte edilmesi henüz ilk aşamalarını katetmektedir. Yine de enerji problemlerinin ortadan kaldırılması için mimaride gelişmiş ve yeni bileşenler etkili bir şekilde kullanılmakta ve uygulanmaktadır. Halihazırda güneş panellerinin kullanımı gelişmekte olan birçok ülke tarafından benimsenmiş olup PV panelleri bir kaplama malzemesi olarak binaların çatıları, cepheleri, bacalar, tavan pencereleri, gölge sistemleri ve hatta bina atriyumlarına yerleştirilmiştir. Güneş enerji teknolojileri halen gelişmekte ve pahalıdır. Yine de insan aktivitelerinden dolayı kaynaklanan tüm çevresel etkilerin arttırılması ve binalardaki enerji kullanımından dolayı kaynaklanan emisyonların açıkça azaltılması yenilenebilir bir enerji kaynağı olarak güneş panellerinin kullanımını sürdürülebilir kılmıştır. Buna ilaveten PV panelleri binalardaki elektrik eneri kullanımını azaltıcı cihazlar olarak da görev yapmaktadırlar. Bu bilgiler ışığında bu tez çalışması binalar için çeşitli PV panelleri, yapım yöntemleri, binalardaki PV panellerinin yönleri, PV panellerinin sınıflandırılması ve çevresel koşullarını kapsayan güneş panelleri ile ilgili temel konuları incelemektedir. Bu çalışmada hem uluslararası düzeyde hem de Kuzey Kıbrıs'da PV panellerinin uygunluk, maliyet, ekonomik görünüm ve mevcut koşullarını incelemek üzere SWOT analizi ile birleştirilmiş nitel araştırma yönteminden yararlanılmıştır. Yapı sektörü ile ilişkili olduğundan dolayı bu çalışmada PV panellerinin genel verimlilik ve sürdürülebilirlik karakteristikleri vurgulanmıştır. Ayrıca sonuçlar kısmında yapı sektöründe güneş panellerini binalara monte etme konusu ile ilgilenen araştırmacılar için bu etkiler ile ilgili öneriler ve tavsiyeler yer alacaktır.

Anahtar Kelimeler: Enerji Verimliliği, Güneş Panelleri, Sürdürülebilir Bina

To my family

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LIST OF SYMBOLS AND ABBREVIATION

PV	Photovoltaic
NREL	National Renewable Energy Laboratory
GW	Giga Watt(Unit Of Electric Capasity)
Twh	Total Watt İn A Houre
EPIA	European Photovoltaic Industry Association
GHG	Greenhouse gases
IEQ	Indoor Environmental Quality
LEED	Leadership in Energy and Environmental Design
BOS	Balance-Of-System
DC	Direct-Current
AC	Alternating Current
W/m2	Watt Per Squre Meter
a-Si	Amorphous Silicon
μc-Si:H	Hydrogenated Microcrystalline Silicon
R&D	Research And Development Investments In Pv
CVD	Chemical Vapour Deposition
SiH4	Gases in PV
ASHRAE	American Society Of Heating, Refrigerating And Air
CdTe	Cadmium Telluride
CuInSe2	Copper İndium Diselenide
DSCS	Dye-sensitized solar cells
EFG	Edge Defined Film fed Growth
CuInSe2	Copper-İndium Selenide

CIGS	Copper-Indium-Gallium-Diselenide
LCC	Life Cycle Cost Analysis
BIPV	Building Integrated Photovoltaic Panel
BAPV	Building Applied by Photovoltaic Panel
HIT PV	Hybrid solar PV systems
EVA	Ethyl-Vinyl-Acetate
Wp	Watt Power
PVF	Polyvinyl Fluoride Of Film
PET	Polyethylene Terephthalate
NOCT	Nominal Operating Cell Temperature
REL	Renewable Energy Law
IREC	Interstate Renewable Energy Council
DSIRE	U.S National Database of Incentives for Renewable Energy
GDS	Governmental Data Services
MW	Mega Watt
KIB-TEK	ElectricityAuthorityof North Cyprus
DNO	District Network Operator
EEG	Renewable Energy Law
MAP	the Federal Industry Ministry of Italy
IEQ	Indoor Environmental Quality

Chapter 1

INTRODUCTION

Over the years, research has shown that the building sector today is one of the main consumers of energy, as well as one of the core contributors to high emissions of CO_2. In addition to that, due to the speedy increase in population growth, technological development, increased costs and high-energy demands; renewable sources of energy are now growing progressively, since it significantly solves most of our energy and environmental problems (Tyagi et al, 2012; p.1384). “Energy is said to be one of the major factors for generating wealth and it is an imperative component to the economic growth of any country and the living standard of people”. With respect to upsurge in energy demand, quite a number of scientific publications have shown that as of 2004 the global every day oil intake is eighty five million barrels of crude oil (Kalogirou, 2004; p.231), and was similarly approximately calculated to surge to one hundred and twenty three million barrels each day in the year twenty-twenty five. Tyagi et al, (2012) also portrayed that “the paramount benefit of Photovoltaic technologies over other sources of energy is its ability to be environmental friendly, relatively available in the market with assorted types, cost-effective, and can be delivered without causing pollution to the environment” (Kalogirou, 2004; p.231; Tyagi et al, 2012).

On the other hand, photovoltaic panels are one of this renewable energy that over the years has highly contributed to the energy issues in both buildings and the environment as a whole, and has been adopted by most developing countries today like Germany and Italy. Photovoltaic offer consumers the opportunity to generate electricity in a clean and dependable way. When the percentage of PV panels is given more attention in the market, this promotes the usage of renewable energies and will decrease the usage of fossil fuel, as a result pollution and consumers of nonrenewable materials will reduce (Brinkworth et al, 1997, p 169; Hegger et al, 2009, p138).

1.1 Statement of the Problem

Consideration of PV systems in building sector is still in its preliminary phase. The integration of this technology into building for the development of sustainable buildings is a new trend. However, only few countries in the globe have fully adopted these renewable technologies in their entire building, by integrating them on south façade and roof (Hegger et al, 2009, p139). So, a sustainable building comprises of many several components, which are made up of mechanisms such as structural, mechanical, and electrical and alteration in any of these undermine the sustainability of the entire building. Building sector currently is one of the major consumers of energy, as well as one of the core contributors to high emissions of CO_2 in our surrounding (Tyagi et al, 2012; p.1385).

Therefore, energy is considered as one of the major factors in the generation of resources and a momentous aspect to the economic growth of any nation coupled with people’ well-being and standard of living. Environmental degradation as a result of fossil fuels combustion is another environmental factor which enhances pollution and is currently worldwide issue. In regards to that, engineers and architects should ponder over designing sustainable buildings that will help protect the environment by maximizing the efficient use of Renewable energy technologies (photovoltaic panels). In addition to that, they should integrate Renewable energies into building industry to make buildings environmentally responsive (Brinkworth& Sandberg, 2006, 89).

In this context, consideration of RE energies in North Cyprus for sustainable buildings is of paramount concern, since they do not have any reliable source of energy, which makes PV an option. Additionally, implementation of this renewable energy will greatly increase the overall comfort level of the entire Island and enhances the stability of the buildings standards as a whole. Encouraging the usage of renewable energies in North Cyprus will also increase the utilization of PV panels and will cut down the usage of fossil fuel, as a result will decrease pollution and consumption of nonrenewable energy.

1.2 Aim and Research Questions

Since North Cyprus, do not have sufficient energy of its own so, the prime aim of this study is to look into the appropriateness of PV panels for sustainable buildings in North Cyprus. In addition, the study will answer this main question; are PV panel's implementations going to be appropriate in the context of sustainability in North Cyprus. To uncover this main question, other sub questions needed to be considered such as; what are the potential of PV panels' in North Cyprus? What are the country and building sector condition of PV panels in North Cyprus in terms of economically, environmentally, socially? All these questions etc. will answer in the framework of this thesis.

1.3 Scope of the Study

This study centered its scope on PV panels' and its applications into residential buildings in North Cyprus to attain sustainable housing for the compatibility and healthy living of the users of the Island in general.

1.4 Limitation of the Study

The issue of insufficient or unavailability of buildings with PV technologies and the installation details on building coupled with the unawareness of this technologies in North Cyprus pose a major limitation on this research. Other factors are time constraint, insufficient income, and equipment has to carry out an intensive research study.

1.5 Significance of the Study

The study would be substantial to architecture and architectural engineering students. In addition, will inform other beneficiaries, such as governmental authorities, public sectors, and research institutions on the importance of PV panels as a major material to be considered in building design to enhance good environment living conditions, or those who may wish to build proficient and acceptable sustainable buildingsin North Cyprus.

1.6 Methodology of the Study

In this research study, qualitative research method was used to identify the appropriateness of PV panels for sustainable buildings in North Cyprus, including the proper comprehension of PV systems and types, integration of the systems into building (construction techniques), classification of the system, climatic condition, aesthetic, safety, cost consideration, market trends, country and sector condition.

Hence, the adopted techniques used include in-depth imperial research (i.e. intensive observation), personal observation (i.e. photographs taken on the selected buildings with PV panels integration; direct observation was made to uncover the orientation and tilt of the PV panels to support this research). Personal interview with occupants of buildings, chamber of North Cyprus electricity, selected PV companies, academic members and intensive literature review on PV technologies (i.e. relevant textbooks, publications, including internet websites, and Germany and Italy in corporate EU selected as case studies around the globe) used to support the data and information that needed in this research. SWOT analysis also used to identify the PV situations in the North Cyprus PV market in general. In this dissertation two country has choose due to the situation of them in PV panel sector and their background of success of them and how they rich current place in world. For instance, the structure of regulation and market of Italy is nearly looking like North Cyprus; however, they pass a long way of experience to occupy the second leather ship of the world.

Chapter2

PHOTOVOLTAIC (PV) PANELS

2.1 Background of Renewable Energy (Photovoltaic Panels)

Research from the past has shown that Photovoltaic technology is not new concept or innovation. Photovoltaic panels or module grants users is the possibilities to produce Photovoltaic electricity in a clean and dependable manner, and are consisting of dark cells, which sometimes called Photovoltaic, or PV cells devices that convert light energy directly into electricity from sunshine (Aysan, 2011). “Photovoltaic” originated from a Greek word (photo), which means light, and on the other hand, (voltaic) which is referred to as producing electricity, and was first revealed by an Italian scientist who lived in the past called Alessandro Volta, which is now called PV panels (Hegger et al, 2009, p138). Its history durations were trace back from the seventh (7^{th}) century B.C. to this present day. “Currently, solar technologies are rapidly advancing, and are used in a broad scope of applications, to reach product consumers, for instance, calculators, systems that supply electric to the whole unit of a buildings, and Photovoltaic powered automobiles or solar cars” (Sorensen, 2004) . Tracing from history, a “French physicist Alexander Becquerel discovered the photovoltaic effect in 1839 and realized an increased in voltage from his wet-cell battery when its silver plates were open to sunlight” (Zauscher, 2006). Subsequently, after about 40 years later, William Adams and Richard Day had knowledge on the photovoltaic effect, called Photovoltaic cells today, in a sample of selenium placed in between two metal electrodes, and was found to be first solid photovoltaic device at that time, which originates from the association of selenium and metal. The first Photovoltaic cell was came into existence and was manufactured by Charles Fritts in eighteen-eighty three approximately, and covered the semiconducting selenium (material) with an very tiny layer material of gold to form the junctions (i.e. with a bottle neck to transmit incident light) and the device was only about or less than 1% efficient (Sorensen, 2004; p.30).

In the 1950s, PV cells attained momentous enhancement and the chance of photovoltaic technological development began to emerge, as a result people started having the awareness of this technology (Griffin, 2010). According to Brink worth& Sandberg (2006) “scientists and engineers started seeing importance photovoltaic cell as a reliable consistent way to make available remote electricity to spacecraft projects, and four (4) years later (i.e. 1954). scientists at Bell Labs discovered the first practical high-power silicon cell or Photovoltaic cell, which was reported to have an initial conversion efficiency of 6%, and progressively, silicon PV cells became well-known as the omnipresent source electricity for spacecraft applications and satellites as stated by (Boyle, 2004; 45). During the development process of PV technology for spacecraft applications, researchers or scientists had only little familiarities with this technology innovation and never had the notion that this technology would be feasible for mass power production on Earth. However, at this point in time, Oil and coal fossil fuels were extremely inexpensive over “electricity manufacturing costs of silicon PV cells. some years later the awareness of the environmental impairment caused by fossil fuels was revealed in the energy crisis of the near beginning in the nineteen seventies, and the industrial nations support for photovoltaic energy began to upsurge considerably" (Stone, 1993; p23). From 1981s subsequently, PV panels' integration in buildings started to emerge, and in the 1990s and 2000s, the awareness in PV progressively increased tremendously.

Aberle, 2009 averred that "photovoltaic industry has grown subsequently and at least 30% year over year for the last decade, which implies that more technological developments are made and economic incentives are put in place for companies to invest capital in this fast paced industry. The overall cost of solar power production will decrease enough to make it an economically viable alternative to energy production via fossil fuels" (Aberle, 2009; p.4706).Burger, 2010 state that "For example, once a PV panel is put in place, it would produce solar electricity with no pollution for decades, while on the other side, coal-fired power plants for instance in the U.S. will emitted approximately two billion tons of carbon dioxide and millions of tons of toxic compounds in 2010 alone as calculated by" (Burger, 2010).

In recent times, research revealed by (Wicht, 2009: Aberle, 2009; p4706: RenewableEnergyWorld.com, 2009) shows that "Photovoltaic panels based on crystalline silicon modules are facing competition in the market by panels that utilized thin-film PV cells, such as amorphous Si, and microcrystalline Si and has been speedily developing and are predictable to account for 31% of the global installed power by the year 2013", up from 14 percent in 2008 as demonstrated in Figure2.1.Cheyney, 2011 declared that speedy deceleration in prices for poly-silicon panels in late 2011 has instigated some thin-film makers to exit the market and others to undergo extremely squeezed profits".

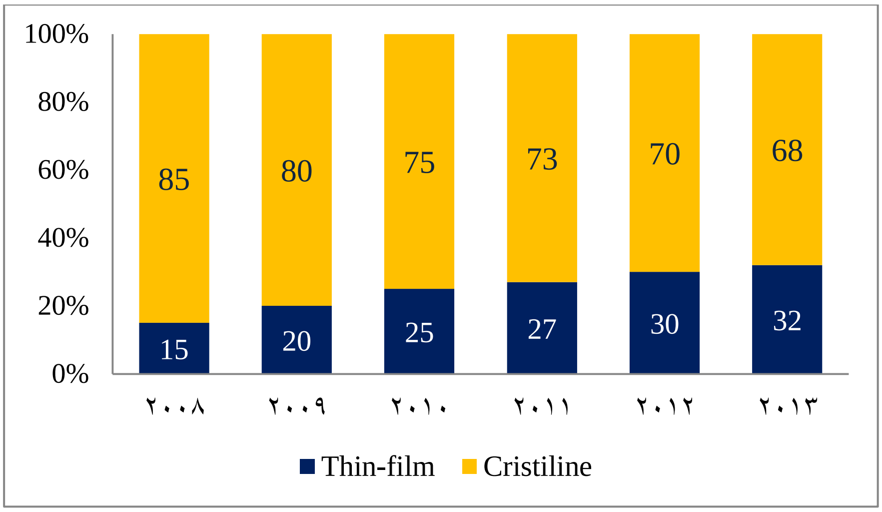
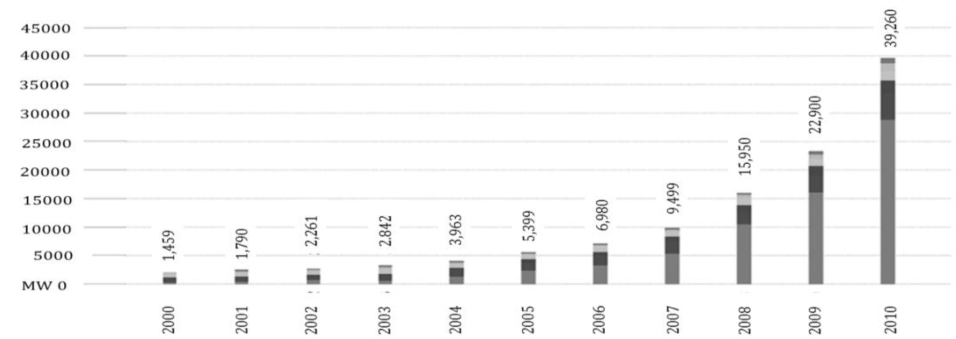


Figure2.1: Graph which shows the thin-film percentage of total PV module production, 2008-2013 (Source: RenewableEnergyWorld.com, 2009).

For example, San Jose-based Company Sun-power manufactured PV cells that have the energy conversion ratio of 19.5% and are well beyond the market average of 12–18% (Sun-power Cooperation, 2012). Several writings have equally shown that states that as from April 2011 until now, the most efficient PV panel in the PV market is a multi-junction concentrator PV cell which comprises efficiency of 43.5% and was recorded to be created by a well-known scientists called in the National Renewable Energy Laboratory (also abbreviated as NREL). As of 2009, the highest recorded efficiencies attained without deliberation was named Sharp Corporation and Boeing Spector-lab PV cells which efficiency is 35.8% and 40.7% respectively, using a proprietary triple-junction manufacturing technology as discussed by (Aberle, 2009; p.4706). In March 2010, research conducted by Caltech group led by Harry Atwater manufactured a Flexible PV Cells with Silicon Wire Arrays was found to have an “absorption efficiency of 85% in sunlight and 95% at certain wavelengths is claimed to have near perfect quantum efficiency as explained by” (Caltech Media Relations, 2010). The terrestrial PV systems was another new technology innovation in PV panels that aims at maximizing the time they face the sun by modifying PV panels to track the sun paths as the sun moves to any directions. “This PV has the attribute to increase as much as 20% in winter and 50% in summer and the stationary mounted systems can be improved by sun path analysis” (Brain & Ray, 2005).

More than 40 years has passed today since the first PV applications in spacecraft to the GW systems planned. Over the last 10 years, PV technology has developed potentially to become one of the major sources of generating power in the world. This vigorous and incessant advancement in PV is predictable to last in the years ahead. Toward 2008, ending the world’s total installed PV capacity was approximately approaching 16 GW and in later years, it was discovered to drastically upsurge to 23 GW. Successively, in 2010 40 GW was recorded to be install in the entire universe, which produces 50 TWh of electricity annually. In 2010 depicts EU leadership with almost 30 GW installed in terms of global cumulative installed capacity, as portrayed in Figure2.2 (EPIA, 2011; p.8).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China	19	30	45	55	64	68	80	100	145	373	893
APEC	38	43	49	57	66	80	112	170	466	718	1,191
Rest of the world	758	814	894	971	1,000	1,010	1,128	1,190	1,303	1,427	1,844
North America	146	177	222	287	379	496	645	856	1,205	1,744	2,727
Japan	318	452	637	860	1,132	1,422	1,708	1,919	2,149	2,632	3,622
EU	181	275	414	613	1,319	2,324	3,307	5,257	10,387	16,006	29,252
Total	**1,459**	**1,790**	**2,261**	**2,842**	**3,961**	**5,399**	**6,980**	**9,492**	**15,655**	**22,900**	**39,529**

Figure2.2: Graph showing the evolution of global cumulative installed capacity, 2000-2010 (Source: EPIA, 2011).

European Photovoltaic Industry Association (EPIA) anticipated report in 2011 demonstrated the future trends of the PV panels market in the European Union (EU) and other continent in the globe, this report discuss the impact of reconsidering future of the EU energy mix and creating new opportunities for a competitive, safe, and reliable electricity source such as PV, it was also estimated that in 2012, 20-30 GW of PV systems could be installed, which amount almost as in 2011, as depicted in Figure2.3. “Unfortunately, the industry’s capacity continues to upsurge, maybe to the same extent as 38 GW”. Prices and profits have crushed down, due to resulting glut of PV panels’ supply. Approximately, 131–196 GW of PV systems by the year 2015 could be installed around the world (Goossens, 2012: EPIA, 2011, p.39).

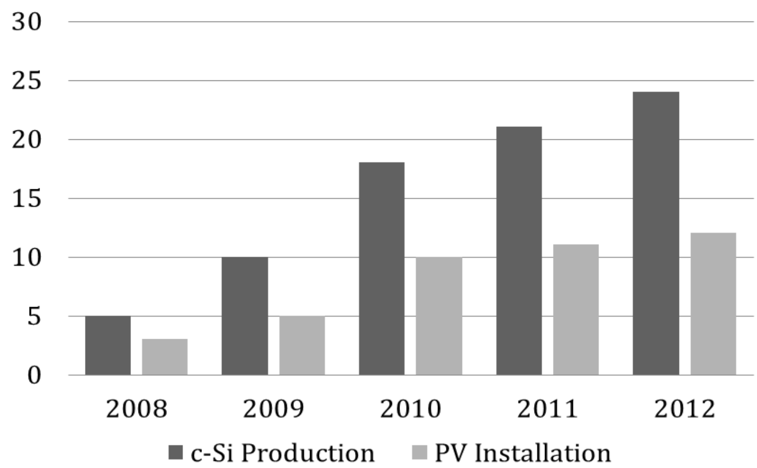


Figure 2.3: Global PV module supplies (production) and demand (installation) 2008-2012 (Wicht, 2009).

Research have shown that within the last few decades sustainable development and building practices have attained great significance due to the undesirable impact of various development projects on the environment, and it is has drew the attention of designers to design environmentally healthy and sustainable built environment (Naga and Amin, 1996; Omer, 2002, p.1257). Several writings have equally shown that residential, commercial and industrial building sectors significantly alter the environment, and are one of the main consumers of energy as well as one of the core contributors to high emissions of carbon dioxide (CO_2) (Olympia & Stapountzis, 2011, P.853).

In the European countries alone, Omer, 2002 anticipated that about 50% of natural material resources taken from nature are relate to building and that over 50% of national waste production comes from the building sector, about 40% of energy consumption is from real estate or building sectors (Omer, 2002, p.1257). The environmental effects of CO_2 are of significant interest in the globe today. Consequently, it could say that the awareness in sustainable buildings or energy efficient in buildings grew along with the environmental movement, accompanied with a significant increase received from the 1973s oil crisis (Stone, 1993; p.23; 28; Miles, Hynes & Forbes, 2005, p.30). Back in those early days energy security and minimizing fuel consumption were of great concerns; but at present the focus has drifted to decreasing fossil energy or Greenhouse gases (GHG) emissions as climate change awareness began spreading. It is not astonishing that the demand for green buildings will also upsurge as more people become environmentally conscious (Yoo et al., 1998; p.151).

Yoo et al, (1998) “designing environmentally friendly or sustainable buildings have much influence on building design types”. Muehleisen, 2010, “besides maximizing energy efficiency in buildings, green building design approaches also have tremendous impacted on design of buildings through appropriate use of good renewable energies, material resource management and consideration of the indoor environmental quality (IEQ) of the building, for example thermal comfort or acoustics issues. On the other hand, “incorporating indoor environmental quality is of great importance to the Leadership in Energy and Environmental Design (LEED) rating systems for all building types” (Galloway, 2004, P.182).

In light of this, Steele, (1997) states that “the passive solar building design for example is termed sustainable architecture” (p.2), Omer, 2002 and “sustainability in the other hand is defined as the extent to which advancement and development should meet the need of the present without compromising the ability of the future generations to meet their essentials” (p1257). Thus, the purpose of achieving a passive solar design is to utilize solar energy without the use of mechanical equipment, such as photovoltaic (PV) panels; thus achieving a reduction in heating fuel needs and carbon emission. However, orientation in the sun path is a key consideration in the passive solar design (Papadakis, 2012). “To that end, various countries around the world today have formulated several policies in the name of reducing carbon dioxide (CO2) discharges, while on the other hand countries like Germany, United States of America, china, Japan and so on are implementing policies towards maximizing the renewable energy share application as a result of global response to the climate change, and designing buildings that can generate its own energy using renewable energy” (photovoltaic panels) (Lund et al., 2011, p.420; Hepbasli, 2011, p.4411).

2.2 Photovoltaic (PV) Panels’ Description

Tyagi et al. described PVs as tremendous way of utilizing solar energy by directly converting it into electricity (Tyagi et al., 2012). According to Langcake (2003); Millick et al. (2004) “the direct conversion of solar radiation into electricity is often delineated as a PV energy conversion which is based on a principle called the photovoltaic effect or PV cells”. The photovoltaic effect on the other hand, simply means the response to visible or other radiation (p.32; p.319). Miles et al (2005) augured “that the photovoltaic effect can be termed as the direct conversion of incident light into electricity by a pn or (p-i-n) semiconductor junction device”. The entire field of solar energy conversion into electricity is therefore referred to as the “photovoltaics” (p.1). Zondag, describe that PV systems comprises of two components, the PV cells and ancillary element which produce electricity from sunlight whenever light strikes them by a physical process which does not require any source of energy such as turbine or heat engine” (Zondag et al., 2006). Figure2.4 depicts a typical PV system component with battery backup.

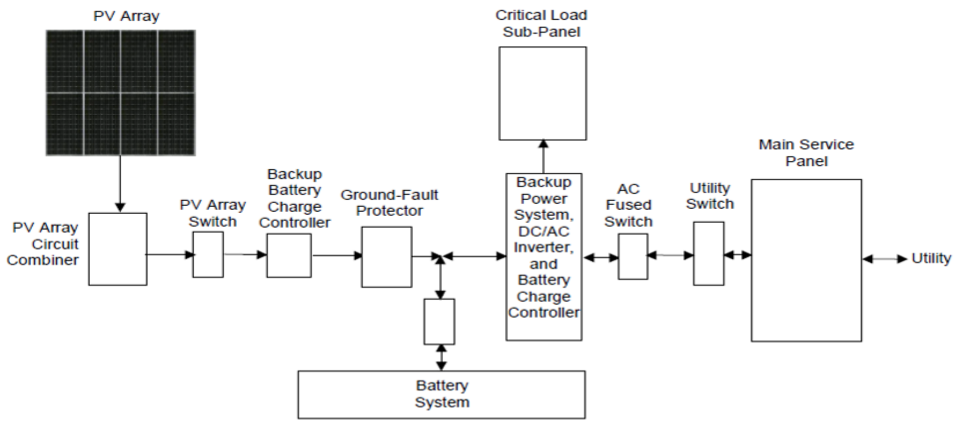


Figure2.4: demonstrate the block diagram of a utility-interactive PV system plus battery backup.

Byabato and Muller, 2006 asserted that “the power generated from a single photocell can only produce a limited amount of power to any practical use, such as in high power applications including the housing industry and for industrial and commercial use several photocells are combined and encapsulated to form larger devices named *Modules* which give larger standard operation parameters” (i.e. current and power) under rated standard test conditions, and can be integrated into many common building elements such as window, facades, skylight, or a classic PV module. “The smallest units of PV used commercially are Photovoltaic PV modules, but when several of them are further combined into groups; PV arrays are obtained” (Byabato& Muller, 2006, p.1), as shown in Figure2.4. SEAI, 1998 shows that “a Photovoltaic (PV) array is normally part of a system that may also comprise energy storage devices, such as batteries and battery enclosures, battery charge controller, separate subpanel(s) for critical load circuits which are collectively called as balance-of-system or BOS”, as illustrated in Figure2.5. In addition to that, UNEP, 2000, declared that “the amount of power from a PV array is directly proportional to the intensity of the light hitting the array; which implies that PV arrays produce direct-current (DC) electricity, yet can be configured to produce any required combination of voltage and current, plus conventional residential alternating current (AC) voltages” (SEAI, 1998, p.14; UNEP, 2000, p.2). Byabato& Muller, 2006 discussed that “the power produced by a sole photocell be contingent on the force of the solar energy shining on it, the angle at which the sun’s rays strike its surface, the type of the cell and its area” (Byabato& Muller, 2006). “They further explained that a typically photovoltaic installation comprises of four basic components namely an array of PV panels, an inverter, batteries and interconnection wiring” (Byabato& Muller, 2006, p.1), as diagrammatically depicted in Figure2.5.

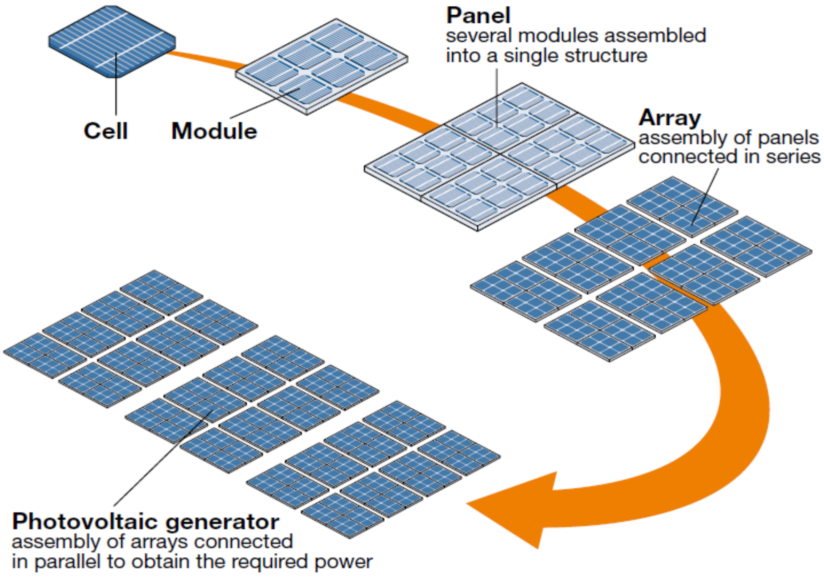


Figure2.5: Depicting the buildup of a PV generator from cell to module to Panel to array to final PV generator (Source: Technical Application Papers No.10, 2010, p.9).

2.2.1 The Working Principles of PV panels Systems

Eiffert & Kiss, (2000) present that "the Photovoltaic (PV) or PV cells can convert sunlight directly into electricity without producing any air or water pollution". Generation and transport inside a two layers semiconducting (an element, whose electrical properties lie between those of conductors and insulators, making it only marginally conductive for electricity) material, which comprises of positive and negative electric charges, through the action of light" (Eiffert & Kiss, 2000, p.58; Boulanger, 2005, p.126). SECO Fact Sheet No. 11, "this material is consisting of two regions, one exhibiting an excess of electrons (negatively-charged elementary particles).

