INTEGRATED DESIGN AND APPLICATION OF A CAMPUS-WIDE DISTRIBUTED-PHOTOVOLTAIC SYSTEM

A Thesis

By

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INTEGRATED DESIGN AND APPLICATION OF A CAMPUS-WIDE DISTRIBUTED-PHOTOVOLTAIC SYSTEM

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To All Green Energy Lovers

ABSTRACT

After releasing the regulations on unlicensed electricity generation in Turkey, the main structure of the regulatory mechanism has just finished in 2014 and renewable energy generation started to grow dramatically. Özyeğin University Campus Wide Solar Energy Application is the first large-scale building integrated, grid-connected system. From the idea of the project to the implementation processes, it is a great success story for the development of the academic researches and solar energy market. The complete process of technical, economical and bureaucratic side will be investigated for the future development while giving insights about the operation period as well.

Özyeğin University has completely rooftop PV system distributed on 4 buildings with a total capacity of 378 kWp. The whole system has a unique design that could be implemented on each buildings similarly. Solar energy production simulations with 4 different database systems, selection of the each component, complete system design, 3D models, financial analysis, static measurement and reports, governmental appointment mechanism, legal approval, installation, commissioning and operation are the main topics that will be covered within the thesis. The most important extraction over the analysis of system outputs is the Operational Performance Index, which should be used as a performance KPI for the photovoltaic system. At the end, the value and the originality will come from not only the system integrity but also modals generated for the development of the market.

ÖZETÇE

2014 yılı itibari ile Türkiye'de lisanssız elektrik üretimi ile ilgili düzenlemelerin yayınlanmasıyla birilikte, düzenleyici mekanizmanın ana yapısı tamamlanmış ve yenilenebilir enerji üretimi dramatik bir şekilde büyümeye başlamıştır. Özyeğin Üniversitesi Kampüs Geneli Güneş Enerjisi Uygulaması, Türkiye’deki ilk büyük ölçekli bina entegre, şebekeye bağlı sistemdir. Aynı zamanda döneminde birçok konuda sektörel gelişime öncülük etmiş proje fikrinden uygulama süreçlerine kadar, akademik araştırmaların ve güneş enerjisi pazarının gelişimi için büyük bir başarı hikayesi oluşturmuştur. Teknik, ekonomik ve bürokratik süreçler incelenecek ve operasyon süreci ve sistem performansı hakkında detaylı analiz sunulacaktır.

Özyeğin Üniversitesi, toplam 378 kWp kapasiteli 4 bina üzerine tamamen çatı üstü entegre PV sistemine sahiptir. Bütün sistem benzer şekilde her bina üzerinde uygulanabilir benzersiz bir tasarıma sahiptir. Tez kapsamında, 4 farklı veritabanı sistemi ile güneş enerjisi üretim simülasyonları, ekipman seçimi, komple sistem tasarımı, 3D modeller, finansal analiz, statik ölçümler ve raporlar, proje başvuru mekanizması, yasal onay, kurulum, devreye alma ve işletme ana konuları oluşturmaktadır. 4 yıllık system çıktılarının analizi sonucundaki en önemli çıkarım ise fotovoltaik sistemler için kullanılması önerilen Operasyonel Performans Indeks’i olmuştur. Projedeki değer ve özgünlük, sadece sistem bütünlüğünden değil aynı zamanda pazarın gelişimi için yol gösterici oluşundan gelecektir.

ACKNOWLEDGEMENTS

This work is final product of my long-lasting study in Center for Energy, Environment and Economy at Özyeğin University.

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF FIGURES

CHAPTER I

1 INTRODUCTION

1.1 Energy Outlook Today

Long before any knowledge of electricity existed, people were aware of electrical shocks from different things. The unidentified skills of fishes causing electrical shock were mentioned in the text of Ancient Egypt dating from 2750 BC. They named these fishes as the 'Thunderer of Nile' and described them as protectors of all other fishes. Then ancient cultures near Mediterranean discovered the interaction between the cat's fur and some certain objects like rods of amber resulting in the static electricity around 600 BC. After 1600, when English scientist William Gilbert made a careful study on electricity and magnetism, we coined the word electricus ("of amber" or "like amber") to refer to the property attracting small objects after being rubbed.

In 18th century, Benjamin Franklin started his study on electricity and discovered the naturel electricity source, lightning. Discovery of bioelectricity by Luigi Galvani, the invention of electric motors by Michael Faraday, mathematical analysis of electricity by George Ohm and the concept of magnetism by Maxwell were the succeeding milestone in early 19th century.

The greatest progress on electrical engineering, which could be accepted as the first revolution on electricity, was occurred in the end of 19th century.

Through such people as Alexander Graham Bell, Thomas Edison, Ernst Werner von Siemens, Nikola Tesla, George Westinghouse, electricity turned from a scientific curiosity to essential tool for modern life, which also became a driving force of the

Second Industrial Revolution. Photoelectric effect discovered by Albert Einstein, transistor was invented around '50s, diodes, RAMs, microprocessors, LEDs, high power batteries, different kind of electricity generation systems, transmission of electricity, electricity cars, storage systems, wireless data transfer from human brain to another and followed on. Our life has eventually settled at the heart of technology. Under the light of such dependency of electricity, the humankind find a various way of electricity generation form the flow of rivers to hydrogen cells.

Michael Faraday discovered the fundamental principals of electricity generation by the invention of electric motor. Today, we still use the same principals to produce alternating current from different energy resources. There are several methods of directly transforming the other source of energy to electricity:

- Static electricity: From the movement of electricity charges.
- Electromagnetic Induction: Electricity generators, dynamos and alternators transforms kinetic energy into electricity. The most used method underlying the Faraday's Law.

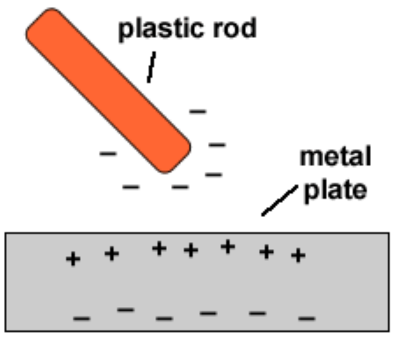


Figure 1-1 Model for Static Electricity [1]

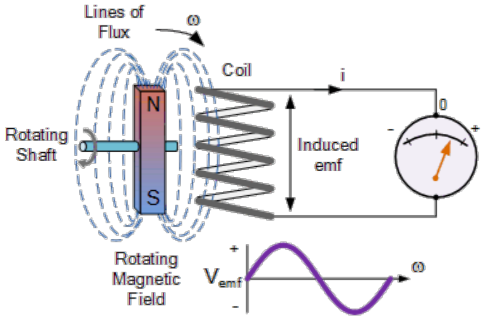


Figure 1-2 Model for Electromagnetic Induction [2]

- Electrochemistry: Direct transformation of chemical energy into electricity, battery fuel cells and nerve impulse.
- Photovoltaic Effect: Transformation of light into electricity with help of semi-conductor technology.

