

**THE REPUBLIC OF TURKEY
BAHCESEHIR UNIVERSITY**

**CHALLENGES AND OPPORTUNITIES OF
ARCHITECTURAL INTEGRATION OF PHOTOVOLTAIC
PANELS INTO BUILDING SKIN IN ISTANBUL**

Master's Thesis

MOHAMMED ALTBASHAT

ISTANBUL, 2017

**THE REPUBLIC OF TURKEY
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Name of the thesis: Challenges and opportunities of
architectural Integration of photovoltaic
panels into building Skin in Istanbul

Name / Last Name of the Student: Mohammed Altbaishat

Date of the Defense of Thesis: 30.05.2017

The thesis has been approved by the Graduate School of Natural and Applied
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Master of Arts.

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scope, quality and content, as a thesis for the degree of Master of Science.

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank God the most gracious and most merciful for making me a curious being who loves to explore the universe and for giving me the power to believe in myself and write this thesis.

Furthermore, I would like to express the deepest gratitude to my supervisor and role model Dr. Mehmet Bengü Uluengin, for believing in me and for his valuable comments, remarks and engagement through the research process of this master thesis. Without his supervision this dissertation would not have been possible. I would like to give special thanks to the program coordinator Dr. Özen Eyüce, and Dr. Onur Turan for being my jury members. Special thanks also to the lecturers of MSc Architecture at BAU for their expertise and motivation during the Masters course. In addition, I would like to thank HRH Princess Dr. Nisreen el-hashemite for introducing me to the topic as well for the support on the way; whose passion for the topic had lasting effects. Also I like to thank Mr. Ahmet Acar and the rest of the participants in the research, who have willingly shared their experience and knowledge during the process of interviewing.

No words in this world can express how much I am feeling grateful to my lovely family, for their unflagging love and unconditional support. My father, Omer Altbaishat for his constant motivation, support and trust, you always make me feel safe. My mother, Zainab Albsool, who has selflessly given more to me than I ever could have asked for. Without your knowledge and experience I would never make it, your path has always been my motivation to the success. My deepest gratitude to my sister and brothers for every single moment you spent supporting and thinking of me, thank you for your love.

A special word of thanks also goes to my special friend Shahinaz for helping me during the data collection process and for keeping me harmonious and helping me putting pieces together and being always there, I will be grateful forever for your substantial support. Last but not least, particular thanks go to my friend Mahmoud and my friend Faris for their moral support, also not to forget my friend Ahmad who revised parts of my thesis. Finally, I have to acknowledge all my colleagues; you were helpful to color my life during the past two years. Other close friend I would like to mention: Ali, Naser, Hashem, Monther, Tareq and Mohammad, thank you for caring and supporting.

Istanbul, 2017

Mohammed Altbaishat

ABSTRACT

CHALLENGES AND OPPORTUNITIES OF ARCHITECTURAL INTEGRATION OF PHOTOVOLTAIC PANELS INTO BUILDING SKIN IN ISTANBUL

Mohammed Altbaishat

Master of Architecture

Supervisor: Assoc. Prof. DR. Mehmet Bengü ULUENGIN

May 2017, 65 pages

Climate change has been one of the hottest topics to discuss in the current time and it is one of the most serious issue humanity is facing right now and must take fast and serious actions to overcome this dilemma. For this reason, humanity must rely more on renewable resources, such as solar energy, rather than fossil fuels to produce required energy to run cities. Since fossil fuels emit huge amounts of greenhouse gases like carbon dioxide and other harmful gases into the environment when burnt to extract energy needed for heating, cooling and lighting. On the other hand, there is an endless source of energy which humanity can depend on as it is free, clean and harmless to humanity and environment which is solar energy .However, in some developed countries like Turkey this value is been neglected in building sector, as no noticeable integration efforts is been shown.

This dissertation tries to clarify the main challenges that are facing the integration of PV into building facade in Istanbul. In order to collect data a qualitative survey of open ended interviews was used among specialists in the field and projects' stakeholders, trying to explore the factors that hinder the integration from their perspective.

The findings of this dissertation uncovered that utilizing PV in Istanbul is facing some challenges such as cultural obstacles, lack of PV awareness, lack of skilled experts, the absence of cooperation between related authorities and some regulation problems. In addition, this dissertation provided some recommendations and solutions to overcome the challenges of PV adoption and integration into building's envelope in Istanbul.

Keywords: Photovoltaic, Integration, Technology in Architecture, Green Buildings.

ÖZET

İSTANBUL'DA BINA CEPHELERİNE PV PANELLERİNİN MİMARİ ENTEGRASYONUNUN ZORLUKLARI VE FIRSATLARI

Mohammed Altbaishat

Mimarlık Yüksek Lisans Programı

Tez Danışmanı: Doç. Dr. Mehmet Bengü ULUENGİN

Mayıs 2017, 65 sayfa

Fosil yakıtlarının aşırı kullanımından dolayı iklim değişikliğinin çokça dikkat çektiği bir dönemde, güneş enerjisi ile çalışan enerjilerin tanınması ve kullanılması insanoğlunun geleceği adına önemli bir rol oynamaktadır. Geleneksel ısıtma, soğutma ve ışıklandırma sistemi muazzam miktarlarda fosil enerjisi kullanır ve çevreyi ciddi boyutlarda kirletir. Halihazırda bulunan binalar kullanım, hasar ve israf bağlamında büyük bir sorumluluk taşırlar. Son yıllarda odak noktası fosil esaslı enerji kaynağının; masrafsız, sonsuz bulunan ve insan hayatına ve çevreye zararsız olan güneş enerjisi ile değiştirilmesi üzerinedir. Ancak, Türkiye gibi gelişen ülkelerdeki inşaat sektörlerinde, fark edilebilir bir entegrasyon çabasının olmadığından, bu konunun ihmal edildiğini görebiliriz.

Bu tez, İstanbul'da PV panellerinin bina cephelerine entegrasyonunun karşılaştığı ana zorlukları açıklığa kavuşturmayı hedefler. Bilgi toplamak adına, bu alanda uzman ve projelerin ilgili taraflarıyla; kendi perspektiflerine göre bu entegrasyonu engelleyen faktörleri keşfetmeyi hedefleyen açık uçlu mülakatlardan oluşan nitelikli bir araştırma yapılmıştır.

Bu tezin bulguları; PV'nin İstanbul'da kullanımını kültürel engeller, PV farkındalığının eksikliği, yetenekli uzmanların eksikliği, ilgili makamlar ile işbirliği yoksunluğu ve düzenleme problemleri gibi zorluklarla karşılaştığını gösterir. Bunlara ek olarak; bu tez İstanbul'daki bina cephelerine PV kullanımının benimsenmesi ve entegrasyonunun karşılaştığı zorlukları aşmak için bazı öneriler ve çözümler sağlar.

Anahtar kelimeler: Fotovoltaik, Entegrasyon, Mimarideki Teknolojiler, Yeşil Binalar.

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ABBREVIATIONS

BIPV	:	Building Integrated Photovoltaic
BREEAM	:	Building Research Establishment Environmental Assessment Method (certificate)
CEDBIK	:	Turkish Green Building Council
LEED	:	Leadership in Energy and Environmental Design (certificate)
PV	:	Photovoltaic
ROI	:	Return on Investment
USGBC	:	US. Green Building Council

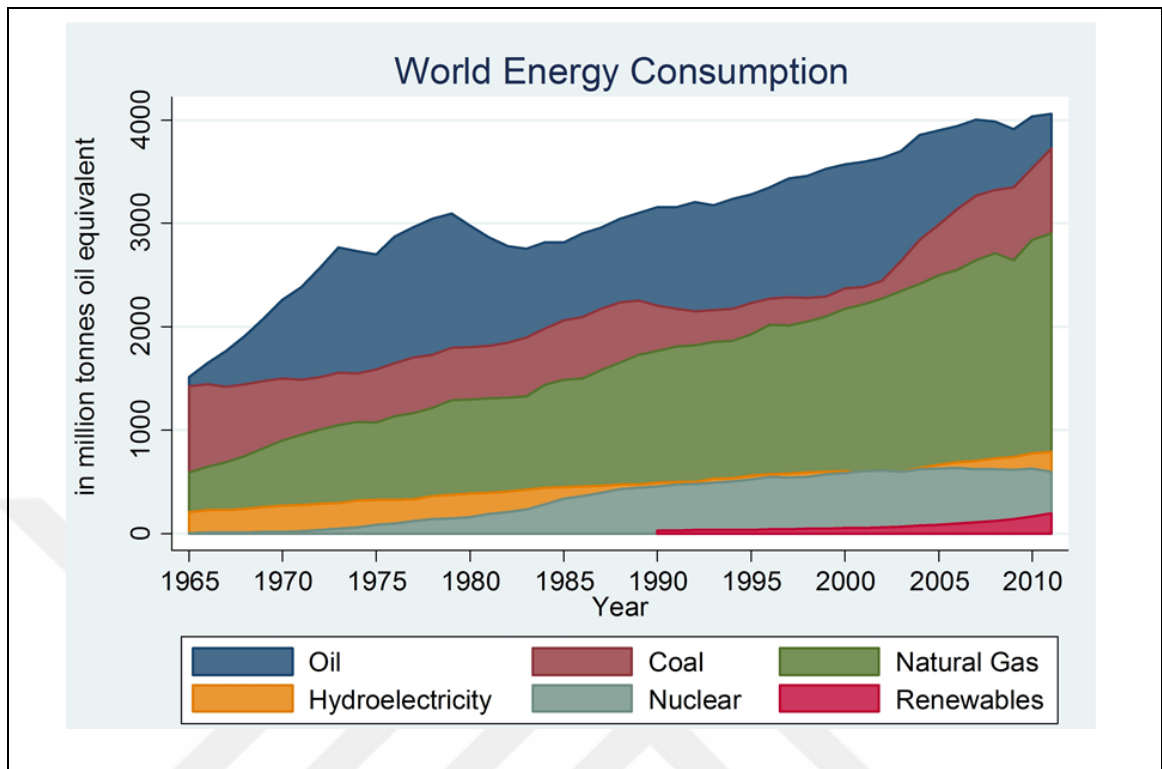
1. INTRODUCTION

1.1 RESEARCH BACKGROUND

Humankind's most significant inventions and achievements have, by and large, relied on fossil fuels; they have been on top of the list of energy sources since the day they were discovered. We are at the end of the second decade of the third millennium, and the reliance on petroleum is still at its peak, ignoring some important facts, that oil is harmfully affecting the environment due to the emissions of CO₂ when consuming it, causing of environmental problems (climate change, global warming and air pollution)(Spooner, n.d.) . Although oil now pays back almost eighty times the energy needed to extract it, studies show that the world is approaching the depletion of fossil fuel due to the excessive use of it, in other words, the world will reach (if not reached) peak oil -world need will be enormously exceeding world supply-. This is referred as energy scarcity (Energy scarcity, n.d.).

Figure (1.1) also approves the continuously increasing need of energy. Hence, all that must encourage mankind to search for new sources of energy, most preferably renewable energy as most of the renewable energy resources and even technologies used to exploit them has firstly, the minimum carbon emission, which helps to minimize our carbon outputs at an international level (Mason, n.d.). And secondly it is inexhaustible resource, as the name (renewable) itself suggests, it exists in nature with unlimited amounts (List of Inexhaustible Resources, 2017).

Figure 1.1: World energy consumption between 1965-2010

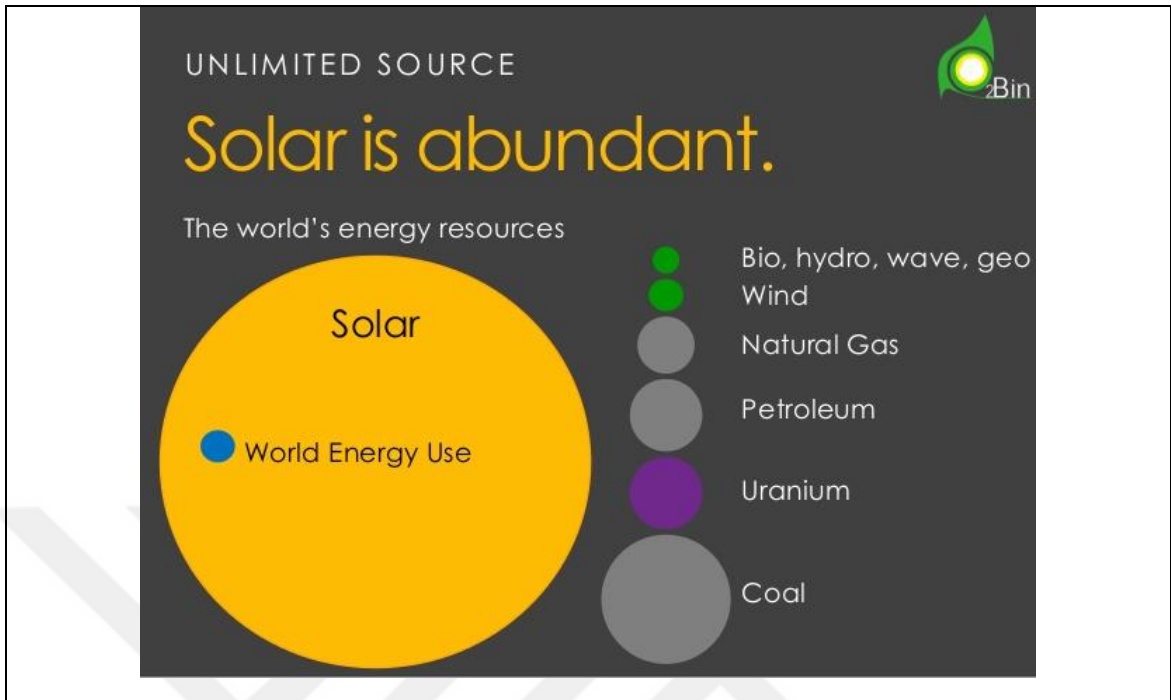


Source: BP statistical report of world energy, 2012

1.2 ALTERNATIVE ENERGIES (SOLAR ENERGY)

Hence, many factors encouraging to harness renewable energy, especially energy generated from the sun as it is widely available enormously. It has been theoretically proved that renewable energy can produce almost 3100 times of global energy needs, knowing that only solar energy can meet about 2850 times of the world energy demands (Wall et al., 2012) (figure 1.2). In addition to that, solar energy is completely free if we exclude the installation expenses, and the sustainability of it does not get affected in case of natural disasters and emergencies. That grants solar energy the potential to get the priority to be used on other types of renewable energy, which is the responsibility of governments, businesses and professionals (architects and engineers).