The other an electron deficit, and are referred to as n-type doped (an extraneous atom introduced into a crystal lattice to alter its properties) and p-type doped respectively", and Boulanger, (2005) "when the former and latter are brought into contact, excess electrons from the n material diffuse into the p material. Then the initially n-doped region becomes positively charged, and the initially p-doped region negatively charged". "An electric field is thus set up between them, tending to force electrons back into the n region, and holes back into the p region. with that a junction (so-called p-n junction) is set up which is of great importance for the function of the PV cell and by placing metallic contacts on the n and p regions a diode is attained" (SECO Fact Sheet No. 11, p.2.Boulanger, 2005, p.126). SECO Fact Sheet No. 11, "when the junction is illuminated, photons (quantum of energy of electromagnetic radiation) having an energy equal to or higher than the width of the forbidden band or band gap yield their energy to the atoms. each photon causing an electron to move from the valence band to the conduction band leaving behind it in turn a hole, also able to move around the material, thus giving rise to an electron-hole pair" (Eiffert& Kiss, 2000, p.58). and if load is positioned at the cell's terminals, electrons from the n region will fall back to the holes in the p region, by way of the outside connection, giving rise to a potential difference (an electric current passes) ,as shown diagrammatically in Figure2.6 (SECO Fact Sheet No. 11, p.2).

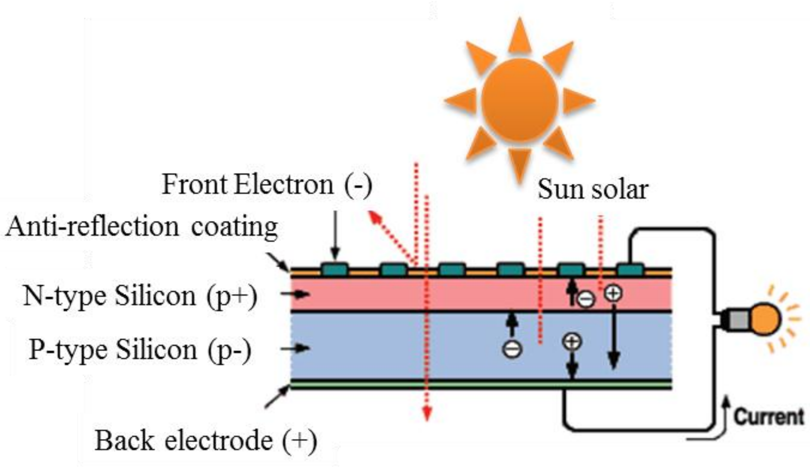


Figure2.6: Basic PV cell construction/ photovoltaic effect (Hamilton, 2001, p.3)

2.3 Types/categories and Subcategories of Photovoltaic Cells

Fanney et al. (2001) asserted that photovoltaic cell comprises of various semiconductor layer materials and each layers material has its own quantities and disadvantage. For a material to be appropriate for PV cell application, the band gap matching to the solar spectrum must be taken into account (Fanney et al., 2001). This band gap should always fall within 1.1 and 1.7 V. However, the material must have a have spontaneously motilities and lifespan charge carriers (Tyagi et al, 2012). Table 2.7 specifies the peak efficiencies attained using different semiconductor materials (OECD/IEA, 2010), and the material used in PV cells which were characterized into three major categories however depending on the type of material used in the construction (Miles et al, 2005).

2.3.1 Silicon PV Cells

The silicon PV is further divided into three main categories; namely, single crystalline, polycrystalline, and amorphous silicon. Those three categories will be review in below sections.

2.3.1.1 Single Crystalline Silicon

From the previous paragraphs, it can said that PV cells have the potential of convert sunlight into electricity, and beside other available materials for PV cells, mostly extensively used semiconducting materials in PV cells are the single-crystal silicon (Zhao, 2004; Tyagi et al, 2012). Miles et al., (2005) averred that “this type of Silicon is the most promising in the PV market; it is safe and readily available material that has the possibility for performing efficiency” (p.4). Research has shown that in the PV market today the best single crystal a-Si PV cells have an efficiency of 24.7% and it has been proven commercially that silicon PV cell modules conversion efficiencies is as high as 18% (Miles et al. 2005). For example, "researchers at the University of Neuchatel in the early 1990s succeeded to fabricate the first hydrogenated microcrystalline silicon (μc-Si:H) cells at 200 °C with reasonable efficiencies and a cross-sectional view of the conventional silicon PV cell structure that has dominated production up to the present" (Aberle, 2009, p.4707) as diagrammatically portrayed in Figure2.7.

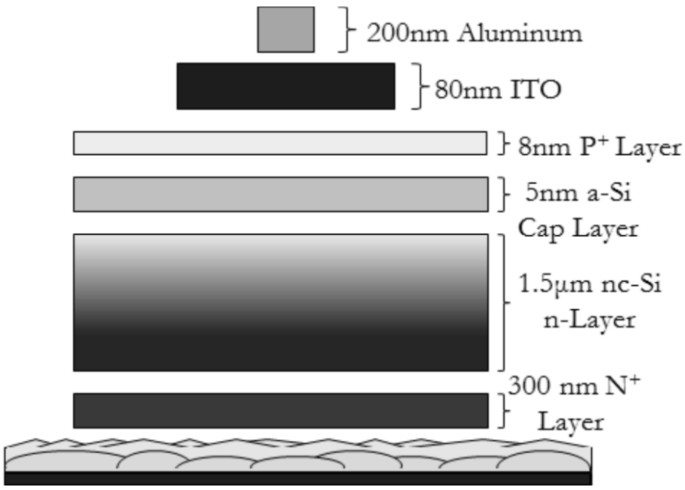


Figure2.7: A cross-sectional showing a silicon PV cell with screen printed contacts (Chakravarty, 2011, p.12)

2.3.1.2 Polycrystalline silicon

Polycrystalline silicon comprises of small grains of single crystal silicon which when compared to polycrystalline PV cells have little energy efficient than those of the single-crystalline silicon PV cells and on the other hand, the grain boundaries in polycrystalline silicon hinder the flow of electrons and as a result reduce the efficiency of the cell as stated by (Mah, 1998). Verlinden, et al., (2004) states that "commercial module manufactured from polycrystalline silicon has an energy conversion efficiency which ranges between 10 and 14%" (Verlinden, et al., 2004, p.1388). In contrasts with single crystalline silicon, polycrystalline silicon material is known to have more durability and can be cut into portions, 1/3 of the thickness of a single-crystal material (Verlinden, et al., 2004) (Figure2.8) illustrates the Pictorial view of polycrystalline silicon PV cell -156MM*156MM). “It also has slightly lower wafer cost and less strict growth requirements” (Verlinden, et al., 2004), and “the average price for a polycrystalline module made from cast and ribbon as of 1996 cost $3.92 per peak watt, somewhat lower than that of a single-crystal module” (Mah, 1998, p.4&5; Verlinden, et al., 2004; Tyagi et al., 2012), as summarized in Table 2.1 the major required R&D efforts for crystalline PVPV cells (OECD/IEA, 2010).

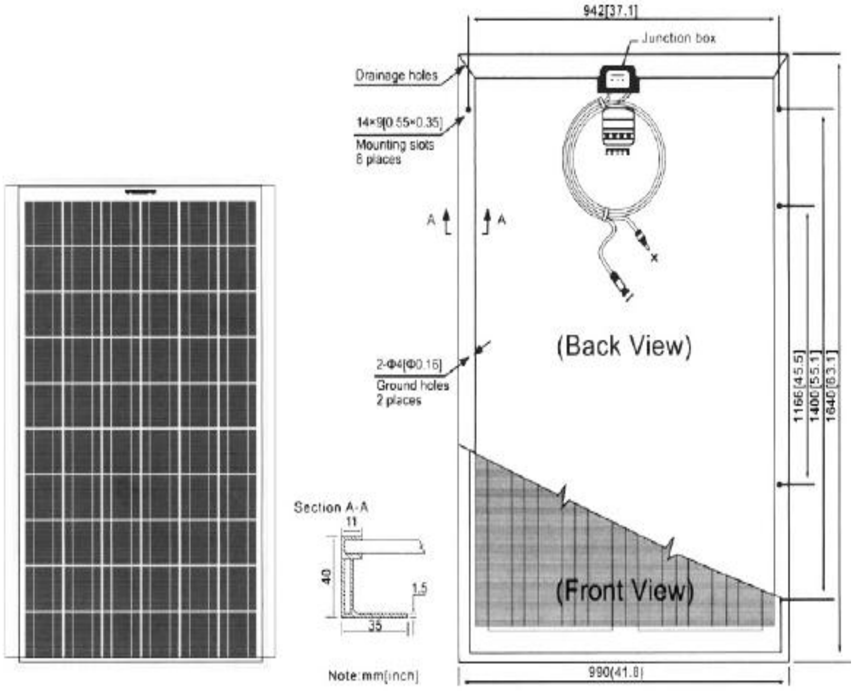


Figure 2.8: Pictorial view of polycrystalline silicon PV cell-156MM*156MM (www.aislu.com).

Table 2.1: Technology objectives and key R&D problems for crystalline silicon technologies

Crystalline silicon technologies	2010 – 2015	2015 – 2020	2020 – 2030 / 2050
Efficiency targets in % (commercial modules)	• Single-crystalline: 21% • Multi-crystalline: 17%	• Single-crystalline: 23% • Multi-crystalline: 19%	• Single-crystalline: 25% • Multi-crystalline: 21%
Industry manufacturing aspects	• Si consumption < 5 grams / Watt (g/W)	• Si consumption < 3 g/W	• Si consumption < 2 g/W
Selected R&D areas	• New silicon materials and processing • Cell contacts, emitters and passivation	• Improved device structures • Productivity and cost optimisation in production	• Wafer equivalent technologies • New device structures with novel concepts

(OECD/IEA, 2010, p.24)

2.3.1.3 Amorphous Silicon

Amorphous silicon is a non-crystalline form of silicon, which has a disorder silicon atoms structure, and are fabricated from chemical vapour deposition (CVD) gases comprising of silane (SiH4), and is usually PECVD or hot wire CVD'' as stated by" (Goetzberger et al., 2003) and diagrammatically shown in Figure2.9. "Presently is still the only thin film technology that has an impact on the overall PV markets and the brain behind why a-Si: H has not been able to overcome share of the global PV market is because of its unstable average efficiency of 6% or less of large-area single-junction PV modules" (Goetzberger et al., 2003). Miles et al., 2005 declared that this kind of silicon can into existence in 1974 and was proven to have a significant advantage as a result of its high (sunlight) absorptivity, which is found to be forty (40) times higher than that of single-crystal silicon. However, the initial efficiency of this type of cells made in the laboratory can be about or >12% commercial modules, but when exposed to sunlight over a period of months degrade to an efficiency of approximately 4-5%" (Miles et al., 2005). The manufacturing process of this type of silicon demand very low temperatures (<600 °C with supporting materials mainly glass), hence less energy input" (Mah, 1998, p.98). As a result, "the total material costs and manufacturing costs are lower per unit area as compared to those of crystalline silicon cells" (Mah, 1998, p.98; Goetzberger et al., 2003).

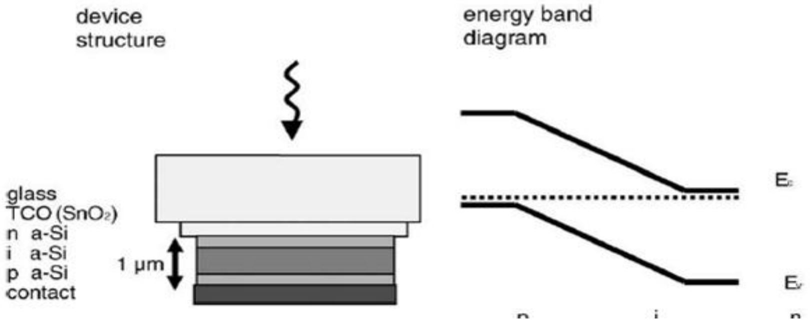


Figure2.9: Structure of an amorphous pin PV cell (Goetzberger et al., 2003, p.28).

2.3.2 Thin Films PV Cells

In this type of PV cell, a thin semiconducting layer of PV materials are placed on affordable supporting layer, like for example glass, metal or fictile foil, and the benefit of this PV cell when compared to crystalline silicon has a lower need for production energy leading to shorter energy payback time (Mah, 1998, p.98). Figure2.10 shows the graphic representation of a Thin-film PV cell, and table 2.2 on the other side summarizes the prospects and key R&D issues for thin film technologies until 2030.

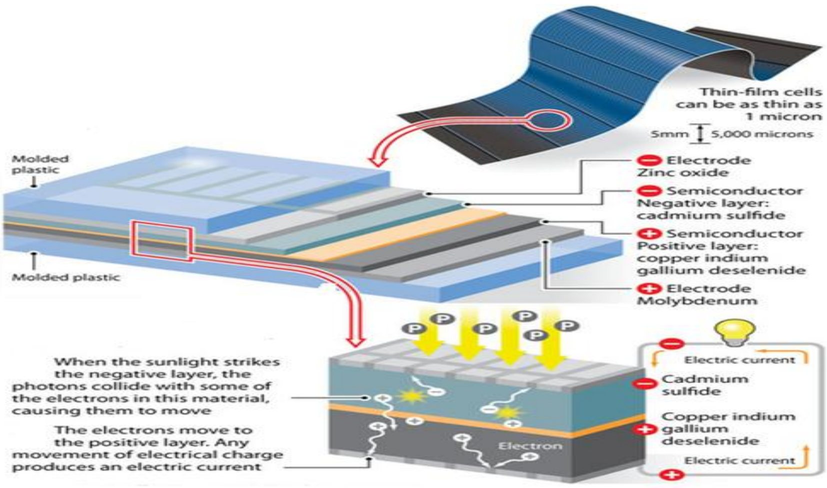


Figure2.10: Graphic representation of Thin-film PV cells (Source: Staff, 2009).

Table 2.2: Technology goals and key R&D issues for thin film technologies

Thin film technologies	2010 – 2015	2015 – 2020	2020 – 2030
Efficiency targets in % (commercial modules)	• Thin film Si: 10% • Copper indium gallium (di)selenide (CIGS): 14% • Cadmium-telluride (CdTe): 12%	• Thin film Si: 12% • CIGS: 15% • CdTe: 14%	• Thin film Si: 15% • CIGS: 18% • CdTe: 15%
Industry manufacturing aspects	• High rate deposition • Roll-to-roll manufacturing • Packaging	• Simplified production processes • Low cost packaging • Management of toxic materials	• Large high-efficiency production units • Availability of manufacturing materials • Recycling of modules
Selected R&D areas	• Large area deposition processes • Improved substrates and transparent conductive oxides	• Improved cell structures • Improved deposition techniques	• Advanced materials and concepts

(Source: OECD/IEA, 2010, p.25)

“Since thin-film materials have higher light absorptivity than crystalline materials, the deposited layer of PV materials is extremely thin; from a few µm to even less than a µm (a thin films PV cell can be as thin as 2-3 µm thick) at T < 600°C using ion-assisted deposition techniques)” (Shah et al., 1995, p.502&503; Sick &Erge, 2008, p.14). The conversion efficiency of thin films PV cells may possibly decreased but this would be more balanced by the gain in power to weight ratio, although over 10% efficiency are being produced and is reduced by approximately 30% due to the light-induced instability called Stabler-Wronski effect (Sick &Erge, 2008, p.14).

Presently research are concentrating on how to decrease this effect by increasing the efficiency of this PV cell (Mai et al., 2005, p.114913-9). Experts in this particular branch of science have uncover that "copper indium sulfide, cadmium telluride (CdTe) as well as copper indium dieseline (CuInSe2)" and alloy for the manufacturing inexpensive thin film PV cells have been accepted as the most favorable nominee for the subsequent generation PV cells (Mercaldo et al., 2009, p.1840).

2.3.3 Dye-sensitized PV Cells

This type of cell abbreviated as DSCS have been widely looked upon by several researchers for more than 16 years as the PV cell that would pull weight in the nearest time in future, because of the uncomplicated structure and low production cost its demonstrate as shown in Figure2.11 (Nazeeruddin, Baranoff, &Grätzel, 2011, p. 1173). DSCS technologies provides economically trustworthy alternative concept to present day p–n junction photovoltaic devices and was reported to be first sensitization of a photo electrode in 1887 by a scientist Moser, J, and the cell was accepted to minimize production costs and energy payback time compared to standard silicon cells or other thin film cells, and the conversion efficiency varies between 6 -10 % depending on the module size and the technology is currently on the pilot plant scale (Mercaldo et al., 2009). Up to date the commercially available PV technology are made up of inorganic substances, which in the preparation consumes highly energy consuming and high costs to produce, however, is still well-thought-out as a low cost and promising solution to solve the energy problem as stated by (Nazeeruddin, Baranoff, &Grätzel, 2011, p. 1173).

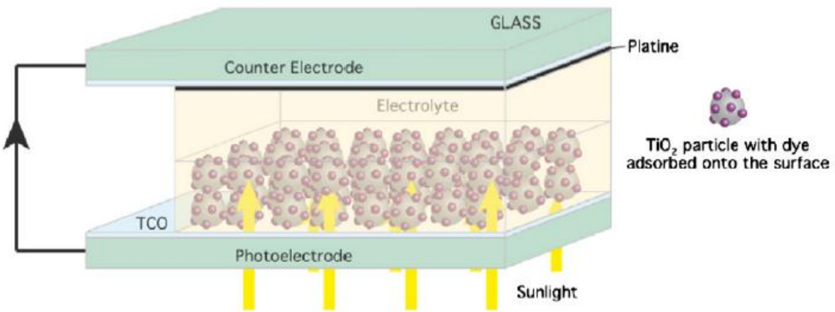


Figure2.11: Schematic illustration of the dye-sensitized PV cell (Nazeeruddin et al., 2011, p.1173).

Table 2.3that shows below try to summarizes the theoretic and practical efficiencies of some commonly used types of PV cells, which falls in the area of II-VI semiconductor compounds, other interesting thin-film materials have been developed, including Cadmium Telluride (CdTe) which relatively has simple production process (industry), allowing for lower production costs and it also has an energy payback time of eight months (economically) and the shortest time among all existing PV technologies in world (Tyagi et al., 2012, p. 1388).

Table 2.3: shows the best practical efficiencies of different types of PV cells

Cell type	Highest reported efficiency for small area produced in the laboratory	Highest reported module efficiency
c-Si (crystalline Si)	24.7% (UNSW, PERL)	22.7% (UNSW/Gochermann)
Multi-c-Si	20.3% (FhG-ISE)	15.3% (Sandia/HEM)
αSi:H, amorphous Si	10.1% (Kaneka), N.B. single junction	Triple junction. Stabilized efficiency = 10.4%

μc-Si/αSi:H (micro-morph cell)	11.7% (Kaneka), N.B. mini module	11.7% (Kaneka), N.B. mini module
HIT cell	21% (Sanyo)	18.4% (Sanyo)
GaAs cell	25.1% (Kopin)	Not relevant
InP cell	21.9% (Spire)	Not relevant
GaInP/GaAs/Ge multi junction	32% (Spectolab), N.B. 37.3% under concentration	Not relevant
CdTe	16.5% (NREL)	10.7% (BP Solarex)
CIGS	19.5% (NREL)	13.4% (Showa Shell), N.B. for copper gallium indium sulfur selenide
Dye sensitized cell	8.2% (ECN)	4.7% sub-module (INAP)

(Miles et al., 2005, p. 3; Tyagi et al., 2012, p. 1388)

2.4 PV Cell, Module, and System Efficiency

Studies have proven the lifetime of PV cell is of 25 years, sometimes this goes in line with the expectations of the PV companies. Some other surveys have also predicted the lifetime range to be from 10 to 30 years, and also studies were published on Monocrystalline silicon cells as being the most known PV technology in use, efforts as put in place to minimize the energy requirement of manufacturing Multicrystalline or polycrystalline silicon cell; the polycrystalline silicon cell is pulling weight as the second leading PVs in the market and have efficiency ranging from 13-15%, as shown in Table 2.4 which compares the cell technologies, including the type of junction, lab efficiency, industrial efficiency, market share, cell color, cell diameters and thinness (Razykova et al. 2011).

Table 2.4: Comparison of different types of PV cells/ modules

Cell technology	Max reported lab efficiency (%)	Industrial efficiency (%)	Approx. market share (%)	Approx. energy payback period (year/s)	Available cell cooler
Single crystalline (c-Si)	25.0	15-17	≤ 30	5	Blue, Black, Violet, Turquoise, Dark and light grey, and Yellow
Multi-crystalline (mc-Si)	20.4	13-15	≤ 60	3	Blue. Violet, Brown, Green, Gold, and Silver
Thin-film amorphous silicon cell (a-Si: H)	10.1	6-10	≤ 10	2-4	Black, and Brown
Thin-film CIGS (cell)	19.6	9-12	< 1	1-2	Black, and Grey
Thin-film CdTe (cell)	16.7	9-11		1-3	Black, and Green

(Razykova et al. 2011, p.1586; Energy-Pedia, 2012)

The efficiency of Thin-firm PV module ranges from 6-10%, followed by CdTe thin-film modules which have an efficiency ranging from 8-10%, and then CIS thin-film modules ranging from 8-12% and is recorded as the most efficient of all and the possibility of being the most popularly used in the future (Miles et al, 2005). The efficiencies of all PV cell types have improved over the past several decades, as depicted in Figure2.12, which show the best research-cell efficiencies from 1975 to

2010 and ongoing research is still on by scientist to still improve the efficiencies further. The highest-efficiency research cell shown was attained in 2010 in a multi-junction concentrator at 42.3% efficiency. Other research-cell efficiencies demonstrated ranges from 15% to 25% for crystalline silicon cells, 10% to 20% for thin film, and about 5% and to 10% for the emerging PV technologies organic cells and dye-sensitized cells respectively. The typical efficiency of crystalline silicon-based PV commercial modules ranged from 14% for multicrystalline modules to 19.3% for the highest-efficiency Monocrystalline modules (average Monocrystalline module efficiency was 14%). For thin-film modules, typical efficiencies ranged from 7% for a-Si modules to about 11% for CIGS and CdTe modules, in 2010, as depicted in table 2.4 (National Renewable Energy Laboratory (NREL), 2011; p.57-58). For example, in grid-connected applications, the average maximum efficiency of inverters in 2009 was 96%, up from 95.5% in 2008, with the best-in-class efficiency reaching 97.5% for inverters larger than 50 kW and 96.5% for inverters under 50 kW (Bloomberg, 2010). Current day, PV modules usually include a 25-year warranty. Standard warranties guarantee that output after 25 years will be at least 80% of rated output and is in line with real-world experience and predicted performance from damp-heat testing of modules (Wohlgemuth& Johnson, 2006).

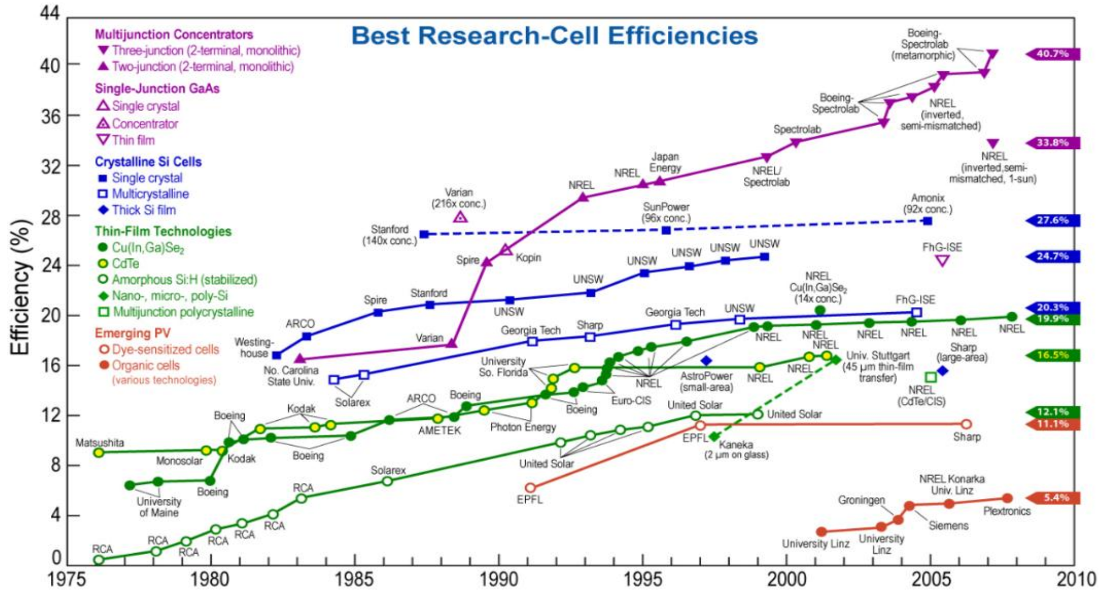


Figure2.12: the best research-cell efficiencies from1975–2010 (Razykova et al. 2011, p.1584).

2.5 Building Integrated Photovoltaic (PV) Systems

Chow et al., 2003 describes the building-integrated photovoltaic (BIPV) described as an application of PV, which is functionally, aesthetically and energy technically integrated into a building envelope. When the BIPV system is removed the house is not complete any longer. Chow et al., 2003 also asserted that this technology has been one of the most important area of PV applications in buildings envelops, which offers an integrated design construction, and maintainable substitute for the built environment (Chow et al., 2003, p.2035).

“The awareness of this technology emerged and became significant in the late 1990s and has been evaluated attractive technology for building integration” (Agrawal&Tiwari, 2010, p. 417). This term can be defined appropriately when the PV modules are incorporated into building fabric, forming an integral part of the building (Byabato& Muller, 2006, p.1; Jellea&Breivik, 2012, p.78). Gumm, (2008) designated BIPV as a new building technology concept which incorporate PV components into the climate envelope of buildings, such as applying them on roof, windows, or walls. Gumm, (2008) advanced by explaining "that BIPV is part of the building and the building energy source that are considered as a functional unit of the building structure, and are architecturally incorporated into the building's design" (Gumm, 2008, p.11; Penga et al., 2011, p.3593). Bloem et al., (2012) on the other hand, described BIPV systems as building components that associate with other functions of the building envelope to provide electricity generation, for example the thin film which is more suitable in coating building envelop due to its elasticity serve this purpose (Bloem et al., 2012, p.63).

2.5.1 Benefits and Limitations of PV/ BIPV Systems

Photovoltaic (PV) panels/ BIPV systems can be used to distribute electric power needed in domestic level and even commercially and community wise (i.e. including provision of electricity for small communities) or at larger scale through utility power applications. BIPV Systems are reported to be green power technology systems that are of advantageous in renewable PV energy and have more advantage compare to conventional power sources, which also have some disadvantages when compared to conventional power systems; as depicted in table 2.5.

Table 2.5: Summaries the main Benefits and Limitations of PV/ BIPV Systems

	Benefit of Photovoltaic Systems	Limitation of Photovoltaic Systems
1.	Reliability. Even in harsh conditions, photovoltaic systems have proven their reliability. PV	Initial Cost. Each PV installation must be evaluated from an economic perspective and compared to

	arrays prevent costly power failures in situations where continuous operation is critical.	existing alternatives. As the initial cost of PV systems decreases and the cost of conventional fuel sources increases, these systems will become more economically competitive.
2.	Durability. Most PV modules available today show no degradation after ten years of use. It is likely that future modules will produce power for 25 years or more.	Variability of Available Solar Radiation. Weather can greatly affect the power output of any solar-based energy system. Variations in climate or site conditions require modifications in system design.
3.	Low Maintenance Cost. Transporting materials and personnel to remote areas for equipment maintenance or service work is expensive. Since PV systems require only periodic inspection and occasional maintenance, these costs are usually less than with conventionally fueled systems.	Energy Storage. Some PV systems use batteries for storing energy, increasing the size, cost, and complexity of a system.
4.	No Fuel Cost. Since no fuel source is required, there are no costs associated with purchasing, storing, or transporting fuel.	Efficiency Improvements. A cost-effective use of photovoltaic requires a high-efficiency approach to energy consumption. This often dictates replacing inefficient appliances.

5.	Reduced Sound Pollution. Photovoltaic systems operate silently and with minimal movement.	Education. PV systems present a new and unfamiliar technology: Few people understand their value and feasibility. This lack of information slows market and technological growth.
6.	Photovoltaic Modularity. PV systems are more cost effective than bulky conventional systems. Modules may be added incrementally to a photovoltaic system to increase available power.	Some toxic chemicals, like cadmium and arsenic, are used in the PV production process. However, these environmental impacts are minor and can be easily controlled through recycling and proper disposal.
7.	Safety. PV systems do not require the use of combustible fuels and are very safe when properly designed and installed.	The output of photovoltaic systems is variable depending on the availability of solar radiation. Areas with greater cloud cover and shorter days will experience lower power generations, and such systems have to be designed accordingly.
8.	Independence. Many residential PV users cite energy independence from utilities as their primary motivation for adopting the new technology.	Extensive installation space is needed for the large production of electricity.
9.	Electrical Grid Decentralization. Small-scale decentralized power stations reduce the possibility of outages on the electric grid.	Overheating reduces the production power of PV panels. Research have shown that to every 1% yield, reduce $10^{0}C$. Although can be

		solved by ventilating back surface of the PV and by selecting a suitable tilt angle.
10.	High Altitude Performance. Increased insolation at high altitudes makes using PV advantageous, since power output is optimized. In contrast, a diesel generator at higher altitudes must be de-rated because of losses in efficiency and power output.	Photovoltaic energy is typically stored in batteries, which increases the costs and maintenance of such systems. However, there is a tremendous thrust to improve energy storage technologies such as solar-hydrogen systems.

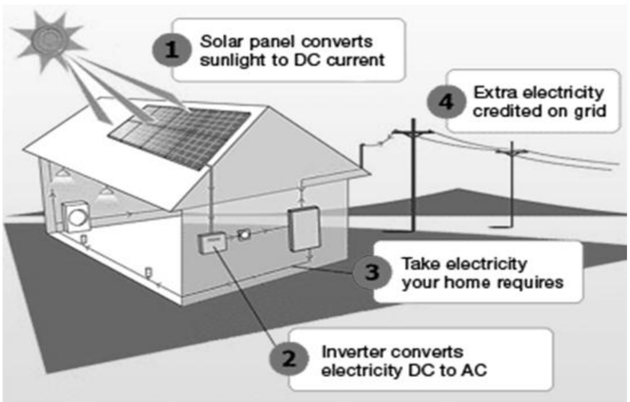
(PV Energy International (SEI), 2004, p.4)

2.6 Types of Photovoltaic (PV) Systems and Connections

Photovoltaic system can be classified into two major types based on the end-use application of the technology, and the two main types of PV systems to be treated here are the grid-connected (also known as grid-tied) and off-grid (also known as stand-alone) Photovoltaic system.