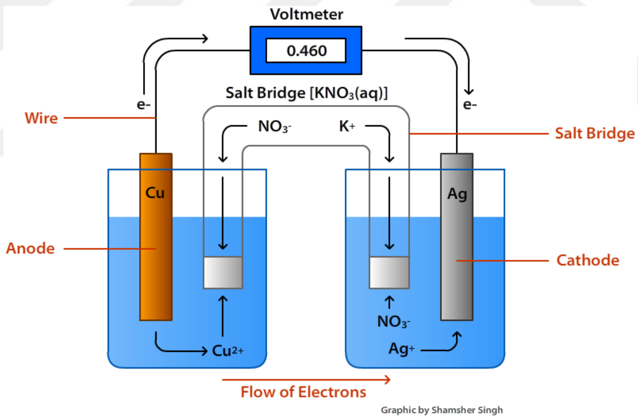


Figure 1-3 Model for Electrochemistry [3]

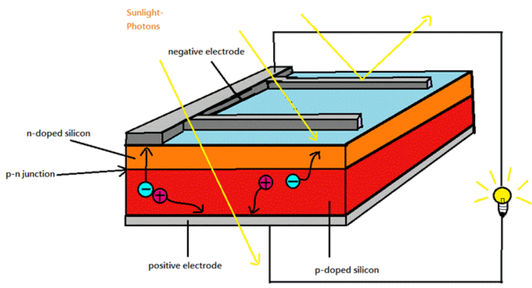


Figure 1-4 Model for Photovoltaic Effect [4]

- Thermoelectric effect: Conversion of the temperature difference, thermocouples, and thermopiles.
- Piezoelectric effect: The mechanical strain of the electrically anisotropic materials can be converted into electricity.

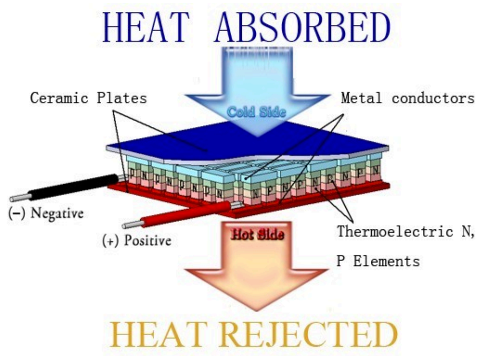


Figure 1-5 Model for Thermoelectric Effect [5]

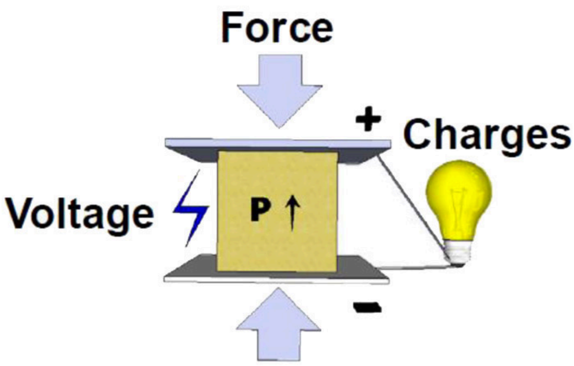


Figure 1-6 Model for Piezoelectric Effect [6]

These methods help humankind meet electricity need from water resources, fossil fuels (coal, natural gas, petroleum) renewable sources (wind, geothermal, biomass, solar, etc.) and radioactive material as nuclear power.

When we look at the today's situation throughout the energy resources point of view, we use Coal/Peat, Natural Gas, Oil, Hydro, Renewables and Nuclear with a portion of 40,7%, 21,6%, 4,1%, 16,2%, 6,0% and 10,6% successively as a primary energy resource all around the world according to the statistics of The World Bank as shown in Figure 1-7.

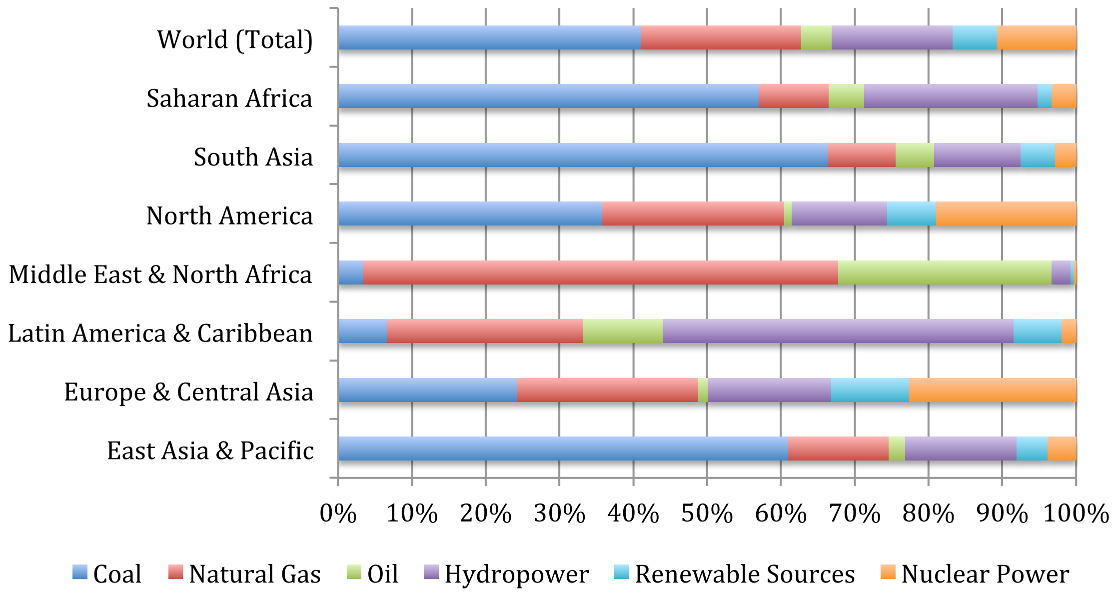


Figure 1-7 World Electricity Production by Regions and Resources in 2014 [7]

World energy resource reserves are mainly located in Asia, Middle East and North America, which result in localization energy production into these regions. The world map in Figure 1-8 shows the distribution of energy production with a unit of Mtoe (Million Tones of Oil Equivalent) by regions.