Figure 1.2: Renewable energy resource of the world



Source: Co2bin Energy Solutions, 2013.

Active and passive solar systems can be considered as the main two ways to benefit from solar power. As both capture and utilize solar energy, the main difference between them is that, Active solar system mainly rely on external systems (such as solar collectors and heat pumps) to collect solar energy and convert it into electricity. While in case of passive solar systems unlike the active systems it does not rely on any external devices, but depending on other architectural solutions such as south-facing windows (to gain and absorb maximum sun rays) and thick insulated walls (Rinkesh, 2016).

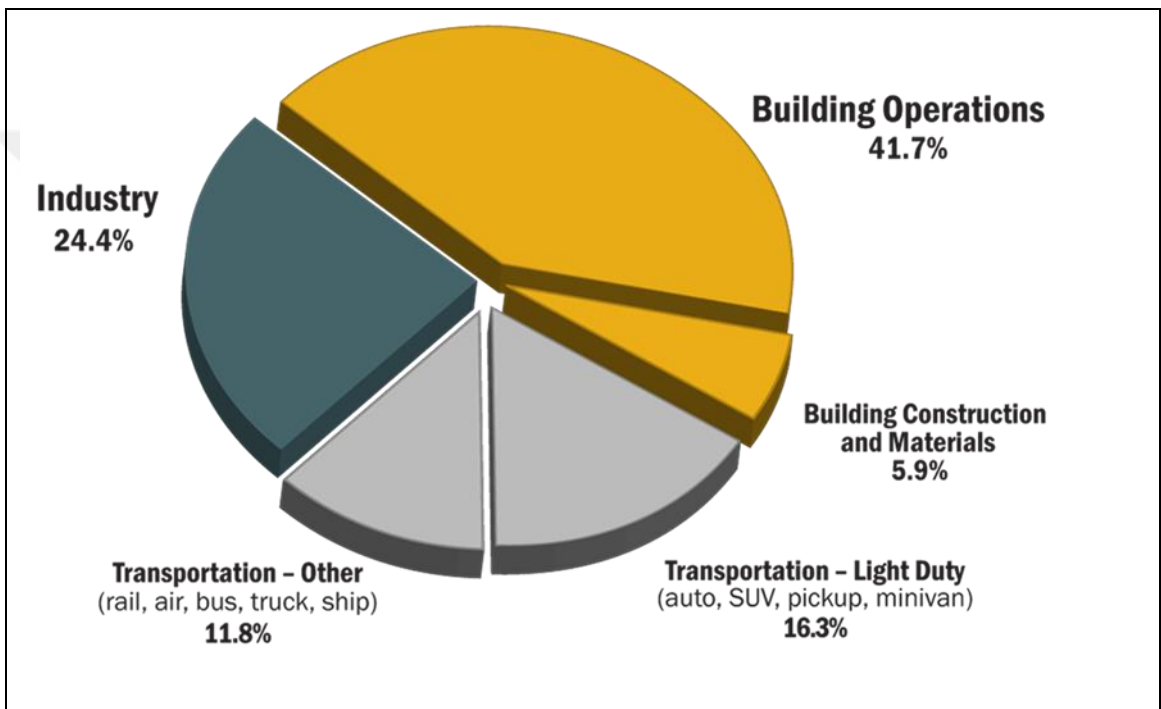
The world witnessed remarkable sales results of solar-based energy systems in the past 3 decades (wall et al., 2012). However, using these systems in buildings is been omitted. Hence, we have to reconsider it as the modern solution of many of humankind's current and future problems.

Turkey is a very rich region when it comes to solar resources. However, it is a disappointing fact to know that this value is being neglected in Turkey while the whole world is competing and starving to exploit this valuable resource.

1.3 BUILDING SKIN AND SOLAR TECHNOLOGIES

Involving solar technologies in building industry is very important to best utilize the solar resource, as almost half of the energy produced in the world is being consumed in buildings (building operations, materials and building construction) (energy information administration [EIA], 2012)

Figure 1.3: Energy consumption by sector



Source: architecture 2030, n.d.

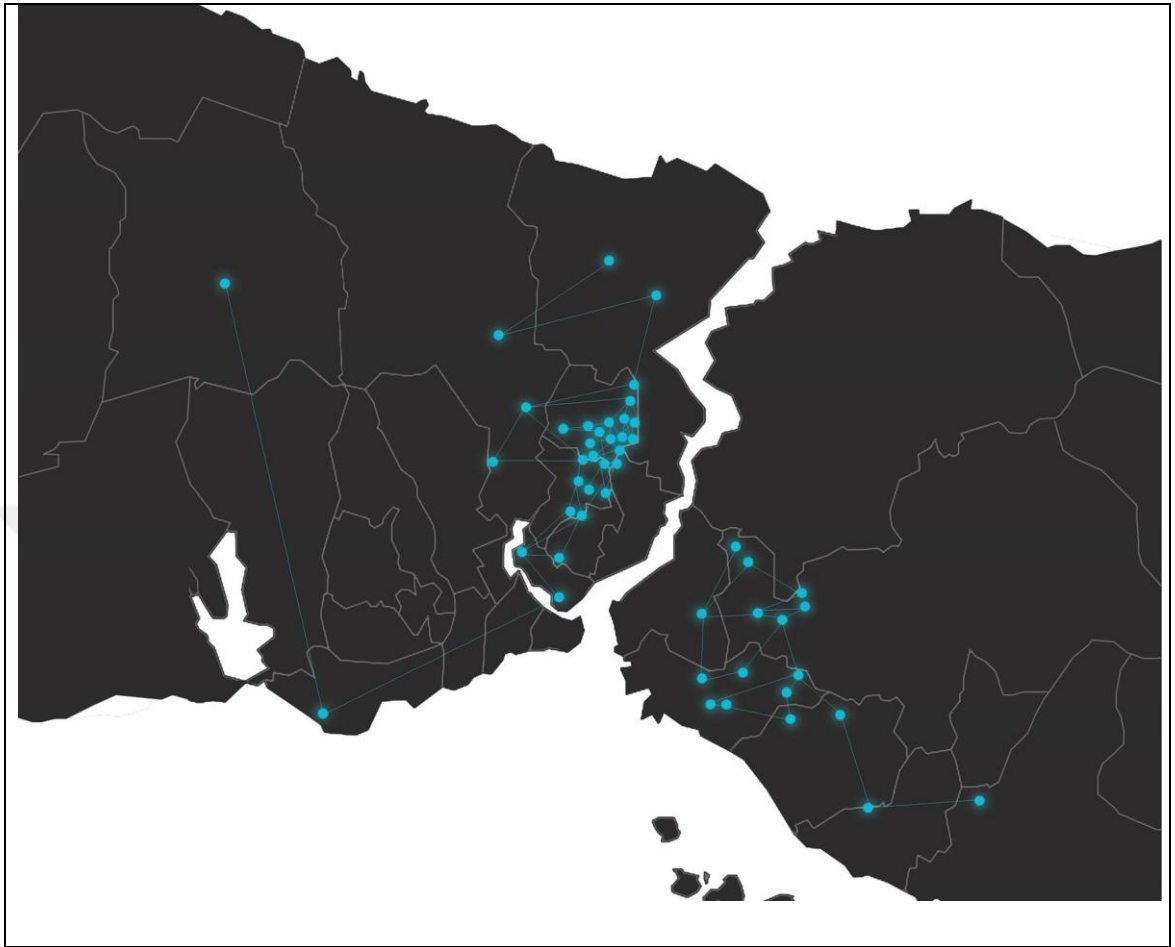
In architecture the concept of passive solar design has been in use since the ancient times. Architects are always concerned about windows placement, walls thicknesses and floors insulation to use solar energy in the most efficient way. However, after the appearance of technologies that boosted utilizing solar energy in buildings such as PV panels, people limited their vision to the conventional ways of using sun power as in passive design and barely benefit from these technologies.

The evolution of the solar architectural integration can be divided into three main stages, depending on the aspects of integration prioritized in each stage (economical, functional, constructional, cultural, social and aesthetic aspects) (Farkas et al., n.d.).

And because functional and economical aspects were prioritized during integrating the first generation of photovoltaic systems into buildings, these components were treated just as elements added to the envelope of the existing buildings (Farkas et al., n.d.). Since then, it is clear enough that there is confusion in understanding the solar architectural integration, where people are mixing between the formal definition of architectural integration and the common definition of architectural integration (building integration). In the second generation the focus was on the constructional aspect, so the cells were more integrated into buildings than being added later. However, now in the third stage some attention should be paid to the aesthetic and cultural aspects if we want to achieve a real development in the solar architectural field (Farkas et al., n.d.). It is very important to understand that the integration of solar technologies into built environment must not be limited on applying solar devices on buildings just to generate energy, but rather these devices should be treated as architectural elements that have thought about from the first phase of the design process to be a part of it. Only in that case we can develop the conventional architectural methods to utilize solar energy.

Istanbul has a very good potential to integrate PV system into buildings skins; abundant solar power and the good number of huge facades and roofs of the towers makes Istanbul a great potential for the BIPV. However, the implementation of PV system on buildings' skin is limited, while the number of green certified buildings is too big when compared to the number of BIPV, knowing that green building certificate paves the way for buildings to utilize PV, since using renewable energy technologies supports the checklist for the candidate building. The following is a study showing buildings with green certificates and their distribution according to area in Istanbul (figure 1.4).

Figure 1.4: Mapping of Istanbul showing green certified buildings



Source: Author

1.4 RATIONALE OF STUDY

The justification of this thesis is to understand how the dynamics in Istanbul play to hinder or to enhance the architectural integration of PV technologies, by investigating people's perception on the architectural integration of said technologies, since similar researches and reports did not focus on such a framework in a developed city like Istanbul. However, the hypothesis upon which this study is based is that the integration of PV panels into building skins in Istanbul is hindered by certain social, cultural and educational obstacles.

1.5 RESEACRH AIM

The aim of this thesis is to investigate the barriers and the potentials of the architectural integration of photovoltaic panels into building skin in Istanbul. Relying on the perception of people and the experiences in the Turkish field.

1.6 RESEACRH QUESTION

After introducing photovoltaic technologies as an alternative energy producer in building sector, the researcher has shaped the following question to be the main research question:

What are the barriers and the potentials of the architectural integration of photovoltaic panels into building skin in Istanbul?

In order to answer the above question in a structure of a thesis, the following questions will help doing that:

- a) What are the current photovoltaic contributions in the construction industry in Istanbul?
- b) To what extent photovoltaic systems can be utilised in the Turkish construction industry in Istanbul?
- c) What are the main challenges that are facing the utilisation of these systems in Istanbul?

1.7 RESEACRH SCOPE

Enhancing the quality of integrating PV into building skin has always been a very significant delayed case. To attain the best of the architectural integration of PV, three main aspects should be studied; the **aesthetic**, **functional** and **constructive** aspect can

be considered as the main aspects to achieve the so called good architectural integration (Probst and Roecker, 2011).

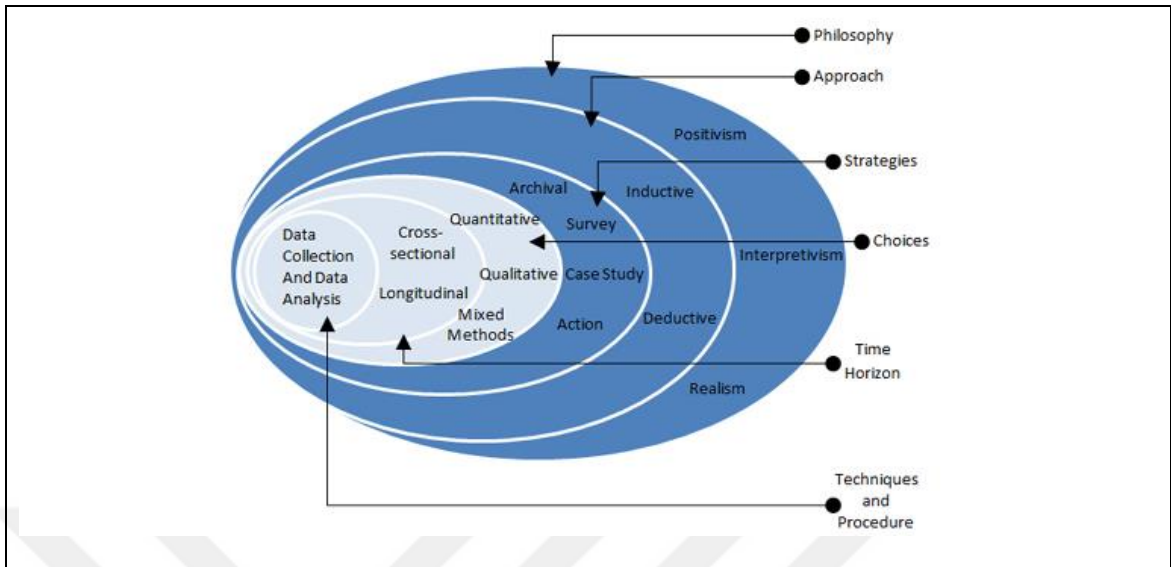
Within this thesis we will try to understand, “to what extent the tripartite functionality of PV can be achieved in building skin in Istanbul”.