2.6.1 Grid-Connected /Grid-Tied Photovoltaic (PV) Systems

A Grid-connected or Grid-Tie PV system is the easiest technique of connecting a system to the electricity grid and its installation is simple in most cases as well, and convert solar energy into direct current (DC) electricity which in turn flows into a Grid-Tie Inverter, converting the initial current into alternating current (AC) (SEI, 2004, p.6). "The inverter consecutively synchronizes the voltage and frequency including that from the grid; and the electricity can be used in the home by standard appliances or fed through a meter, back into the electricity grid (in some instances, feed the surplus energy back into the grid) as expressed by (Sick &Erge, 2008, p.17&18). Grid-connected can only produce electricity if the electricity grid is available to feed electricity to the buildings, homes, cottages or business. On the other hand, the Grid-Tie or Grid-connected Inverter is the system component that interacts with the grid, and is programmed in such way that if the utility grid goes down (i.e. power failure), the inverter on the other side will automatically shuts off and will not feed PV generated electricity back into the grid. In other word, the inverter will break in the flow of electricity to the grid for safety reasons. The core distinct between a Grid-Tie system and other systems is that there are no batteries, which makes the system less expensive, more efficient, and simpler to install. Grid-connected PV systems also required little ongoing maintenance and are highly reliable (Eng& Gill, 2008, p.6; EMA & BCA, 2011, p.5). Figure2.13 and 2.14 diagrammatically shows a grid-connected PV system.



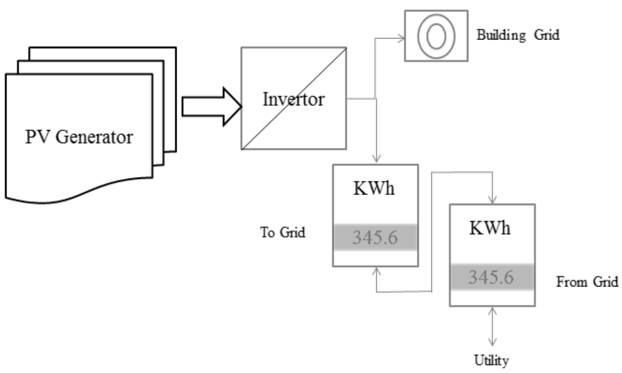


Figure2.13: Grid-connected /grid-tie PV system configuration (BCA, 2008, p.7).

Figure 2.14: Principle schematic of grid-tie PV system (Sick &Erge, 2008, p.18).

2.6.2 Off-Grid / Stand-Alone Photovoltaic (PV) Systems

Stand-alone or the off-grid systems are completely independent from any electric utility grid; and are most appropriate for remote locations, where connection to the electricity grid is either not possible or expensive, and are most cost effective when electricity requirements are relatively low. Stand-alone PV systems are used for collecting and storing solar energy to be used by household appliances. "They typically generate current ranging from 100 Watts to 5 kilowatts" (Belfkira, Zhang, &Barakat, 2011, p.100 & 102). The electricity generated from off-grid PV systems during the day is used for powering the home and charging the batteries. While, at night and during rainy days, the charged batteries are responsible for powering the household or building. Stand-alone systems comprise a battery bank (a storage battery), inverter (If required, drive AC loads by transforming DC to AC electricity), battery charger "(a charge controller supervises the charge/discharge process in order to ensure a long battery lifetime)" (BCA, 2008, p.7) and a fuel generator set (optional). Stand-alone PV "systems usually power DC loads which includes telecoms systems, rural lighting systems, parking sign lights, lightings in parks" (Bala&Siddique, 2009, p.138), "medical facilities, water quality, environmental data monitoring, irrigation pumping, aviation obstruction lights, environmental data monitoring, street lighting, desalination etc.", as illustrated schematically Figure2.15 (BCA, 2008, p.7; Sick &Erge, 2008, p.18).

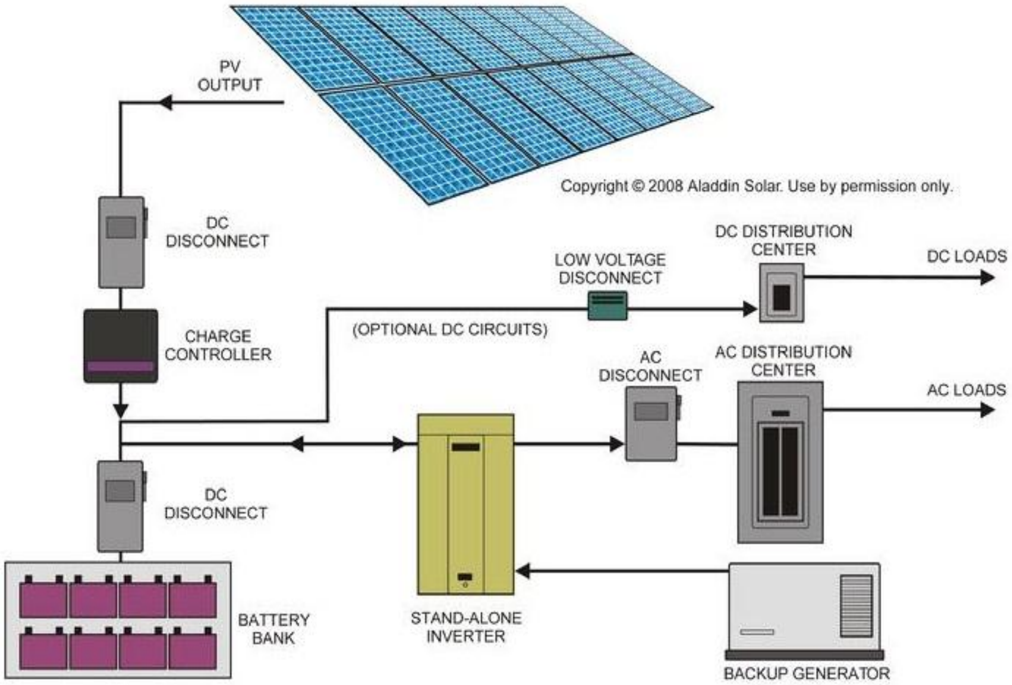


Figure2.15: Schematic of a typical stand-alone PV system (Source: Eiffert& Kiss, 2000, p.59).

2.7 Photovoltaic (PV) Modules and Fabrications

The PV modules are designed and manufacture for outdoor condition (i.e. all products available are suitable to be exposed to sun, rain and other climatic influences) so as to be part of the building skin (Dufo-López& Bernal-Agustín, 2005, p.33). Though, different encapsulation technologies have resulted in a range of PV modules having unlike performances as a constructive element. However, the number of modules in series will determine the system voltage and current level, and they must be protected from damage by environment in which they operate. The current of the plant can be sized by parallel connection of module strings (Deutsche GesellschaftfürSonnenenergie, 2008, p.51), as demonstrated in Figure2.16 and 2.17.

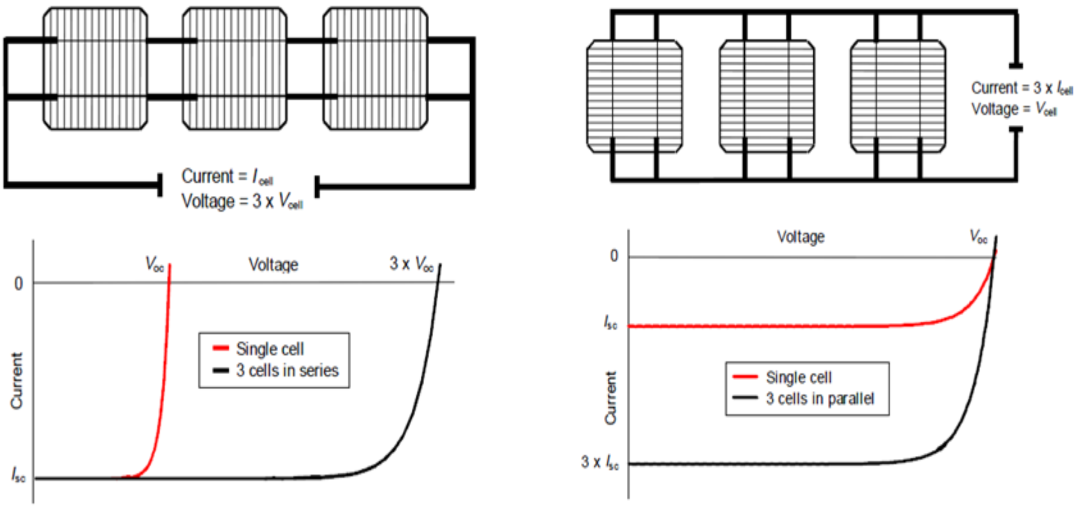


Figure 2.16 and 2.17: (a) PV cell in series connection with resulting current-voltage characteristic. (b) PV cell in Parallel connection with resulting current-voltage characteristic (Zhang and Barakat, 2011)

The anticipated output plant power is the product of system voltage and current, and is sometimes as high as 500 to 1000 V when a large number of modules are connection series (Zhang and Barakat, 2011, p.100 & 102). It is says that one PV cell can produces as much as 3W at 0.6V DC (Bala&Siddique, 2009, p.138). To attain higher power unit and higher voltage, about 30 or more identical PV cells must be connected in series to form a PV module with high voltage or current (see last Figure), “this means that a manufacturers have to manufacture several square meters of PV modules with peak power outputs of several hundred watts” (Carr & Pryor, 2004, P.285). Research shows that quite a number of PV module manufacturers are in the market today and each manufacturing company perhaps have 5 to 10 different module types for choice (Sick &Erge, 2008, p.23&24).

2.7.1 Photovoltaic (PV) Modules Classification Types

Photovoltaic (PV) modules and laminates available in the market today are of different types, and can be classified as in table 2.6. Modules that are fabricated in laminating processes in the industries such as, “EVA; Ethyl-Vinyl-Acetate, PVB and Teflon encapsulation” are called laminates. In other words, they are called as film laminates, glass-film laminates or glass-glass laminates and are always protected from humidity, fraction and corrosion (Sick &Erge, 2008, p.23&24). If the term “laminate” is mentioned, then it should be refers to glass-film laminates only, and sometimes it is called frameless modules in general. Apart from other existing PV modules available in the market, standard modules, special modules, and custom-made modules are manufacture or fabricated and are used in various countries for building application, for example to retrofit existing buildings. In the industry, standard modules are fabricated per square meter to achieve high-energy yield at the lowest module production cost, and are integrated into roof and façade without any difficulties (Deutsche GesellschaftfürSonnenenergie, 2008, p.73).

Table 2.6: Classification of the different types of PV modules

TYPES PHOTOVOLTAIC (PV) MODULES		
Cell type		- Mono-crystalline modules - Polycrystalline modules - Thin-film modules (amorphous, CdTe and CIS modules)
Encapsulation	Encapsulation material	- Teflon module - PVB modules - Resin modules (the EVA classification module is not generally used)
	Encapsulation technology	- Lamination (with EVA, PVB or Teflon; see the following section on 'Laminates')

Substrate	- Film modules - Glass-film modules (or glass-Tedlar modules) - Metal-film modules - Acrylic plastic modules - Glass-glass modules
Frame structure	- Framed modules - Frameless modules
Construction-specific additional functions	- toughened safety glass (TSG) modules - laminated safety glass (LSG) modules - insulating glass modules - insulating glass modules for overhead glazing - stepped insulating glass modules - laminated glass modules
Standard modules	
Special modules	
Custom-made modules	

(Source: Deutsche GesellschaftfürSonnenenergie, 2008, p.72)

Standard modules are mostly glass-film laminates encapsulated in EVA, which are offered with fixed dimensions and outputs and protected against humidity, fraction and corrosion. The standard modules can be manufacture of two different types' with and without aluminum frames, as shown in Figure2.18, 2.19, and 2.20. They are arranged strategically where no special needs are made on the modules in terms of shape and size, either as rack-mounted systems or incorporated with special profile systems as part of building-integrated systems. On the other hand, a typical standard module is made up of 36 to 216 and has a power output of 100Wp to 300Wp, for example, crystalline cells. The cells are often ordered in four (4) to eight (8) successive rows, which results in a rectangular module with dimensions of 1.6m x 0.8m. Today due to material savings, simplified mounting, new system designs and, aesthetic demands; standard modules are available in different power rating and dimension such power ratings of up to 330Wp and dimensions of 2.15m x 1.25m respectively (Deutsche GesellschaftfürSonnenenergie, 2008, p.73; Roberts &Guariento, 2009, p.25).

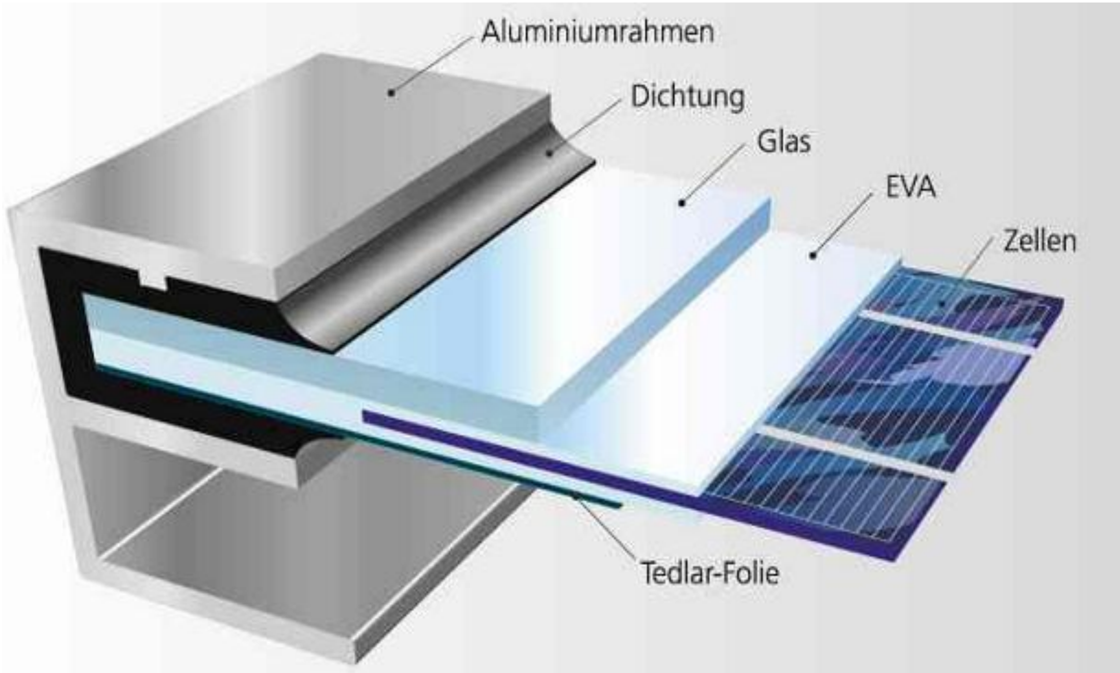


Figure2.18: Schematic frame of a standard module (Alibaba.com, 1999-2012)

Figure 2.19 & 2.20: Schematic of framed PV module (Solar Planet Earth, 2008). Schematic of framed PV module (KF Solar Tech Group Corp, 2010)

On the other hand, the *special modules* are modules that are produced in mass for special intention or special materials, although a special frame may be required. These types of special modules are practical in all small-scale applications and lightweight modules such as for solar vehicles, boats camping, and solar tiles. Table 2.7 summaries the suitability of different module types and dimensions in cm2 for building integration; where:

Table 2.7: illustrates the suitability of different module types for building integration ((+) represents high suitability, (±) low suitability, and (-) not suitable.)

Module construction technique	**Typical**	**Application suitability**				
	dimension in cm2	Slope roof	Flat roof	wall	wind ow	shadi ng

Standard module with plastic or metal frame (glass multi-layer non-transparent black sheet	33×130 45×100 55×155	+	±	±	-	±
Standard laminates as above without frames	33×130 45×100 55×155	+	+	+	-	+
Glass-glass modules with predefined transparency	All dimensions between 15-200	±	±	+	+	+
Glass modules with transparent plastic between back sheet	All dimensions between 15-200	±	±	+	+	+
Modules with metal back sheet and plastic	15-150	+	+	+	-	+
Roofing modules (tiles/slates)	To fit with standard roof sheet	+	-	-	-	±
Custom-designed-modules	Various dimensions	+	+	+	+	+

(Source: Sick &Erge, 2008, p.86)

The latter require a frame, for instance, to ensure that the roof is protected against rain and snow. Another type of module is the *custom-made modules* which are specially fabricated or manufactured for a specific location such as for a cold or warm facade, a glazed roof or a shading device. The module's structure, size and shape are decided by the location (Deutsche GesellschaftfürSonnenenergie, 2008, p.74).

2.7.2 Transparency in PV Module

There are two categories of crystalline PV modules that is the transparent (translucent) and semitransparent or opaque. In other words, Semi-transparent and transparent PV modules have a wider ability to combine both electricity and natural lighting effect, which create fascinating light outcome in building envelopes.

2.7.2.1 Semitransparent PV Module

In a glass-glass laminate or semitransparent PV module allows light called semitransparency or light-filtering to pass through it, and it is incorporated where only some amount sunlight penetration is needed, sometimes added mainly for aesthetical reasons rather than structural consideration, as demonstrated in Figure2.21 and 2.22.

Figure2.21: Monocrystalline PV in a semitransparent module-glass on the back (Robert and Guariento, 2009, p.27).

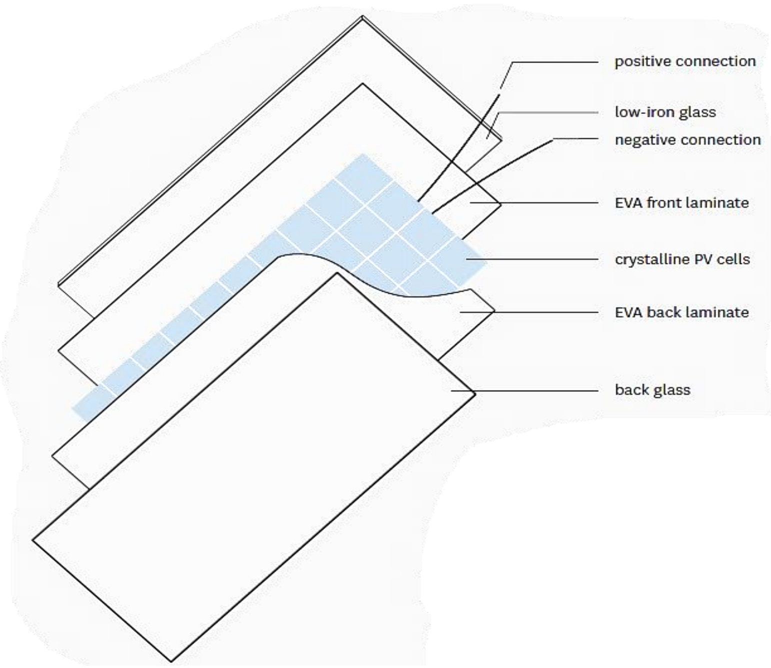


Figure2.22: Depicts an archetypal assembly of a crystalline silicon module that is semi-transparent by having a back glass (Robert and Guariento, 2009, p.27).

Semitransparent PV modules are also generally used to provide sun or wind protection to building surfaces and interiors (Montoro et al., 2011, p.17 and18). They are also applicable in building such as semi-transparent facades, roofs, skylights, curtain walls and shading structures (canopies, atrium roofing) integrated for electric generation or thermal and day lighting. In semitransparent PV modules, a transparent cover is used (Tiwari and Mishra, 2012, p.132 and133). In crystalline silicon technology, the adequate amount of light that penetrates into building structure is attained by adjusting or measuring the cells spacing (i.e. the space between cells can be can be adjusted from 1 to about 30mm) as illustrated in in Figure2.23, whereas thin-film is customize during fabrication procedure, i.e. the cell spacing can be increased for strip-like transparency and this gives an interesting evenly pattern neutrally colored average transparency values of 10–15% when joint with spaced cell (Kiss &Kinkead, 1995, p.13), as described in Figure2.23 and 2.24.

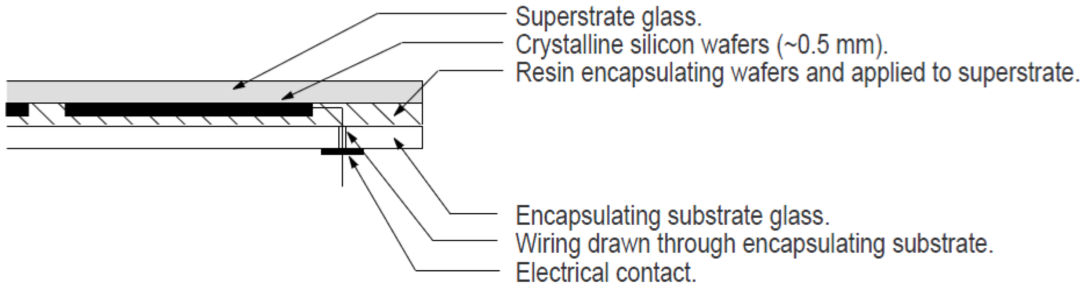


Figure2.23: “Demonstrates a section detail of crystalline silicon PV module” (Kiss &Kinkead, 1995, p.12)

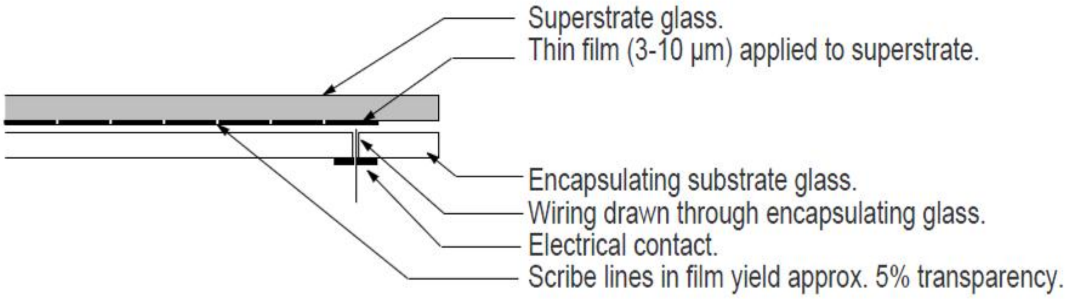


Figure2.24: “Detailed section of a thin-film supersaturate-type PV module” (Kiss &Kinkead, 1995, p.13)

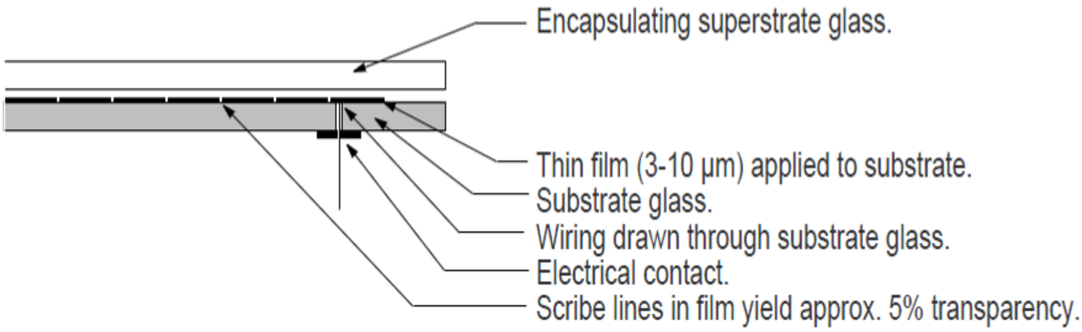


Figure2.25: “Characteristic detailed section of a thin film PV module substrate-type” (Kiss &Kinkead, 1995, p.13)

“The backing in standard modules with EVA encapsulation is generally a thin opaque film-Dupont trade name for a film of polyvinyl fluoride, PVF-polyethylene terephthalate (PET) or metal as schematically shown in Figure 2.23" (Montoro et al., 2011, p.17&18). The backing of a glass-glass laminate can always be glass for transparency in between the cells (Robert and Guariento, 2009, p.27). However, it should be noted that the more transparent a module is the lower its energy efficiency, and semitransparent module are mainly for commercial use basically which gives a building structure an appealing look and natural lighting when applied in a large area, for example on window (Montoro et al., 2011, p.17&18).

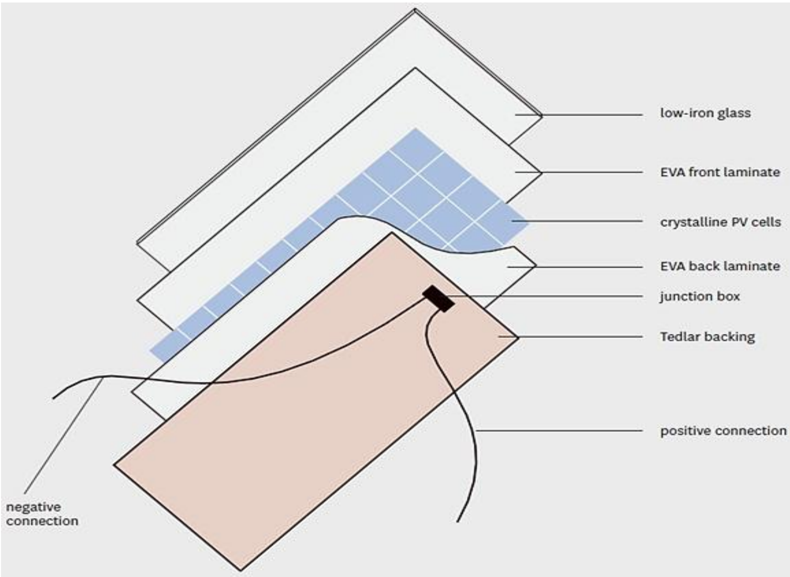


Figure2.26: "Classic assembly of crystalline silicon PV module made opaque by the Tedlar backing" (Robert and Guariento, 2009, p.24).

2.7.3 PV Module as a Glazing Material

With the advance in glass technology, glass materials has been improve to fit into architectural structure with the notion to control energy flow or consumption in building envelopes, as a result of this, glass industries has presented a increasingly sophisticated line of products. Under appropriate conditions or circumstances for sustainable buildings and energy flow in buildings, single-pane glazing productions can be substituted with a standard BIPV module, as itemized below by Kiss &Kinkead, (1995, p.8-10);

2.7.3.1 Transparent Glazing

- ***Clear float glass*** –This kind of glass is basically needed or applied where maximum light reflectiveness and clarity are of paramount concern, compromising thermal control and safety.
- ***Tempered or toughened glass*** – This type of glasses are treated glasses manufactured to withstand wind and thermal loads, and is usually applied in building entrances, storefronts and curtain walls. Its estimated cost premium over clear glass is 36%.
- ***Tinted float glass*** – Tinted float glass are painted glass which controls sun light transmission by decreasing solar heat gain radiation into buildings. In other cases, it is observed that green or blue tints permits more sufficient light and are applied in skylight or atria, whereas on the other side gray and bronze tints are applied where minimal light transmission is needed, for example in office buildings and hotels and its Estimated cost premium over clear float glass is 43%.
- ***Laminated glass***– is manufacture in the industries by combining two or several layers of glass together with an adhesive interlayer, which makes it extra stronger with the ability to reduce sound in buildings. One of its drawbacks is that it can be broken under loads or pressure which makes it appropriate for sloped glazing and skylight application and its approximate cost premium over clear glass is 61%.
- ***Reflective glass*** –It has an applied reflective coating which serves as light transmittance and reflectance controller and equally has the capability of

minimizing heat gain, and is applied mostly as skylight or atria, but have more efficient performance than tilted glass with approximate 76% cost premium over clear glass.

- ***Low-emissivity (low-E) glass*** – This kind of glasses are made up of solar thermal performance and neutral colored coating which makes use of visual light transmittance and serves as UV transmission barriers. It is applicable where more light transmittance and sufficient energy performance are of predominant concern and its approximate cost premium over clear glass is100percentage.

2.7.3.2 Semitransparent Glazing

- ***Fritted glass*** –This glazing type are made up of opaque ceramic paint which are fired onto glass to minimize and it's also hinders views interior and exterior and is commonly applied as a design element. Fritted glass is found mostly in high tech designs or construction, for example the fascinating "United Terminal at O'Hare airport in Chicago" and the Washington Federal Judiciary structure, and this glass approximate cost premium over clear float glass is120%.

2.7.3.3 Opaque Glazing

Spandrel glass – are mostly used in curtain walls to close areas floors where view or light transmission is not of affect. This type of glass are made up of special materials to be suitable with the appearance of reflective or tinted vision glass and sometimes can the back are painted to have colored opaque unit which has approximate 73% cost premium over clear float glass.

2.7.3.4 Insulating Glazing

They are superior in terms of thermal performance, are applied in more than 80% of transparent building glazing construction, and are manufacture from two layers of glass fragmented by an insertion and closed. The most available types in the market are 25mm (1”) thick unit which is composed of two layers of 6mm (1/4”) glass disconnected by a 12mm (1/2”) air space and sometimes composed by triple glazing, gas-filled units and so on. Its applications sometimes can be suitable or appropriate for building with atriums and is used as skylight. PV module can be integrated as an external element in insulated units (Kiss &Kinkead, 1995, p.15) as shown in the detailed section of PV insulating unit (Figure2.27) or inner glass element as represented in detailed section of PV insulating unit with PV in Figure2.28. However, either approach has certain benefits and limitations.