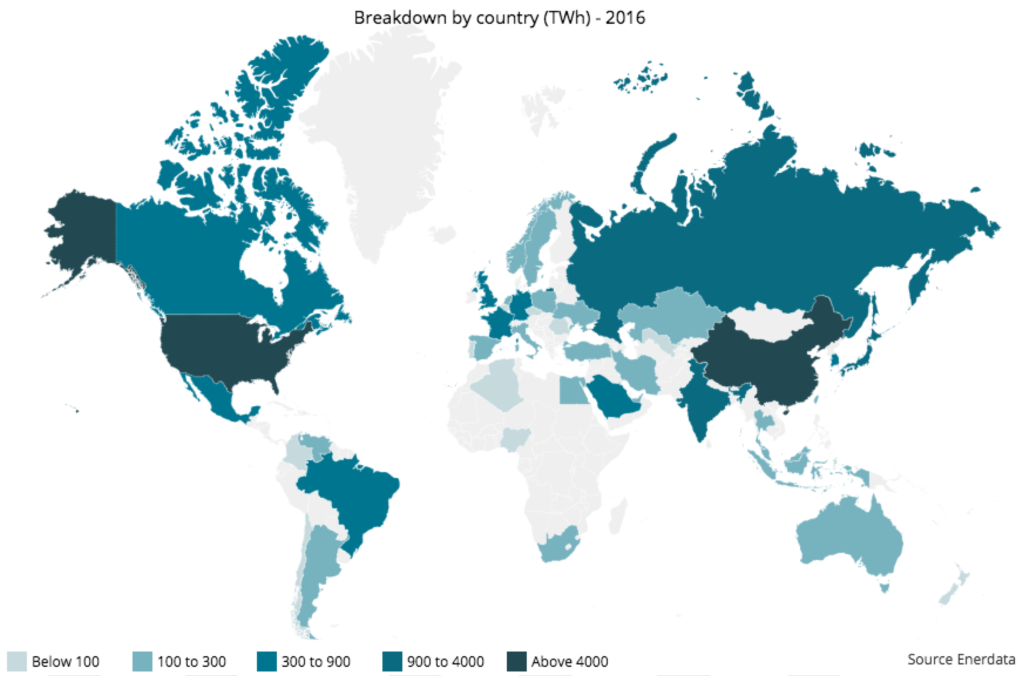


Figure 1-8 Localization of Energy Production around World in 2016 [8]

Energy consumption differs from the actual energy generation due to energy loss including technical losses, inefficiencies and theft. In 2016, total energy generation was 13,909.00 Mtoe globally [8]. The gap between energy generation and consumption was around 400.00 Mtoe referring to 2.9% of global energy generation. In 30-year period, global energy consumption decreased for the first time in 2009 by 1.1% because of the financial and economic crisis, which reduces the world GDP by 0.6%.

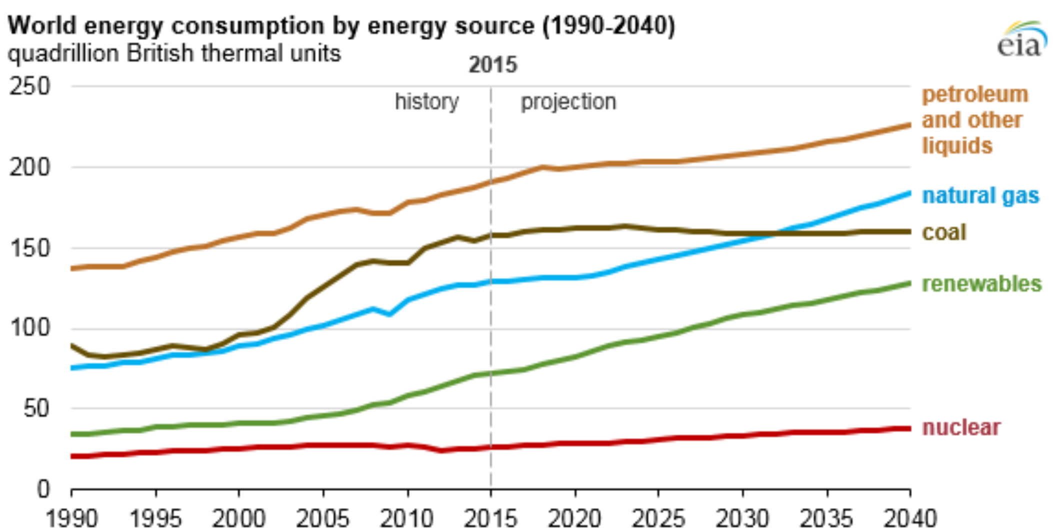


Figure 1-9 World Energy Consumption by years (1000 x TWh) [9]

2010 has arrived with a dramatic increase in global energy consumption by 5%; China became world's largest energy consumer by 18% that increased from 8% in 2009.

Even though energy generation distributed over globe according to the location of resources, energy consumption totally depends on the country's development level and population. After a major restructuring of the energy industry in 2009, all the variable of the global energy equation has changed and move to Asia, India and China without any change in the position of U.S. [10]

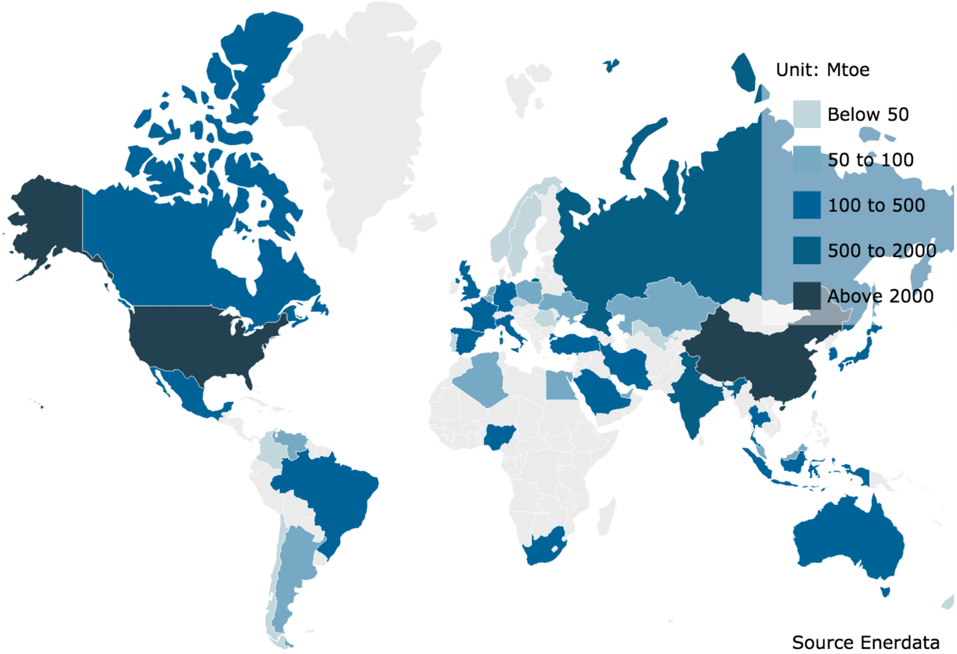


Figure 1-10 World Total Energy Consumption by Countries in 2015 [11]

Another big issue occurred after 2009 crises is a global mind shift on renewable energy usage. It was clear that world's health is not going well considering the climate change, global warming and CO_2 emission levels of last decade. All countries got alarmed about decreasing the CO_2 emissions and nuclear energy especially after Fukushima nuclear disaster in March 2011. Taking glance on the CO_2 levels of last decade shows us that most of the countries starting from China crossed the border of air pollution limits [12].