1.8 METHODOLOGY

It is very important for the researcher to decide on the methodological choice of the thesis as it is leading the decision of the tools and the methods utilized in the research (Saunders and Tosey, 2012). Quantitative and qualitative research designs are the main options of the methodological choice, and deciding on one of them or either a mixture of both fits to a specific type of researches and will lead the whole process of the thesis accordingly. According to Golafshani (2003) “the process of research consists of developed questions and procedures that are related to participant’s environments”, and since the goal of this thesis is to understand, investigate and discover the essence of research question, focusing on the quality of experiences, a qualitative research method was applied for a more flexible and evolving goals.

The research onion helps the researchers to determine their position while choosing which methods and tools to use, going from outer layers to inner ones as illustrated in the figure (1.4). Hence, depending on the nature of this research, the study is composed of two main parts (entities). The first one is the literature, in this part theoretical background information were provided through filtering and reviewing the literature on PV technology. It starts by introducing PV technology then continues by illustrating the characteristics of PV in buildings and the aspects of its integration into buildings. The accumulated knowledge about this relatively new topic was analyzed to show PV abilities of integration into building skin.

Figure 1.5: The research onion



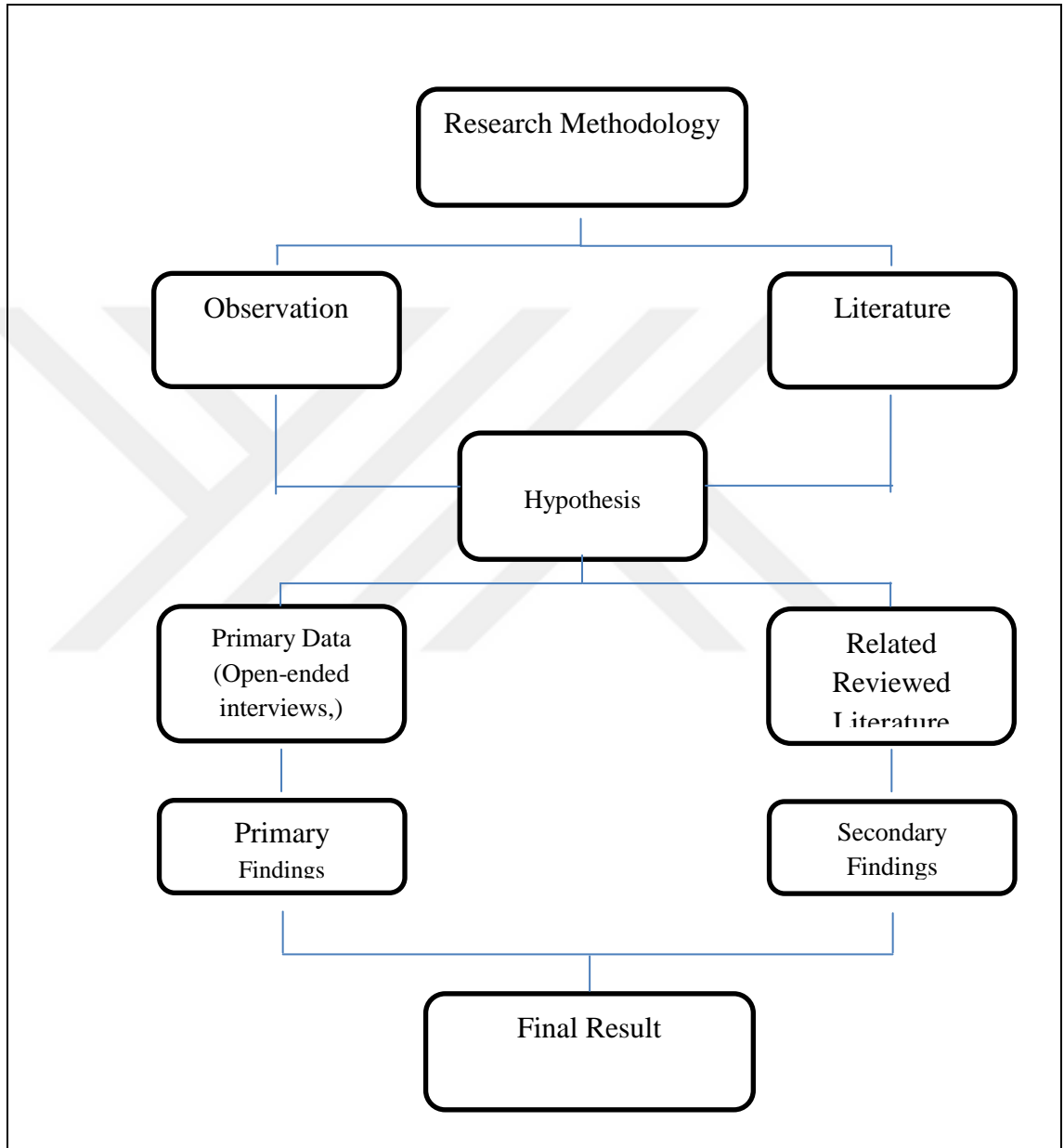
Source: SAUNDERS ET AL, 2009.

The second part is the qualitative inquiry; open-ended interviews were adopted for data gathering. Since, these interviews will help to understand the perception, of people on the integration of photovoltaic into building's envelope. However, the interviews were conducted in an estimated time of three months; the researcher started a convenient sampling technique then then relied on the snowball strategy to choose the participants of the study, as they were mainly 13 participants, between specialists in PV technology, expert in the field, architects, electric engineers, environmental engineers and users.

For the interviews some certain questions were prepared, so as for the researcher to guide the interview towards the satisfaction of thesis objectives, but additional questions were brought up during the interviews.

The collected data are subjected then analyzed and discussed in reference to the related literature, depending on a coding technique created by the author. moreover, a concluding statement including general observations about the topic of the research, proposing research's extensive points to be studied further by other researchers.

Figure 1.6: Thesis framework



Source: Author

1.9 STRUCTURE OF RESEARCH

Chapter 1: in this chapter the author puts the introduction of the research, which explains our need for energy, and introduce some alternative solutions based on solar energy, then gives a brief on the integration of solar technologies into building facades based on photovoltaic systems, it also illustrates the methodology, the rational and the aim of the study, in addition to the research question and its scope.

Chapter 2: within this chapter relevant former literature were analysed. Therefore the name Literature Review was given to this chapter. It contains theoretical studies about PV cells and modules, and explains the three families of PV panels; monocrystalline, polycrystalline and thin films, then analyses the important characteristics of photovoltaic, then talks about the integration of PV systems into building's envelope in detail.

Chapter 3: This chapter presents the data gathered in the research; it illustrates the conducted interviews with thirteen participants and explains how the data were gathered. Therefore the name of this chapter is Data Collection.

Chapter 4: This section of the thesis mainly deals with analysing primary data that were presented in the previous chapter from the conducted interviews with participants from the field in Istanbul through analysis themes. In addition to that this section also discusses the findings emerged in the analysis. Therefore, this section is named as Data Analysis and Discussion.

Chapter 5: In this chapter the conclusion of the thesis took place, where further recommendations were proposed for decision makers, players in the field and for future researches as well. Chapter named as conclusion.

2. LITERATURE REVIEW

2.1 PHOTOVOLTAIC

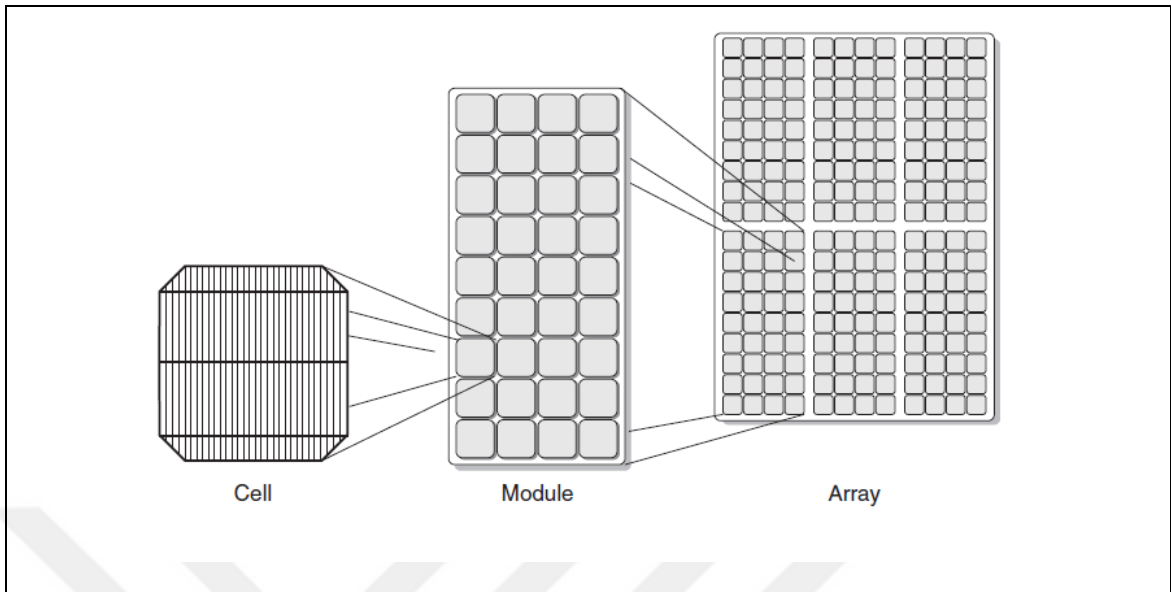
There are many technologies that can be utilized to exploit solar power. One of these technologies is photovoltaic. The process of solar power conversion based on the photovoltaic effect in which sun rays is being converted into electricity generally describes photovoltaic technology (Zeman, n.d.). Photovoltaic effect refers to a chemical phenomenon, which can be defined as the generation of a current between two materials upon a radiation exposure (Boer, n.d.). For a better understanding of the terminology, photovoltaic is combination of two words (photo-voltaic), “photo” is derived from the word “phos” which means light in Greek, while “voltaic” is derived from the name of the pioneer of electricity and power Alessandro Volta (Zeman, n.d.).

As soon as the light hits the two layers of the semiconductor diode of the PV cell, some of the photons will be absorbed, this will push the electrons to flow from one layer to the other one (from negative to positive) producing the electric current (SECO, n.d.).

Although photovoltaics (PV) is not a new technology as dated back to the early 19th century, it took us a lot until we started benefiting from the electricity generated from PV (EERE, n.d.). However, this technology has proved that it is developing very fast in the last couple of decades, since it has been integrated with many sectors such as aviation, transportation and the construction industry (EERE, n.d.).

As illustrated in the figure (2.1) the small-sized cell is the main PV system unit. Connecting these cells together forms a module and if modules are wired in series that is called a PV array (SECO, n.d.).

Figure 2.1: Photovoltaic cells, modules and arrays



Source: (SECO, n.d.)

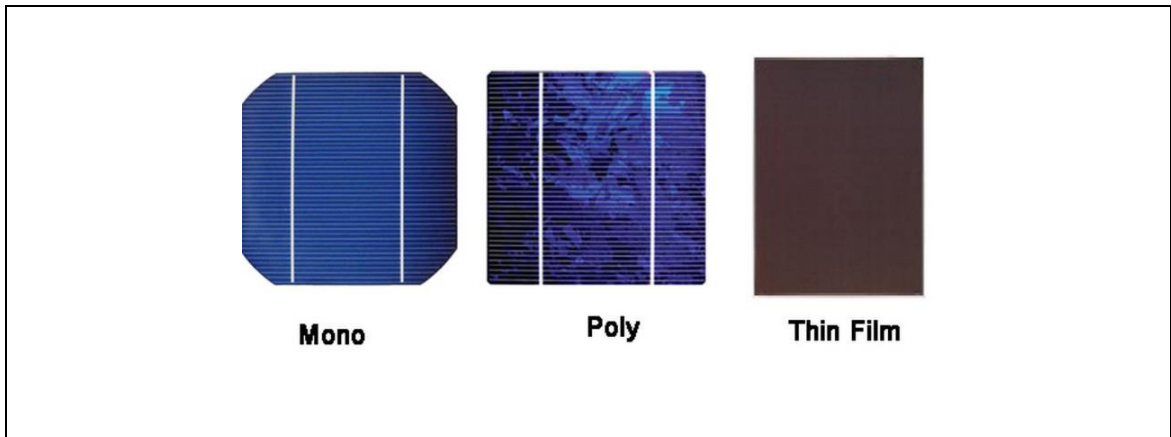
2.2 PV CELLS & MODULES

As mentioned before PV cells are the smallest main devices in a PV system. Hence, they are considered as the fundamental building block of a PV module, and that helps these systems to be formed in numerous shapes and forms to fit any purpose. In addition, new technologies enabled PV cells to be produced in varied characteristics, technically and aesthetically (Fuentes, 2007), which gives it the pliancy to be more involved and better integrated into buildings.

However, each and every module is encapsulated with a transparent layer on the sun-facing surface and another protective layer on the bottom of the module, and because of the different encapsulation technologies, the quality and the performance of the cells varies.

PV cells can be categorized into three major types as follows, mono-crystalline, Poly-crystalline and thin film (Suntronicsolar, 2017).

Figure 2.2: The three major types of PV cells



Source: (suntronicsolar, 2017)

2.2.1 Mono-crystalline cells

This type is the oldest, the most expensive and the most efficient as compared to other techniques (Solardirect, n.d). Their production requires a huge amount of pure silicon since they are made up of high purity silicon crystals, a continuous silicon crystal is cut into a wafer with a thickness of 0.3 mm. Considering silicon to be derived from sand, the second most abundant matter of earth, and it should be extremely purified in order to be used as a photovoltaic cell and this explains why this type is expensive as compared to others (Wholesalesolar, n.d.). In term of shapes and appearance, usually mono-crystalline silicon modules have a circular shape which can be trimmed in order to reduce the lost space however they, more or less, preserve their rounded shape, moreover their colors lay between black and blue so they are monochrome (Basnet, 2012). There are more colorful less efficient types. The efficiency of these modules is high and reaches up to 17% (Solardirect, n.d).