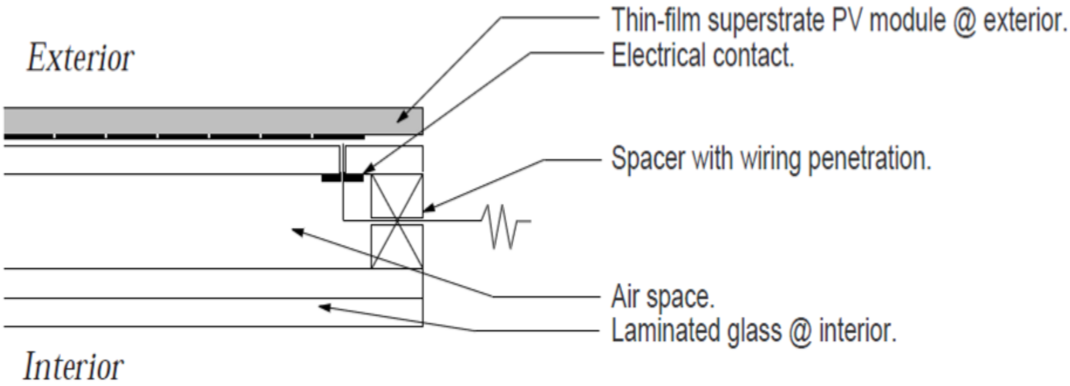


Figure2.27: “Comprehensive section of PV insulating unit using PV as outward lite” (Kiss &Kinkead, 1995, p.15)

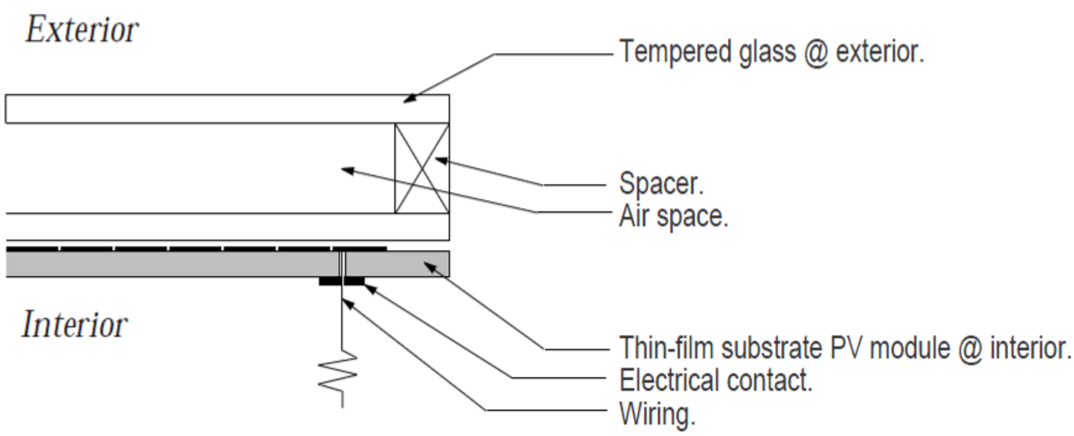


Figure2.28: "Thorough section of PV insulating unit using PV as inner lite" (Kiss &Kinkead, 1995, p.15)

2.8 (PV) Modules versus Climate/Temperature Characteristics

Research have shown that environmental factors such as climates, latitude, precipitation, humidity, dust, wind loads, average temperatures and seismic conditions will have effect or reduce the productivity of PV panels, however, dependent upon how it is incorporated into the building envelope. It is sure evident that cold and clear weather upsurges the performance of a PV panel, while on the other side hot and overcast climate undermine PVs efficiency. Air pollution also compromises the performance of the PV modules, in the contrary, when proper solar irradiation, or climatological data are missing, then the issue of oversizing comes in, and in this case the designer increase the number of PV modules and the battery size for a proper output. Whereas if the proper solar data are discovered by the designer, then a satisfactory tilt angle for the PV panels can be selected at the best possible way to suit the required task, and the size of the PV system can be decided pragmatically (Asl-Soleimani, Farhangi, &Zabihi, 2001, p.459). Photovoltaic (PV) modules work more efficiently when inclined at the appropriate angle in colder regions. The limitations of PV in hot regions are the temperature affect, which decreases the output of the PV modules. The cell temperature of photovoltaic modules in standard condition should not be greater than 25°C for efficiency performance. Practically, PV efficiency decreases when module temperature increases (i.e. cell temperature ranging up to 60°C will cause a module to lose 0.5% efficiency per degree centigrade). However, the drop in output is more realistic in crystalline as compared to amorphous silicon. Figure2.29 schematically express an inexact energy balance of an archetypal Monocrystalline module. In that case, PV should be properly ventilated by leaving an air gap or space which should not be lesser than 15cm particularly in hot regions to permits cooling or circulation of heat of the PV laminate (Hankins, 2010, p.52), as shown in Figure2.29. In the case of crystalline silicon cells, the competence vicissitudes virtually in a linear manner by 0.4% for every level increase in temperature. In contrast, amorphous silicon cells are more stable compared to crystalline silicon cells, although contingent on the precise production procedure. The temperature distinction between PV module and ambient temperature strongly rely on the irradiation intensity (UV) and can rise as much as 40°C in some cases. In summer period it is speculated that high ambient temperatures can affect the PV temperature and consequently can rise approximately up to 70° to 75°C. It observed that Photovoltaic (PV) panel occasionally produces nominal operating cell temperature, abbreviated as NOCT, and this cell temperature is concluded for an irradiance of 800W/m2, in other word an ambient temperature of 20°C and a wind velocity of 1m/s as stated by (Robert and Guariento, 2009, p.24).

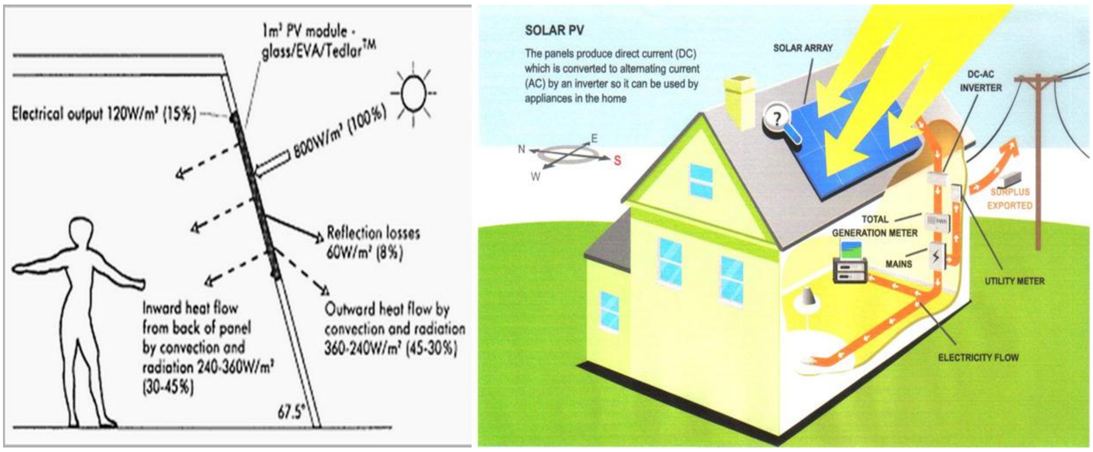


Figure2.29: Demonstrates an imprecise energy balance of a typical Monocrystalline module (Thomas, Fordham, & Partners, 2001, p. 13) from left and an Installation of array on top of a roof with a gap between the PV for cooling effects (Robert & Guariento, 2009, p.40) from right.

2.8.1 Tilt Angle and the Orientation of PV Modules

PV modules are most effective when they are perpendicular to the sun's rays as diagrammatically shown in Figure 2.30. The horizontal placement is for simplicity, but consequently causes the PV modules to accumulate dirt and debris and makes it difficult for the modules to partially self-clean in the rain (Balfour, Shaw, & Nash, 2013, p.80). In light of that, Balfour, Shaw, & Nash, 2013 also specified that the tilt angle have a pronounced effect on the amount of energy collected from the sun by a photovoltaic (PV) module or panel. Furthermore they averred that the orientation and tilt gives a clear idea on how much irradiance, i.e. the amount of light incident on a surface at one point in time that the PV system can collect, and direct irradiance on the other hand is reliant on the sun's position and the sun's path with different angle recordings during the daylight and period of 365 days. While diffuse irradiance is as a result of irregular climatic problem such as clouds and haze, and affect the PV yield as shown in Figure2.31. (Roberts &Guariento, 2009, p.33) There are wide-ranging rules of thumb to follow when orienting a fixed tilt system. In theory, the optimal orientation, or surface azimuth, is true south and the optimal tilt is always equal to the latitude. Eiffert & Kiss, 2000 states that PV orientated north of the equator perform in the best possible way when slanted towards south and the tilted at angle 15 degrees and must be surpass the site latitude (Eiffert& Kiss, 2000, p.60). However, based on observation, it is generally preferred to have the system facing the equator and tilted at approximately 10-15^{o} less that the local latitude for best performance. This is principally a consequence of poor climate being concentrated in the winter months. Additional influences that have impact on the optimal orientation and tilt are the following (Luque&Hegedu, 2011, 9.6.3):

- Convenience (an existing slope is often less expensive to install upon).
- Local obstructions (i.e. shading due to trees and surrounding buildings).
- Asymmetrical microclimates (consistent morning fog or afternoon showers).
- Sensitivity to time-of-delivery generation.

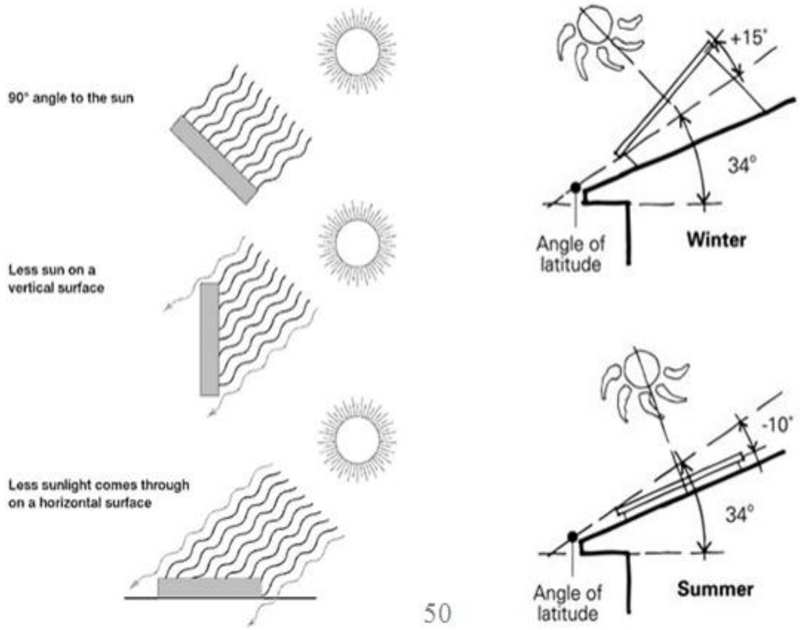


Figure2.30: Illustration of how module tilt can affect absorption (Balfour, Shaw, & Nash, 2013, p.80; Stapleton et al., 2010).

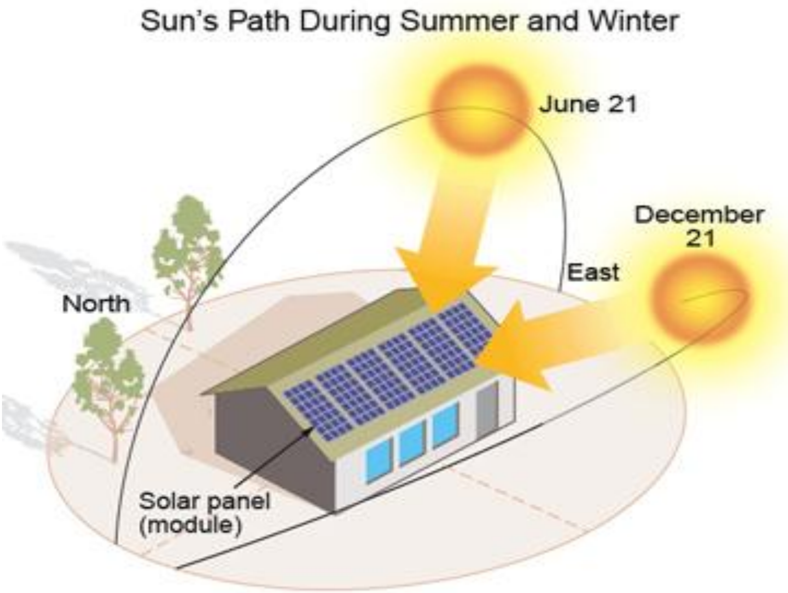


Figure2.31: Sun paths range over the year for the summer and winter solstice predicted for Europe or Northern latitude (Deutsche GesellschaftfürSonnenenergie, 2008, p.11).

For instance, Californians incentive programs provide the largest rebate to system optimized for May to October energy. In this case the system should be at slightly lower tilt angle than otherwise would be chosen to maximize annual generation. Therefore, tracking systems orientation issues are less significant inasmuch that the system tracks the sun all the way through of the day, improving the output of PV modules by as much as 20%. The single-axis trackers move along with the sun from east to west, whereas double-axis trackers moves with the sun from east to west, as it gets higher and lower in the sky; as depicted in Figure2.32 (Luque&Hegedu, 2011, 9.6.3; Balfour, Shaw, & Nash, 2013, p.80).

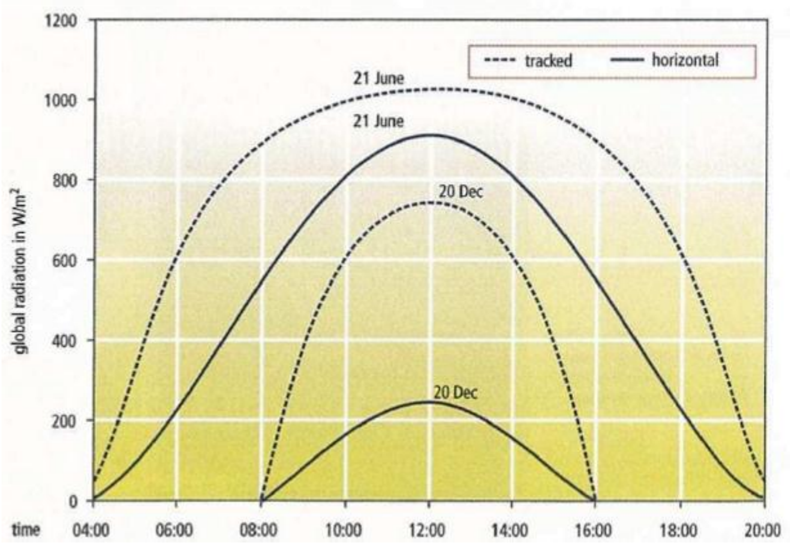


Figure2.32: Differences in irradiance on horizontal and solar-tracking surfaces for cloud-free days and 50° latitude (Deutsche Gesell schaft für Sonnen energie, 2008, p.15).

PV systems performance depends on the modules collecting solar energy. Module tilt angle (i.e. the preferred angle of a solar collector measures from the horizontal) and azimuth angle (i.e. the horizontal angle measured clockwise from true North) are the central to PV system design. Figuring out where to place the modules requires great consideration. The optimal orientation for modules in Northern hemisphere is facing due south at a slope equivalent to the latitude, and is the most appropriate direction to obtain maximum yield. This implies that the orientation will maximize year- round solar power production. Using a flatter or plane angle level in the summer upsurges seasonal performance. In the other hand, steeper angles improve winter performance. The finest tilt angle is the angle that produces the maximum year-round energy yield for the location and mounting conditions (as illustrated in Figure2.33&2.34). When designing a PV module, the following should be considered with regards to orientation and tilt angles (Balfour & Nash, 2011, p.71):

- For maximum yearly yield, the tilt angle should be equivalent to the latitude

- During winter, maximum collection tilt angle should be latitude plus 15 degrees
- To maximize for summer, the tilt angles should be minus 15 degrees (p.71).

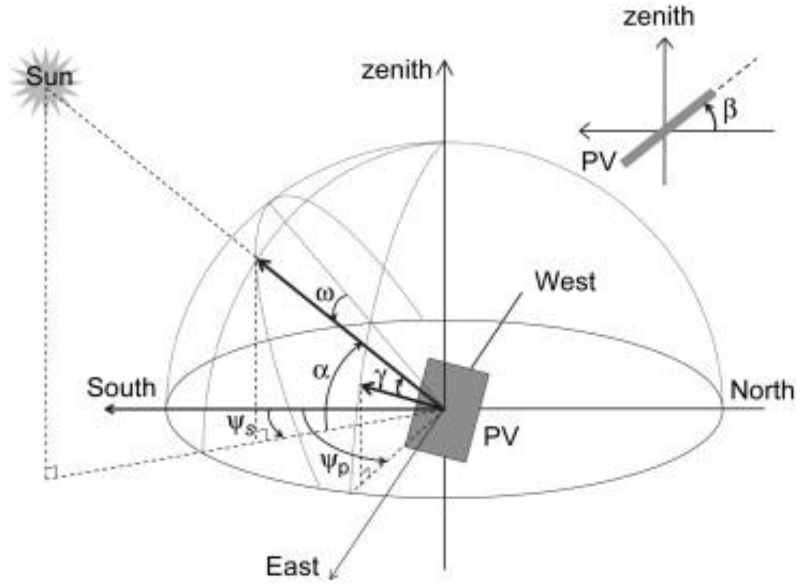


Figure2.33: Illustration of proper (Schaeffer & Pratt, 2005, p.70).

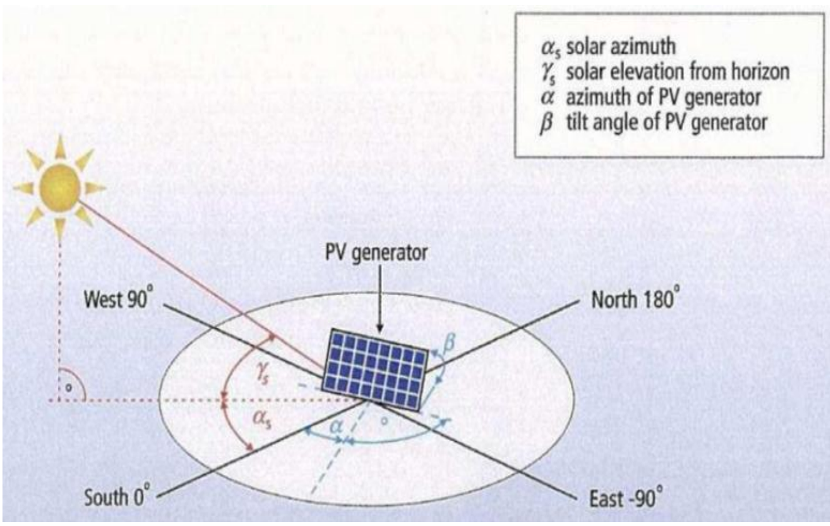


Figure2.34: Depiction of angles in PV techniques (Deutsche GesellschaftfürSonnenenergie, 2008, p.11).

2.9 The Chances of PV Integration in Building Industry

PV systems are modular and hence offer a diverse range of integration into building envelopes. Furthermore, any building exterior facing the sun can be readily available for the incorporation of PV inasmuch that the building envelope withstands interior and exterior environmental climatic conditions. In addition, consideration of airtightness level to prevent excessive heating and cooling of space in consequence of unrestrained airing is of importance to allow efficient performance of airing systems (Roberts &Guariento, 2009).

Building gives, great chances with their large external area to offer energy by incorporation of PV system in several part of the building envelop, like for example, into roof (sloping or flat roofs) and facade of buildings. PV modules are also applied as shading glazing elements to regulate natural daylight in a manner that serve as a passive way to mitigate solar heat gain in other to bring forth clean electricity at the same time. Furthermore, PV modules are also incorporated in balconies, also atrium and serve the purpose of skylight (Norton et al., 2011, p.1634).

The PV façade also have the ability to carry out diverse purposes as an example of natural day lighting, safety, passive heat gains, confidentiality (privacy), and airing (ventilation). “Other functions of BIPV system are air tightness, color, image, size, durability, maintenance, and safety during construction work cost etc.” (Roberts &Guariento, 2009, p.45). The suitability of PV incorporation is affected by the building pattern and size, materials surface finishes, etc., which implies that these must be careful, considered right from the design stage of PV integration. Figure2.35illustrates the potential locations for installing a PV system and 2.36demonstrate the integration of various phenomena for a PV component applied to a building envelope (Bloem et al., 2012, p.65).

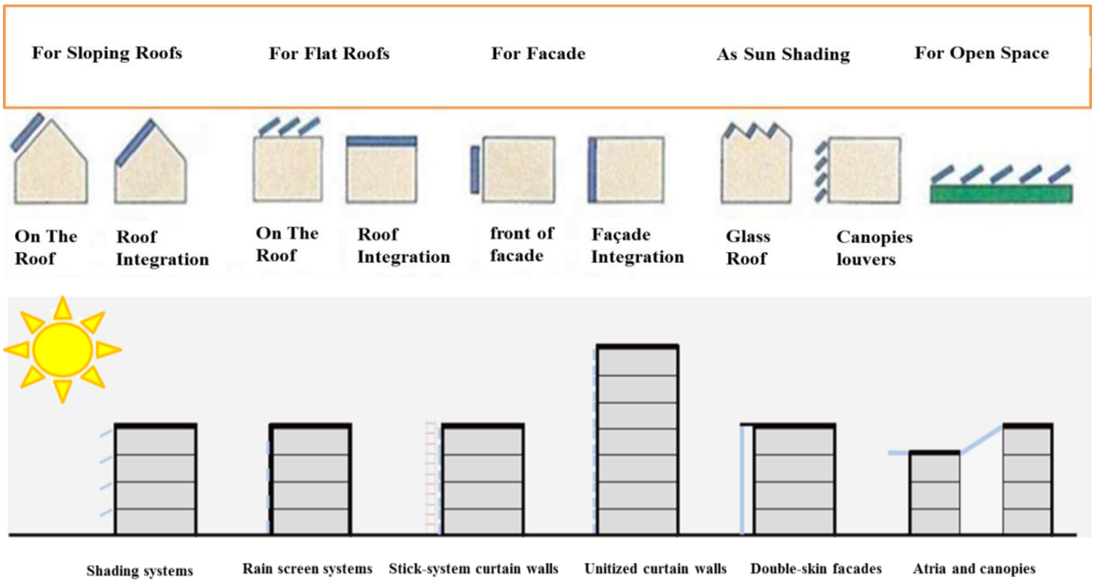


Figure2.35: Illustrates the potential locations for installing a PV system(Roberts &Guariento, 2009, p.45)

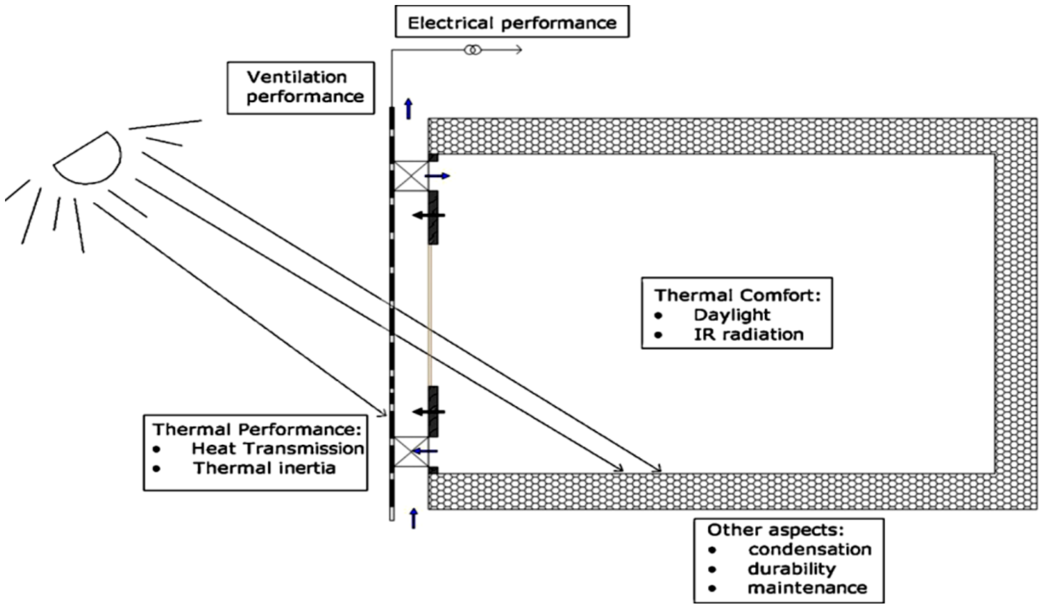


Figure2.36: Interaction of several phenomena for a PV component applied to a building envelope (Bloem et al., 2012, p.65).

The other type of chance of integrating in building envelope classified as below:

1. PV Integration on Building Roof

2. PV Integration on Pitched Roofs

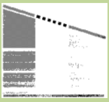
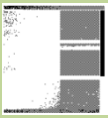
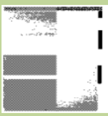
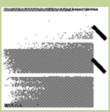
3. PV Roofing Tiles and Shingles
4. Application of PV on Atria/ Skylight and Canopies
5. Application of PV Modules as Shading Devices
6. Integration of PV on Building Facades and Curtain Walls

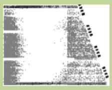
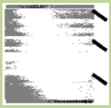
2.10 Integration Techniques and Building Examples (Cases studies)

In contemporary buildings, there are good opportunities to combine PV modules into building envelopes and can be classified or categorized according to position integration such as in inclined roof, roof with integrated tiles, saw-toothed North light roof, curved roof/wall, atrium, vertical facades, vertical facades and windows, inclined PVs with windows, Inclined wall with windows, fixed sunshades, moveable sunshades, as demonstrated in table 2.8.

Table 2.8: List of the main PV roof and facade application, their characteristic including cases studies

Position of PVs	System	Characteristic	Building example (cases study)
Inclines roof 	PV roof panels	Combine with roof structure system	- K2 apartments in Melbourne, Australia. -Upton ZED terrace in Northampton, UK.
Roof with Integrated tiles 	PV roof tiles	Roof tiles are familiar product and are likely to find easy acceptance	
Saw tooth roof	PV panels	Allow delighting	

			
Curved roof/wall 	Opaque PV flexible substrate (sheet metal or synthetic material) or rigid nodules arranged on a curve	Extended design possibilities	-Shell solar factory in Gelsenkirchen, Germany: Framed laminates. -Alan Gilbert Building, Germany.
Atrium 	PV roof panels	As for the inclined roof. Variation includes part-glazing, part-opaque PVs, and semi-transparent PVs.	-Atrium of the German Foreign Office in Berlin: -Central Station in Berlin, Germany. -Nottingham University Jubilee Campus in Nottingham, UK
Vertical wall 	Curtain walling system	Standard, economical construction. PVs can be mixed, i.e. some being opaque and some semi-transparent.	-Tobias Grau GmbH Head Office. -Wal-Mart Experimental Supercenter.
Vertical wall 	Rain screen Cladding Double-skin facade	Rain screen designs incorporate a ventilation gap which is advantageous in getting rid of heat; the gap can also be used for running cables.	-The Co-operative Insurance Tower. -Xicui Entertainment Complex in China. -PompeuFabra Library in Mataró, Spain.
Vertical wall inclined PVs 	Glazing or rainscreen cladding	PV efficiency improved. Complexity of construction increased. Potential to provide shading of windows (if	-Northumberland Building in Newcastle upon Tyne, UK. -Kaiser clothes store in Freiburg, Germany.

		desired) but a degree of self-shading.	
wall with window 	Glazing	Potentially enhanced architectural interest. PV output is improved compared with a vertical wall. Less efficient use of building floor area.	-Hastra (Hanover Municipal Utilities), Germany: Sloping warm façade - transparent; insulating glass modules.
Fixed sunshades 	Glazing	Can enhance architectural interest. Entails a loss of daylight.	
Moveable sunshades 	Glazing	Can enhance architectural interest. Entails some loss of light but less than with fixed shades. Increased PV output compared with all fixed systems	

(Source: Adapted from Thomas et al. 2001, p.24-28)

Chapter 3

SUSTAINABILITY AND PHOTOVOLTAIC (PV) PANELS

3.1 Defining Sustainability

From an elementary standpoint, sustainability reflects pure necessities, such as the air we breathe in, the water that we drink, the earths that our crops or food grows upon and come from are essential to human survival in the universe. Therefore, the basic imperative of human existence is to sustain the conditions life depends on, and from this viewpoint, the idea of sustainability is simple. However, the term sustainability is also multifaceted and is hard explaining what sustainability means. Researches have also shown that, there is no uniformly accepted definition for sustainability, and is undefined without further reflection on values and principles. Thus, any discourse about sustainability is essentially an ethical and is subjective by nature and open to debates from various aspects (Bosselmann, 2008).

In a broader context, sustainability referred to as the society ability, such partial system like ecosystem, or on functioning into the future indefinite without actuality force into decline through the fatigue or overloading of main funds on which that system depends (Baker, 2006). Reboratti, defines sustainability in other words as firstly appertains to ecology and it mentioned to the potential of an ecosystem to outlast over time (Reboratti, 1999).Therefore, when the term development incorporated with the term sustainability, then the focus on ecology will drifted to that of the society, which gives rise to word “sustainable development”. We can now agree that “sustainable development “based its stress on social life, and its purpose is to comprise sustainable environmental considering in the steering of social changing, particularly through the economy functions (Ekins, 2000).

3.1.1 Sustainable Development

The World Commission on formulating of environment the definition of “sustainable development” and Development (WCED) led by the Norwegian prime minister Gro Harlem Brundtland, in 1987, and was define as the development that meets the needs of the present without compromising the ability of future generation to meet their own needs (Brundtland et al., 1987). From this definition, it implies that the word development comprises of two basic aspects or concept and it is limitless to a disciplines number or areas, but it is appropriate to all-around the world, everything on it, present and in the forthcoming. Furthermore, there is no set goal, but the continuation of developing is the goal of the growth. The two main concepts are ; needs and including of the conditions to maintain an tolerable life standard for all people, and the concept of limits of the capacity of the environment to fulfill the needs of the present and the future, determined by the state of social and technology organization (Hui, 2005).

In other words, Sustainable development aim is ensuring quality of life in best way for current and future generations. Sustainable development will reach by four objectives key that should be considering, includes; social progress which recognizes the needs, protection of the environment, be cautious of the using of natural resources, and maintenance of economic growth and develop in high and stable levels (DEFRA 2003). The needs firstly include the basic needs such as food, clothing, shelter and job. Secondly, everybody in the world must have the opportunity to raise his or her life level above. The limits consist of natural limitations like un-renewable resources, but also of deteriorating output caused by overexploitation of funds, declining quality of water and shrinking of biodiversity (Wilson, 2002). For our common future, it would therefore be best if needs are best fulfilled while limits are not increased, but preferably decreased. This would lead to the quite simple conclusion that all political, technical and social developments can easily evaluated in the light of sustainable development by these two arguments. Any development should help fulfill needs and should not increase limitations (Baker, 2006).Sustainable development has three components, which include the economic, environmental, and social dimensions, as shown in Figure3.1.