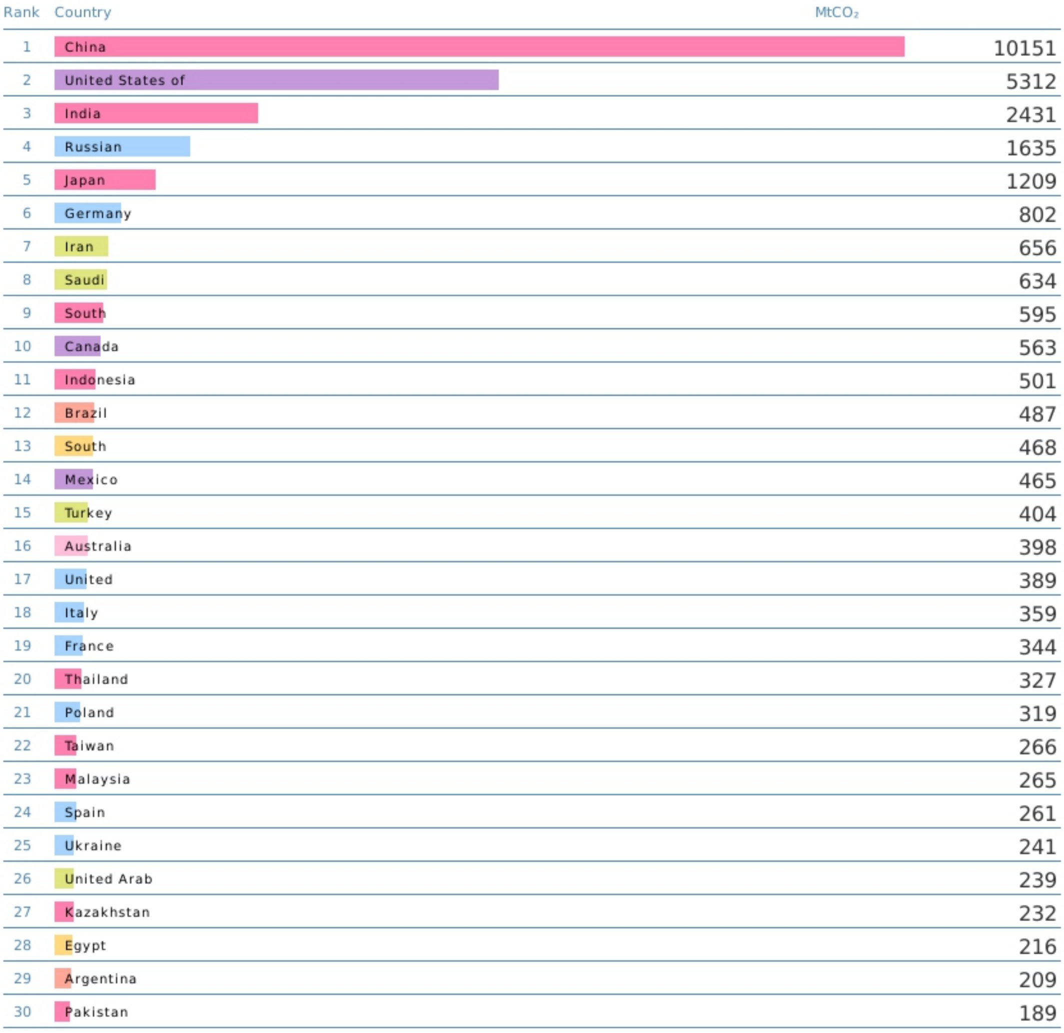


Figure 1-11 Carbon Dioxide Emissions of First 30 Countries in 2016 ($MtCO_2$) [13]

Last 10 years, there has been a worthwhile decrease on the unit cost of renewable resources. For instance, while a rooftop PV system between 10-100kWp costs for 4.7 €/Wp in 2006, it decreases to 1.25 €/Wp in 2016 and for the MWp scale installation market unit cost could reach to 0.9 €/Wp for turnkey systems [14]. Figure 1-12 shows this dramatic decrease on historical price experience curve of PV modules since 1980 published by Fraunhofer Institute in Feb 2015 [15].

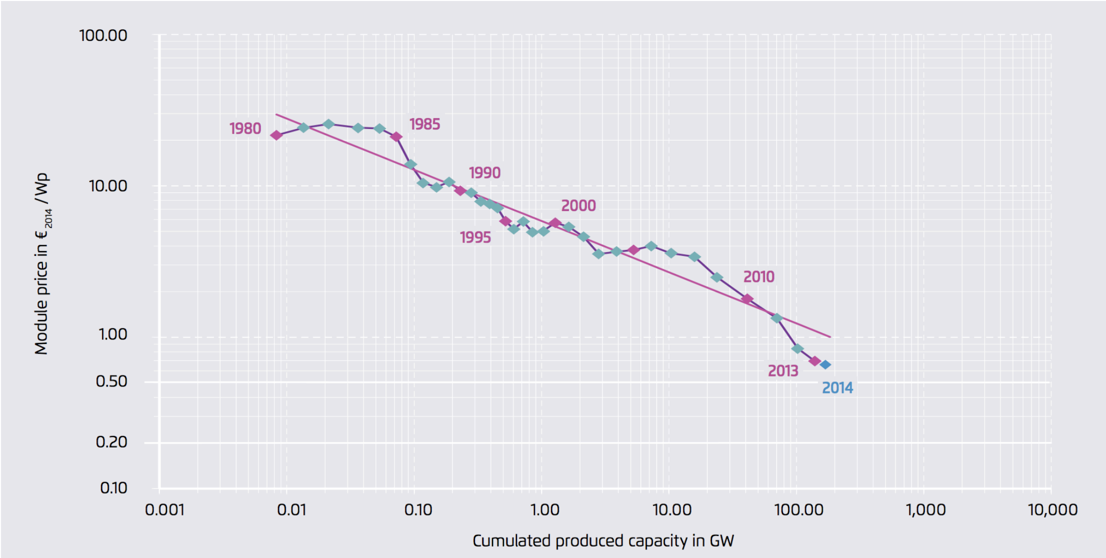


Figure 1-12 Historical Price Experience Curve of PV Modules since 1980 [15]

This market price movement affects all energy resources and current cost level changes in the range of 0.04 and 0.20 according to the levelized cost of electricity by resources. Levelized Energy Cost (LEC) is an economic assessment of the cost of electricity generation including initial investment, operational expenses, maintenance cost, cost of resource. It is very useful while comparing cost of energy generation from different resources. And it can be defined in a single equation [16]:

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where,

LEC= Average lifetime levelized electricity generation cost

I_t=Investment Expenditures in year t

M_t =Operations and Maintenance Expenditures in year t

F_t =Fuel Expenditures in year t

E_t =Electricity Generation in year t

r = Discount Rate

n = Life Time of System

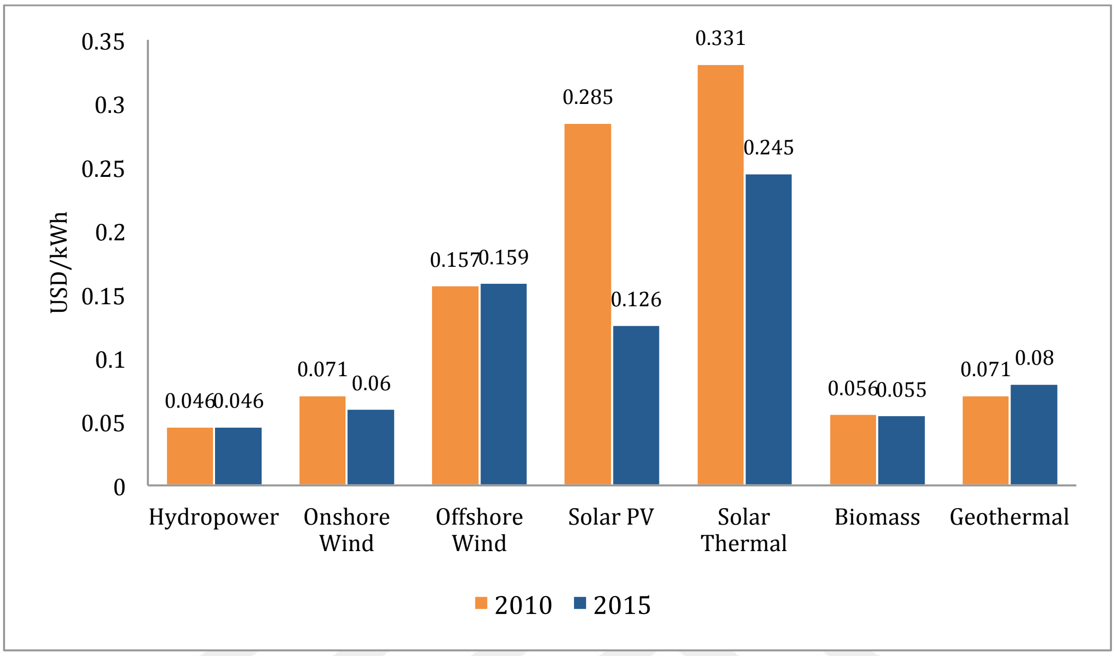


Figure 1-13 Levelized Cost of Electricity in USD per kWh (2010-2015) [17]

And in this competition solar energy and wind energy became key actors considering economical, technological and environmental variables. Total renewable capacity has doubled from 800 GW (without Hydro 85GW) in 2004 to 1,985 GW (without Hydro 560GW) by the end of 2015. In this period PV system capacity rose from its ashes and reached to 227 GW. While average yearly growth rate of all renewable was around 9% from 2004 to 2015, the growth rate of solar energy systems reached 3 times more, 26% from 2014 to 2015. During this period, regulation and country policies has also changed. The number of renewable energy related regulations and targets jumped to 144 from 48. As a result, renewable energy share over global energy generation has reached to 24% including hydro as of 2016 [18].

		2015	2016
INVESTMENT			
New investment (annual) in renewable power and fuels [1]	billion USD	312.2	**241.6**
POWER			
Renewable power capacity (total, not including hydro)	GW	785	**921**
Renewable power capacity (total, including hydro)	GW	1,856	**2,017**
Hydropower capacity [2]	GW	1,071	**1,096**
Bio-power capacity	GW	106	**112**
Bio-power generation (annual)	TWh	464	**504**
Geothermal power capacity	GW	13	**13.5**
Solar PV capacity	GW	228	**303**
Concentrating solar thermal power capacity	GW	4.7	**4.8**
Wind power capacity	GW	433	**487**
HEAT			
Solar hot water capacity [3]	GW_{th}	435	**456**
TRANSPORT			
Ethanol production (annual)	billion litres	98.3	**98.6**
Biodiesel production (annual)	billion litres	30.1	**30.8**
POLICIES			
Countries with policy targets	#	173	**176**
States/provinces/countries with feed-in policies	#	110	**110**
States/provinces/countries with RPS/quota policies	#	100	**100**
Countries with tendering/public competitive bidding [4]	#	16	**34**
Countries with heat obligation/mandate	#	21	**21**
States/provinces/countries with biofuel mandates [5]	#	66	**68**

1) Investment data are from Bloomberg New Energy Finance and include all biomass, geothermal and wind power projects of more than 1 MW; all hydro projects of between 1 and 50 MW; all solar power projects, with those less than 1 MW estimated separately; all ocean energy projects; and all biofuel projects with an annual production capacity of 1 million liters or more

2) The GSR 2016 reported a global total of 1,064 GW of hydropower capacity at end-2015. The value of 1,071 GW shown here reflects the difference between end-2016 capacity (1,096 GW) and new installations in 2016 (25 GW). Differences are explained in part by uncertainty regarding capacity retirements and plant repowering each year. Note also that the GSR strives to exclude pure pumped storage capacity from hydropower capacity data.

3) Solar hot water capacity data include water collectors only. The number for 2016 is a preliminary estimate.

4) Data for tendering/public competitive bidding reflect all countries that have held tenders at any time up through the year of focus.

5) Biofuel policies include policies listed both under the biofuels obligation/mandate column in Table 3 (Renewable Energy Support Policies) and in Reference Table R25 (National and State/Provincial Biofuel Blend Mandates).

Figure 1-14 Numbers for Global Renewable Energy Market [19]

China is the pioneer for the global renewable energy growth with 240 GW capacity increases since 2006.

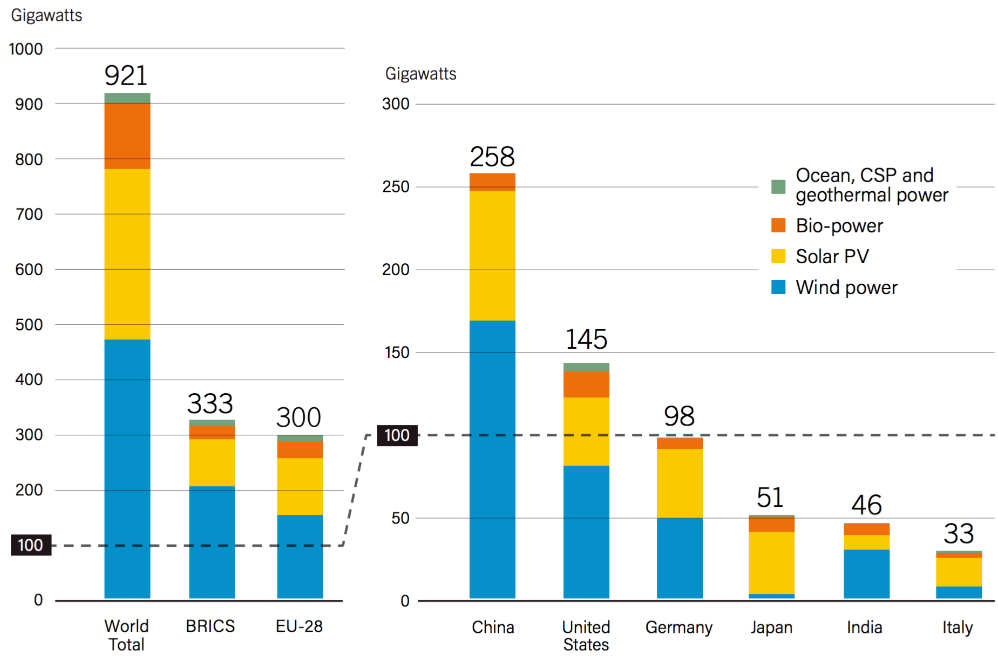


Figure 1-15 Renewable Power Capacities in World, BRICS, EU-28 and Top 6 Countries, 2016 [20]

1.2 Solar Energy Market in World

The year 2013 was another historic one for solar photovoltaic (PV) technology, which has experienced remarkable growth over the past decade and is on the way to becoming a mature and mainstream source of electricity. The world's cumulative PV capacity surpassed the impressive 130 GW, which is sufficient to generate about 0.85% of electricity demand on planet. Each year these PV installations save more than 70 millions tons of CO_2.