2.2.2 Poly-crystalline cells

Polycrystalline modules are considered to be aesthetically more pleasing, less efficient and require less manufacturing cost. Although these modules are made up of silicon material too, the process of production is fairly different. Instead of being cut from a single continuous crystal, silicon can be extracted from waste materials, resulting in less manufacturing costs (Solardirect, n.d). Silicon is crushed, heated and melted in vacuum,

poured into a mold later, and this results to an imperfect and random arrangement of crystals within the module when the material cools down. Consequently, this process leads to the creation of different shades of blue on the surface of the cell thus aesthetically appealing cell, looking like “gemstone” will be formed (Wholesalesolar, n.d.). In addition, the dimensions of these modules usually are equal, thus less space to be lost when mounted (Fuentes, 2007). In terms of efficiency, polycrystalline modules are less efficient compared to mono crystalline, with efficiency of 11% maximum.

2.2.3 Thin films

This type of modules need less silicon material, less power consumption thus lower cost, however thin film cells are less efficient (Suntronicsolar, 2017). The manufacturing of these modules does not require wasting time, energy or material in order to cut pure silicon crystals into wafers (Wholesalesolar, n.d.), on the contrary, silicon is exposed to high temperatures then let to vaporize and deposit on glass, stainless steel or plastic glazing (Solardirect, n.d) thus making thin film modules more flexible, thinner and lighter as compared to other cells (Wholesalesolar, n.d.). In addition, a wide variety of colors can be produced (Basnet, 2012). Moreover, thin film modules are easy to apply and some of them can behave better in low light conditions (wholesale solar) yet they are less efficient, merely 8% comparatively, which requires the application of more cells in order to get the desired energy amount (Wholesalesolar, n.d.).

2.3 POTENTIAL CHARACTERISTICS OF PV FOR INTEGRATION

There are many aspects that should be thought and considered when integrating PV system into a building. For example, PV modules should be architecturally and aesthetically accepted since the physical properties of PV modules have a great impact on the appearance of the building so PV modules should be in a great harmony with other building elements in the scoop of texture, color size and shape.

2.3.1 Material and texture

Silicon is the main semi-conductor to be used in the production of PV cells. Since there are many types and various production strategies PV modules will consequently have different textures. Mono-crystalline cells, for example, are produced by cutting a single silicon crystal that is why they have homogenous surfaces and more regular texture (Farkas et al., n.d). On the other hand, polycrystalline cells are produced by melting and pouring silicon crystals thus they have an “an anomalous” surface, silicon crystals are visible (Farkas et al., n.d). To add more, there are metal conductor strips passing through cells, usually made up of copper, and are highly visible from close distances (Farkas et al., n.d). Moreover, glass is sometimes used to cover modules to create a semi-transparent affect however since glass is highly reflective this may cause unwanted glare occasionally and the efficiency of modules may decline thus glazing is sometimes coated with a non-reflective coating to increase the efficiency of modules and energy transmission (Basnet, 2012).

2.3.2 Color

Integrating PV modules is becoming more popular than ever, thus increasing the demand of making them more acceptable architecturally when integrated to any building element and color is one of the most important elements to be put in consideration in this case. In fact, generally speaking, different elements of this system do have a variety of colors, for example crystalline color is blue however the anti-reflecting coating which used to increase efficiency and absorption of energy and reduce emission loss, are mostly black or dark blue. In addition, there are different types of thin film cells and this makes a wider color range for such modules like black or greenish cells thus helping in creating different patterns in building envelope. Moreover, depending on the reflected sun light on the surface of modules and the angle of vision many other colors can be visible such as violet, blue and red including dark green and dark brown but very little. To sum up, there are many different products out there in the market thus designers and users should decide the type of technology desired and try to explore those products.

2.3.3 Size

There are many factors that should be taken in consideration. For instance, all the architectural elements and BIPV should be in a great harmony in order to get the desired aesthetic and architectural result since solar panels and collectors will appear as an architectural element they should have “attractive expression” when they are used on a limited part of the building (Basnet, 2012). So producers are trying to create modules which fit easily with their surrounding like roof tiles or other facade elements, in an attempt to make them more architecturally and aesthetically accepted (Basnet, 2012). In addition, the desired amount of energy plays an essential role in determining the space where integration of modules takes place thus the size and amount of BIPV changes relatively. Generally, the size of a single cell, usually mono-crystalline and poly crystalline cells is 10 x10 cm or 12.5x12.5 cm (Farkas et al., n.d). However, thin films can be more flexible and has no limitation of size. Moreover, to increase freedom when using PV cells a new cut-to-size technology can be used directly on site (Basnet, 2012).

2.3.4 Shape

The shape of modules must be in harmony and compatible with all other elements existing in facade or roof systems (Basnet, 2012). In fact, PV modules tend to acquire significantly limited shapes, ranging between quadratic and semi quadratic, round and half round (Farkas et al., n.d). However, the most dominant shape is the quadrat since it can be applied easily with the minimum space loss possible depending on the energy output amount desired (Farkas et al., n.d).

2.3.5 Jointing details

As mentioned earlier, the shape and size of PV modules should be in a great harmony and highly compatible with the surrounding elements of roof or facade systems. Since, there are many types of joints; they must be carefully selected to work in harmony with the system with relation to building and building elements. In addition, there should be a great similarity between the structure grid of the modules and the systems it's attached to.

2.3.6 Cost

Determining the costs of BIPV systems require many aspects to be put in consideration. Firstly, the type of the system, whether it is standardized or customized, will significantly affect the costs, in addition to “balance of system” components such as inverters, electricity storage units and wiring which will also add to the bill. Secondly, design and installation costs, generally integrating a PV system in to a building will add 7% to 10% of the total cost of construction and design as compared to traditional cladding materials. Moreover, there are maintenance and cleaning costs, regularly PV modules are cleaned every six month as to make sure the amount of output desired in not in inclination, however if the maintenance and cleaning costs are higher than that of the reducing of power output, it is more wise to skip this process, such a problem can be seen in high-rise building or geometrically unusual ones. Despite the fact that PV modules can be costly on the current time, this technology is improving rapidly thus getting cheaper and more available to users (Fuentes, 2007).

2.4 INTEGRABILITY OF PV MODULES INTO BUILDING INDUSTRY

The constant development of this field continues every day to explore the ways PV systems can be integrated and implemented within the building design itself, not by attaching them as add-ins and external plugins, but by considering them as building elements, a part of the envelope that interacts directly and sufficiently with no need for a supporting structure or Auxiliary devices saving additional investments and costs.

Replacing passive conventional building elements with active PV systems as integral part of the design is a productive approach due to their functionality in producing energy and decreasing the whole cost. Such manner should be studied in the early stages of the design phase to ensure that the composition of the building is coherent and efficient from part to whole (Jahanara, 2013).

The terms ‘component integrated’ and ‘building integrated photovoltaic’ (BIPV) refer to the concept of integrating photovoltaic elements into the building envelope, creating a new kind of architectural system aimed at improving the functional and economic

dimension of buildings, establishing a symbiotic relationship between the architectural design, functional properties and economic recovering energy conversion (Odersun, 2011).

It is the implementation of new renewable energy systems that possess the function and performance of conventional materials with additional innovative features. This requires combining energetic, architectural design and engineering with economic studies.

Thus, architects and engineers should understand their role in unveiling the potential of (BIPV) and draw out the advantages to widely apply it in larger scales to form new kinds of infrastructure.

To understand the application of these systems, the physical aspect should be examined with regard to the aesthetic side and visually analyse the outcome to control the overall impression the building gained from this integration, this added system should increase the value of any design further. Without any doubts, a well-designed building with a nicely integrated solar system will be accepted by people (Reijenga and Kaan, 2011).

Of course, the designer must achieve balance between the different aspects since PV systems are quite demanding in standards (position, direction and orientation) to get the best result and enhance their effectiveness, while some design aspects of the building can be more flexible, and therefore there might be some compromises in the process of integration in favour of PV systems' needs (Jahanara, 2013).

PV or “collector systems” on buildings follow one of two integration processes, architectural integration, building integration, or both. An example of that would be the following, in a building integrated PV roof; the roof would be manufactured to have PV modules fixed as its external part. While in an architecturally integrated PV roof, the PV cells would be placed normally on the building's surfaces using normal construction techniques that can be used to place the PV modules roofing elements. In both ways the integration may add on to the aesthetics of the roof and the building as whole, thus called architectural integration (Hestnes, 2012).

It should be noted that making the PV and solar thermal collector systems hidden or not recognizable is not the purpose of integration. As it is not about hiding or shy placement

of an element, and more about the harmonious co-presence between them (Hestnes, 2012).

In conclusion from this example, building integrations can be seen as architectural integration, but does not work in reverse necessarily. It depends on the architectural quality enhancement in order for us to call it architectural integration. However, the following are some advantages of PV integration (Reijenga and Kaan, 2011).

- i. No need for additional land since the installation is part of the building, which saves spaces in densely-built urban areas.
- ii. The cost of an integrated system is economical more than the cost of replacing elements.
- iii. Power is generated on site for electrical uses that manage power usage to avoid losses.
- iv. A grid-connected PV system ensures security, and avoids high cost storage.
- v. The architectural appearance is well integrated and accepted as elegant (Jahanara, 2013).

2.4.1 Methods of integration

The positioning process of PV and STC into buildings can be done by following specific implementing techniques that dictate the where, how and why to apply them. Usually there are three locations for integrating these systems into buildings. They are the roofs, facades and building components like balcony railings, sunshades and sunscreens (Reijenga and Kaan, 2011).

And they can be placed either by superimposition – attachment over existing building envelope, or integration – attachment of system as an integral part of the building envelope (Fuentes, 2007).

2.4.1.1 Superimposed

Suitable for existing buildings cases, simply mounting the solar modules on a structure in a parallel position to its surface whether on roof or building envelope, the underneath materials are not replaced and thus adds to the quality by preserving the existing surfaces and frees the process from some technical constraints. If this superimposition

made the building elegant then it can be called architectural integration, it is a simple method and the impact is minimal, no savings is achieved in substituted elements, it is more as a layer system added to a current structure.

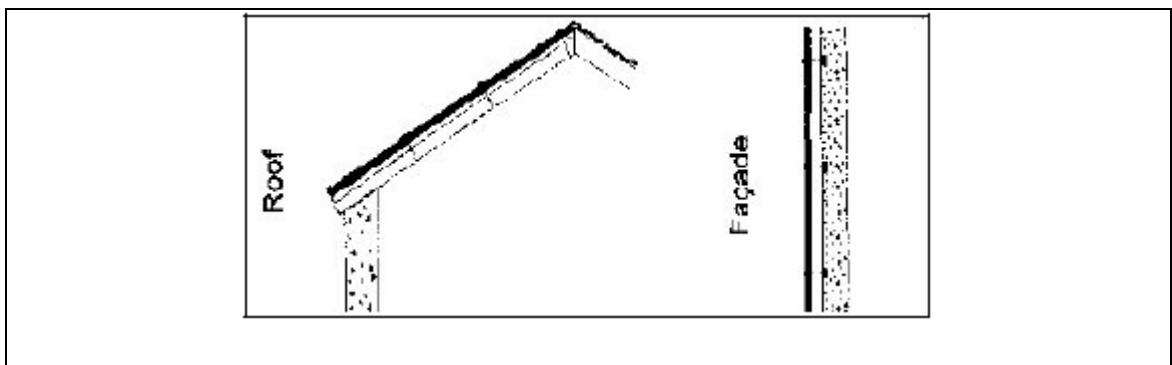
2.4.1.2 Integrated

Suitable for new buildings since this method uses the PV systems as architectural elements making them more functional and energy productive. The conventional constructive elements are substituted by PV materials. The appearance is neat, well designed and savings are possible since the substituted elements are more economic than the traditional ones. Following are some common techniques that discuss integration methods (Fuentes, 2007).

Over-cladding technique

Solar panels are placed as an external layer with thermal insulation by using waterproof materials and fixing them over the opaque layer, this insures that sufficient ventilation reaches the PV modules since it is essential for optimal cell efficiency. This technique is the most efficient as it significantly saves more cost. Figures 2.3 and 2.4 illustrate this technique.

Figure 2.3: A drawing shows solar collectors added as an external layer



Source: (Fuentes, 2007)

Figure 2.4: An example of solar collectors added as an external layer



Source: (Fuentes, 2007)

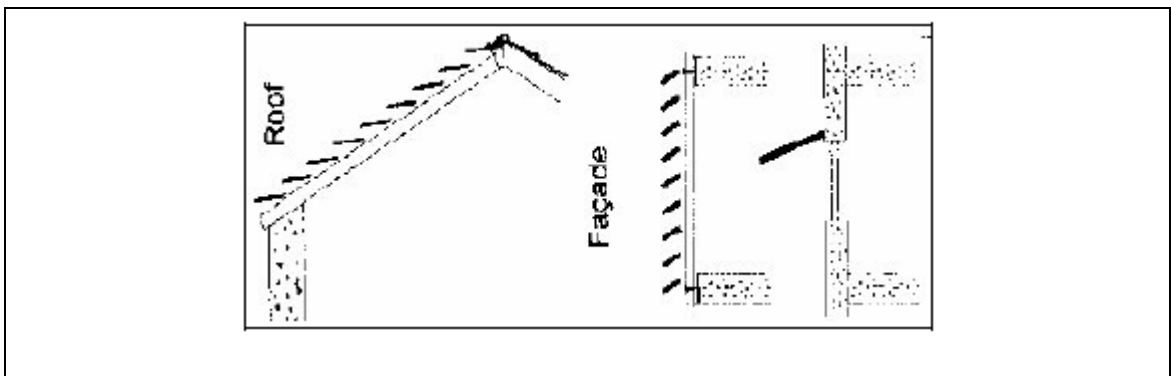
Enclosure technique

Solar panels act as the roof or facade. In this scenario, adapted conventional glazing systems are used for PV cells placement (mullion-transom or structural glazing). Savings in this option are optimal and impact the entire building performance, on an ecological and economic level, positively.