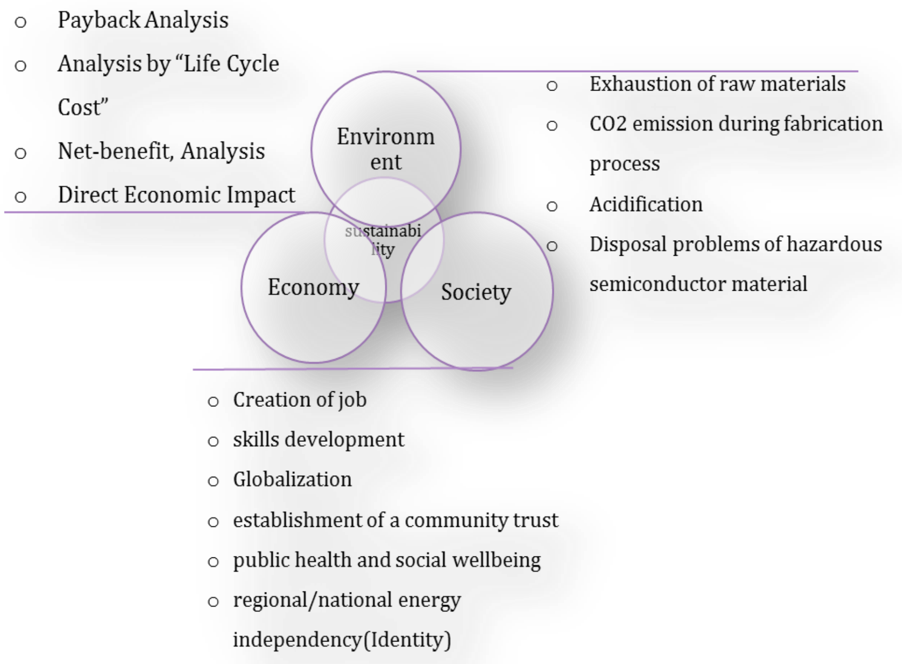


Figure3.1: The three elements or pillars of sustainability (Hui, 2005)

In other words, these are often denoting to as the triple bottom line, and use to measure the achievement of a specific development project. It is crucial that each dimension given the same attention in order to guarantee a sustainable result. This balance becomes understandable when each element observed independently (Rogers, Jalal, and Boyd, 2008). Ekins (2000) mentioned this three dimensions or pillars of sustainable development as; the approach of economic is to affection the allocation and dispensation of scarce resources. The social that relates to the human etiquette and avail, relation and nature. The ecological that involves the contribution the economic, the social, their environment and its resources (see table 3.1) (Ekins, 2000).

Table 3.1 shows a brief and comprehensive overview of the three dimensions

Economy Dimension of sustainability	Environment Dimension of sustainability	Social Dimension of sustainability
Payback Analysis Analysis by "Life Cycle Cost" Net-benefit, Analysis Direct Economic Impact	Exhaustion of raw materials CO_2 emission during fabrication process Acidification Disposal problems of hazardous semiconductor material	Creation of job skills development Globalization establishment of a community trust public health and social wellbeing regional/national energy independency(Identity)

(With kind permission of Hui, 2005)

3.1.2 Sustainable Architecture

Architecture can refereed as proficiently architecture providing that offer a quality environment in high level, which make the cost optimal, reliable and efficient energy at all steps of construction and costumers. Furthermore, owners and designers, plus contractors in sum up by all sectors try to found techniques or technology to create an environment, which efficiently use all resources and minimize waste, as result of keep the natural and environment healthy and durable. From this perspective, several sources revealed the sustainable architecture principle to guide designs and designer (Bromberek, 2009).

From this context, sustainable architecture hence requires consideration of issues that have the scope considerably broadened from those involved, for example solar architecture. It has also defined as the creating and responsible management of a healthy built environment based on ecological and resource-efficient principles.

On the other hand, sustainable buildings final goal is to make barrier impact on the environment in energy efficiency and resource limitation and elaborating (Bromberek, 2009). According to Bromberg definition, Sustainable architecture expectation is bringing the five main elements:

a. Environmental sustainability
b. Technological sustainability
c. Financial sustainability
d. Organizational sustainability
e. Social sustainability

In an elaborated context, architecture challenges are reduce the negative impact of building industry in environmental via optimizing and tempera ting the materials usage and energy consumption. The demand behind sustainable architecture is to make sure those human actions and decisions in current time do not barricade of the future generations opportunities. The term of sustainable architecture may also refer to as an energy and ecologically conscious approach to the design of the built environment (Williamson, Radford, and Bennetts, 2003).

Furthermore, Sanuel Mockbee of Auburn University clarifies that: sustainable architecture as the combination of values, aesthetic, environmental, social, political, and moral. It is about using one's imagination and technical knowledge to engage in a central aspect of the practice; designing and building in harmony with our environment. The smart architect thinks rationally about a combination of issues including sustainability, durability, longevity, appropriate materials, and sense of place. The challenge is finding the balance between environmental considerations and economic constraints. Consideration must give to the needs of our communities and the surrounding ecosystem (Hui, 2005).

3.1.3 Sustainable Buildings

With the increase 40% impact on global material and energy flows, buildings excellently built to meet up with sustainable approaches. Architects and contractors who build sustainable try to decrease and ultimately eradicate these influences through efficiencies and innovations in building design, construction and operation (Klotz, 2008).

There is no commonly accepted definition of sustainable buildings; however, the defining feature of the concept is a significant reduction in environmental influences (See Figure3.2). For example looking at it from social point of view, the social impacts of buildings can have an influence on local communities as a whole. While on the other hand, economic aspects of sustainable buildings can be consider as, reduced operation cost through energy and water efficiency and improved productivity, which can achieved through the provision of better working environment (Cavanagh et al., 2007)

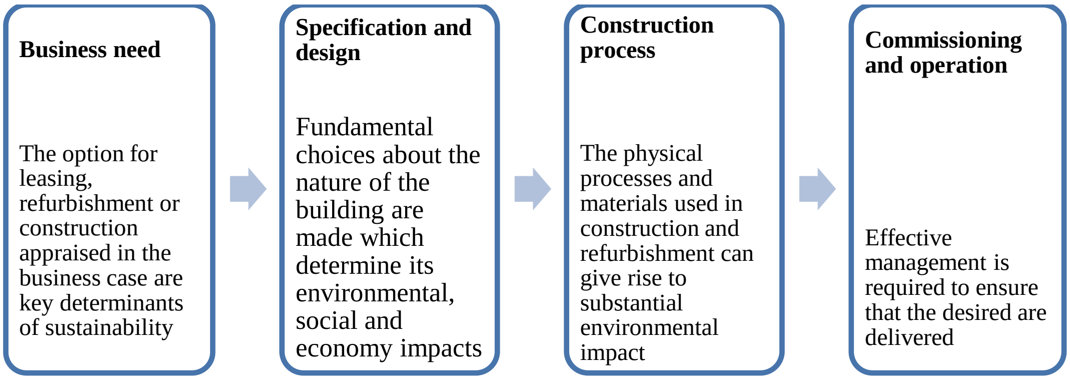


Figure 3.2 shows how building sustainably can reduce environmental impacts Great (Cavanagh et al., 2007).

In other words, sustainable buildings are those building, which optimize the site potentials. (i.e. reduce impact on ecosystems, required transportation, and energy use through consideration of correct location, good landscaping, proper orientation such as correct placement and design of windows, louvers/shading devices), protect and conserve water. Sustainable buildings are also indicating factors that decrease runoff, use efficiently, and consider reuse or recycling; use environmentally preferable products or construction materials, which have reduced impacts on human health and the environment. It also exploit the use of sustainably sourced and recycled materials, increase indoor environmental quality (IEQ) by making the most use of day-lighting to reduce initial and recurring costs of providing artificial lighting systems, and control moisture and airing systems (ventilation) (Cavanagh et al., 2007).

Sustainable buildings cuts energy usage and associated emission of carbon dioxide (i.e. in other word reduce the release of pollutions). Promoting of sustainable travel choices through public transport and cycling provision can also be attained through sustainable buildings; conserve or enhance biodiversity. Optimizing operational maintenance practice by ensuring that the building operates as intended and minimize the environmental impacts of building maintenance is accomplish through ecological buildings design. Adopting recommended R-value of insulation throughout the building and optimizes energy use can be obtained through substantial renewable energy devices such as photovoltaic solar energies(ICAEN (Institute Catalád'Energia), 2004; Klotz, 2008).

3.2 Relationship of Sustainable Environment with PV Panel

In all indications, to every energy generation and transmission process there must be an environmental effect. It is certain that some conversional source of producing energy might have impact on the air we breathe in, the climate we live on, the water we drink, land and wildlife, landscape, as well as raise the levels of harmful radiation from the sun. In this light, researches have shown that renewable energies are considerably harmless which present a solution to many environmental and social hitches related with fossil and nuclear fuels (Tsoutsos, Frantzeskaki, and Gekas, 2005). There are many environmental advantages on solar energies, which promote sustainable development human activities, when compare to other kind of conventional sources of energies, as shown in Table 3.2. The main advantages of renewable energies are associated to the mitigation of CO2 emission, which have addition positive effects. such as; decreasing the emissions of the greenhouse gases which are mostly (CO_2, NO_x) and avoidance of toxic gas emissions (SO_2 particulates); recovery of degraded land; decreasing of the required transmission lines of the electricity grids; and upgrading of the value of water resources (Karapanagiotis, 2000).

Table 3.2: Environmental and social indicators of solar energy technologies

Indicator	Central solar thermal	Distributed solar thermal	Central PV power generation	Distributed PV power generation	solar Thermal electricity
CO2 emissions saving	1.4 kg/kWh or 840 kg/m^2 a	1.4 kg/kWh or 840 kg/m^2 a	0.6-1.0 kg/kWh	0.6-1.0 kg/kWh	Annually 688 t/MW when compared to a combined cycle plant 1.360 t/MW when combined to a cola fired plant
Production employment (EU wide)	4000 jobs/a	4000 jobs/a	2-3000 jobs/a	2-3000 jobs/a	1 permanent job/MW for operation+10-15 jobs/MW for 12-18 month construction
Total employment	12,000 jobs/a	12,000 jobs/a	4-5000 jobs/a	4-5000 jobs/a	1000 permanent jobs for 1000 MW

(Tsoutsos, Frantzeskaki, and Gekas, 2005)

PV systems produce no harmful environmental emissions when producing energy, and this goes in line with the research conducted by Scientists. Brookhaven National Laboratory in the USA examined the hazards associated with producing and using Si, CdTe and CIS thin film modules, and was reveals that large scale manufacture of Si, CdTe and CIS thin film PV cells may perhaps lead to health and measures for safety are not taken. Similarly, safety precautions taken when using pyrophoric SiH_4 in the manufacture of amorphous silicon cells, health concerns are associated to Cd compounds, only little obtainable information this compounds, so precautions must when in exposure to them. Another significant environmental concern that has been taken care of by PV transportation engineers is noise. this is an issue that have been addressed by manufacturing PVs to serves as an effective sound barrier covering material which under normal circumstances will mitigate as much as 25dB of noise, and as part of the building, noise barriers offer an extra and ingenious opportunity to integrate PV in buildings for sustainable hosing (Montoro et al., 2011, p.17).

1989 mark the first PV noise barrier and was situated near Chur in Wallisellen, Swiss Confederation and was approximately calculated to be 10kWp system, as a result of this PV technology innovation six more prototypes was been built in Germany and Swiss Confederation which leads to worldwide idea competition. Another fascinating example was the national environmental strategies in the city of Australia that incorporated PV plan into its glasshouse gas reduction policies and as an outcome, the Australian commercial multistory PV-integrated building demonstrated this goal by reporting diminution of one thousand six hundred tons of Carbon dioxide per annum (Eiffert, 2003, p.16 & 17).

Prasad and Snow states that an example of environmental benefits was demonstrated in the New Munich Trade Fair Center in the United States which was portrays to be the largest and most technically advanced rooftop PV plant installed in the globe as of that time (Prasad and Snow, 2005). “And this grid-connected system according to Fact Sheet for New Munich Fair Trade Center was calculated have an efficient output of 1 megawatt. and supplied electrical energy of 1 million Kilowatt-hour per annum, and was estimated to be equivalent to German households consuming annual power of 340 and speculated to reduce CO_2 emissions of one thousand tons yearly" (Fact Sheet for New Munich Fair Trade Center, 1996).

3.3 Relationship of Sustainable Economy with PV Panel

Economic aspects of PV can carried out as soon as the technical requirements of a PV application have been state and a PV system design is completed. The economic valuation of PV comprises both costs and benefits of the system (Whisnant, Johnston, and Hutchby, 2003). The main question is that how we can prepare any formula or any tools to calculate that which type of PV cell are appropriate for your house? According to this issue, it has lots of way to understanding of appropriateness. However, it should be analysis in some items like efficiency, cost, life period of PV panels and availability in market. The first and probably an effectible issue is cost, so the panel or module has to be exanimated for finding which type can be more acceptable by user.in this section some analysis tools will review.

3.3.1 Payback Analysis

The pay-back duration is the least time to recover the investing cost or duration of PV panels that producing electricity equivalent (E. Alsema). Duration times calculate by the total initial cost plus addition cost should divide by incomes of production in a year. In payback analysis (PBA), the measurement item in pay-back analysis is the number of years on investment cost. According to this analysis, the PV with short payback has low risk. Simple PBA estimates only preliminary costs and energy production cost at present. This analysis neglects numerous substantial cost factors, such as escalation cost rate and the capital-cost so; PBA can over-rate the real payback period, and thus, the measurement of time in this method risk is too high for cover the investment. The main two variations in PBA are tax pay-back and cut-rate payback. Tax Pay-back contains as rate of final tax evaluation and depreciation. In the cut-rate (PBA) method, future incomes are more than current incomes.

For investing financial, who aspect to return- rapid money in the PV Panel market the financer becomes more pleased when the pay-back time decreases. Fundamentally, the pay-back time is the break-even point. Payback might be considered as the determination of Min. time that system spent to cover the main investment costs.is pay-back really depend many issue. For instance, Alsema estimated that 650 Kwh/m2 energy produced by multicrystalline cell or 450 kWh/m2 by Monocrystalline is used to make near-future, frameless PV systems. Assume that 12% efficiency by standard circumstances and “1700 kWh/m2 of available” sunshine radiation (yearly), Alsema assume the pay-back is four years for available Monocrystalline PV module. Prominent 10 years to the future, his mention is "solar-grade" with 14present efficiency, reducing the pay-back about two years. Another calculation support is for amorphous cell. Alsema approximations, the amorphous PV cell without frame and 120 kWh/m2 with a frame and supporting structure for the roof, standalone system at 6 % efficiency in standard conditions in the same available sunshine radiation shows that payback by current thin-film PV systems is three years (Alsema, 2010). Kato and Palz calculation shows are even less than paybacks for amorphous cell both going from one to 2 years (Kato and Palz, 2011)

3.3.2 Analysis by “Life Cycle Cost”

“Life Cycle Cost Analysis” show in similar condition and applying initial cost and all of the investing money in available time analyzer to find out which one is more efficient if it is unacceptable by the user either acceptable. In LCC examination, all related components are present and future costs link by the duration of energy system although, in present, future or annual value period such as the long-life of system. These analyses are not limits to energy, any type of achievement, installation-type, duration, maintenance, operations, and any kind of repair, national interest and discount ratio. Comparison of differ system an alternative controls are the most function of the analyses (LCC analysis). In this method, the computations of two systems are different so, it might be lower or equal (Rough and Marshall, 1990).

3.3.3 Net-benefit, Analysis

The Net-benefit analysis's it is the mensuration tools to calculate differentiation of net-cost and the cost-benefits of PV module in co-corporation of present or annual value currency. The Net-benefits or net-present values duty is to find variance of between present value and the cost value in present. In this Analysis tool represents the cost effectiveness positive if the module is appropriate. Decision about the BIPV systems has direct mark in process and time-line. Evaluation of PV benefits cannot be identifying whiteout considering of direct and indirect economy impact as well as the quality of value.

3.3.4 Direct Economic Impact

Integrating any buildings by PV panels generally is obtained by construction budget. Generating Electricity by PV system and integrating into building save and reduce budget. Reducing electricity costs and decreasing of construction material costs is the main target of BIPV system in addition of improving quality and reliability of power. The combination of building and PV may affect investor or owner of the building to save financial performance of the portfolio (EPIA, 2011).

3.4 Relationship of Sustainable Social with PV Panel

From social sustainability dimension standpoint, this aspect can be tackled from workers health and safety or security, impacts on local communities or quality of life, impact on employment and benefit to disadvantage groups such as the disable people. From construction point of view, PV creates employment and business opportunities, plus the opportunity for skills development and on-site training. On the other hand, looking at it from operational standpoint, the main social issues affecting the operational stage is from positive impacts, which include employment creation and opportunities for business. It also create opportunities for skills development and training; Benefits associated with the establishment of a community trust; and establishment of infrastructure to generate renewable energy (Barbour and Rogatschnig, 2012).

Photovoltaic impact on public health and social wellbeing is from the atmospheric potentially hazardous materials during its production. For example, during production of silicon cell possibly may have effects on health which includes lung and kidney damage. While in the case of gallium arsenide technologies, the harmful part of it is from the cadmium or arsenic compounds during processing and handling in manufacturing industries, and can pose health effects that can lead to kidney damage, hypertension, and, possibly, carcinogenesis; while on the other hand arsenic, carcinogenesis is the primary potential effect. In this context, we can say that the danger of PV to health depends on toxicological properties of materials, however some of this toxic materials are sometimes carcinogenic or flammable; intensity or concentration and can have effect on human health. Vulnerable to low levels of toxic materials over long periods could affect both workforces and the entire public. Sometime, it can be subject to the obtainability and efficiency of safety and pollution control systems (see table 3.3) (Fthenakis and Moskowitz 2000).

From the simplest standpoint social impacts comprises, increase of the regional/national energy independency; provision of significant work opportunities; diversification and security of energy supply; support of the deregulation of energy markets; and acceleration of the rural electrification in developing countries (Theocharis,Tsoutsos, Frantzeskaki, and Gekas, 2005).

Table 3.3 Social Impacts on Health Risk of PV Cell Components

S/N	PV Cell Component	Effect on Human Health
1	Silica (Si02).	The mining of metallurgical grade silica can produce silica dust that has been associated with silicosis, a severe lung disease.
2	Cadmium (Cd)	Known carcinogenic. Extremely toxic (EPA and OHSA). Potential to cause kidney, liver, bone, and blood damage from ingestion. Lung cancer from inhalation. Workers may be exposed to cadmium compounds during manufacturing. It is restricted by RoHS directive.
3	Silane (SiH4)	Most significant hazard. It is extremely explosive. Dangerous for workers and communities. The semiconductor industry reports several silane incidents every year, although some companies use an alternative that in turn could be used in the PV industry.
4	Chlorosilane (HSiCB)	Very toxic and highly flammable

5	Silicon Tetrachloride ($SiCl_4$)	Extremely toxic substance. Causes skin burns, and is a respiratory, skin and eye irritants.
6	Hydrogen selenide (H_2Se)	Highly toxic and dangerous at concentrations as low as 1 part per million in the air. Will present occupational health and safety issues.
7	Sulfur hexes fluoride (SF_6).	Extremely potent greenhouse gas. Accidental or fugitive emissions will greatly undermine reductions gained by using solar power
8	Selenium dioxide (Se02)	Potential formation at high temperatures. It is a tissue poison like arsenic. The recovery of selenium is very high but not 100 percent.
9	Sodium hydroxide (NaOH), hydrochloric acid (HCL), sulfuric acid (H2S04), nitric acid (HN03), hydrogen fluoride (HF), phosphide	These components require special handling and disposal procedures because of possible chemical bums and risks from inhalation of fumes.
10	Kerf (waste silicon dust from sawing c-Si wafers)	May generate silicon particulate matter that will pose inhalation problems for production workers and those who clean and maintain equipment
	Lead (Pb).	Highly toxic to the central nervous system, endocrine System, cardiovascular system, and

		kidneys.

Silicon Valley Toxics Coalition, 2009)

3.5 Chapter Conclusion

In this chapter review the effect of PV panel in sustainability (The main reason of relationship of PV panel and sustainable is energy production).So, according to definition of sustainable building PV has been analyzed according to three major components such economy, social and environment point of view. As social effectiveness of PV panel in recent days may classified intoCo2 emission or generally is pollution of our environment. PV panel industry can promote sustainable development human activities, when compare to other kind of conventional (un-renewable) sources of energies. On the other hand, product the energy by householder or local government led to national dependency. The main advantages of PV panel's usage are associated to the mitigation of Air pollution, which can decreasing the emissions of the greenhouse gases and avoidance of toxic gas emissions or in stand-alone might decreasing of the required transmission lines of the electricity grids that will reduce material usage and cost as economy issue. In addition, we have lot s of tools to calculate the economic status of PV panel in compare of fossil fuel source. However, the result may change according of circumstance of the region that should apply. PV industry has positive effect in social in view of sustainability such creation of jobs, intercommunity and associates in sociality. Further information has shown in table 3.1.

Chapter 4

PHOTOVOLTAIC STATUS AND PROSPECTS IN EUROPE

4.1 Introduction

This chapter highlights the applications and policy of PV market trends in European Union countries and selected 2two cases studies in Europe countries, such as Germany and Italy. In addition, it also discusses about detail of energy consumption in relate to use renewable energy and analysis the German and Italian strategy's in the PV module, promotional and institutional aspects, state and local policies, incentives, building permit rules and regulations, building planning and permitting barriers for PV cells/module situation. The reason to choose those cases is; Germany is leadership in the whole world market and this promote is indebted to advance technology and hard work plus focus of the government to reduce fossil fuel by successful regulation and registrations. All detail of German model shown it is best model to practice and follow. On the other hand, Italian model was not success till 2005, meanwhile now they are occupied the second leader ship in PV industry. On the other hand, Italian model start with many mistakes and problematic strategy and much permeation needs. This situation make Italian model in bureaucratic impaction but now days Italy is second leather ship in world. In fact, they can be perfect example of success to promote the PV industry and apply to new regulation of North

Cyprus. However, EU regulation and legislations is the main source for all EU country, especially for North Cyprus that wants to be part of it in early future.

4.2 EU

According to annual report of UE institute, The European Union has twenty- seven member-states and the total population is approximately (501M) by total wealth value 16.3 trillion ($) in 2010. As it is clear four of the world largest economies located in the European Union (Germany, France, UK, and Italy). EU tries to achieve low-carbon emotion in case of climate change and be sure that these types of energy (RE) secure economic growth and create job. The Idea of changing of climate goals is the main most EU legislation issue. The EU is 17% of the world energy consumption and the main role-plays by Buildings approximately 40% of the total energy. The (Figure4.1) shows that, industrial sector has 34% of this share (EPIA, annual report.2009).

However, the transport sector share of energy usage is almost 26%. Approximately 50% of total energy that produce in EU is utilizes by Germany, France and UK and 20% of total volume energy employ by Italy, Spain and Poland (Figure4.2).

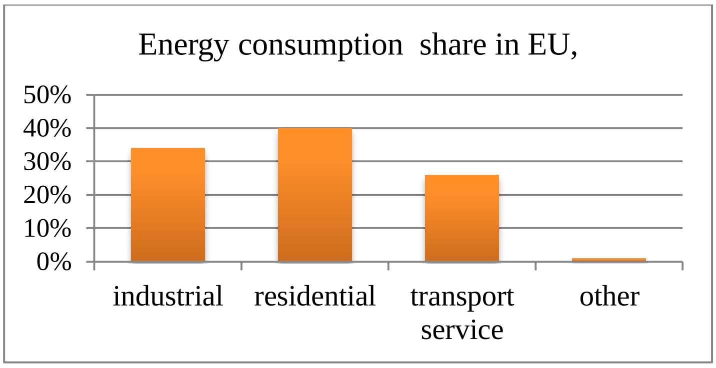


Figure4.1: Energy Consumption Share in EU (Wissel, &Voß , 2008, p. 14).

Moreover, For Cyprus, Greece, Luxemburg, Ireland and Malta countries, 70% of their energy based on oil due to transport sector. Sweden, Norway and Finland in Nordic regions and Czech Republic, Slovakia, Hungary and Romania in central European countries decide to decrease their oil reliance energy source and replaced by electric and gas source in average of 25%. In addition, Biomass has the main role to supply energy in Austria, Latvia, Estonia, Finland and Sweden (Red Eléctrica de España, 2009, p9).

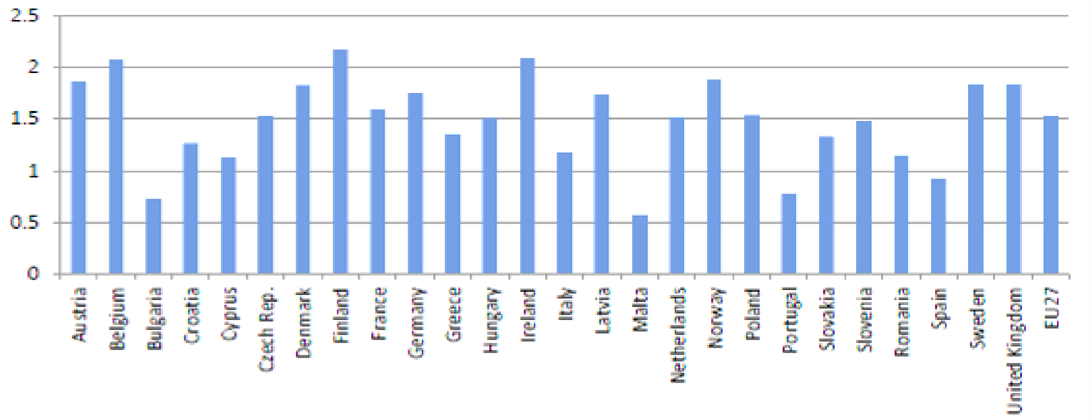


Figure4.2: Utilization of energy in EU.

4.2.1 EU PV Market Structure

Bloem et al. present that, The EU place as first major of the Photovoltaic (PV) market in worldwide by utilize more than therteen13 GW installed between 2010 till 2011, and total capacity of installation of the PV module in that moment changed from 16GW to nearly 30GW in 2012(Bloem et al., 2012). This situation was due to Germany, Italy and the Czech growth of producing in PV industry (Figure4.3). On the other hand, in 2010 France rapidly grows and they installed 719 MW. After Spain disaster in 2009, Spain recovered self-market moderately, and they reach 369MW annually. In addition, also other parts of EU market grow up in sustain mood.

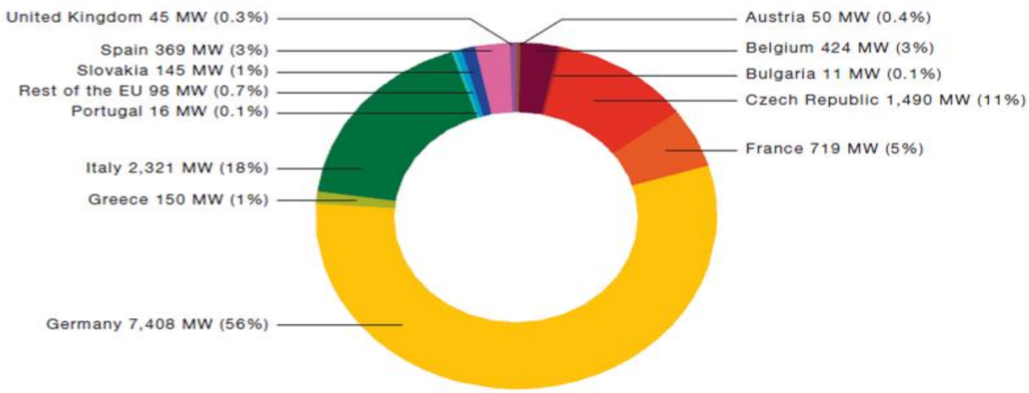


Figure4.3: EU market share in 2012(Bloem, 2012).

Within limit time, European Nordic markets gradually adapt to energy efficiency production, and the result was forming of legislation. The German market is the most developed and competitive market for energy efficient sectors and subsector. Their businessmen and financier in PV industry survey produce 67 Billon €, this amount made Germany more than 10% of the entire World shareholder (Figure4.4).

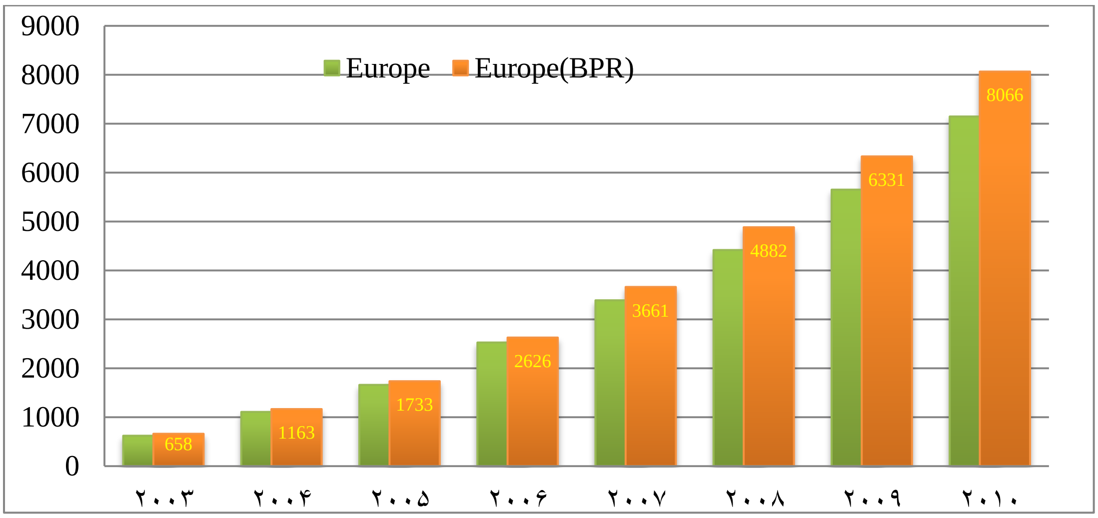


Figure4.4: Estimation of the Cumulative Installed PV in EU. (Source: EPIA, IEA)

4.2.2 EU Photovoltaic Strategy, Regulation Framework

The PV Policy database focused on market-policy promotion. That policy based on the national level, so in the part most important key is first, measuring of demand and government definition for improves the attractiveness of the PV panels' investors. In addition, control the developing of the sales markets for usage of RE. The reciprocal exchange and transfer of the knowledge are second aim of The PV Policy data-base in between the countries. The focus in European policy is strategy that draws the future of PV panels in Markets and convinces the producers and investors by several incentives tools in economical aspect.

4.2.3 EU PV Industry Structure and Development

European Practice Report, estimate that the Production capacity in EU is 30GW and The Photovoltaic panels has generate more than 35 TWh of electricity. Spain produced 6.3 T. Watt hours by PV in the summer of 2010 with 3.5 GW capacities (Table, 4.1). This view shows 1.2% of the European countries the electric demand. In the Policy-Driven scenario, around 15 to 20 TWh could produce additionally each year until 2015, adding 0.5 or 0.6% of PV to the generation mix in the EU every year (EBPR, 2010).