Besides the photovoltaic technology, solar energy has had a wide range of application areas such as architecture, agriculture, transportation, heating, hot water, process heat, cooking and electricity production with different kind of technologies since the birth of humanity. Technological developments lead us to the cutting-edge applications in various fields. Recently, in academy, scientists have been working on solar energy printers, solar paintings, solar cells producing electricity under nightglow, highest efficiency rate close to 45% and so on.

Recent technological classification of the solar energy technologies is shown on Figure 1-16. There are two main ways of using the Sun's energy: thermal and electricity, which is called photovoltaic. Especially for the photovoltaic, there are many type of technology to convert energy of photons to electricity. The most commercialized ones are crystalline silicon based solar cell and thin films. Considering the cost of those technologies, multi crystalline silicon based solar cells come forward and get common in the market.

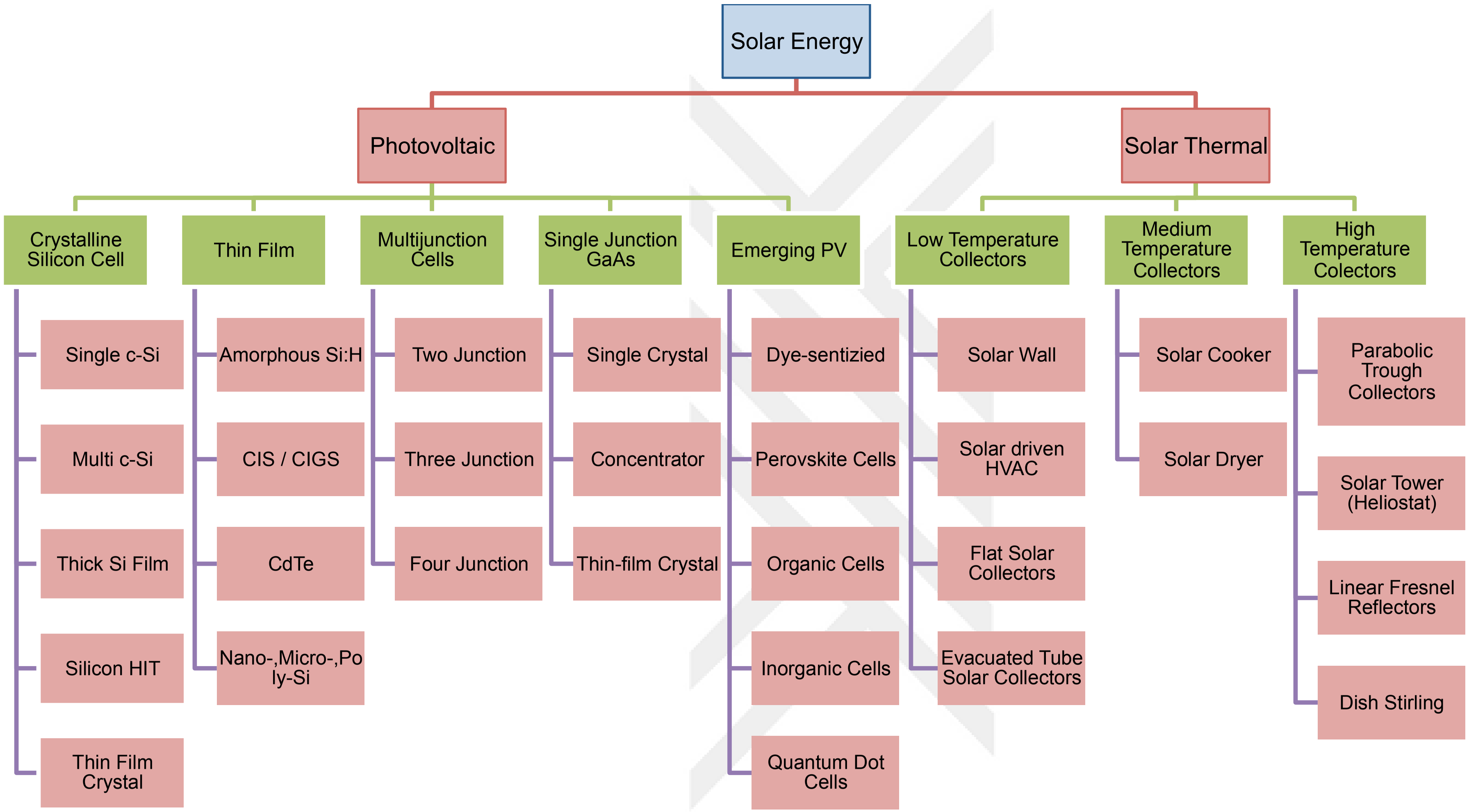


Figure 1-16 Solar Energy Technologies [21]

Comparing the solar thermal technologies and market size, photovoltaic systems can be accepted as it has recently entered to the market. Even though the invention of photovoltaic technology is date back to the beginning of 20th century, the growth in the market has just caught in last decade, which is mainly because of the cost of the technology. Starting from the early 2000s, photovoltaic systems began to take its place into market. Cumulative installed capacity firstly reached to double digits GW values in 2008, reached to 3 digits number in just 5-year time around 2013 and reached to 300GW by the end of 2016, which covers 1.8% of global energy need.