Shadow devices

These are best suited to PV applications due to the heaviness of PV panels. Solutions such as blinds or awnings provide shading to the interior space, shielding direct sun while allowing diffuse, indirect light. They work well with tracking systems to optimize the generated PV electricity. Figures 2.5 and 2.6 illustrate this technique.

Figure 2.5: A drawing shows solar collectors as shadow devices



Source: (Fuentes, 2007)

Figure 2.6: An example of solar collectors as shadow devices



Source: (Fuentes, 2007)

2.4.2 Roof integration

In the design process, roofs were often studied to be functional to the building since they offer a large area to be used either esthetically on the top of the building, gardens, service placement and many other uses, or to enhance its function entirely was to make it more productive with PV system which is a need in sustainable design. There are multiple ways to apply this integration (Reijenga and Kaan, 2011).

2.4.3 Facade integration

Facades are the exterior envelope of the building, with direct contact and effective usable surfaces, which makes them a great potential to integrate PV cells into them. Many treatments are possible to cover these surfaces, with protective cladding and insulations, using different materials that provide different visual effects whether the cladding is wood, metal, glass panels, or PV modules. High buildings with large facades tend to be really costly in cladding opaque parts, especially with materials like natural stones, granite or aluminum, PV modules can be a better replacement of such materials since it is less expensive and more efficient (Jahanara, 2013).

Facade design with such modules can offer a variety of rhythms and formations. An important aspect that helps facilitate the visual integration in the eye of the public. In a

lot of cases the cells are completely detached visually and thus are immediately called-out by the observer as a negative public element, on the contrary, the usage of geometric systems and rhythms that absorbs the new elements into a bigger whole. For example, the south facade of Portugal's Solar XXI building (SHC, 2012) was treated with photovoltaic panels in an alternative rhythm with the glazing in the formation of vertical bands (figure 2.7). This proves that modular systems with PV panels can provide for an aesthetically pleasing visual integration with the glazing part of the facade through the use of recurring patterns.

Figure 2.7: The facade of Solar XXI building with PV integrated into its opaque surfaces.



Source: (www.enginsolar.com)

The structural grid for constructing structural glazing facades can be done with sophisticated profile systems such as curtain walls with which different types of sheets and panels can be filled, like glass and frameless PV modules (Reijenga and Kaan, 2011).

This allows for controlling day light coming into the building since various panels can be placed and PV modules are available as transparent and semi-transparent to control the sunlight intensity. This adds a thermal advantage to reduce cooling loads, along with protection from weather conditions (SHC, 2012).

Treated elevations should face the right sun orientation of course, thus the typical direction is the southward facing walls with vertical alignment and the most active time of the year during summer when the sun is in a high position. However, vertically placed PV panels are less productive than the sloped ones due to the proportion of exposure. Also, placing PV units at an angle would cast shadows on the interiors during summer reducing direct light on glass facades, and in winter allows solar heating since the low sun will enter into the building according to Solar-Fabric (Wolter, 2003). Therefore PV modules should combine four important tasks in one element:

- a. Solar protection,
- b. glare protection,
- c. Visual connection
- d. Producing electricity.

The common problems of glazed facades such as overheating and high cooling loads can be solved with such features and enhance their architectural functionality by keeping the visual connection between the interiors and exteriors, since transparency is a great visual aspect of architectural forms to represent openness with the city and near building environment, allowing daylight for the interiors with less artificial lighting. Following are the different ways of integrating PV cells on facades in terms of their positioning (Farkas, 2013).

2.4.3.1 Vertical Integration of PV

Simple layout mostly applied on opaque surfaces using opaque PV units to cover large parts of the facade, or integrated within a glazed facade by using transparent and semi-transparent units, this vertical alignment may not bring PV systems to their best effectiveness, but both solutions produce an ecological facade with high tech performance, along with presenting an elegant touch on the facade giving it a more modern look. This method can be applied with the majority of buildings, rendering the slight disadvantage of lower efficiency unimportant in comparison to its vast application possibility (Basnet, 2012).

2.4.3.2 Inclined Walls Installation

The main goal in integrating PV units in inclined walls is to yield maximum energy possible facing the sun; this would guarantee a better performance in maintaining the needed angle to absorb daylight. Also such integration offers a variety of positioning solutions to achieve a special design with an interesting composition.

This is a fashionable approach since it is unique and produces interesting results when integrating PV modules in curved shapes, the west elevation of the Vocational College in Austria was designed in a similar way making it attractive and an indispensable part of its architectural expression (M9 Architects, 2009).

Figure 2.8: Inclined PV integration into the west facade of Vocational College, Austria



Source: (<http://www.m9-architekten.at/>)

2.4.3.3 PV as sunshades

Passive sunshades do control daylight and cast desirable shadows to the interiors as they face the common overheating problems in summer of interior spaces and the need for more air conditioning which consumes energy. Therefore, in efficient sustainable buildings, external PV sunshades could provide a comfortable interior environment while avoiding heat transition to the internal parts of the building attaining a stable temperature, especially at the south facade, where sun radiation would rise a lot and must be dealt with.

Louver systems were developed to have PV cells integrated into the louver glass and can be installed vertically or horizontally to make them multifunctional elements by providing the required light absorbing and shading to the building with the ability to generate energy. The advantage in louvers is that they are adjustable and dynamic to be fixed to the perfect angle facing the sun; of course opaque PV units can be installed in louver systems too, as a shading device.

This architectural integration can add a lot to the buildings appearance and aesthetical value specially if it has a special dynamic mechanism when it adjusts to the suitable angle (Quality Domains Ltd, 2012).

2.4.4 Integration into new buildings & existing buildings

When tackling integration of PV cells with existing buildings and dealing with their current contemporary or historic state, we are still offered with a variety of ways and possibilities in integration means. But the challenge is for this juxtaposition to comply and be suitable for the situation, and to preserve the identity of the building by keeping its characteristics evident without effecting the general look of it, nor eliminating other existing functions of the roof or elevations, in this case all the elements of the building must be studied to determine the best part to adjust whether in replacing some of its passive particles or creating a new supporting layer (Jahanara, 2013).

An important notion is to understand that installations of this kind may be complicated because of the limitations of space and limited surfaces with specified dimensions that might not be enough to place standardized products, thereby there is a need for customized products specially made to be applicable for each design case considering it a unique one, and such innovative call can make integration tasks easier which differ depending on the possibilities of interventions (Hermannsdorfer and Rub, 2005,).

As we have previously mentioned that usually we are to make compromises between the needs of the PV cells and the buildings in favor of PV cells due to their demanding nature, in the case of a history building for example, these compromises are no more acceptable and PV units must be as unique as their future host in order to achieve the required level of homogeneous integration.

Observing known cases in which replacements must have specific regulations regarding every aspect of the building, we take the church in Carlow, Germany as an example; custom made tiles were manufactured to match the church tiles in color and shape to create a polycrystalline module, each module replaced six roof tiles of counted numbers of tiles on the roof using a small part of it in the integration, hence the historical character was preserved with a small intervention protecting the monument appearance. (Hermannsdorfer and Rub, 2005).

Some historical cases require other treatments where the building itself may have certain restrictions and limitations in terms of space, while potential interventions here might compromise the historic character of the building. Here, PV systems can not be placed on the building and must find an alternative by examining the location and the specifications of the work and its context such as the site and neighboring buildings (Jahanara, 2013).

Accordingly, it is much easier to work with new buildings keeping the integration of photovoltaic or solar thermal collector systems in mind since this allows several steps to be taken into account from the beginning, toward a successful holistic design, and multiple choices to make the forms and materials suit the architectural concept.

If the potential of solar cells as materials that we can design with is recognized, then the relation between design elements would be tangible and lead the design proposal to a more appropriate concept driven by these systems to a higher tech level design.

Integrating PV systems needs a lot of experimenting with elements and ways of attaching materials to understand the final architectural result we hope for. Of course, on one hand, working with an existent case imposes certain conditions to adjust the building to meet the needs of these active systems, while on the other hand dealing with a new building integration can be easier comparing it by the degree of flexibility we have (Lundgren and Torstensson, 2004).

3. DATA COLLECTION

3.1 INTRODUCTION

Within this chapter the author presents reports for all the data collected from interviewing thirteen participants in Istanbul. The participated people were a LEED Consultant, a General Manager of a solar systems company, a solar systems Specialist, a Project Manager at the Turkish Green Building Council (CEDBIK), an Architect, an Energy Efficiency Expert, a CEO of a renewable energy firm, an Electrics & Electronics Engineer, a LEED GA, Geophysical Engineer, Electrical engineer, three Mechanical engineers, and Environmental engineer_

The conducted 30-50 minutes interviews were open-ended interviews, as 11 of them were face to face interviews and two interviews were conducted via email and phone calls.

The emerged data was manually transcribed verbatim after each interview then copied to a special designed table by the author where ice-breaking questions and unnecessary statements were ignored for a better quality data analysis.

3.2 DATA PRESENTATION

As presented in the table (3.1) the author has used a coding system for the interviews that have been conducted with different participants as it will be used in the next chapter. However, these interviews are illustrated in the following tables:

Table 3.1: Participants coding system

LC	Participant number one that is referring to a LEED consultant.
GM	Participant number two that is referring to a general manager of solar systems company.
SS	Participant number three that is referring to solar systems specialist.
PM	Participant number four that is referring to a project manager at the Turkish green building council (CEDBIK).
ARCH	Participant number five that is referring to an architect and a LEED AP.
EE	Participant number six that is referring to an energy efficiency expert.
CEO	Participant number seven that is referring to a CEO of a renewable energy firm.
ENG	Participant number eight that is referring to an electrics & electronics engineer.
LGA	Participant number nine that is referring to a LEED GA.
GE	Participant number ten that is referring to a Geophysical Engineer and solar systems Specialist
EEPM	Participant number eleven that is referring to an Electrical Engineer and Coordinator and project manager
EEME	Participants number twelve that is referring to Environmental Engineer and Mechanical Engineers
ME	Participant number thirteen that is referring to a Mechanical Engineer

O	Those Participants representing players with a very important role in the field with no action .
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Table 3.2: Interview with a LEED consultant

	Note	Participant 1 (LC)
N1	General information	We are a green building consultancy, and I am the general manager of the company, being into the field for more than 15 years.
N2	Usage of renewable energies in Istanbul	With no doubt, PV systems is the most used renewable energies technology in Istanbul
N3	Integration of PV panels into building's envelope	I would say the integration is limited in both aspects, since just a few buildings using PV systems in Istanbul.
N4	Coordination between different parties	We always work with architects, but we mostly concentrate on other qualities and applications than we do on PV within our cooperation... and that is because most architects ignore these technologies on facades due to the lack of options they have when it comes to facades.
N5	Difficulties/problems that limit using PV systems in building's envelope	Well, most of the buildings do not apply PV on the facade but on roofs, and what makes it inefficient on facade : -expensive as facade material. -lack of variety & alternatives of PV module (shape, color and texture). -you cannot apply it to 4 elevations of a building facade, because the sun will just hit two elevations efficiently, so it is better to be applied on two elevations only, and that might affect the material choice because each two elevations will have different materials which affect the external look of the building, it might look

		<p>ugly.</p> <p>-lack of encouragement, for example, the points a building can gain if applied PV panels within the LEED criteria is not encouraging owners to use it.</p>
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Table 3.3: Interview with a General Manager

	Note	Participant 2 (GM)
N1	General information	It is specialized in the renewable energy industry, offering development and project management, and I am the general manager of the company.
N2	Usage of renewable energies in Istanbul	I have to say PV systems even it is not used too much.
N3	Integration of PV panels into building's envelope	In my special opinion the integration of such systems into building is really bad in Istanbul, especially if you ask about the facade part, very few number of buildings use it.
N4	Coordination between different parties	Unfortunately we rarely work with architects.
N5	Difficulties/problems that limit using PV systems in building's envelope	<p>-the cost of PV is an issue for sure as it is almost 10 times the price of glass, but it is considered as an investment at the same time... and here where people need to increase awareness and get information about.</p> <p>-another important problem is the adjacent buildings in Istanbul and trees in some cases which increase the risk of shadow. That reduces the production of the panels and destroys their function.</p>

	Others	architects do not prefer to use PV systems on facades and they do not even offer it to clients (because it is expensive and many technical problem occurs before and while applying), but we have to know that these systems are developing by time and most of these problems that architects think about, can be solved, but architects do not have the updated knowledge and enough experience about these systems.
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Table 3.4: Interview with a solar systems specialist

	Note	Participant 3 (SS)
N1	General information	The company is specialized in PV systems, project development and project management
N2	Usage of renewable energies in Istanbul	Solar power is the easiest renewable resource to be integrated with buildings and according to that PV panels is the most used renewable energies technology in Istanbul.
N3	Integration of PV panels into building's envelope	I am not sure if we can call it integration, I believe it is bad. Even we are working on a building with PV system on facade, the number of buildings with such systems still too limited in Istanbul.
N4	Coordination between different parties	We did work with architects, and we are still working. Working with architects as a team from the first phase makes our job easier.

N5	Difficulties/problems that limit using PV systems in building's envelope	<p>I believe some governmental regulations create some difficulties in using PV systems in building sector in Istanbul. Our project for the Horizon 2020 with a transparent PV facade -full PV facade- faced many regulation problems.</p> <p>There are no incentives to use PV systems.</p> <p>I have to say that the number of architects with the knowledge about PV is very few and even those who have the knowledge they do not update their knowledge and rely on their experience if they have.</p>
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Table 3.5: Interview with a Project Manager

	Note	Participant 4 (PM)
N1	General information	Actually our organization was established in order to contribute to the development of the building sector in Turkey in the light of sustainable principles.
N2	Usage of renewable energies in Istanbul	Well, Turkey is a very rich country in solar power, and PV systems are the best technology to be integrated with building and that is the case of Istanbul.
N3	Integration of PV panels into building's envelope	I think it is not preferred in building sector in Istanbul, which limits the integration in terms of number of buildings using PV systems and the quality of the integration...
N4	Coordination between different parties	To succeed in projects with such properties like PV panels, I think it is a must to work with architects, civil, mechanical and electrical engineers. But the most important is to work with all of them as a team together.