Table 4.1: Electricity capacity in EU. (Source: EPIA, IEA)

country	Capacity (2010)
Germany	12 TWh
Italy	1.7 TWh
France	0.6 TWh
Spain	6.3 TWh
UE(total)	35 TWh

If this rate continues, by 2020 more than 6% of total demand could be provide by PV, as forecast by the Accelerated Growth scenario of the EPIA SET for 2020 report. To reach the 12% target forecast by the Paradigm Shift scenario the same date would require an additional 1% of PV in the total electricity production mix every year until 2020. In terms of energy produced based on expected growth in energy demand by EBPR in 2010, this represents around 40 TWh of additional PV production each year for the next 10 years (EBPR, 2010). This would mean an average yearly market for PV of 35 GW, in comparison with the current annual market of 13 GW.

Photovoltaic panel is the most important renewable energy technology in terms of size grows up in 2011.in addition Figure4.5 Show the total power energy generation capacity (renewable and nonrenewable) energy in2011.

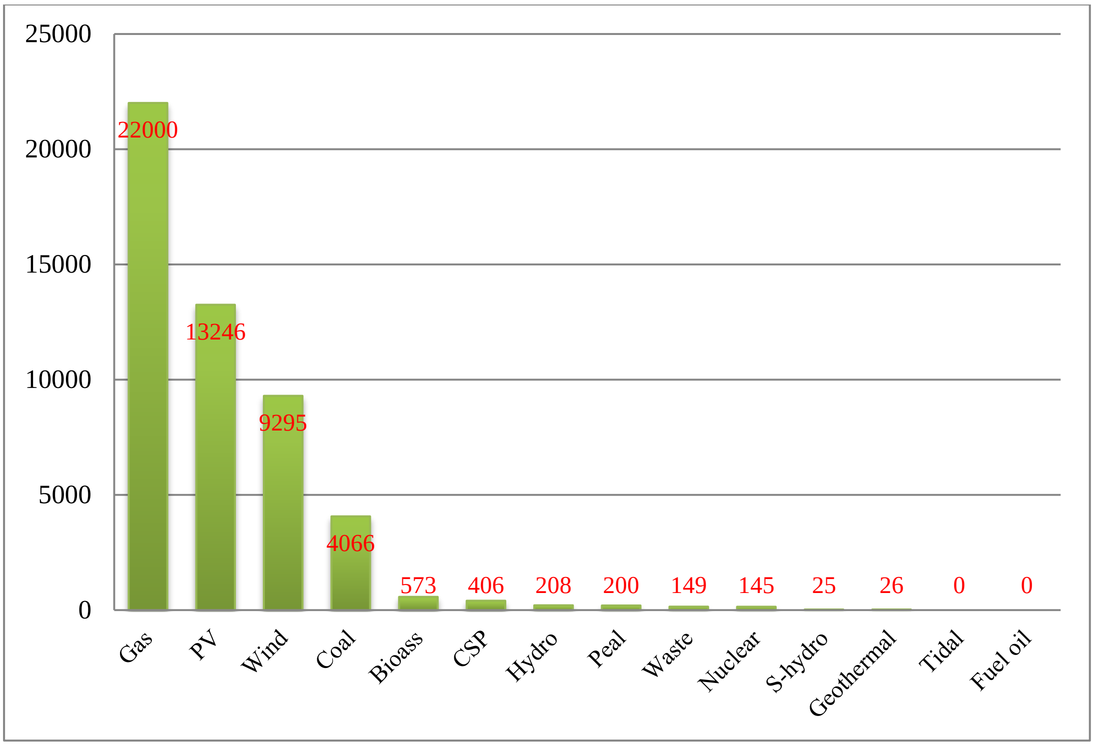


Figure4.5: Power Generation in 2011 in EU (Source: EPIA, IEA).

4.2.4 EU Policy Background

In 1997, the European white paper (committee) set up a strategy for double-up existing share of renew energy situation as 12% in 2010, this European strategy was based on pre-Kyoto protocol. The aim focused generally on member potential, encourages them, and increase of renewable energy accordingly (Krauter, 2006, p. 95). Then, foundation of “The European Photovoltaic Industry Association (EPIA)” merges (3GWp) and installing Photovoltaic generator up to (2010) and creates at least “100.000 jobs” in this market (EPIA, *annual report*.2007). 2001, was the beginning point of Green Electricity Directive commission, their aim were create the unswerving framework for promote the PV usage and producing energy in European Union. This committee in 2005-6 was assessed drew the existing national models for the achievement of national targets.in spite of this strategy, The Lisbon Strategy mentions 3 focal mission: firstly, Imperatives Growth , Competitiveness and finally Employment (Krauter, 2006).

4.2.5 EU Regulation in BIPV

Generally, increasing policy opportunities to support Buildings that Integrate by the Photovoltaic panel via custom-made incentive programs have been promote. These measures made the buildings necessities and efforts to prepare law or code regulations. According to this assessments the experiences in Italy and Germany, Incentive programs such as feed in tariff for BIPV can help to growth market opportunity (EUpD-R&D, 2009).

In the small scale of BIPV such rooftop, the “feed in tariff” made PV installation by more than 10% grow up and specific “FIT” has influence to low-digression rates markets (EPiA, 2010). These definitions do not cover traditional building, and some government have labeled them as building applied by Photovoltaic panel (BAPV).

Italy and Spain are the example of occurred unexpected TAX, where the main tax for residential PV sector was help them to charge” VAT” for selling the power to the grid. The benefits of BIPV its multi-functionality and its appealing aesthetics and ability to be building transforms to apply to roof, facade ,atrium ,and etc. but, in some regulation PV panel act as unobtrusive active energy generator. Although, the BIPV market has been rapidly grow up due to mechanisms of support. It is mainly happening in Italy and France, where the share of BIPV in 2002 and 2009 totally changed (see table 4.2).

Table 4.2: BIPV Market Mechanism in EU.

Country	Feed In Tariff	Tax Incentive	Subsidies	Loan	Other
Austria	Yes	Yes	Yes	Yes	no
Czech Republic	Yes	No	Yes	Yes	Yes
Denmark	Yes	Yes	Yes	Yes	Yes
France	Yes	Yes	Yes	No	Yes
Italy	Yes	Yes	Yes	Yes	No
Spain	Yes	No	Yes	Yes	Yes
N-Cyprus	Yes	No	No	Yes	No

All European Union countries have especial support mechanism for incentive the market and producer such as:

- Special FIT
- Tax incentive
- Investment subsidies
- Incentive programs
- The Green loan or financial support

In the table 4.2, modify the euro counties have or have not specific incentives for BIPV. However, in UK, special requirements for renewing buildings take into account the potential of integrate the PV to the building requirements. At least in UE definition of policy is the government and administration right in this reason government has duty to approbate of the existing products and qualified them (Talaretti, & Zizzo,2009). Talaretti survey that, explanation and any type of understanding of laws, modifying, improve are government title. Especially in France and Italy the definition and explanation of PV, policy is very important and because of this problem, they start their BIPV tariff and other issue lately. The definition is affecting PV manufacturers as they try to develop products and preparing the future strategic, according to their competitive approach. Other duty of the policy is controlling and recognizes standardize the products manufactured at large scale.

4.2.6 SWOT Analysis of EU PV Panels

The SWOT analysis (in case of the EU Photovoltaic status) focuses on two level: first, the analysis of the strengths and the weaknesses, and secondly, the opportunities and the threats. For the SWOT analysis, we have identified a number of key issues that deal with PV technology section.in this reason, the main issues key on the subject of S-W-O-T are:

- Research and Development
- Industry
- Policies regulation and registration
- Market structure
- Intruding technologies

As result, the main findings and conclusions from the SWOT analysis present in the table 4.3.

Table 4.3: SWOT Analysis of EU PV Industry

EU PV Strengths
Europe has strong and high level R&D quality in PV covering all major technologies well Spread.
The high-tech nature of PV is appealing and countries with a PV industry recommend sustained R&D efforts.
Well-developed R&D communication networks mainly due to EC funded projects that help to create teams with various competencies into PV RTD projects.
The SME structure of the PV business in Europe enables fast reactions to the market needs
European R&D strong in thin film cells, organic cells, polymers, BIPV and advanced stand-alone systems.
The existence of the roof program that stimulate the PV market.
European industry is strong in BOS and stand-alone systems.
EU PV Weaknesses
Because PV RTD is evenly distribute both in technologies and geographically, effort is dilute and may not keep Europe competitive in key areas.

Too few countries have dedicated PV program.
Not enough countries have fully coordinated program.
Communication between the academic and industry R&D with policymakers is not frequent.
Academic R&D and industry have different priorities.
European PV companies, which are often SME, are not making enough profit to be able to develop, on their own ground, new technologies/concepts that are not immediate commercialized.
EU PV Opportunities
EC policies on security of supply, the Renewable Energies directive and the fulfillment of the Kyoto targets stimulate the PV market.
Renewable Energies including PV have by their nature long-term potential.
Research co-operation between Europe, Japan and the USA speeds up PV RT
The extension/increase of current roof programs and widening to other EU member states creates more solid base for PV industry.
A stable PV market stimulates industrial involvement and availability of financial risk capital.
Developing countries offer remarkable market for stand-alone systems and small

grids in.
Thin films (other than α-Si), polymer cells and combinations between crystalline silicon cells and thin film technologies open up potential for cheaper and new type of PV module production.
Cross-fertilization with other industry, areas (thin film, glass coating) create possibilities for new production concepts.
Co-operation with the building sector helps them to understand what PV cab Offer and PV industry understands about the building sector trends.
EU PV Threats
Resources spent on PV R&D without substantial commercial success may result in redirection of R&D funding.
PV RTD is a long-term investment and the current PV market relatively small so that stakeholder's interest directs somewhere else.
Latest strong growth of PV is based on roof programs. If they reduced, that may threaten RTD programs.
Liberalized markets tend to favors low cost, off-the-shelf technologies, which is a threat PV technologies being a "new" creation.
Developing countries offer remarkable market for stand-alone systems and small grids in.

Big parent companies become impatient in poor profitability of PV and reduce forts to it.
The stop and go of policies and funding programs create uncertainties to PV RTD.

4.3 Italy

In EU annual report in 2008 mention, one of the greatest talented RE sources in Italy is producing energy by PV. The PV market was motionless until 2006 and faraway from other European countries. The condition changed totally for the last 3 years. This country has a potential of renewable resources for the PV energy. High sunshine irradiation with annual variance of less than 10% heavy necessities on imported un-renewable energy like fossil fuels, and Kyoto Protocol aims on decrease of CO2 emission (Figure4.6); drive Italy to increase RE production.

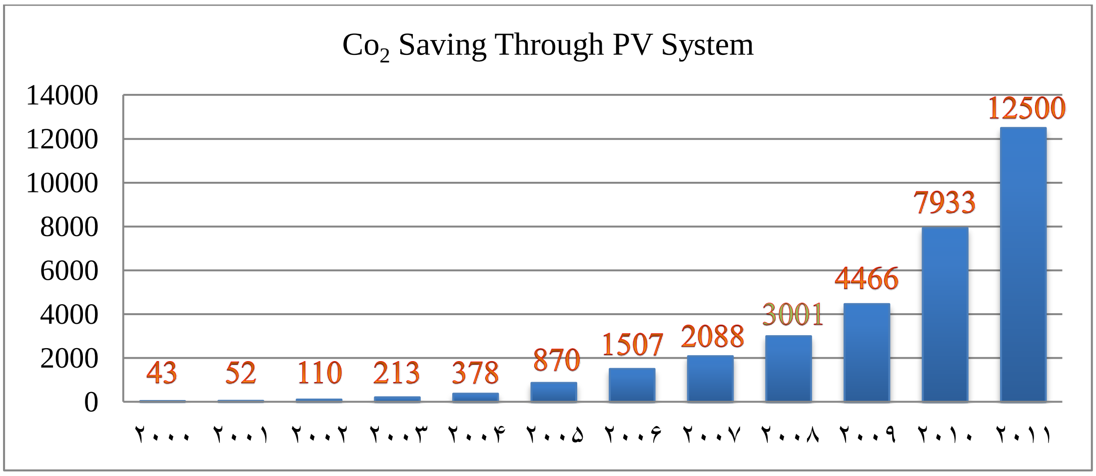


Figure4.6: co2 saving during 2000 until 2011(Source: BMU, BSW-Solar 4/2012).

Therefore, Italy has started this system with several incentives to use more renewable resources. Two main incentives in this relevance are:

1. Tax concessions
2. Aid for investments

The policy incentive instruments was the most successful patronage tools is feed-in-tariff that confirm remunerative prices for long-term producers (Abengoa Solar, 2008).

4.3.1 Italian PV Market Structure

After of extensive and investing in plants project in 1980-90, the Italian Photovoltaic markets in recent years has been experience that very sluggish development. The reasons were long postponements and operation problems of political resourcefulness.in addition; the existing market status obviously dominated by the small scale of “grid-connected” systems. Less than 20 kWp promote by the national support system (“Tetti Photovoltaic”).then the Italy Photovoltaic industry try to expect the administration of the new feed in tariff since 2005. Photovoltaic image and acceptance level was still low in compare of EU view and strategy (IEA:”Electricity from the Sun”, 2007.P.8).

The R&D & Priority Techno of the European in 2010 report that “(Strategic Energy Technology Plan, web page) Annual installed capacity was more than 6 MWp in 2004 and during 2003 they produce more than 4MWp”. “In comparison in EU Total capacity in 2004 installed was 36 MWp and 30 MWp in 200”3. In Europe Union Annual growth rate was further 50% in 2004 and that report mention in 2003 growth was 20 %. Since the early feed in tariff released, some market actors calculate, it will grow up 80 MWp in 2007 until 2008. The 68% of Market structure and Market segmentation are grid-connected system base and 32 % occupied by standalone market in Italy (R&D UE institution, 2010). The new feed in tariff should be present if the grid connected market increase the shareholder. Administrative processes show that Complexity of planning process was very bureaucratic due to influence of the government. Strategic plan action for the small scale of Photovoltaic installations was v domain by the application of subsidy and granted by region proposals. When the agreement not approve, the real planning and implementation parts will not start. There were No any experiences in large scale in the Photovoltaic project until 2008, but the wind energy sector was very different. The new feed in tariff has start in 2009.

The transmission of the grid connection operator changed the centralized authority process of the Photovoltaic panels' situation to good condition (EPIA: "Photovoltaic Industry Association," (2010). In 2009, the PV market grew unexpectedly fast as a result of the larger than expected expansion in several countries, one of which was Italy with 730 MW installations (Inflation.eu, 2010). This shift made Italy the second largest market in Europe. By August 2010, the cumulative capacity reached 1.5 GW54. Summary of the Status Qua shown in the (Figure4.7). Some of the developments have a very significant influence on the expansion of the photovoltaic market in Italy from the economic viewpoint. The first step in this country was the electricity price increase (6%) for the end-user to create incomes and more investing in the Renewable Energy R&D. The scheme was later replace by obligation for producers and importers and provide at least 2% of their previous year electric production into the avidity (Etrion, 2010).

Average irradiation (kWh/m2/year)	1650
Residential electricity rate (EUR/kWh)	0,22
Estimated year of grid parity	2015
Electricity power generation (2010)	84 GW
Cumulative installed PV (Auq 2010)	1.5 GW
High irradiation levels south of Rome	
High retail electricity prices High FIT rate	
Among first to reach solar grid parity	

Figure4.7: Statues of Qua In Italy. (Source: Etrion, 2010)

Guaranty by Government and volume of solar radiation in a year are the critical factors for the stability of investments. Also Wholesale prices are another cause to increase the growing demand for electricity. Due to technical developments and current oversupply in the market, most probably Equipment prices are expected to decrease. In addition, one of most important facets is the “grid parity”, which is the fact of electricity from RS equals or cheaper than the grid electricity network. Italy reaches the first “grid parity” PV market in EU. The Photovoltaic market expands, in 2009, amount of energy production was extending to 200 kW, and this allows the PV sector produce electricity at the same price as the grid (Gregg et al., 2003).

By focus on the European Photovoltaic Industry Association report, two reason growths the PV market for the next 4 years. The first one is the consideration of moderate market development without major political support, but does account for adequate follow up of the Feed in Tariffs. Another based on the policy-driven scenario, which assumes strong political support in combination with FIT, dropping of administrative barriers, and improving the grid-connection facility. Those reason made Italy market as the second largest PV market in Europe Union with a positive vision. “Jefferies & Company” claims that, Italy has best opportunities to attract projects in large-scale for instance solar parks. Another motivation is Italian banks that provide a source for keeping Internal rate of returns of projects by increase debt financing resource. Higher encouraging in terms of Feet in Tariff for Building integration Photovoltaic Panels (BIPV) systems (Jefferies & Company, 2011) supports innovation in production and applicant for rooftop systems. On the other hand, in Italy one of the main bugs in the Photovoltaic market is still complex actions of government. To guarantee of future growth streamlined and harmony should be consider.

4.3.2 Italian Photovoltaic Strategy, Regulation Framework

First National PV target in 2000 was to producing the 300 MWp until 2008 this was the Italian government “White Paper” target. However, this target has change to producing total Renewables energy set to 100 MWp until 2012 that means increasing in future if it’s possible. Italian National PV strategy plan worked on this strategies and policy framework for Renewables Energy raise, but the result was negative. The national support scheme “Tetti Photovoltaic” although budget was well but they never reach those targets. The mine cause was administrative problems especially in operation. Using the green certificates” in 2002 was not appropriate for RE based on fix feed in tariffs decision. In this reason, they edited new Renewables policy and published in end of 2003. However, one more time discussion about the details delayed submission. Finally, new policy was launch in 09/2005.The Italian energy policy control and applies by “the Federal Industry Ministry” (MAP) in company with the Environmental Ministry (MATT). MATT plays an important role for regulations of the electric sector and authorities of the grid operators. The feed in tariff system, which show in blow table (Table 4.4) by GRTN was the central authority and introduce coordinated competitive tender system.

Table 4.4: Feet in Tariffs in 2011.

Feed In Tariffs						
Power capacity	1 January 2011 to 30 April 2011		1 May 2011 to 31 August 2011		1 September 2011 to 31 December 2011	
	PV plants installed on buildings	Other type of PV plant	PV plants installed on buildings	Other type of PV plant	PV plants installed on buildings	Other type of PV plant
kWh	euros/kWh	euros/kWh	euros kwh	euros/kWh	euros/kWh	euros/kWh
1<P<3	0,402	0,362	0,391	0,347	0,380	0,333
3<f<26	0,377	0,339	0,360	0,322	0,342	0,304
26<P<200	0,358	0,321	0,341	0.362	0,323	0,255
200<P<1000	0,355	0,314	0,335	0,363	0,314	0,266
1k<P<5k	0,351		6,357		0,362	0,244
P>5k	0,333	0,297	0,311	0,275	0,257	0,251

Source: thermo-solar-conto Energia)

4.3.3 Italian PV Industry Structure and Development

Gregg et al. assessor shows that the PV module producer and companies, which produce the Photovoltaic panel mainly, focus on export to the global market rather than self-marketplace. The main aim output was increased “8.4 MWp” in2004, and manufacture capacity was further extend to 13 MWp in 2005. Early in 2011 The annual Photovoltaic power in Italy archived more than 33% of the worldwide marketplace, this place change the Italy as second market worldwide leadership of the year (before Germany which anyway maintained the leadership for the accumulated power with 2.47 Twp. (Gregg et al., 2009). Moreover, Italy produces 1.27 TWP and in May they became1.31TWp in world. With nearly 340k, PV in this country the generating of electricity from solar source is 1.4 TWh per year and still continuously growing. The region which shows in Table 4.5 produce most installation is Puglia region by producing at least 17.1% and next is Lombardia by 10.3 %.

Table 4.5: Most Install Region in Italy

location	Produces of energy	number of plants
Puglia	17.1	12.3
Lombardi	10.3	14.7
Emilia Romagna	7.2	9.7
Veneto	9.6	13.6

Montanino claim that 49% of the total installed generator in Italy is on the ground and 41% of them placed on roof-top. The Shelters percentage is 6%and residual occupied 4% oh whole share (Figure4.8).

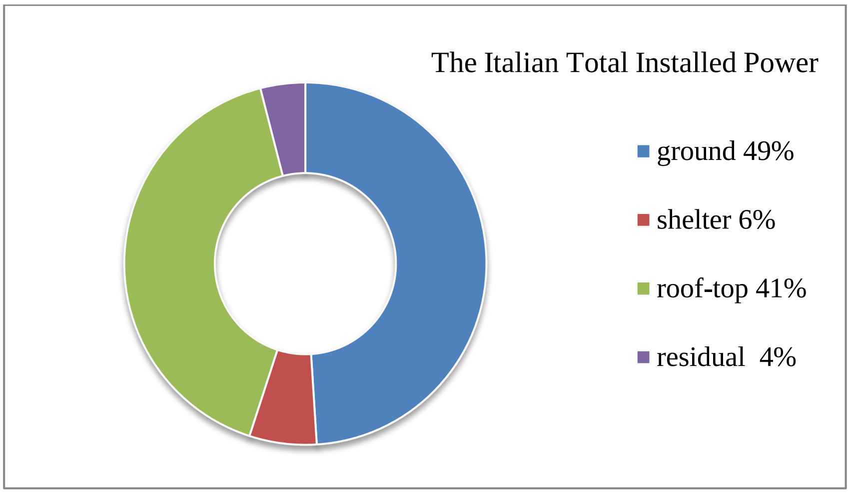


Figure 4.8: Italian sector shareholder in 2012.

Montanino also present that: In terms of producing by PV cell has mention, 70%of the Modules are single or polycrystalline in compare of 23% Monocrystalline and the rest is thin-films (7%).(Figure4.9).

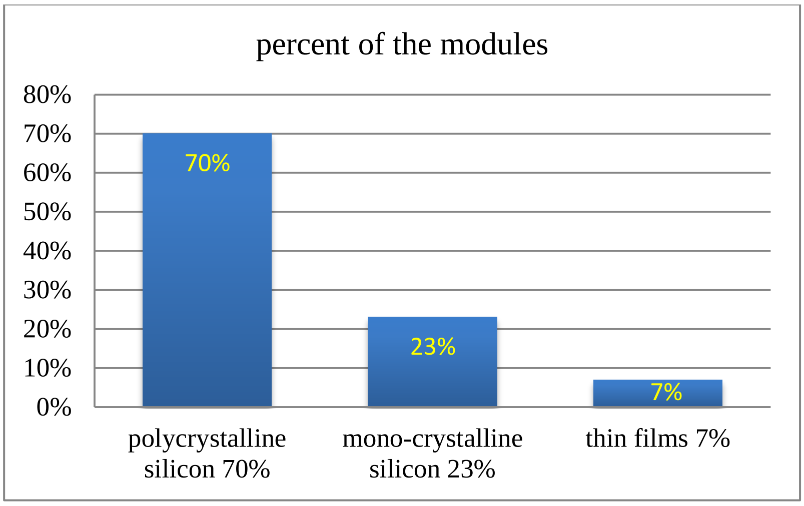


Figure 4.9: module proportion in Italy.

Approximately 65% of the PV panel electricity are supporting the manufacturing sector, meanwhile the agriculture and services section use just 26% equally share and the 9% left for the residential sector (Figure4.10).

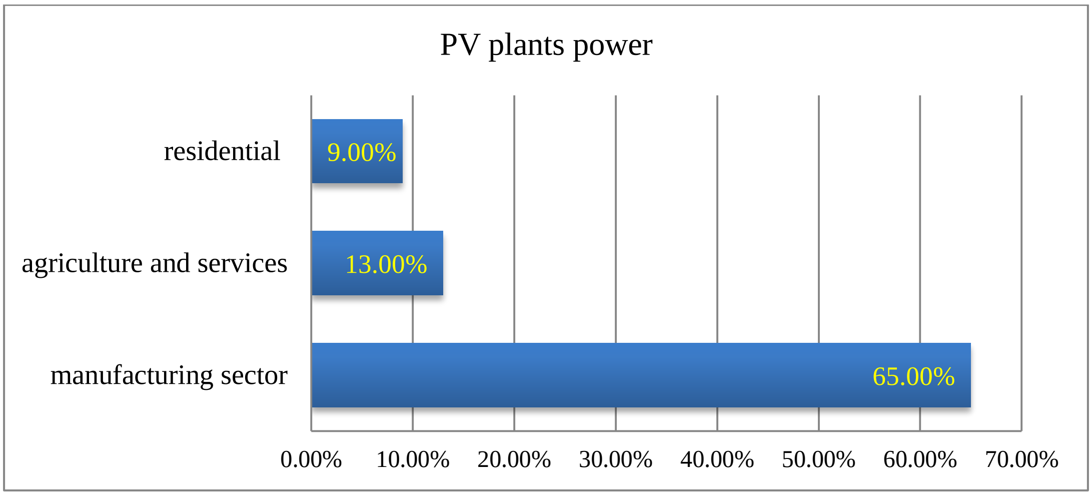


Figure 4.10: electric consumption sector in Italy

The contribution of producing power in the Italian market shows that shareholders of companies are 89% and energy product in the private sector are less than 9% (Figure4.11) (Montanino, 2011).

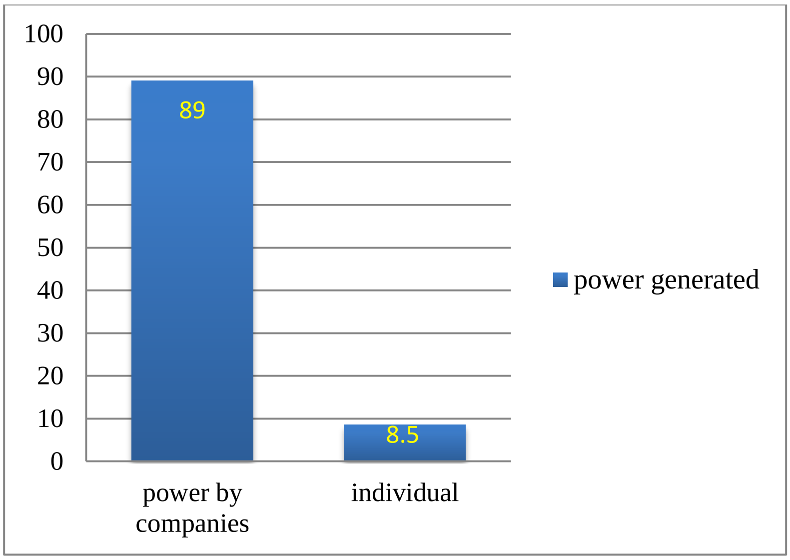


Figure 4.11: energy production share in Italy.

4.3.3.1 Permissions in Italian PV Industry

Four different permissions have to take by the investors.

1. Building permission
2. RES plant registration (feed in tariff)
3. Grid access concession
4. Tariff contract

The permission for BIPV is necessary and should be approving by municipality. Other requirements are local administration duties. In addition,it will take by the sponsor. For large-scale projects like Plant Park, an environmental impact analysis (V.I.A.) is requisite too.

Local administration, Local grid-operator and utility National grid-operator GRTN are the permeation-required authority in Italy.According to GRTN official web site, Duration of permeation and process of plan for the investor is at least 18 months averagely, and average of subsidy application is less than 1 year. The Large-scale schemes are approximately 2 or 3 years. The new regulation streamline of governmental processes in maximum three (3) months for agreement (GRTN, 2010). According to Caprioli (2009), mention that “the Grid access approval and utility within further is one month and commissioning of the plant within 12 months and 24 months (a year)for installations less than 50 kWp equipment”.

4.3.4 Italian Regulation in BIPV

The last edition of Italian the “feed in tariff” (“ContoEnergia”) the aim is increase the volume of PV generator in market and inject to grid. Mostly new installations are grid connect system which applied or integrated to building (BIPV). However, in

Italian guideline not mention any specific regulation or standard about Building Integration of PV. Integration of any types of PV panel into the building envelope it should be calculate as a building element and all fulfill requirements are contained as “Normetecniche per le costruzioni” contains the whole set of Italian standards and relation of plan and realization of building sector. However, for grid connection systems all relevant rules just stated in the “Guida CEI 82-25 and realization Guideline for PV systems connected in Medium and Low class (GazzettaUfficiale, 2005).

4.3.5 Advantages of the Italian PV Market

Italian market expected to remain to offer above Market yields due to low risk (Jefferies & Company, 2011). Italian banks donate to keeping the projects in high position by improving debt financing in case of subsidy or green loan. Total prices expected to increase; because of demand will be increase for energy. Another advantage of PV market in Italy is extended net metering that means allows the PV producer to involve electricity production value in same price from the grid. If there is extra electricity or overflow in grid, operator of the PV plant can obtain a credit for the excess of electricity production.

4.3.6 Disadvantages of the Italian PV Market

Italy promotes charming, promising and engaged opportunity for stockholders. Meanwhile, the number of restrains enhances the risk factors for financier in PV industry and amongst

1. The regional permitting issues
2. Installation costs is to high

3. Influence of Mafias on the PV market
4. Too much Taxes and Penalty
5. Bureaucratic imperfection

Furthermore, the complicating in administration process due to the bureaucratic augments the resource and time. This authorization process to take a license to connect energy in grid-confused administrative authorities so, regulations are mostly contrast, and this is the cause of, a lot of projects frozen in point of authorization, in this reason permitting is extremely difficult in overall. Another factor to increase investing Italian PV market risk is the doubt and suspicion of the support scheme. The providing any incentives lately make the industry more and more attractive, additionally, high sunshine hours are the most important factor. Therefore, discount as a subsidy is extremely appropriate for improve the PV market systems but, assume by changes in the incentive in whole system, the market might get excited leading to "speculative-bubble" in PV industry. In addition, there is no certain plan or program to revise the existing support scheme by government after overflow of installation of photovoltaic panels. In addition, there is an opinion that very extensive incentives are able to create an unstable growth. According to the EUPD Institute report (Figure4.12), another disadvantage for investing into PV market is the high installation costs.

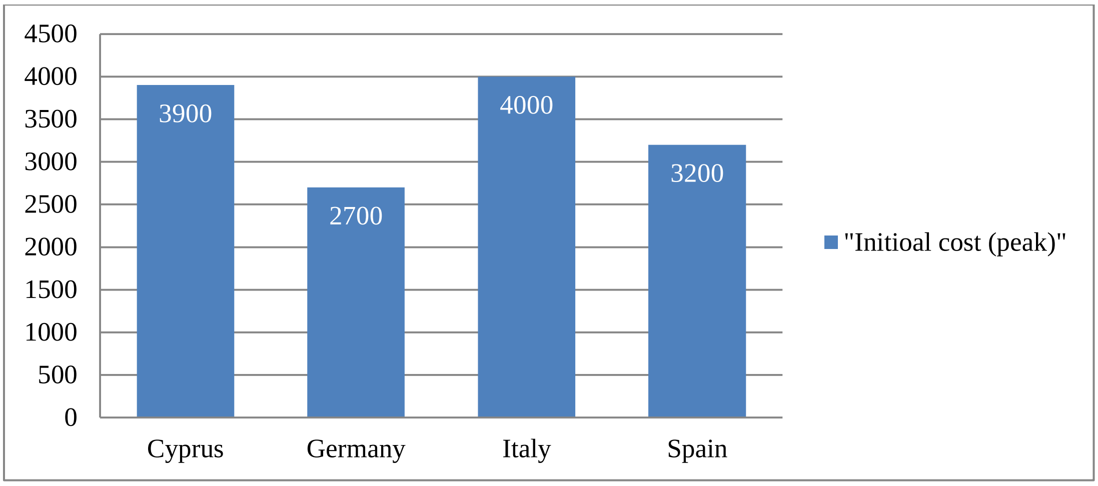


Figure4.12: Installation of (3kW) system in Italy is 43% more than Germany (12% more than Spain).