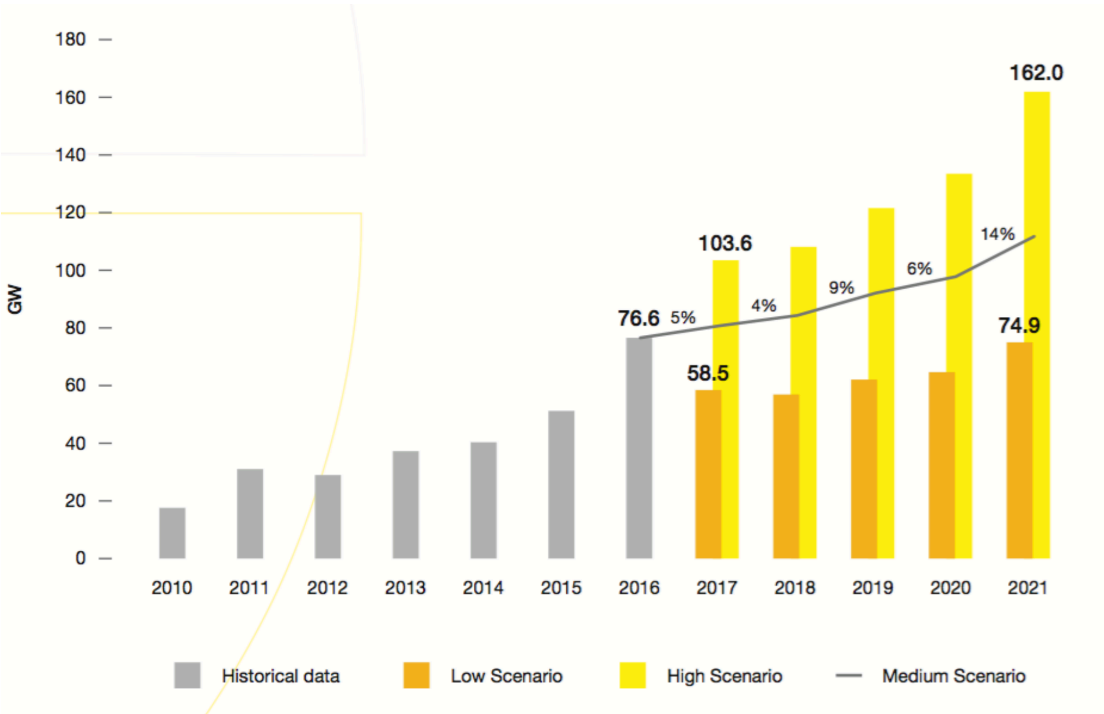


Figure 1-17 World Annual Solar PV Market Scenarios 2017-2021 [22]

Considering this huge market growth, there are several leading countries both for technological and installed capacities. Starting from 2006, Germany, Italy, Spain, USA, Japan and China released new regulations to promote renewable energy, gave different incentives and purchase guarantee for the investors in order to be a global success with a highest renewable energy production. Then, they reached that goal and are continuing in that way.

#	Nation	Total Capacity (GW)
1	China	78.07
2	Japan	42.75
3	Germany	41.22
4	United States	40.3
5	Italy	19.28
6	United Kingdom	11.63
7	India	9.01
8	France	7.13
9	Australia	5.9
10	Spain	5.49

Figure 1-18 Cumulative PV Capacities of Leading Countries by end of 2016 (MW) [23]

They are now the first 6 top countries in world by covering 74% of global installed PV capacity with more than 110 MW.

While there is a competition among countries and their technologies, the share of PV technologies used in market differs in each year. The most common technology is solar cells based on Crystalline Silicon (c-Si), which is separated into to different technology, multi-Si and mono-Si. The main things affecting the market share of each technology are cell efficiency and cost of system. As an example, Thin-film became a hot topic in 1995 and 2010 however; the efficiency and rapid cost decrease of crystalline silicon made it get the highest share over market.

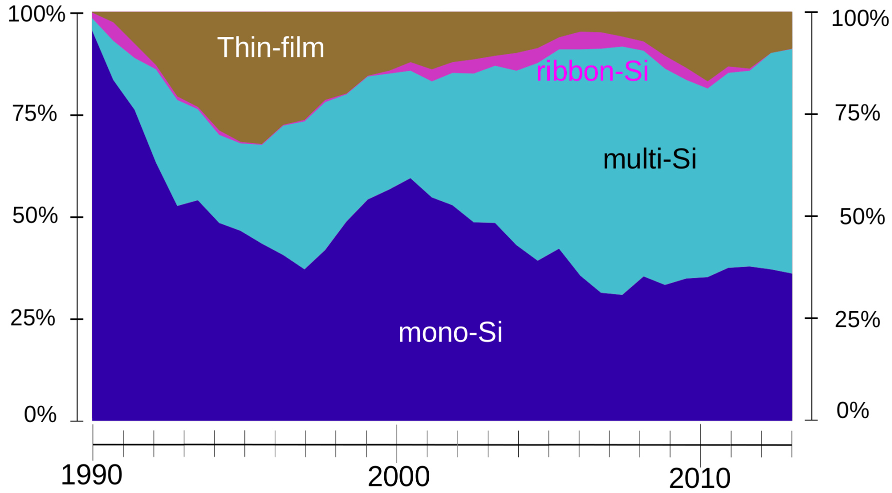


Figure 1-19 Global Market Share by PV Technologies (1990-2013) [24]

Beside technology, there is also diversity on the installation types. All the systems works with same principle in a big picture however, legal procedure, their effects on electricity grid, design requirements and control scenarios differ according to the size and installation type. Most common installations are mainly focused on residential (which can also be separated as rooftop and BIPV), commercial, industrial and ground mounted. There are also stand-alone (off-grid) systems covering only 1% of global PV capacity. Industrial systems, which are connected to the grid from medium or high voltage level, have the highest share with 69% according to the Grid-Connected PV Systems Market – Growth Analysis and Forecast by Technovia. [25] Residential and Commercial systems have almost same portion although residential is one step ahead of commercial installations in some markets.

Last but not least, the players of the market from module manufacturers to inverter producers and mounting equipment are the key factor on the market growth.

1.3 Turkey as a Developing Market on PV Systems

While energy demand in Turkey has been doubled between the years 2000-2010 and is expected to increase 4 times between 2000-2025, the importance of local energy resources is getting higher. Considering the geographical position, Turkey has a great potential for solar energy usage with annual average total insolation duration of 2,737 hours (7.5 hours per day on average) and 1,527 kWh/m^2-year annual solar radiations with 4.2 kWh/m^2-day averages. This means that covering 0.5% of land area of Turkey would be sufficient to meet all electricity usage.

Solar energy technologies are separated into different groups regarding methodology, materials, and technology level. The two main common technologies in Turkey are Solar Thermal and Photovoltaic. Thermal technologies are mainly used for hot water need in residential and industrial facilities and energy generation in power plants. By 2015, total installed power of solar thermal technologies may measured by the total solar collector coverage area, which exceeds 18,000,000 m^2 [26]. The annual energy production from solar thermal technologies in 2015 are 811.000 TOE (tons of oil equivalent); 528,000 TOE of them used in residential, 283,000 TOE of them used in industry. Beside that Turkey is one of the first three countries used solar thermal technologies according to the installed capacity, which is around 47 MW/year, Concentrated Solar Power technologies has recently started to be applied in different regions for experimental aims.

Since Turkey has a special geological location considering the solar power potential, photovoltaic technologies comes as two with a dramatically increase after solar thermal. As PV system pricing decreases and regulatory base settle down; the PV market in Turkey concretely grew within last 10 years.

With the introduction of incentive mechanism by government within the Renewable Energy Law in 2015 and subsequent amendments in 2007, 2010, 2012, 2013 and 2016; the photovoltaic market has started to grow with both manufacturing and power plant investments.