N5	Difficulties/problems that limit using PV systems in building's envelope	<p>PV can produce almost 200% of the energy need of the building, if we use high capacity panels but still it is expensive, with a long payback period (although it is getting shorter) but still a lot when you compare with different systems and materials can be used on facade.</p> <p>architects have the most important role in the process, they have to have the knowledge and the vision, which in Istanbul very few of them have it, for example architects has to know and consider the LCA (life cycle analyses) of the materials and the system they design, and when they come with something wrong or not sufficiently analysed in terms of life cycle or environmental impact, then the whole team will have difficulties to adapt it into building or to make it real...</p>
	Others	<p>in Turkey we mostly use PV for commercial buildings, and only 4% of the LEED buildings are residential</p> <p>As a part of their global policy, big international companies in Istanbul, care about environment and find it as a kind of prestige to get green building certificate (which force them in some cases to use PV systems...)</p> <p>The main point I believe is to put the right people together from the first phase of the project, then we should get good results.</p> <p>In many cases green building certificate is considered as a check list, and in other cases, people are getting fake certificates as well, which loses the value of such technologies in building sector.</p>

Table 3.6: Interview with an architect

	Note	Participant 5 (ARCH)
N1	General information	I am an architect at ONEY architecture design office.
N2	Usage of renewable energies in Istanbul	Solar energy has the most potential to be integrated into buildings.
N3	Integration of PV panels into building's envelope	It is like 100 years back here in Turkey compared to other developed countries around the world regarding this subject. The integration is really weak.
N4	Coordination between different parties	We worked with a solar provider, we designed 4 solar panel parking plots with more than 400 m2 parking area for each, but still that was not a building integration but we are looking forward to be involved more.
N5	Difficulties/problems that limit using PV systems in building's envelope	<p>First of all, I think in Turkey we still old school minded; we do not pay attention to these technologies.</p> <p>I am pretty sure that you are aware of the fact that most of the investors or developers if they see a potential in the project (economical potential) they would try to integrate the sustainability factor in it, and if not they do not have the vision or the capacity to do such a thing. Because they do not see what they could benefit out of it.</p> <p>So whenever we try to promote that aspect in our projects, the developers or investors controls us so our role becomes secondary.</p> <p>Another thing that impedes us is the lack of awareness that people and clients have, as sometimes it might be the municipality or even a private party who do not have the vision, so they simply do not care.</p> <p>I believe that the chamber of architects should be linked to the low of construction in somehow regarding this issue.</p> <p>I think there is a huge gap or miscommunication or a leak between our chamber of architects and municipalities</p>

		and other organizations linked to government, they do not promote each other.
	Others	I was doing my study overseas in New York so I am very interested and familiar with the subject because the whole world is very much a head. And since I moved back to Istanbul it has been a few years now and we are trying to integrate more responsible designs, especially with this kind of technology as well.

Table 3.7: Interview with an energy efficiency expert

	Note	Participant 6 (EE)
N1	General information	I am an energy efficiency expert at a green building consultancy.
N2	Usage of renewable energies in Istanbul	Because of the size and mechanism (the way it works, it does not have moving devices with complicated mechanisms) of solar technologies, I think it has the best chance to be integrated into building sector.
N3	Integration of PV panels into building's envelope	Even there are some examples of roof integration, I do not know if there is any on facade in Istanbul. However, in the last couple of years these technologies are getting more famous and the quality of integration is getting better.
N4	Coordination between different parties	We work with architects all the time, actually we have architects in our office, and they are educated from that aspect.

N5	Difficulties/problems that limit using PV systems in building's envelope	<p>Well, to use PV panels on the facade can be less effective, because of the shading parameters (the angle of sun rays). And as a facade material the cost is too much if compared to the profit.</p> <p>In addition, using PV systems on facade is affecting benefiting from natural sunlight in the inner space so they avoid using such technology on facade. However, there are on roofs.</p> <p>another thing that I believe the payback period is more than 6 years now so project owners do not prefer to use these systems because of the cost, they just think about the immediate profit, they do not have sustainable thinking mentality. However this period is getting less by the time passing as the technology improves.</p>
	Others	<p>Regarding the LEED certificate it is not a must to use PV panels to get the certificate, we for example have a gold LEED certificate and we do not use it. They do not manufacture PV cells in Turkey, so they import it from china mostly, that is why this leaves a bad feedback for people because has a bad quality.</p>

Table 3.8: Interview with a CEO of an energy company

	Note	Participant 7 (CEO)
N1	General information	Our company is an EPC (Engineering Procurement Construction) company and an investor in PV, Wind and Biomass Projects.
N2	Usage of renewable energies in Istanbul	I can talk about the most renewable energy technology that have potential to be used not the most used, and it is solar technology because its usage is still not on a wide range in buildings.
N3	Integration of PV panels into building's envelope	Well we are not into building sector yet, and our company is considered as one of the biggest solar technologies companies in Istanbul, so I would not say there is integration except of some individuals.
N4	Coordination between different parties	<p>I think we have to work with architects from the beginning; we need to start working with architects at the design stage, because when you design a building it has to be designed in a sustainable way, which is really hard to be done if the building is already designed or built.</p> <p>We worked with architects, our own architects. We were working on that building for a LEED certificate and the architects looked at the LEED criteria then changed some of the design so the cost was 20% more, but for sure there was a return on that because you are making a lot of savings; and we had PV panels on the roof.</p>
N5	Difficulties/problems that limit using PV systems in building's envelope	<p>Some governments are really slow actually in adopting these technologies and encouraging people to use them, and this is the case in Turkey, instead they are trying to place taxes on these technologies. In the future there will not be any grid lines systems (like we have now); I believe it is going to be a production and consumption at the site that is how the train is going. I believe everything will be handled within the location.</p> <p>We need to place PV panels in a certain angle to get the best production, usually between 15-25 degrees which is hard to be</p>

		achieved on the facade, and if we put it flat, still there will be a production but much less, like the efficiency falls down. I mean it is not the best option. However, there are many new technologies, for example there is this paint which is produced with nano technology, still the efficiency is low but the existence of such new technologies means that there is a hope.
	Others	We have a construction company and also we have a solar company, we are thinking of combining a team of both to start an idea, which is basically to build a couple of projects here and there and show it to people to see how they will react, and having those two companies and the idea of combining them will make our job easier.

Table 3.9: Interview with an electric & electronics engineer

	Note	Participant 8 (ENG)
N1	General information	We are a solar company we provide the technology of photovoltaic systems.
N2	Usage of renewable energies in Istanbul	PV panels and STC (Solar Thermal Collector) are the best to be used in buildings in my opinion.
N3	Integration of PV panels into building's envelope	There are a lot of examples of STC (Solar Thermal Collector) and PV panels on roofs. Even it is not famous on facades but we are still getting good energy production results.

N4	Coordination between different parties	We do work with architects and we always work as a team of engineers and architects.
N5	Difficulties/problems that limit using PV systems in building's envelope	<p>I have to say that PV is a fast developing technology, which makes it hard for everybody to keep their knowledge updated unless they are very much interested in PV, and it is not common to see architects with such tendencies.</p> <p>This is the situation in Turkey, and with no architects interested in such technologies, there will be no designs integrated with such technologies.</p> <p>So that is why we see these technologies just on roofs or rarely on facades –because if we tried to apply it on roofs then architects do not need to design or to do amendments on the design, because we are just aligning these panels with the help of the team, which will not affect the main design of the building.</p> <p>There is one more thing I want to say here, these kinds of technologies need some care and maintenance works from time to time, which makes the decision maker or the owner to rethink twice before using it.</p>

Table 3.10: Interview with a LEED GA

	Note	Participant 9 (LGA)
N1	Usage of renewable energies in Istanbul	I think PV systems are the most used in building sector.
N2	Integration of PV panels into building's envelope	The usage of PV systems in buildings is not so common in Istanbul; in fact people are not paying attention to these technologies.

N3	Coordination between different parties	Unfortunately, I did not work with architects in the field of PV panels.
N4	Difficulties/problems that limit using PV systems in building's envelope	<p>The examples of PV panels integrated into buildings are really rare, I think using PV panels in buildings is not feasible, it is expensive. However, there are some projects tried to integrate these technologies on the roof, but the scale of the buildings is too big compared to the amount of PV integrated.</p> <p>One of the factors should be taken into consideration to attain the best efficiency of PV systems, is the angle of the sun hitting the panels, which is a concern on the facade while it is easier to be achieved on the roof. So the alternatives of how to use PV on facades is a bit limited so people avoid using it.</p> <p>Another problem I can think of, is that people are still picky when it comes to facade, because owners want their buildings to have a good appearance with the minimum cost and PV ruins the appearance of the building and it is expensive as well, so I believe that PV might not be a good architectural solution for facades but maybe on roofs</p>
	Others	We give consultancies for buildings in order to be environmentally friendly and get a certificate like LEED or BREEAM, but that is not enough to encourage people to apply such technologies too much because just a few points are dedicated for using these technologies.

Table 3.11: Interview with a Geophysical Engineer

	Notes	Participant 10 (GE)
N1	General information	<p>I am Geophysical Engineer and solar systems Specialist, Freelancer.</p> <p>I have been working as PV system integrator since 2007.</p> <p>My core business is Solar Water Pumping and PV Off-Grid systems.</p> <p>Project design, procurement, construction, preparation of the financial model inputs, managing communication with consultants, subcontractors, market research and relevant reporting, strategic planning.</p>
N2	Usage of renewable energies in Istanbul in general and on building`s facade in specific	<p>The most used renewable energy in Istanbul is solar thermal systems and PV system.</p> <p>PV panels are used on the roofs of Kayabaşı Konutlari (TOKI) project in Istanbul the panels are supplying all the houses with heated water and the lighting in common areas.</p> <p>I think the usage of PV panels on building`s facade is not enough for sure, there are no buildings using it on facades as far as I know.</p> <p>Lack of information is the reason why it is not popular, people do not know that PV panels can be applied on building facades and also the reasons I mentioned above.</p> <p>We cannot do anything to promote this technology but the government can, the process must be easier and the rules and the regulations must be simpler and there must be some encouragements as well.</p>
N3	Integration of PV panels into building's envelope	<p>The usage of PV panels on buildings facades is limited because of the developers` way of thinking in Istanbul, the developers are not convinced of the system yet because of two reasons:</p> <ol style="list-style-type: none"> 1.it is too expensive. 2. The difficulties of government regulations (it is very complicated when you want to sell the extra energy produced by PV panels to the main electricity network.)

N4	Difficulties/problems that limit using PV systems in building's envelope	<p>As curtain walls are not common in residential buildings, using PV panels on the facade of residential buildings is very difficult. However, it can be used only on curtain walls like towers. In Istanbul maybe there are about 300-400 business towers which PV panels can be applied on but the reason I think is because most of the buildings' owners do not know that PV panels have the ability to be applied on building facades, and even if they know about this technology I think they would not do it because of the difficulty of governmental rules and regulations. They also would not do it because the PV panels needs periodic maintenance and cleaning. And about using PV panels on the roofs of building is also not common because in Istanbul the structure of roofs of the existing buildings is weak, as a high percentage of the roofs in Istanbul are illegal, and when you want to apply PV panels you need to prepare a report of the roof for the municipality, which is a problem.</p>
N5	Advantages/Disadvantages of using PV panels	<p>I do not think that there are any disadvantages of using PV panels, maybe the investment cost is high but it is not a big deal. The source of the energy we already use is the natural gas and if we manage to get it from PV panels it will be better for us for the long term; for sure it depends on the quality of the panels, the cost, the installation quality and the scale of the project. so shortly there is no reason not to use PV panels. But as I mentioned before in Istanbul the governmental regulations is complicated, that is why there are no buildings in Istanbul using PV panels on facade.</p>
N6	Others	<p>There are three important steps to utilize PV panels in buildings:</p> <ol style="list-style-type: none"> 1. Doing estimated analysis, of how much energy and electricity does the PV panels produce. And this is the most important step of the process. 2. Doing feasibility analysis. 3. Starting the governmental issues and regulations. And it is the most complicated step.