4.4 Germany

According to BMU and EU National report in 2007, "Germany accounted for 85 % of total European PV capacity in 2005". The report added this amount was follow by only eight countries that installed ten MW PV capacities. Purely Germany showing strong domestic market development and only a few other markets such as Spain, Italy, Greece, and France. That has lately moved-in grow up by applying sufficiently attractive policy and incentive financially. In 2009, other EU Members develop their PV markets and industries.

4.4.1 German PV Market Structure

Ordinary conditions in solar radiation in Germany are 1000±150 kWh/m2 and detailed of energy production of the PV-plant arrange from 750 to 950 kWp. The German Market in the last five years in Germany develops to the PV global market. This growth is beholden the "Renewable Energy Law (EEG)" that launched in 2000 and in 2004, edited again. In the agreements guaranteed necessarily and protected feed in tariffs for the PV investors. Present trends of success of the PV market continued in 2013.however, in contradiction of the risk of renovate of the "EEG" after the change of the government next "federal elections in 09/2005" German PV companies are making for the study of global markets. The image of Photovoltaic panels in German market is brilliant during these years.

Annual set up capacity in Germany was more than 450 MWp in 2004 and rise by 200%. In 2004, they reach the first place in EU market and worldwide. Total amount of install volume was 920 MWp in 2004 again become "number one" in Europe Union and worldwide. Annual development ratio was more than 200% in 2004 and"+87% "in 2003. PV Industry Association or (BSI) expects around was 1000 MWp in 2010. This growth ratio was mostly focuses on the grid-connection sector although, the off-grid marketplace was probable to sustain at approximately "3 MWp" in this reason, Marketplace structure sector divide in to first: 91% grid-connection and second: 9percentage off-grid system. However, currently Germany is an untainted on-grid market. Accordingly, average of project has increased continuously until "1.000.000 PV-roof program" done. The "roof-top systems" on householders were well leading. After the elimination of the limitation of an import of existing market situation is requested by PV public parks of the "MegaWatt".by patterned the Local area distribution may have found in Germany the Photovoltaic panel installations are very abundant focused in to South of "Bayern and Baden Württemberg". These estimates show more than 80% of total installations in 2003 has place "Bayern and Baden Württemberg".

Complexity of the German-model plan process and develop actions for small-scale photovoltaic panel for installations of 5 kWp are honestly Up-front. Also for large scale developments project such 500 kWp the actions only differ noticeably the PV systems are not install on top-roof. Three permissions for the small-scale of the PV projects necessary are:

1. “Grid connection”
2. “Grid use”
3. “Feed in tariff”

Typically, take permeation in public scale and type is not necessary for the PV projects, but the BIPV should register by the local administration government for the numbers of authorities for small projects on grid or utility and fiscal authority to get status of energy producer, But generally governmental difficulty and Bureaucracy is too low. Principal of duration for small installations and the planning process now are below two months, but for bigger projects may take even one year or more.

In the previous years, the German government and Photovoltaic panel industry has grown powerfully. Although, great degrees of race of development (industrialization and innovation). So many companies have developed in marketplace but in international scale, they are not successful. In Germany Photovoltaic, industries depend deeply on the imports of the semiconductor business. The product volumes until 2007 displays similar growth applied in to wafer production. In this country 90% of market share are crystalline cells and total amount of cell capacities production in 2004 were 225 MWp. Also the report clime that thirty percent (30%) of production amount (1874 MWp) exported. at present six (6) German PV cell factories are all consider on investing money to extended the capacities of production. Further than twenty (20) Photovoltaic cell builders have, manufacture accommodations in this country. Buscher clime that; “The total number of capacity was 200 MWp in 2004” (Buscher et al, 2011, p39). Their production yield in recent years has continuously are lower than national demand, so the share of imports from other country was not less than 50% or 70% .also most manufacturers have stated extra, massive production capacities (ENEL, 2012).

Because of over ten years of skill with grid connection components of Photovoltaic panel system, Germany producers are leaders in international scale. Currently they have twelve (12) inverter manufacturers in Germany.

4.4.2 German Photovoltaic Strategy, Regulation Framework

“National strategy plan and framework for Photovoltaic system” promoting in Germany was based on no official Photovoltaic target until 2010.also National strategy of the Photovoltaic promoting construct in a strategy which is follow simplicity.by this simple strategy, they try to support investor by “soft loans”. The German “(National PV administration government) “or the PV policy plan is widely adapted to national federal situation. This coordinating includes the Ministry of Environment also. The (HTDP) program manages by the public community promotion.

The background of the successful “German model” in PV panel sector build according to the Renewable Energy law (EEG) that lunched in early 90, with a first funding program *(“1000-PV,roof-tops”)* and first feed in law (“*Stormed in speisungsgesetz*”). Those measure tools and (subsidy*)* program (“*10000-PV roof-tops*”) start since 99 were necessary help the national Photovoltaic market to reach this affectedness was not reach earlier until twenty-one century. The merging of

(EEG) and (HTDP) protected the commercial orientation Photovoltaic investors to full payback of their investing. In addition, now Fiscal incentives are exist in that country, but in limited relevance. On other hand, Tendering systems not exist. The Grid access permeation involve in 2004 for the Renewable Energy policy. The grid access and grid usage contract should sign with local utility so; the new independent regulation has placed in 2005. Nevertheless, registrations of National plants not start since 2006.

Building segment regulation or building integrates of PV panel regulations standards and permission is just required in some special cases like under control areas but ordinary project it is not necessary to take any relevance for the PV sector. "German municipalities" apply several test creativities. Many regulations effect to building integrates of PV panel (BIPV) it depends on the type of cell setup and the respective of regional building low, if an especial permission is required. "International European quality standards" qualify the standard for PV module. In this milieu, installations and grid connect system has to be get by professional certification.
"Renewable Energy Law (EEG)" is place in beginning of 21th century and following version lunched since 2004(Figure4.13). The current "EEG" started in 2012, was for edition and improvement of the feed in law from 1991.According to EU report (17.8 TWh) RES injected to the grid system in 2002. Price of this amount was one and half billion euros. In 2003, these amounts improved to "twenty one TWh" by approximately "two billion euro". Soft loan, which give to householder, has the interest rate from 4.5% and more.

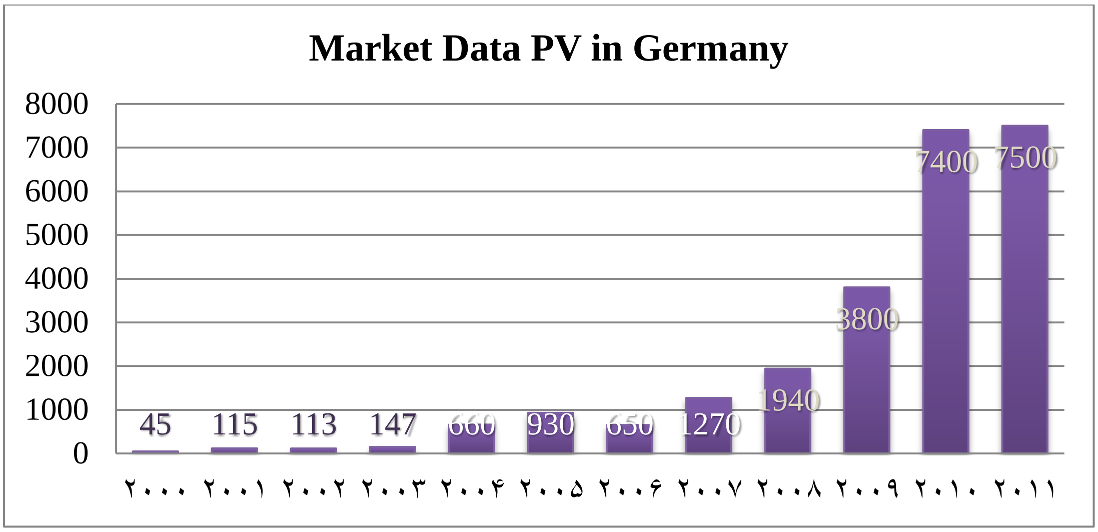


Figure4.13: Cumulative installed solar PV capacity (2004-2011) (Source: BMU 2012).

4.4.2.1 German Feed-In-Tariff View

The overview of the German Renewable Energies Foundations Act was (EEG) in 21century, and it changed in 2004. The main success of the German PV market is the regulation that elements is a (*fixed tariff / kWh*) of electricity on grid system. This feed-in-tariff (see Figure4.14) allows operators to run a PV system with a sufficiently attractive return on investment.

This development in Germany based upon the following important point:

- “Fixed feed-in-tariffs and guaranteed duration of payment of 20 years.
- Guaranteed and preferential grid access for all PV systems.
- All electricity consumers collectively carry Independence from public budgets as cost burden of the EEG.
- No market caps...
- The annual decrease of the FIT for new contracts motivating the industry to reduce costs through research and technological development”.

⌗ Different feed-in-tariffs for different PV plant types and sizes

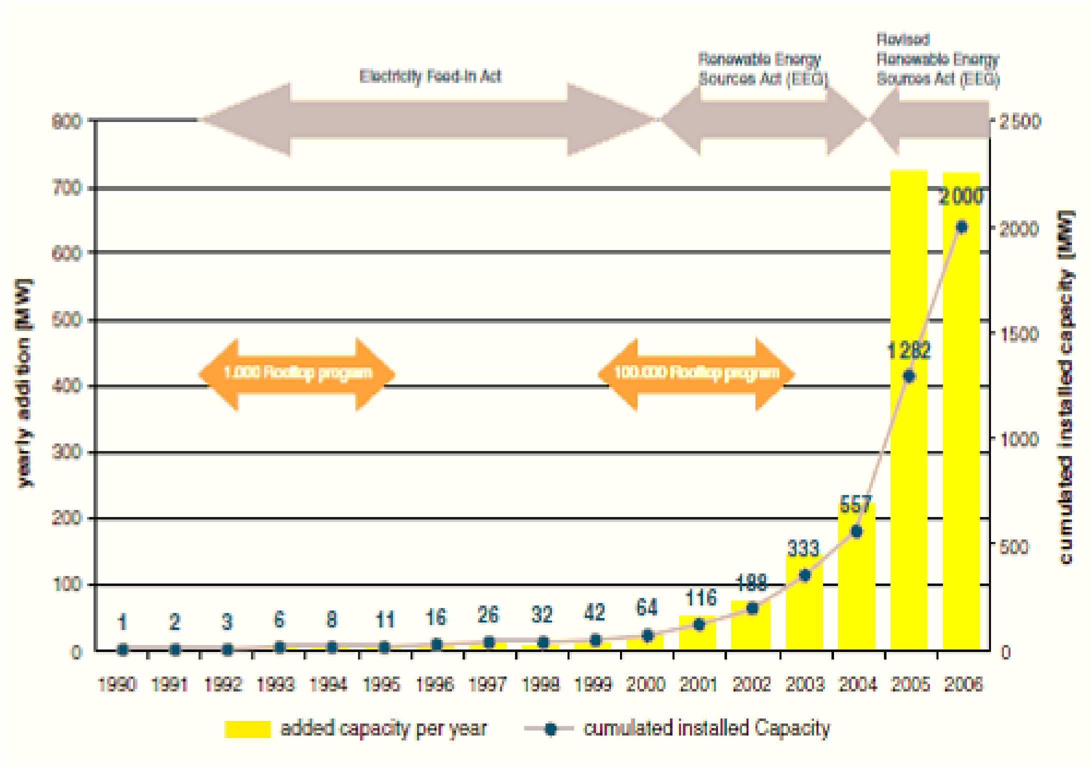


Figure4.14: Estimating and Situation of PV in German Market.

4.5 SWOT Analysis of the German and Italian Models

Relevant to discussion in this chapter, SWOT analysis of German and Italian model will review. SWOT analysis method use for understanding and evaluate of Strengths and Weaknesses as internal factors and Opportunities and Threats as external factors that involved in a projects. The flowing table shows the SWOT analysis.

Table 4.6: Strengths analysis of German and Italian Policy

	Germany	**Italy**
	Strengths	
1	Governmental incentive finance	Governmental incentive finance

2	No limitation in investment	Second leader in EU
3	No require any special skill	Improve the policy according to experience background
4	Leader ship in EU	Detail focus in their Policy
5	Develop in simple Policy sustain	subsidy and green loan whit low risk
6	Duration of permeation is too low	Rapidly growth after 2005
7	Low maintenance cost in PV market	New feed-in-tariffs affect
8	subsidy and green loan by low interest	Provide the new finance source by Italian bank

Table 4.7: Weakness analysis of German and Italian Policy

	Germany	**Italy**
	Weaknesses	
1	Depend to import material for PV panel	Many permeation needs for BIPV and bureaucratic impaction
2	PV monitoring in market	High initial cost in tax and penalty
3	According to Subsidy (stop & go) effect	subsidy and green loan by high interest
4	Limited usage in policy	No reach to 20% of RE
5	Limit duration and time frame in HTDP	Sluggish PV market

6		Postpone approve of regulation till 2004
7		Future growth is not harmony in BIPV

Table 4.8: Opportunity analysis of German and Italian Policy

	Germany	Italy
	Opportunities	
1	Flexibility in German policy	Sun-shine radiation in a year is too high
2	Perfect strategy in future	Many Demand is not cover yet in market
3	Race in PV market and develop	Improving the grid-connection facility
4	Has good condition in large-scale project	Focused to export to global market

Table 4.9: threats analysis of German and Italian Policy

	Germany	Italy
	Threats	
1	Economy crises	Price of other energy source in too low in campier of RE price
2	Change in customer preferences	Prepare of new registration take lots of period

3	Lake of national PV industry	Effect of Mafia in energy Lobby

4.6 Chapter Conclusion

According the information that presented above situation on PV plant and BIPV in Italy and Germany is mostly considering on being profitable investment. High feed in tariff and higher amount of sunshine radiation make their projects more conducive when compared by many EU countries. However, potential financier is extraordinary costly which effect negatively to investment in this market. Although, prices of Photo voltaic panels will reduce due to reduction of forthcoming of FIT and growth of supply In Italy still they are expensive than most country in Europe country like Germany. Italian duty system (TAX) is one of the most important barrier that imposes by the government to investor and electric generator. In Italy, most of banks do not have financial reserves to be able to fellowship loans to run from crises if it is happen (unlike Germany). In addition, in both countries opportunity to get loan in low interest condition is very critical or at least is depending of advantage of investor. Finally, bureaucracy also in Italy could be the main impediment for development in this market in these view generators of renewable energy requires many approvals from government entities, municipality and government departments but simplicity of strategy and permeation in Germany led to one of the success country in EU. To decrease the risks it is recommended to invest in major size of PV projects within a tariff which allows to reach the profitability and benefiting from the reduced costs due to the scale of economy.

On the other hand, The Renewable Energy policy in Germany (EEG) allows to cost-effective operation in PV plants also. They have long-term securities and safety of investing and legally guaranteed code. The (EEG) Renewable Energy law in Feed-in-tariff repaired the administrating difficulties and subsidy circumstance (grant-in-aid) program. In addition, no artificial limitation in market development of the EEG is another benefit of German model.in addition, No “stop & go” strategy according to the budget limitations and organizational processes make them successful. Fiscal planning has this ability to provide for the cost and interest ratio to reduce distributing of federal (Government) budgets and over the entire period of soft-loans for 10 years so, the result was 50% decrease of risk (COM. Brussels, 2010).

Although, the Germany is leather ship in world but German model has some disadvantage. Limited duration and limit of capacity in small-scale projects are unnecessary obstacles of market development and the most disadvantage point of HTDP in German policy. Subsidy a program in the HTDP financed by federal budgets similar to all incentive investment is exposing to “stop & go” effects (hopelessness of market if whose use the subsidy may withdraw and omitted suddenly. The fact is impact on selling prices this call as “stop & go” effects). This circumstance decreases development of security for investors is considerable. Photovoltaic panels Marketplace monitoring and intensive care are still insufficient stage, special in off grid (stand-alone)sectors, in addition, import and export relations are not sufficiency considerable way.

Chapter 5

ANALYSES OF PHOTOVOLTAIC SITUATIONS IN NORTH CYPRUS

5.1 Introduction

Cyprus is an island located in the Eastern Mediterranean between the latitudes 34º 33' - 35º 34' N and longitudes 32º 16'-34º 33'E, and is estimated to be the biggest island in the around Mediterranean Sea after Sicily and Sardinia. This island at present is dividing into two politically distinct zones after the intervention by Turkish forces in 1974. North Cyprus (as shown by a diagram in Figure5.1) occupies the Northern part of the island, with an area of 3,355 km2. The problems of conventional electrical energy usage in housing are common to both parts of the island (George Part asides, 2010). The design and installation of solar energy plants requires knowledge of the average solar radiation at the place of interest throughout the year. The climate of Cyprus is that of a Mediterranean climate accompanied with hot and dry summers, becoming very hot and humid at night hours. During winter, the weather is warm and rainy, becoming cold at night (Oktay, 2002). The solar radiation received in Cyprus, based on historical data collected by the various meteorological stations on the island, is 7 kWh/m^2in the summer months and 3 kWh/m^2 in the winter months (as depicted in Figure5.2), making Cyprus a potential candidate for using photovoltaic panels system. Although the North Cyprus authorities have heavily invested in conventional fossil based energy, there is considerable interest in the use of solar energy, especially among the owners of private homes and factories (Ibrahim and Altunc, 2012).

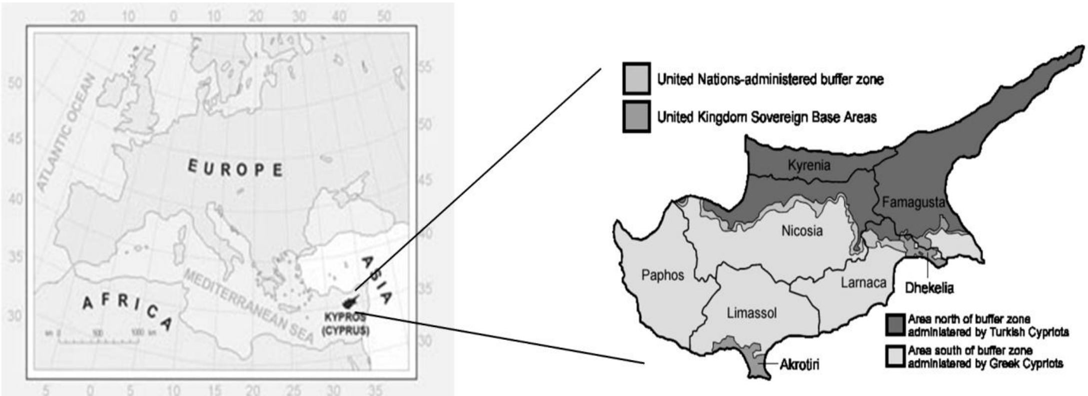


Figure5.1: Location of the three basic cities in North Cyprus map (Ibrahim and Altunc, 2012)

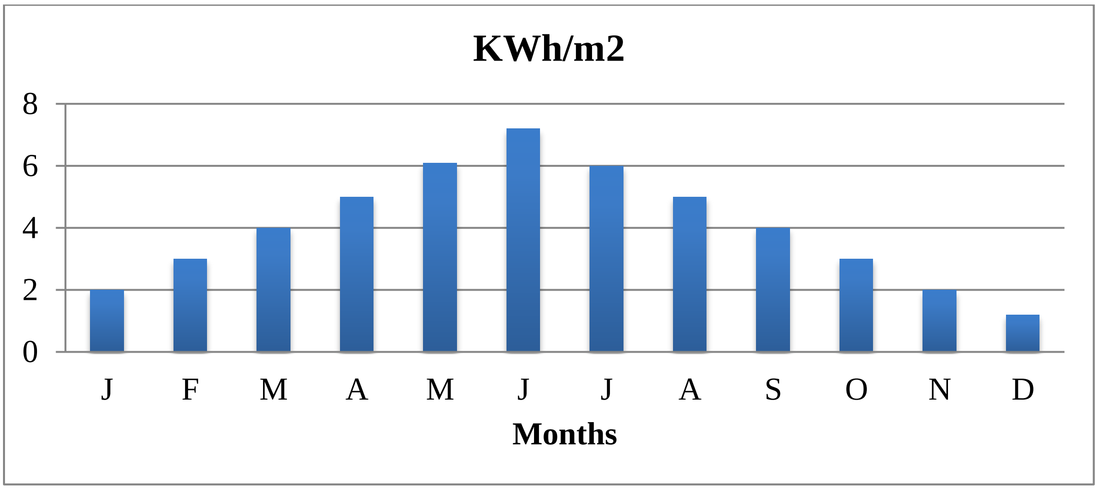


Figure5.2: Average daily global solar radiation in Cyprus. (Ibrahim and Altunc, 2012)

5.2 Social Overview of North Cyprus

North Cyprus strongly reliant on imported oil and petroleum products to generate electricity. The “Cyprus Turkish Electricity Authority” also well known as (KIB-TEK) controls energy production, transmission and distribution in North Cyprus. Total electricity generation capacity of KIB-TEK is about three hundred and forty six point three megawatts (346.3 MW), as demonstrated in table 5.1. Turkish Republic of Northern Cyprus (TRNC) has no reactive power tariff yet (still in approve position). Consequently, industrial or commercial consumers do not have to install reactive power compensator or harmonic filter. This as a result intensely influences the quality of power. However, in line with financial constrain plants are using cheap fuel oil to generate power. High sulfur rates in this product can affect the environmental stability, yet it is not an issue in Northern Cyprus in the meantime, since there are no strict laws and legislations to thwart the use of environmentally hazardous materials as stated by Ilkan et al, (2005). According to annual report in 2007, total generation capacity of KIB-TEK (362.5 MW), This capacity was not adequate for the current energy demand due to population increase which as a result increases electricity demand (Ilkan et al., 2005).

Presently, transmission lines in North Cyprus can be considered in three basic voltage level, which include 132 kV and 66 kV, couple with the distribution system consisting of a medium voltage lines of 11-22 kV and low voltage lines of 415/240V(see Figure 5.3 for KIB-TEK power per station). End of 2008, total length of transmission lines was 554 km. The Total installed capacity started in north of the Island with 60 MW in March 1995, 120 MW in March 1996 and 327.5 MW in 2008 respectively. The power generation of 2008 was record to be 1.22 GWh, at a 15.6% increase of the earlier years. After 2004, construction sector developed much faster, and was estimate that development of construction sector will keep growing in the next 20 years (Ozerdem and Biricik, 2011). It was also estimate that by the year 2020 total consumption expect to exceed 1GW, what a tremendous increase as demonstrated by Ilkan et al. (2005) in the Figure 5.3.

Table 5.1: The KIB-TEK power per station

Power Stations	Power	Units
Teknecik	2x60 MW Steam Turbine	120 MW
Teknecik	1x20 MW Gas Turbine	20 MW
Teknecik	1x10 MW Gas Turbine	10 MW
Dikmen	lx20MW Gas Turbine	20 MW
Kalecik	4x17,5 MW Diesel Generator	70 MW
Teknecik	6x17,5 MW Diesel Generator	105 MW
Guzelyurt	1.3 MWp Photovoltaic| Plant	1,3 MW
Total Installed Capacity		346,3 MW

(Ozerdem and Biricik, 2011)

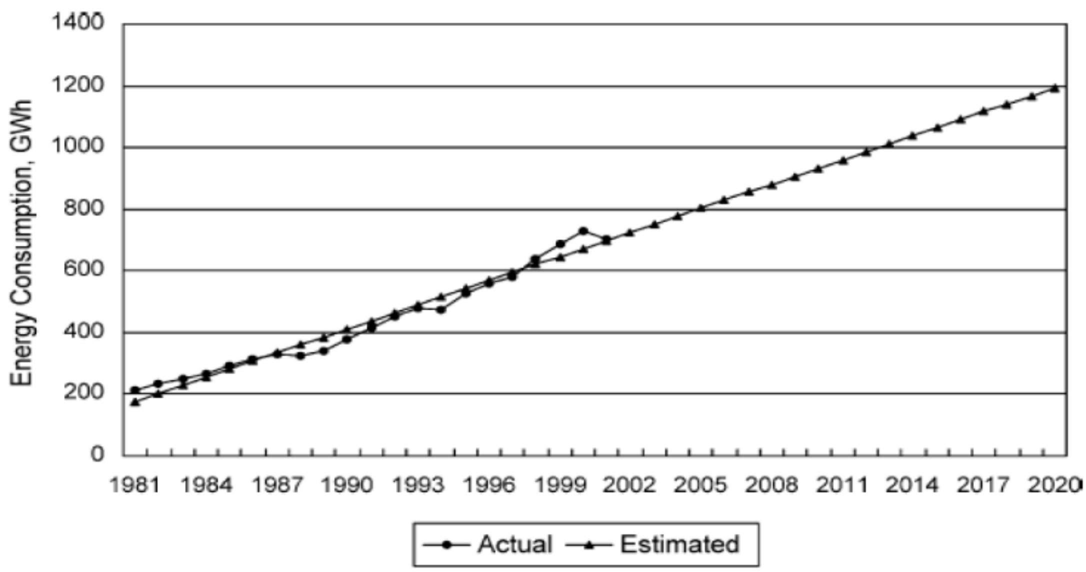


Figure5.3: Portrayed the exact and proposed yearly energy consumption (Ilkan et al., 2005)

Circumstance of energy market in North Cyprus obviously indicates need for alternative energy generation technologies. Electricity price in Northern part of Cyprus is significantly too high, as high as 0.20€/WH compared to the southern part of Cyprus which is calculated approximately to be 0.15€/Wh. In line with this context, authorities have been instigating to conducted significant investigations and projects regarding the use of renewable energy sources in Northern Cyprus. It was discover that among other sources of renewable energies, PV technologies are most suitable and feasible for Northern Cyprus. However, there are very little cases where small numbers of off-grid PV systems are install for residential use only. In the meantime, there is no feed-in-tariff policy in North Cyprus and metering technology does not allow feed into the main grid, all the systems are stand-alone. However, KIB-TEK proposes to change all the electrical meters and implement smart meters in every building in North Cyprus. Because of that, electricity consumption and demand values could be measure more efficiently and production plans could be form according to these values. At present, PV installation capacity in North Cyprus is trivially low and under these economic conditions, it is not suggest installing PV system to houses because of the existing fossil fuel technology and high installation costs of PV systems.

5.2.1 Photovoltaic Plant in North Cyprus

The KIB-TEK has chosen an ideal site for a PV plant at the Serhatkoy, North Cyprus. The site is almost situated in a relatively flat land with very low level vegetation, with an above average solar radiation characteristics, and is directly adjacent to high voltage electric public utility lines (as shown in Figure5.4), animal farm house, footpath and all fundamental elements for a PV power plant. The site was initially use for illegal animal farming before the Cypriot government gave it for PV power station and is relatively flat, making it highly suited for a PV plant. Low-level brush has populated the land over time. The plant on the site is a 1.3 MWp pilot photovoltaic plant project, which demonstrates the first PV connection in North Cyprus and the largest in the entire Mediterranean region. The project was financed by European Union commission and it costs approximately 3.7 million € uses 6,192 PV panels each 206 watt on 20 km^2 of land, as depicted in Figure5.5. The PV plant construction started January 2010 and operations commenced May 2011. The PV system is be used by KIB-TEK, and the Project is proposed to produce two GWh of clean energy yearly.

Figure5.4: Photograph of access road near site, indicating local electric distribution and transmission lines.

Figure5.5: Photograph of the PV plant 20 km2 land, looking south-west.

North Cyprus is appropriate for electricity generation from wind and has an average wind velocity of 5-7 m/s. The calculated wind potential is between 30 and 60 MW. Pashardes produced wind speed map of the south of the island and Christofides in their publication in 1995 (see Figure5.6). On the other hand, North Cyprus wind-map preparation studies continue. Research conducted by Ozerdem and Biricik (2011) indicated that more than a few areas were verified as having an annual mean wind velocity that is more than five meters per second (5 m/s) at ten meters (10m) height. The collection of wind data started ceaselessly from the year two thousand (2000) and measurements was conduct at one site called Serhatkoy, which seems to be more appropriate for a wind turbine installation. Three other possible sites have been under examination since then for application of power supply for the Northern part of Cyprus. Surrounded by a short time for the production of electricity from wind energy is expecting to open international tender by KIB-TEK (Ozerdem and Biricik, 2011).

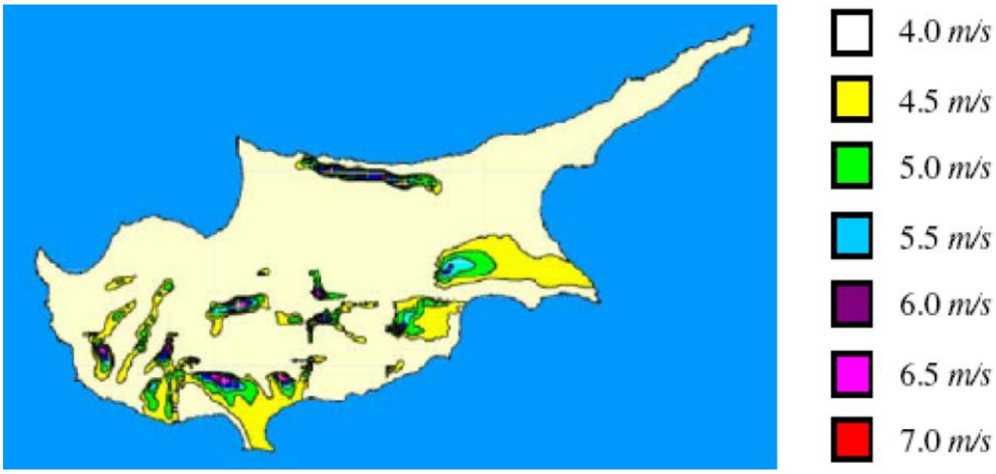


Figure5.6: The wind map of Cyprus (Ozerdem and Biricik, 2011)

5.2.2 BIPV Status in North Cyprus

PV technology for residential use is a new concept in Northern Cyprus market, and there are only a few installations at very low capacity. From the study, it was observe that, residential units occupied almost half of the energy consumption in North Cyprus. According to State Planning Organization (DPÖ), about 71.45% of the dwellings in North Cyprus have a solar thermal heating system installed in their residential building mainly for heating water generally. However, this technology is not the same as PV systems but at least gives an awareness to people how to convert solar radiation to energy and create a little consciousness towards PV systems. It was observed that some building in Tuzla only benefit from the use of PV panel systems, which is used as shading devices, as shown in Figure5.7 and Figure5.8 depict the building electrical plan.