Table 3.12: Interview with an Electrical Engineer

	Note	Participant 11 (EPPM)
N1	General information	Electrical Engineer and Coordinator and project manager at ANEL ENERJI
N2	Usage of renewable energies in Istanbul in general and on building`s facade in specific	<p>The most used renewable energy in Istanbul is PV panels on the roofs of the buildings.</p> <p>The architects also face another problem, which is the shadow resulting from using PV on facade because PV panels reduce daylight entering the building, which is a problem for architects. And also the aesthetic factor is another concern for architect as well. It is architects decision to apply panels on facade or not according to their design.</p> <p>I think it is possible to integrate PV into building in some Appropriate places and Appropriate buildings, and I think it is very beneficial for the environment and very important to increase social awareness about the sustainable factors and these technologies among people.</p>
N3	Integration of PV panels into building's envelope	<p>This technology is not accepted among architects yet (architects still not convinced about it) especially on building facades because PV panels reduce daylight entering the building, which is a problem for architects, even if we use Thin-Film solar panels, as everyone prefer to take advantage of daylight . We tried to apply PV panels (as a test) on Istanbul Technical University building`s facade, it was perfect in terms of collecting sunlight but the inside of the building was dark.so this is an architectural problem. Unless if group of architects collaborate on solving this problem. So in that case all the energy produced by PV will be consumed to light up the inside of the building. So the building owners who trying to get LEED certificate or such, prefer to apply PV panels on roofs to generate energy and at the same time to protect the aesthetic appearance of the building.</p> <p>Nejat BABUR - Director of Engineering department at Anel Group: according to my experience in New York city the towers in Times Square applied</p>

		<p>this technology on facades and they achieved only 18% as ROI which is not enough of course and they decided to cancel the project. And that was for the reason that the towers there were so close to each other, so the sunrays were blocked to reach parts of the facade due to the shadow of the towers.</p>
N4	<p>Difficulties/problems that limit using PV systems in building's envelope</p>	<p>About the government regulations and rules there are no difficulties I believe; you will deal with TEDAŞ and get the confirmation easily. But all the electricity you produce you have to consume. However, if you want to sell it then it will take a longer process and you will have more difficulties with the governmental issues.</p> <p>This means, if a building generate energy to sell that energy, then there will be a lot of governmental complications. it is hard anyway to produce a surplus of energy here in Turkey.</p>
N5	<p>Advantages/Disadvantages of using PV panels</p>	<p>In my opinion one of the biggest disadvantages is that the payback period is too long, as its almost 5-15 years; for example, a 20000 m2 area needs about 1 megawatt which costs about 1.5 million dollar, and this case the project needs almost 15 years to payback the investment cost. And here people do not prefer to wait more than 7 years.</p>
N6	<p>Others</p>	<p>Producers who do unlicensed production are benefiting the most, but for people working legally there is no encouragement to produce extra energy because they cannot sell it in a higher price easily. And to be able to do so, they need to attain some hard conditions, like to be a land owner and to follow the right legal procedures.</p>

Table 3.13: Interview with an Environmental & Mechanical Engineer

	Note	Participant 12 (EEME)
N1	General information (this interview was conducted with three participants at once)	Environmental Engineer and two Mechanical Engineers
N2	Usage of renewable energies in Istanbul in general and on building's facade in specific	<p>The most used renewable energy is PV; it is the most popular system in Istanbul.</p> <p>I think BIPV in Istanbul is not so popular; the energy output value of using PV is still unclear, we are not sure about it. However, we know that there is a new developing technology, called AR-GE, promising of an immensely increment in the energy production.</p>
N3	Integration of PV panels into building's envelope	PV is not preferred on the facade because the production value of these systems on facade is low; it is much preferred on roofs
N4	Coordination between different parties	I think in order to get better results of integration, there should be a cooperation going between architects and electrical engineers in projects using PV panels.
N5	Difficulties/problems that limit using PV systems in building's envelope	<p>I think the prices of PV system are high as an investment. And there are no varieties in the architectural designs that tried to integrate PV into buildings.</p> <p>Another thing is that it is hard to allocate an appropriate space for the technical devices of PV.</p>

N6	Advantages/Disadvantages of using PV panels	I think PV has some disadvantages; again the high cost of these systems is one of these disadvantages. And the estimated useful life of these technologies is relatively short (15-20 years). And the maintenance need, all these I believe can be disadvantages of PV.
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Table 3.14: Interview with Mechanical Engineer

	Note	Participant 13 (ME)
N1	General information	I am a Mechanical engineer and Energy system planner.
N2	Usage of renewable energies in Istanbul in general and on building`s facade in specific	I do not think that there is any effort or initiative to use renewable energy technology in Istanbul.
N3	Integration of PV panels into building's envelope	The facade companies do not have enough experience in this regard and the costs are still high. Problems related to cleaning and maintenance must also be taken into consideration after installation.
N4	Coordination between different parties	We have not received such a request from any architect before, but some projects stakeholders asked us to study and evaluate the feasibility of glass embedded PV systems. However, it was abandoned because of the costs.

N5	Difficulties/problems that limit using PV systems in building's envelope	I believe besides technical difficulties, costs and legislation issues are a source of concern in Istanbul.
N6	Advantages/Disadvantages of using PV panels	Maybe I prefer saying problems more than disadvantages, because of the low efficiency of these systems on the facade due to building design (depending on building's location), as well as cleaning, difficulty and the lack of experience of labours.

4. DATA ANALYSIS & DISCUSSION

4.1 INTRODUCTION

This chapter describes the analysis of the collected data, as well as the findings derived from the data presented in the previous chapter. The data is analysed to understand and describe the barriers and the potentials of the architectural integration of photovoltaic panels into building skin in Istanbul from the perspective of the interviewed participants in the study.

Thematic coding will be used to analyse the interviews. Therefore, the chapter begins with introducing the code structure, by listing sets of codes categorized into main themes. The themes are derived based on keyword analysis, which will be further explained in the next section.

4.2 PRIMARY DATA ANALYSIS

Code structure was developed in stages and in accordance to multiple reviews of the data. However, the code structure was labelled as ‘understanding the current photovoltaic integration in Istanbul’. The following illustrates the main three themes showing the dimensions of each.

Research question: “what are the barriers and the potentials of the architectural integration of photovoltaic panels into building skin in Istanbul?”

- a. Cultural obstacles
 - i. Lack of awareness among people
 - ii. Lack of knowledge among architects
 - iii. Lack of encouragement
 - iv. Regulation problems (legal arrangements)
 - v. Miscommunication among authorities

- b. Cost
 - i. Cost
 - ii. payback period
 - iii. Maintenance need

- c. Technical issues
 - i. Efficiency problems
 - ii. Quality of PV panels in Istanbul
 - iii. Affecting utilizing sunlight
 - iv. Aesthetic appearance
 - v. Lack of varieties

4.2.1 Cultural obstacles

The first theme aims to understand the Turkish cultural situations/factors that affect utilizing PV systems in building's envelope from the perspective of the participants. Within this section five related dimensions (codes) were defined and analysed. First one is the lack of awareness among people. According to ARCH; the mentality of people has a big influence on the viability/applicability of PV technology:

“First of all, I think in Turkey we still are old school -; we do not pay attention to these technologies. I am pretty sure that you are aware of the fact that most of the investors or developers if they see a potential in the project (economical potential) they would try to integrate the sustainability factor in it, and if not they do not have the vision or the capacity to do such a thing because investors do not see what they could benefit out of it...It is like 100 years back here in Turkey compared to other developed countries around the world regarding this subject. The integration is really weak.” (ARCH)

From the above quote, it is realized that PV technologies are perceived as secondary tools in the Turkish construction industry, in other words, the importance of these elements is being neglected, ARCH attributes that to the mentality of the investors as they do not have the right precognition (vision) of the benefits of PV technology, while

their main concern is the profit of using such tools, which is considered worthless in their perception. However, GM thinks that people are not aware of the economic potentials of building integrated photovoltaic (BIPV) system. He perceives it as an investment, in terms of annual savings and payback:

“The cost of PV is an issue for sure as it is almost 10 times the price of glass, but it is considered as an investment at the same time... and here where people need to increase awareness and get information about.” (GM)

In addition, Istanbul has hundreds of business towers where PV systems are applicable on their facades, yet the integration is still very limited, GE refers that to the lack of information among buildings’ owners as most of them do not know that PV panels have the ability to be applied on building facades.

“...most of the buildings’ owners do not know that PV panels have the ability to be applied on building facades” (GE)

However, the PM provided a different view where the lack of awareness among people was given another reason:

“In many cases green building certificate is considered as a checklist, and in other cases, people are getting fake certificates as well, which causes such technologies to lose their value in building sector... As a part of their global policy, big international companies in Istanbul, care about environment and find it as a kind of prestige to get green building certificate (which force them in some cases to use PV systems)” (PM)

The above quote contains clear insights into the consequences of ignoring the importance of BIPV system and its functions, due to confining using PV to obtain green building certificates such as LEED or BREEAM, as some companies perceive these certificates merely as a prestige which consequently affects the quality of the integration, hence, leads to a distorted perception among people about the true value of these systems.

The second dimension illustrates how people in Istanbul perceive the role of architects in integrating PV system into building envelope. However, that was covered within two frames, lack of knowledge about PV systems among architects from one side, and on

the other side ignoring integrating these systems into building envelope. On the lack of knowledge among architects the SS stated that:

“I have to say that the number of architects with the knowledge about PV is very few and even those who have the knowledge they do not update their knowledge and rely on their experience if they have.”(SS)

The PM stated that:

“Architects have the most important role in the process, they have to have the knowledge and the vision, which in Istanbul very few of them have it.” (PM)

According to the above two quotes, it can be argued that a very few number of architects are educated and have the knowledge on the PV system. Additionally, even architects with the knowledge on PV, have missing information, since they do not update their knowledge whereas the field is continuously developing. The ENG provided a similar view on architects’ knowledge:

“I have to say that PV is a fast developing technology, which makes it hard for everybody to keep their knowledge up to date unless they are very much interested in PV, and it is not common to see architects with such tendencies.” (ENG)

From the above quote, it could be seen that there is a common view on the lack of knowledge among architects, as it agrees that within this fast developing field architects should keep their knowledge up to date which is hard to be achieved without having the tendencies to such technologies. In terms of ignoring the use of PV, LC stated:

“...Most architects ignore these technologies on facades due to the lack of options they have when it comes to facades.” (LC)

Reference to the mentioned quote above, it can be argued that BIPV is avoided by architects, due to the limited alternatives of PV system modules. On the other hand, there is a wide range of PV technologies in this innovative and immensely growing market, which results in interesting architectural solutions and good opportunities for the architectural integration (Oderson, 2011). Additionally, the GM provided another view on the behaviour of architects regarding the use of PV in building’s envelope:

“Architects do not prefer to use PV systems on facades and they do not even offer it to clients (because it is expensive and many technical problems occur before and while applying), but we have to know that these systems are developing by time and most of these problems that architects think about, can be solved, but architects do not have the updated knowledge and enough experience about these systems.” (GM)Based on the above quote, architects avoid integrating PV systems into the building envelope, because they perceive it as an expensive solution and difficult to be applied due to many technical problems before and while the integration process. However, the GM adds that PV market is rapidly growing and overcoming the major obstacles to the integration is possible by now.

This can reflect that architects’ mentality is influenced by mirage challenges, which prompt them to avoid using PV panels. In other words this can reflect a lack of knowledge among architects.

The third and the fourth dimensions analyse the government’s role in integrating these systems into building’s facades, in this regard some people in the field perceive lack of encouragements for owners to use these systems, they argued that there are no efforts from the governmental authorities in terms of pushing the integration, since Turkey is too slow in adapting these technologies to its system, resulting in a very slow progress to see efforts or attempts to encourage integrating these technologies, as both CEO and ME stated:

“Some governments are really slow actually in adopting these technologies and encouraging people to use them, and this is the case in Turkey” (CEO)

“I do not think that there is any effort or initiative to use renewable energy technology in Istanbul.” (ME)

In addition GE and EEPM find the regulations to use PV systems on buildings very complicated:

“We cannot do anything to promote this technology but the government can, the process must be easier and the rules and the regulations must be simpler and there must be some encouragements as well...But as I mentioned before in Istanbul the governmental

regulations is complicated, that is why there are no buildings in Istanbul using PV panels on facade.” (GE)

“This means, if a building generate energy to sell that energy, then there will be a lot of governmental complications. it is hard anyway to produce a surplus of energy here in Turkey.” (EPPM)

From the above quotes, it can be argued that the complicated regulations in the integration process and in the case of producing extra energy, are delaying the adaptation of these technologies in Turkey. The government is the primary responsible of increasing the number of BIPV and the quality of integration, since the legal process of applying PV on buildings is still complicated according to GE and EPPM.

Another barrier was stated in terms of the absence of communication among authorities. Similarly, EEME and ARCH provided their opinions based on practical experiences:

“I think in order to get better results of integration, there should be a cooperation going between architects and electrical engineers in projects using PV panels.” (EEME)

“I think there is a huge gap or miscommunication or a leak between our chamber of architects and municipalities and other organizations linked to government, they do not promote each other.” (ARCH)

Reference to the previous quotes, it can be argued there are miscommunication problems between the responsible authorities in Turkey, there are a lack of coordination between different sectors private and public, academic and construction, and other stakeholders.

The conducted results derived from section 4.1.1 have shown that the outdated perception of PV technology and the lack of knowledge among people and architects in Istanbul, which also can be referred as the perception barrier, is misleading and underestimating the added value of PV system hence hindering the integration of photovoltaic into building skin. This is due to the fact that the educational campaigns (to increase awareness among people and knowledge among architects) in Istanbul are very limited, as the chamber of architects and other responsible authorities have no related

interests. However, The Building Information Centre (YEM) / Istanbul, is taking the lead in this aspect with a couple of related events, which might help to overcome this obstacle, but yet not enough and much more efforts still needed.

There is also, however, a further argument to be discussed, that the behavior of public authorities is not encouraging BIPV. The access to the voltage grid still has to be regulated and procedures for the grid-connection have to be simplified (EPIA et al., 2008), the standards of BIPV in Istanbul are still lacking, in addition to the lack of the photovoltaic and BIPV long term implementation programs, which hinders the development of PV application. Additionally, the missing link between stakeholders was mentioned in the analyses as a barrier to the BIPV. However, to bridge the gap between the responsible stakeholders, especially architects and other stakeholders, architects should consider the use of photovoltaic technology from the design phase.

4.2.2 Cost

The aim of this theme is to understand the relationship between the cost and the return on investment (ROI) of PV system in the construction industry and how they play to hinder or to encourage its integration into building's envelope from one side, and on the other side show the role of life cycle expenses (maintenance and operational issues) in the integration in the perception of people, on the cost and the ROI of PV systems, EE stated:

“...As a facade material the cost is too much if compared to the profit...I believe the payback period is 6-7 years now so project owners do not prefer to use these systems because of the cost.”(EE)

And LC stated that:

“Most of the buildings do not apply PV on the facade ...because it is expensive as facade material.” (LC.)