Figure5.7: Building example in Tuzla with PV panels as shading device.

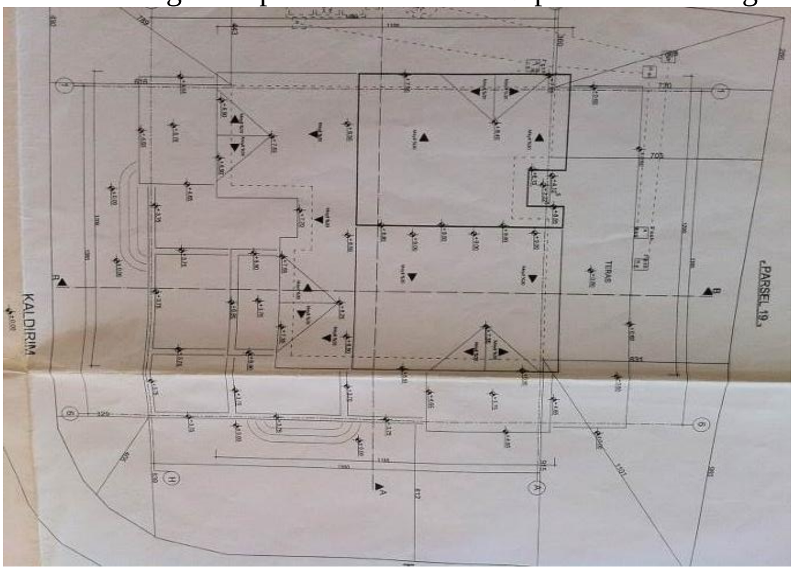


Figure5.8: Building electrical plan.

The site observation reveals that, electric transformer station is approximately 300m away from the buildings. The cost to transfer electricity from the grid system to the buildings was too expensive, as a result building owners decided to use PV panels to generate electricity. It was also observe that control panel, battery and inverters have to be enclosing in an area to avoid climatic factors. The size of the enclosed area found to be 120cm by 170cm and the vertical height of the control panel from the inverter was 120cm. The current generated by PV panels was use to power all the application except air conditioner, because of high watts. Special application are used, such washing machine with A label specially designed for the circumstance. LED television and lamps are use not to undermine the PV installation, as shown pictorially in Figure5.9. The users were so please with the PV panels outputs, and one of the users interview said it is clean, safe and environmentally friendly.

Figure5.9: Demonstrate the LED

5.3 Environmental Overview of PV Panel in North Cyprus

There are no doubt Installed PV cells or panels pose minimal risks to human health or the environment according to review in other chapter and conducted by the Brookhaven National Lab and the Electric Power Research Institute. In this case, Health and Safety is one of major aspect of using of PV technology especially in North Cyprus Individual. PV cells are typically link together with copper wire coated with tin. Some PV panel manufacturers utilize solders that contain lead and other metals that if released into the environment can pose environmental and human health risks. Module assembly is not a likely pathway for human exposure to these metals as this step in the assembly process is typically automat. Although, this process that make PV panel it is not available in North Cyprus, but it should be consider during the process of development on this issue.in addition, PV panels made process are encase in heavy-duty glass or plastic, there is little risk that the small amounts of semiconductor material present can be released into the environment. By looking to chapter, two that explain advantage of PV industry, usage of PV panel basically focus on environment protection. The environments condition of North Cyprus generally prepares the base PV plat form in best condition.

In Cyprus there are some areas with average wind velocities of five to six meter per seconds (5-6 m/s), and a few areas with six point five to seven meters per seconds (6.5-7 m/s). It is report that the estimated maximum exploitable wind potential on the island is 150-250 MW. Although some studies are being carried out for the installation of wind turbines on the Southern coast of Cyprus the cost is expected to be high due to the high depth of the sea close to the shore (more than 30 m deep at 300 m from the shore) (Papastavros, 2007; Ibrahim and Altunc, 2012). After the separation, the two parts have followed distinct pathways in their economic and technological aspects, which are illustrate in a comparative way in Table 5.2.

Table 5.2: Comparison of the two parts of in respect to economy, adoption and laws

	Republic of Northern Cyprus	**Turkish Republic of Northern Cyprus**
Economy	• Prosperous and diversified economy • Base for several offshore businesses • Well-developed tourism	• Free-market basis • “Physically disabled in terms of private and public investment”. • High shipping cost and lack of learned labor

	sector	
RSE Laws	• Enacted in line with EU legislations	• A draft had been prepared but not enacted yet
PV Adoption	• Installations started from 2006 • Feed-in-tariff policy exist • PV panel production facilities exist	• No feed-in-tariff policy • A few individual installation

5.4 Economy Overview of PV Panel in North Cyprus

The purchase of a PV system in North Cyprus characterizes a spending of investment resources at specific time with hope of benefits in the form of electric energy delivered over future period, which is generally the life of the PV system. For any type of scale of the PV system, primarily the value of the electricity generated may realize 10 to 25 periods. Thus, the main issue is how we can measure the value of benefits of future from present. Furthermore, the issue is how to compare that value for a PV system with alternative electricity resource exist in the North Cyprus like the diesel electric, fossil fuel generator and electricity from the grid. Rescue the value at the end of the system life is one of the future benefit. The maintenance cost and the replacement of failed modules are primary examples. In addition, we generally recognize intuitively that the value of a cost or benefit in the future is not equal to the same cost or benefit today. If we were to receive $100, we would rather get it today than five years from now. The value of money possessed now as opposed to later can be measure in this simple way. All of this goes to say that there is a “time value of money,” and defining that time value pervades the whole process of economic analysis for PV systems. These expenditures and benefits, as measured in monetary terms, are usually call cash flows which is explain in chapter 2 two.

Assume that the system value of electricity generated for 25 years, which is available in North Cyprus market, there are replacement costs of 5000 TL in each 5 Years. For a PV system, the value of the generated electricity is usually determining by the avoided cost of the electricity that would otherwise need to be purchase. Note that the annual electricity production in kilowatt-hour from the PV system is implicitly included in this example through the determination of the electricity cost stream.

A sum received or spent now has a present worth, (P). A sum spent or received at a future time (n) years hence has a future worth, (F). If (P) is invests at an interest rate of (i) percent per year, then its future worth at the end of the first year is

$$F = P + P\,i = P\,(1+i)$$

The future worth at the end of the second year is

$$F = [P\,(1+i)]\,(1+i) = P\,(1+i)^{2}$$

In addition, the future worth after (n) years is

$$F = P\,(1+i)^{n}$$

Conversely, the present worth of a future sum given by

$$P = F\,(1+i)^{-n}$$

Equation ($P = F(1+i)^{-n}$) shows that the present worth of a sum received (n) years in the future is reduced by the factor $(1+i)^n$. When equations ($F = P(1+i)^n$ and $P = F(1+i)^{-n}$) refer to the money deposited at interest, the factor (i) is the interest rate offered by the bank, but when an investment in an energy system is being considering, the factor (i) referred to as a discount rate. The discount rate is the value that the system owner puts on the capital invested in the system, and often calls the opportunity cost of the investor; that is, the rate of return foregone on the next most attractive investment.

By understanding this formula now, we can calculate the appropriateness of PV panel in compare of existing electricity resource in North Cyprus. For instance, we have a panel. The cell is multicrystalline (3200Wp) by 15 years 100% efficiency guarantied and after those 10 years will work by 85% efficient and the price is 27000 TL, (17-panel).on the other hand, we can use grid line by pays approximately 250 TL per month. Feed-in-tariff is shows in the chart and they are tax-free. ((i) is 12%)

System Size	Feed in Tariff
Less than 4(kWp)	+15.44
4- 10(kWp)	+13.99
10- 50(kWp)	+13.03
50- 150(kWp)	+11.5
150- 250(kWp)	+11.0

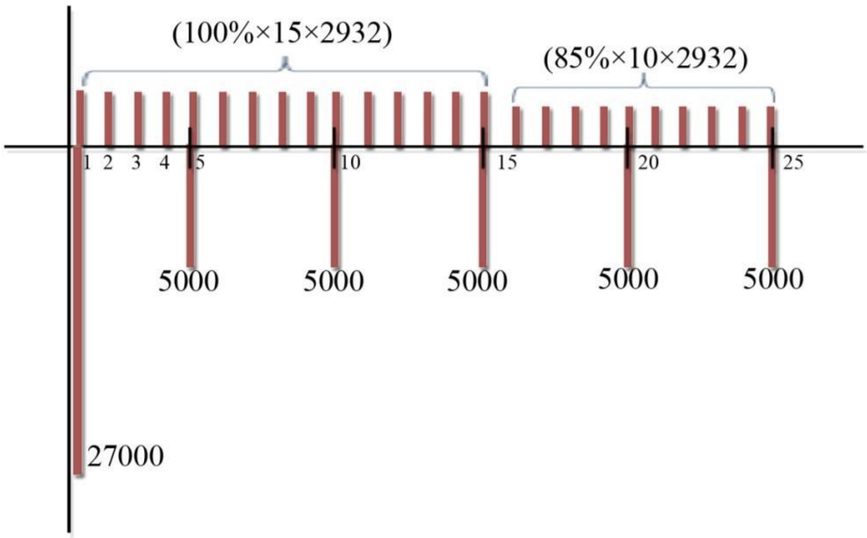
In this stage to understanding the answer, we have to flow this stage:

$3200 \times 15.44p = 494.40$ TL every months

5932.8-3000 = 2932 extra payback money for householder in a year (save money)

On the other hand, 2932 TL will pay in 15 years (100% efficiency)and 10 years save money is 2932×85%=2492 TL

On the other hand, 5000 TL each 5 years is including as replacement costs:



So the result will found by this equation:

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

Or result may found by:

$$F = A\left[\frac{(1+i)^n - 1}{i}\right]$$

(P) Refer present and (F) refer to future. However, (i) refer to interest. (P) Of FIT in first 15 years is 2932×4.56×15=200548.8 TL and (P) of FIT for rest 10 years is [2932× (85%)] ×5.64×10=140561 TL

Total income is 200548.8+140561=341109.8 TL

We have 5 times replacement so, the (P) of that amount is 32480 TL for repair.

Total invest is 32480+27000=59480 TL

Due to sum of investing is less than sum of save money so, the usage of PV is appropriate in North Cyprus.

5.5 North Cyprus PV Market Structure

Over the last few years, the photovoltaic (PV) market has undergone an extraordinary boom. More precisely, in the last two or three years, the photovoltaic market has attained a cumulative installed capacity of approximately forty Gig watts world-wide, with an annual added capacity of sixteen point six Gig watts. The photovoltaic power is still on its climax to become a fully competitive part of the electricity system in the European Union (EU) and an increasingly important part of the energy mix all over the globe. When the EU accepted using PV panels as a regulation, the South part of Cyprus replace 20% of their electricity source with Photovoltaic system. The market reflects to the EU decision on PV panels, which grow up rapidly within 2 years. On the hand, North Cyprus market opportunity would grow more rapidly within one year due to limited population compared to the southern part as soon as the Government grants the permit. From the interview with Cypriot Company, it was discovers that Monocrystalline PV is pulling weight and is the most available in the market due to its cheapness and durability, as depicted in Figure5.10. On the other hand, off-grid does not have any limitation. The PV market favors mostly the private sectors. Nevertheless, for the on-grid system they have to get permeation from the government for the installation of two-way electric meter to install in their houses. The overall electricity generation capacity of KIB-TEK is three thousand six hundred and two point five megawatts (362.5 MW), however estimated to increase to one Gig watts (1GW) in the year 2020.

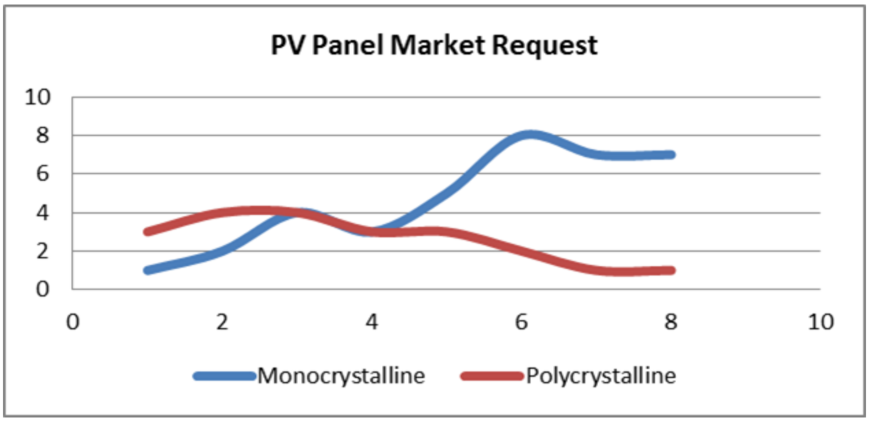


Figure5.10: Shows the assumption of PV panel market request for mono and polycrystalline in North Cyprus

5.6 North Cyprus Strategy, Regulation Framework

In 2009, TRNC government tries to prepare a regulation and registration policy to organize the using of Renewable Energy although it is not approve yet. Cyprus government is the name of a group that defines by eight members and as sub-authority after president. Those members has to select in order of a person from mechanical engineering, 2 person from academic, a person from chamber of electricity, ministry of Economy and vice president. In 2012 the (legislation) and (registration) has written by Cyprus government and it is in approve position (not approved yet).

The main strategy in North Cyprus is to reach replacement of 20% of total energy by Renewable Energy. In this scheme all building sector should take permeation from Cyprus government under sign of president but without spot of building type. This permeation has no limit but it must publish in governmental newspaper and duration begins from 15 days up to 6 months depend on type of function (trading of private sector). North Cyprus policy focuses is safety and EU standard. All of selection and installation of PV panels and performance has to be accept domain which classifieds by government such as KW, amount of Electricity generated and extend of equipment if is necessary.

Feed in tariff as Financial Incentives also another code in North Cyprus policy to motivate investor as shown in Table 5.3. The entire codes target is On-grid system and cover 15 KW PV modules and more.

Table 5.3: Feed in Tariff in North Cyprus.

PV Panel Feet In Tariff	low	15 kW'ta kadar(till)	0,25 €/kWh
		15 kW'ta fazla(more)	0,22 €/kWh
	medium		
			0, 20 €/kWh.
	commercial		0, 18 €/kWh.

According to another standard for using of PV panel has mention in Cyprus protocol law 12(1), in this code PV standard, inverter standard, duration of Panel and efficiency, frequency of PV classified in ten (10) sub-laws. PV panel long-life should not be less than 25 years and in the 10 first years the performance has to be 90% and calculated 80% for next 15 years left. Panel efficiency should be 15% or higher. Minimum the inverter output is at least 97%.maximum square meter for 1 KW is eight m^2. Inverter should be automatically to turn off and on in On-grid system. In addition, inverters should have this ability to, emergency shutdown, overload and over-temperature protection, AC and DC sides of the circuit breaker. AC frequency should be in range of 5 Hz until 50 Hz.

All of PV panel should follow Panel standards, IEC 62215:2005, IEC 61646:2008, EEC61730- 1:2004, 61730-2:2004, DEC 60 664, ISO 9001 reference As specified in the documentation. In addition, the panels based on the "Power Controlled Certificate "TUV, KEMA, or CESF organizations as well. Construction standards are, DIN 15,085-2 (Class 1), DIN 18800-7 (Class E), DIN EN ISO 3834-2 (Class 1), DIN V 4113-3 (Class C), DIN VDE 0100 in the documents referenced. In addition, renewable energy sources, PV and wind power intended and all kind of tools, materials, equipment and hardware standards and technical specifications, has to be according IEC (International Electro technical Commission). BS (British Standard) and EN (European Norms).Calculation to find the consumption follows this formula: The total annual electricity consumption (kWh) 1.2 times the transformer, so extra KWp can sale to grid system.

5.7 SWOT Analysis of North Cyprus Situation

There is no doubt, this country has a worthy potential of renewable resources for the PV energy. For rehearse, one of the most affective part of PV industry and reflection in PV market is the FIT pat. Although it may have long term worth inflation but at least it may calculate as one of the most important encouraging gizmo to exiting the investors or producers in beginning steps. In addition, the financial incentives by TRNC government are not limit to feed in Tariff. The privet user can take 25%of total initial cost. This incentive is none-back finance, which focuses on BIPV in Private Sector. In sum, by drop any limitation in importing and exporting in this sector shows that the future of PV market in TRNC is bright. Furthermore, more information has written in table5.4 below:

Table5.4: Strengths of National PV Policy Framework in North-Cyprus

	Strengths of National PV Policy Framework in North-Cyprus
1	Government gives financial resources to the building users and the EU to North Cyprus government for installation of PV plant.
2	There is no limitation to importation or investment on PV market in North Cyprus
3	Users do not require special skills to maintain PV in their houses.
4	PV technology improves skills in research and development.
5	PV aids Infrastructure investments to sustain or support a liberalized gas or fossil fuel and electricity market.
6	Growing awareness of climate issues in North Cyprus.
7	High level of insolation

Weakness of PV industry in North Cyprus is much more than norms but it seems its will solve in early future. Although the North Cyprus government "(White Paper)" as the main strategy is to reach replacement of 20% of total energy by RE, but the strategy and the plan is not exist until March 2013. (For more information, see table 5.5)

Table 5.5: Weakness of National PV Policy Framework in North-Cyprus

	Weaknesses
1	Lack of authority (i.e. difficulties to obtain authorization)

2	Architects are not included in the committee in-charge on PV issues in North Cyprus
3	Dependent on constantly cost reduction
4	Weakness of nation industry
5	Difficulties to integrate the PV panels into historical buildings or cities
6	Frequent change of regulatory framework in North Cyprus pose a weakness to PV market.
7	Limited number of company in distribution

And then the third analysis is the Opportunities of National PV Policy Framework in North-Cyprus that shows in table 5.6

Table 5.6: Opportunities of National PV Policy Framework in North-Cyprus

Opportunities	
1	Potential growth in the PV market
2	Increasing demand in North Cyprus market
3	The Renewable Energy Sources Act
4	Immense focus on environmental friendly energy solutions
5	High oil and gas prices
6	PV can remove barriers to international trade

7	The emergence of new PV technology can pave way to opportunities.
8	PV Creates job opportunity for the new generation

And then finally the Threat of National PV Policy shows in table 5.7

Table 5.7: Threat of National PV Policy Framework in North-Cyprus

Threats	
1	Reduction or elimination of government support on off-grid PV system
2	No expert or knowledgeable person in the PV market
3	Economic crises
4	Changes in customer preferences
5	Foreign company cannot invest in North Cyprus due to increase in trade restriction
6	Lack of recognition by other foreign countries, pose a barrier to importation, and as a result increase the cost of PV and limitation to the brand.
7	The cost of installing photovoltaic electricity can equally pose a threat to PV market.
8	Investments in energy are long-term, and the North Cyprus are slow to address the challenges related to the growing dependence on imports of fossil fuels, climate change, environmental problems and economic growth.

5.8 Chapter Conclusion

Increasing of the number of population in native sector and immigrants whereas limitation of un-renewable source in North Cyprus and decency of North Cyprus to import the energy (especially electricity) from other country make the PV panel sector in high potential position. Although, regulation and strategy of TRNC government is not clear fid yet, but the according to this chapter the market structure will show the perfect reaction to this change. However, to promote the new system of usage of PV panel should change many infra-structure of country such as grid system and apply smart contour to the residential part. According to social analysis of North Cyprus status the PV industry will cover the mine aim of PV definition (creation of new jobs) whether imported or assembling or producing in region. On the other hand, according to annual report of North Cyprus report Total electricity generation capacity of KIB-TEK is about three hundred and forty six point three megawatts (346.3 MW), which it not support the whole user connected to grid (the result is power cut in week).in addition, High oil and gas prices and limitation of grid access might have influence to rapid growth of using of renewable energy in North Cyprus. Howbeit, the PV panel industry effective in economy and market share in compare of EU is might be risky but the future of this sector is bright.in this chapter SWOY analysis will give further information in (5.7)

Chapter 6

CONCLUSION AND RECOMMENDATION

Although, the PV panel is appropriate for North Cyprus but some part should consider, due to the speedy increase in population growth, technological development, increasing costs and high-energy demands, plus problems encountered by public utilities in supplying those demands (some houses does not have any access to grid especially in karpaz or it is not Affordable to connect to public grid) with clean and efficient energy; renewable sources of energy are now growing progressively, since it significantly solves most of our energy and environmental problems. From the survey and other related sources, it was observe that building sector currently is one of the major consumers of energy, as well as one of the core contributors to high emissions of CO2 in our surrounding. From this context, consideration of un-renewable energies in North Cyprus housing to attain sustainable environmentally friendly buildings that depend on renewable energy is of major concern. The lack of reliable renewable sources of energy, calls for use of photovoltaic technology. Implementation of this technology in North Cyprus will lead to an increase sustainability in social and will consequently, lead to business opportunities in foreign trade markets and will dramatically increase building's sustainability as a unit. In this regard, the utility department of North Cyprus has made major investigations and projects regarding renewable sources of energy and the outcome of these efforts were to use photovoltaic technology due to feasibility.

Present economy conditions and high implementation cost of PV technologies in North Cyprus are among major difficulties faced while implementing this technology in housing facilities hence the usage of old fossil fuel technologies. It is obvious that the energy market in North Cyprus will grow rapidly in one-year time as soon as government grants the permission to the usage of PV technologies. It is discovered in an interview with Cypriot Company, that Monocrystalline PV cells are the most favored PV technology present in North Cyprus due to its low price and durability. Same study shows that there are a few buildings in Tuzla, North Cyprus that are currently using non-integrated PV panel systems as shading devices on building facades to generate electricity. This is a way of bursting or promoting the use of Photovoltaic panels in North Cyprus. Therefore, it is suggested that North Cyprus' government looks into the advantages of using PV as a renewable energy source and promote the market to develop sustainability.

Furthermore, the study has depicted how PV modules can used to generate electricity for sustainable buildings in North Cyprus. Emphasis led on residential buildings and the implementation of PV system for other applications as well. The study also highlights, particularly from technology point of view on PV possibilities to generate electricity in North Cyprus. It is feasible to install photovoltaic panel's power for fulfilling electricity needs of resend entail buildings in North Cyprus is feasible from both technological and economic viewpoint. Other consideration, which is a long term perspective is on the growth of the country and as a result, the recommendations for installing PV modules for electricity generation in North Cyprus buildings are necessary with the below viewpoints.

1. There are power shortages in many areas of the island where there is grid. But there is large number of areas where grid has not yet reached in North Cyprus. Supplying power to all requires use of alternative sources through PV system or power plants would be appropriate to burst their standard of living and would save cost.
2. North Cyprus is fortunate to have a good amount of sunshine or solar radiation, which makes Photovoltaic panels appropriates as an alternative source of generating electricity for sustainable buildings. The sunshine is available bright enough in most areas of the island for generation of PV electrical energy; from this standpoint, the government should encourage the use of this substantial source of energy by giving loans to building owners to incorporate PVs on their buildings to enhance sustainable living in North Cyprus.
3. The implementation and use of PV power would be useful in reducing the pollution, and would serves as public awareness. Increased public awareness can be useful in setting appropriate policies for long term sustainable development in North Cyprus.
4. Use of PV power in North Cyprus would make aware about the climate change, availability and use of alternative energy sources. From educational standpoint, research on PV panels should be encouraged to aid researchers and policy makers in future; skilled researchers and knowledgeable policy makers are desirable for the country's growth.

Solar energy and PV industry is where the largest growth will be in the next several years. As funds and programs for other renewable energy technologies dry up, Photovoltaic system will become the most economical option. When you look at the average carbon footprint of buildings in both the commercial and residential markets, 40 percent to 60 percent of that is for heating, cooling, and hot water, which can be generate most effectively with Photovoltaic system technology.

Finally, history has shown that governments have been playing a great role in fostering new industries from rail and coal, to oil and natural gas, to nuclear energy. There is no doubt renewable energy sources are not much different. Clean energy industry in North Cyprus, mainly Photovoltaic system, needs and deserves more support from government in the short term to maintain and achieve a reasonable growth.

To sum up, North Cyprus has bright status in PV market. The new regulation in North Cyprus make situation readable, by check the local people easily will found the are aspect to replace current situation by new system. Much comment in several social networks shows us the future of PV panel is bright. As review in chapter 3 the main target of PV industry and usage of PV in European country are, first creation of the job and finally, reduce co_2 to protect environment. Although, those targets are main focused of North Cyprus strategy, but the differentiation make situation more critical. One of that differ may have effect on PV market is the number of population. However, the amount of sunshine and clear days in year cannot ignore. As observe the North Cyprus residential houses that make electricity by PV panel shows us they can easily prepare their life. Moreover, they are interest into use and their causes are dividing:

1. Environment
2. Have many financial intensive such as green loan and feet in tariff

3. In some case they don't have access to grid network
4. Initial cost and electricity bill is to high
5. Efficiency of PV panel in 25 years range

Although bureaucracy like Italian model dominates, the situation in Cyprus But this method has not been institutionalizing yet. A legislator looks to the laws of North Cyprus and has a more punitive approach to prevent growth of the industry and the market. Categories of existing laws and memorize every sector experts should encourage and create new jobs, but a lot of definition and separation make strategy fault and chaos and In the face of opposition, members make the growth path slow like Italy during 2000-2004.Another point is the liability rules based on knowledge of the people, but if we accept that the main goal to use of PV panel is building, so it should architecture be one of the member for edit of regulation (In this regulation unfortunately not mention).In addition, in this regulation permeation in BIPV and limitation omitted. This weak point will sluggish the market. Use of e-Government Services may reduce the risk of bureaucracy. It may develop a Government Data that will contain information from various IT systems of the public service domain. In addition, Installation of PV systems in schools, governmental buildings, and military camps by government will encourage the people to use PV panels.

Cyprus has a small and isolated energy system without potential interconnections with other Networks, within the period covered by this strategy. On the other hand, the major challenges is that the North Cyprus are still in the macroeconomic and microeconomic and employment phase. The country's strategic aim is macroeconomic stability, feasible economic development, and social cohesion. Enhancing the competitiveness of the economy, as a tool to achieve greater social cohesion, remains at the heart of the development effort. In North Cyprus, regulation provides an interesting and detailed for example any kind of house that rented can be installed the PV panel and make contract as hostel producer or subsidy to incent for using of PV panel but the economist point of view, stop and go effect is one of the feature of subsidy in long term. Emphasis that you have to be Cypriot for installing PV panels is a main threat in the regulation thus, make barrier for investing by other nationality and international company. Insisting on usage of especial PV panel is also another barrier. In this point Revision of photovoltaic systems should Support Schemes for instant protraction, constant funding during the contract period. New support plans may be needed in case of increasing the capacity of Photovoltaic Systems from 20 KW to 100 KW. It should be noted that importing the PV panel has to pass by several filter specific for import anything North Cyprus and those filter will increase initial cost.

One of the notable's points of promoting the PV panel is economy. This issue analyzed and the result was satisfied. PV cells would pay back the energy used in their manufacture within 1.5-2 years in compare of their 25-year lifetime in depend of type of cell and installation type. The result is, Account for the reduction in your energy bills if you use your own power. In addition, one of the great advantages of Photovoltaic system is the simplicity of its installation, and generally, a certified installer, and those are not charge normally.

North Cyprus regulation and registration it is not approve yet. However, approving process, it may take long issue but it should formulate as soon as possible, although the time is gone but at least the experience of European Union is good study to not iteration their mistake. Important achievement factor for the (FIT) system is the strict, in some detailed-calculation of the threshold (shire) for profitable operation of Photovoltaic plant ("break-even point") and 6 % risk extra. The demand of market does not respond regularly to the amount of the feed in tariff, but in small investment, sector barriers are very sensitive. That means changing the FIT may have deep affect to their interest to use of PV panel.

In most history of usage of Subsidy programs in world shows, that subsidy can be too effective for short term strategy to excite the market ("PR-effective"); however, a sustainable campaign strategy for renewable energy should not depend only on the typical government budget and limitations of subsidy organizations. Without the parallel rough guide of the Germany program ("EEG-HTDP") might be definitely have been unsuccessful. A necessity for a current market monitoring system is high. Hence, great budgets to install and start a system are essential. There is a highly need for a consistent monitoring-system on European Union scale rather than just national improvement approaches.

6.1 Recommendation

In the following section, a few recommendations are stated that will lead to facilities the market of photovoltaic technology in North Cyprus' housings, urban and rural structures. Generally, the field of renewable energy technology is a conservative field. In addition, because it is project based it involves a vast network of assets. The coordination of this network needs experience which leads to performance improvement, value maximization. Another important concept is to reduce resistance to adapt to new concept and technology. These being said the aim of the policies should be:

- Licensing and authorization procedures are the main problems faced in building related photovoltaic projects, briefly mentioned in the previous section, hence eliminating these barriers will lower project risk.

- Implementation of a monitoring system to allow updating the transition and applicability of capacity caps.

- To increase public awareness and to reduce the resistance to adaptation, development of a communication strategy is of most importance. This development should be targeting both private and public sectors.

- Create the conditions for training certified installers, architects, engineers, financing and insurance sectors.

- Establishment of a mold to certify product and to overcome other barriers such as:

    1. Issues regarding constructional and electrical safety
    2. barriers related to authorization procedures at local level, in particular those related to building permits;
    3. Barriers related to local urban planning instruments (e.g. master plan), namely restrictions related to visibility of PV systems in historic areas;
    4. barriers regarding including insurance of PV systems within the context of other building-related insurance packs;
    5. Barriers related to financing of PV systems within the context of housing long-term bank loans. Most of the required framework of action to deal with these prospective barriers should then be of normalization and/or regulatory nature.

6. The present recommendation is essentially aim at the core policy actions: technology capacity caps, feed-in tariff structure, licensing framework and authorization procedure, and monitoring system. Further developments should make in what regards accompanying measures and its detailed establishment (e.g. development of the communication strategy and of training and Accreditation programs for installers).

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