Although the above quotes provide abstract views on the cost of PV, it can be argued that, PV system is perceived as an expensive technology in the Turkish construction industry. Additionally, it could be seen that investors' mentality has a key role in overlooking BIPV as they are more concerned about short-term investments, whereas

the current technology's payback period is more than 6 years. This can reflect that, the cost of integrating PV into buildings is seen as a major barrier rather than considering the value of cost savings when integrating PV within building's life-cycle. For example, a 20000 m² area needs about 1 megawatt which costs about 1.5 million dollars, and in this case the project needs almost 15 years to pay back the investment cost. And people do not prefer to wait this much time here (EPPM, 2017). On the other hand, a more detailed view was provided by LGA who stated:

“Another problem I can think of is that people are still picky when it comes to facade, because owners want their buildings to have a good appearance with the minimum cost and PV ruins the appearance of the building and it is expensive as well.”(LEED GA)

From the above quote, it can be argued that the bilateral (dual) desire among people to achieve a satisfying appearance with a minimal budget is quite challenging for facade systems. In addition, it indicates how using PV in the building envelope can be costly. Despite that, GM has agreed with EE, LC and LGA on the high cost of the PV, he does not perceive it as a barrier:

“The cost of PV is an issue for sure as it is almost 10 times the price of glass, but it is considered as an investment at the same time...”(GM)

Reference to the previous quote, PV can be considered as an investment; regardless the expensive price of BIPV, the GM claims that there will be a return on that investment. This was confirmed by the CEO with a real example when they increased the cost of a project to attain a good return on the investment:

“We were working on that building for a LEED certificate and the architects looked at the LEED criteria then changed some of the design so the cost was 20% more, but for sure there was a return on that because you are making a lot of savings; and we had PV panels on the roof.” (CEO)

However, In terms of the role of life cycle expenses ENG stated:

“There is one more thing I want to say here, these kinds of technologies need some care and maintenance works from time to time, which makes the decision maker or the owner to rethink twice before using it.” (ENG)

And GE stated that:

“...They also would not do it because the PV panels needs periodic maintenance and cleaning.” (GE)

In the light of the above quotes, it can be argued that the maintenance need and the operating of PV are being perceived as a barrier to the BIPV, the need for frequent maintenance works and its expenses impede owners to decide on the PV integration. Additionally EEME stated another important point regarding the estimated life for these systems, in which the period that PV system is projected to provide efficiency is relatively short, which also can be considered as a barrier to the BIPV:

“I think PV has some disadvantages; again the high cost of these systems is one of these disadvantages... And the estimated useful life of these technologies is relatively short (15-20 years). And the maintenance need, all these I believe can be disadvantages of PV” (EEME)

Each of the above positions makes an important contribution to our understanding of the cost factor of BIPV. The previous analyses have shown that there is almost a complete unanimity on the high cost of BIPV, whereas it is perceived as an investment by some others. Although it is true that PV system is still relatively expensive compared to conventional facade materials; there is no shortage of disagreement that an expensive module of a better quality and higher architectural integration abilities has a better business proposal in the long-run (Fieber, 2005). However, the cost of BIPV varies according to the size and the type of the panels, and whether it is specially manufactured as a customized product. Nevertheless, there is a foreseen decline in the cost of PV systems due to technological and technical advances, as well as the increasing demand on these technologies (Fuentes, 2007).

In addition, the cost of installing, operating and maintenance work of PV system should not be a cause of concern, if compared to the time and efforts needed to take care of each; since it is recommended to periodically check and clean the system, by removing the debris and cleaning the exposed PV surfaces to the environment regularly, it is also recommended to conduct a yearly detailed electronic test (Fuentes, 2007). And that further explains the shown argument in the analysis (section 4.1.2) that the maintenance routine of PV impedes the integration. However, in some cases such as high-rises or buildings with unique geometric forms, the cost of maintenance work can be relatively expensive (Fuentes, 2007).

4.2.3 Technical issues

The aim of the third theme is to explore the technical values and barriers that are facing BIPV. This theme contains five different dimensions, in which each dimension reflects different views of people on the technical issues of BIPV. First dimension is titled as efficiency problems. Accordingly, GM stated that:

“...Another important problem is the adjacent buildings in Istanbul and trees in some cases which increase the risk of shadow. That reduces the production of the panels and destroys their function.”(GM)

And EEPM stated that:

“According to my experience in New York City the towers in Times Square applied this technology on facades and they achieved only 18% as ROI which is not enough of course and they decided to cancel the project. And that was for the reason that the towers there were so close to each other, so the sunrays were blocked to reach parts of the facade due to the shadow of the towers.” (EEPM)

Based on the above stated quotes, it can be argued that the integration of PV into building's facades is influenced by buildings layout in Istanbul. In other words, the density and the arrangement of buildings (the high number of attached buildings) might affect the amount of the gained sun rays, due to the increased possibility of shadow. However, it can be also understood that the problem of buildings layout is not a specific issue for the case of Istanbul, since in New York City the same problem occurred.

Similarity, for the efficiency problems that are facing building integrated photovoltaic, EE has stated the following:

“Well, to use PV panels on the facade can be less effective, because of the shading parameters (the angle of sun rays).” (EE)

And LGA stated that:

“One of the factors should be taken into consideration to attain the best efficiency of PV systems, is the angle of the sun hitting the panels, which is a concern on the facade while it is easier to be achieved on the roof.” (LGA)

Reference to the mentioned quotes above, it can be argued that using PV on the facade is less preferred than on the roof because of the difficulty in attaining efficient sun angle on the facade, as the efficiency of PV differs according to the angle of sun rays hitting the panels. This is quite unequivocal in CEO’s opinion in the following:

“We need to place PV panels in a certain angle to get the best production, usually between 15-25 degrees which is hard to be achieved on the facade.” (CEO)

The second dimension describes how the quality of PV panels in Istanbul affects people’s perception on the integration of PV system. As EE stated:

“They do not manufacture PV cells in Turkey, so they import it from China mostly, that is why this leaves a bad feedback for people because has a bad quality.” (EE)

From the previous quotes, it can be argued that people have a negative impression on using PV panels in buildings. Additionally, the previous quote has clear insights into the low quality of the PV panels imported from China; this therefore makes people reluctant to decide on the PV.

However, the third and the fourth dimensions illustrate the impact of PV panels on the architectural characteristics of buildings. Therefore this section deals with PV impacts on utilizing natural sunlight from one side and on the other side PV impacts on the aesthetic values of buildings. On utilizing natural sunlight EE stated:

“In addition, using PV systems on facade is affecting benefiting from natural sunlight in the inner space so they avoid using such technology on facade.” (EE)

And EEPM stated that:

“The architects also face another problem, which is the shadow resulting from using PV on the facade because PV panels reduce daylight entering the building, which is a problem for architects.” (EEPMM)

Based on the above quotes, it can be viewed that the challenges were stated in respect to PV effectiveness on natural sunlight qualities in the interior spaces. It can be argued that integrating PV panels into facades is unhealthy for utilizing sunlight in the interior as it blocks natural sunlight to reach the interior of the building. This is quite unequivocal in EEPM’s opinion in the following:

“This technology is not accepted among architects yet, especially on building facades because PV panels reduce daylight entering the building, which is a problem for architects, even if we use Thin-Film solar panels, as everyone prefer to take advantage of daylight...We tried to apply PV panels (as a test) on Istanbul Technical University building’s facade, it was perfect in terms of collecting sunlight but the inside of the building was dark...”(EEPMM)

The previous quote also bears out that PV affects utilizing sunlight; it can be argued that it is not considered an efficient architectural solution as a facade material since most of the energy produced by PV will be consumed to light up the dark inside of the building as sunlight does not go through it. Additionally, in terms of the aesthetic values of buildings, LC stated:

“Another problem I can think of is that people are still picky when it comes to the facade, because owners want their buildings to have a good appearance with the minimum cost and PV ruins the appearance of the building and it is expensive as well.” (LGA)

Although the previous quote does not provide detailed insights into the influence of PV integration on the aesthetic aspect of the building, it argues that PV is a bad architectural

choice in terms of its aesthetic appearance as a facade material. Similarly, a more detailed view was provided by LC:

“You cannot apply it to 4 elevations of a building facade, because the sun will just hit two elevations efficiently, so it is better to be applied on two elevations only, and that might affect the material choice because each two elevations will have different materials which affect the external look of the building, it might look ugly.”(LC)

The above quote agrees with the negative feedbacks on the aesthetic characteristics of PV. It can be argued that the emerging assortment in the facade materials -due to the inability of applying PV panels to four building's elevations (see previous quote) - ruins the aesthetics of the building, since it would be hard to find harmony in the combination of materials on building's facade.

In the fifth dimension, the lack of PV varieties is taken into analysis, as it was argued on two different occasions that the lack of adequate choices of PV technology is one important reason to avoid its integration into buildings by architects; specifically a lack of color, shape and texture options of PV (LC, 2017).

Furthermore, another technical problem that was stated by GE regarding utilising PV on roofs, considering the critical roofs' legal status, as there are many illegal roofs in Istanbul which is considered a problematic situation in the procedure of a licensed PV integration, prompting owners to avoid using PV system:

“And about using PV panels on the roofs of building is also not common because in Istanbul the structure of roofs of the existing buildings is weak, as a high percentage of the roofs in Istanbul are illegal, and when you want to apply PV panels you need to prepare a report of the roof for the municipality, which is a problem.” (GE)

The conducted results derived from section 4.1.3 have shown that the integration may not bring PV systems to its best effectiveness due to the difficulty in attaining efficient proportion of exposure on the installed panels on the facade. It is important to acknowledge that this challenge is valid in case of vertical alignment of PV (Basnet, 2012). However, there are other solutions to overcome this challenge such in the

integration into inclined walls as it would guarantee a better performance in maintaining the needed angle to absorb daylight and the louver systems as they are adjustable and dynamic to be fixed to the perfect angle facing the sun (Quality Domains Ltd, 2012).

In addition, the analyses have shown that using PV panels on the facade is negatively affecting the interior natural lighting quality; some participants, moreover, criticize the lack of varieties of PV modules. These two results can be linked as cause and consequence. However, controlling day light coming into the building is possible by now since various modules are currently available as transparent and semi-transparent to control the sunlight intensity (SHC, 2012). Additionally, the technology is offered with a variety of different ways and positions of integration as well as a variety of technical and aesthetic characteristics (Fuentes, 2007).

There is also, however, a further argument to be discussed from the analysis; that the appearance of PV modules ruins the aesthetic values of the building. Although in a lot of cases in which the cells are completely detached visually it would be called-out by the observer as a negative public element, the various types and characteristics of modules in the market and the numerous integration methods available open new horizons in front of the visual integration (in terms of the aesthetic value). An example for that can be PV integration into louver systems as it can add a lot to the buildings appearance and aesthetical value specially if it has a special dynamic mechanism when it adjusts to the suitable angle (Quality Domains Ltd, 2012). Another example is PV integration into the south facade of Portugal's Solar XXI building (SHC, 2012), as it was treated in an alternative rhythm with the glazing in the formation of vertical bands; This proves that modular systems with PV panels can provide for a nice visual integration with the glazing part of the facade through the use of reoccurring patterns.). However, the designer must achieve balance between the different aspects since PV systems are quite demanding in standards (position, direction and orientation) to get the best result and enhance their effectiveness, while some design aspects of the building can be more flexible, and therefore there might be some compromises in the process of integration in favour of PV systems' needs (Jahanara, 2013).

5. CONCLUSION

Renewable energies became one of the most controversial fields of study related sustainable development in the last few decades, especially solar energy source and PV technology. However, in spite being the most abundant renewable energy source in Istanbul, using solar energy in buildings is not the best possible and is not researched and studied, thus this arena of research has produced limited theoretical progress in this manner.

With an aim to define the barriers and the potentials of the architectural integration of photovoltaic panels into building skin in Istanbul, the thesis has tried to investigate people's perceptions and views on the current BIPV and its barriers in Istanbul. Starting by introducing the present scenario of energy scarcity and risks of the incessant use of fossil fuels trying to emphasize the prominence of utilizing renewable energy sources especially solar energy as it is free and abundantly available. Then discusses the recent literatures shedding light on the integrability of PV systems into buildings' envelops.

It was established from the findings based on open-ended interviews that there are seven challenges which are facing PV on building skins according to people's perceptions, the challenges are lack of awareness to PV integration, regulation problems and lack of encouragements, lack of knowledge among architects, the absence of public and private sector collaboration, technical obstacles (represented in efficiency problems and architectural problems) as well as it is perceived to be expensive. Hence, PV on building skins is not as wide spread as it could be.

The thesis has shown that the perceived obstacles: lack of awareness, regulation problems, lack of encouragements, lack of knowledge among architects and the absence of public and private sector collaboration which are combined in one theme (cultural obstacles) are Reflecting a realistic picture (situation) of the local Turkish context. However, a better education focusing on the importance of BIPV and sharing the responsibility for increasing the knowledge of PV significance in the construction industry can be recommended to increase the level of awareness among people and

between the responsible authorities and encourage them to use PV on buildings envelope.

The thesis has also shown that despite the expensive cost of PV on building skins the promising decline in the prices of these systems will help to overcome this obstacle. However, the perception in Istanbul on the technical issues facing PV on building skins is merely a delusory challenge, in which it is concluded that experts in the field have either missing information or out-dated information; consequently, a recommendation of keeping pace with the development of these fast growing technologies would change this negative perception and help to integrate PV more into building facades. Moreover, the following are some important points recommended for future researches:

- i. Making a thorough research on solutions or recommendations and deliver it within the frame is highly recommended for every conducted challenge within the research.
- ii. There can be an analysis in the future which studies the countries that have integrated PV into the buildings and those which have not.
- iii. In addition, a review on projects which have integrated PV systems in developed countries and making a comparison between them would be useful.
- iv. Conducting researches which bring more attention on PV systems as energy source and architectural element in order to increase the understanding of these systems especially in countries which do not usually adopt this system like Turkey.
- v. Using PV systems can be studied more thoroughly in order to illustrate the role of public and private sectors in adopting the system.

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