1.3.1 Technological Background

In 5-year time, Turkey exceeded several levels to reach the reasonable stage in terms of local manufacturers. Considering the whole product chain from solar cell to inverter, Turkey had one PV module Lamination Company, Anel Enerji, and basic production infrastructure for mounting equipment in those days before 2012. Since Renewable Energy Law with PV market incentives, the number of companies and type of photovoltaic components manufactured in Turkey has dramatically increased.

As it is shown in Figure 1-20, there are more than 25 companies working on different fields; mounting equipment, inverter, PV module, solar cables, switching equipment and junction boxes. Starting with the solar cell manufacturing investment of Chinese company CSun, couple of Turkish companies set to work on solar cell production. The latest update about the incentive mechanism to support those companies has just released in April 2018. Government published a regulation to provide them tax exemption for 10 years time [27].

By the end of 2017, more than 120 companies are working on PV market in Turkey in different expertise Equipment-Component Manufacturing, Consulting, Engineering - Procurement and Construction, and Marketing etc.

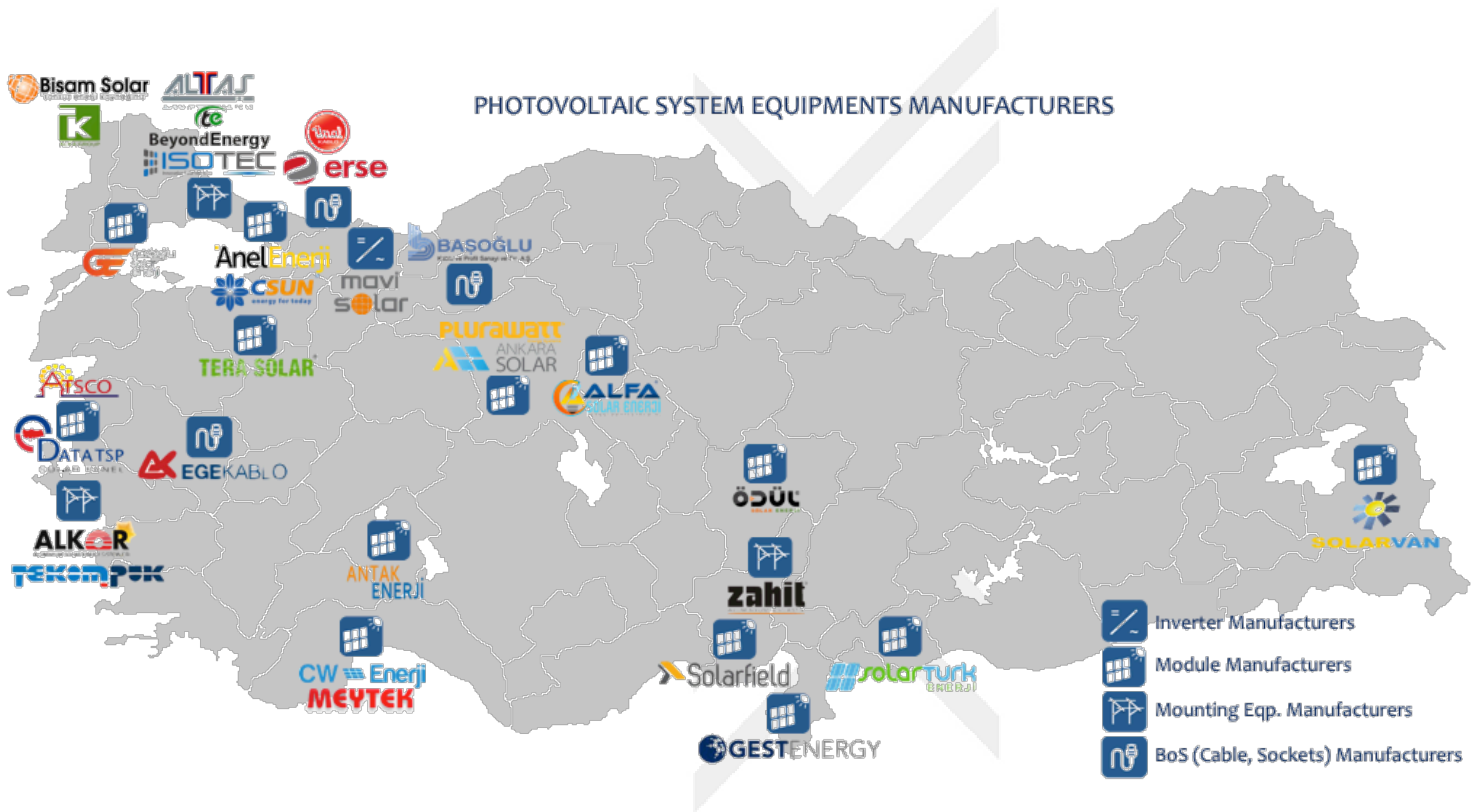


Figure 1-20 Companies in Solar Energy Business in Turkey by 2017

Before these improvements, the most common products were Yingli Solar, SunPower, Asunim, Anel etc for PV modules; SMA, Fronius, REfusol, Kaco for Inverters; Multi-Contact for cables/connectors and Schletter for mounting equipment.
The most important booster for PV market and manufacturers were the R&D studies by universities, institutes, and research centers and events during the year.
Among different Turkish Universities; Ege University, Middle East Technical University, Istanbul Technical University and Yıldız Technical University have the leading research institutes or centers developing the products for the local market. Solar Energy Institute in Ege University mainly studies on engineering, components and systems; while Center for Solar Energy Research (GUNAM) and Application at METU studies mainly on different types of solar cell production. With these studies, GUNAM produced the first made-in-Turkey c-Si and thin film solar cells.
Since 2015, there are many EPC companies having full experience on PV power plants and provide a turnkey solution for the investors. They have experienced on the projects from 1MWp to 40MWp projects as well as the government and regulatory structure.

1.3.2 Regulatory Structure

Energy market has highly regulative structure in all around the world while dominating the whole economical balances. Today, the problem behind the disagreements and especially wars between countries is mainly based on energy issues. Except from the conventional energy resources that have limited number but huge capacities, renewables and new generation energy resources are mostly distributed even on individual level with small capacities. The distributed generation systems come with complex structures, individual-level security problems, special licensing and investment models for the countries.

Turkish government had talked about the renewable energy law for more than 10 years, however the first part of the law related with solar energy, called Renewable Energy Law, was released in January 2011 [28] with a full of deficiencies.

1.3.3 Renewable Energy Law

Considering the existing electricity system coming from 50s in Turkey, photovoltaic market starts with a capacity limitation because of the infrastructure capacity in 2011 although Renewable Energy Law was released in 2005.

Taking account first regulation based on the Solar Energy Power Plants with licensed and non-licensed models; the most potential areas around Turkey was selected according to the availability for solar energy applications and transformer capacities at first [29]. And all the details by region defined in that regulation.

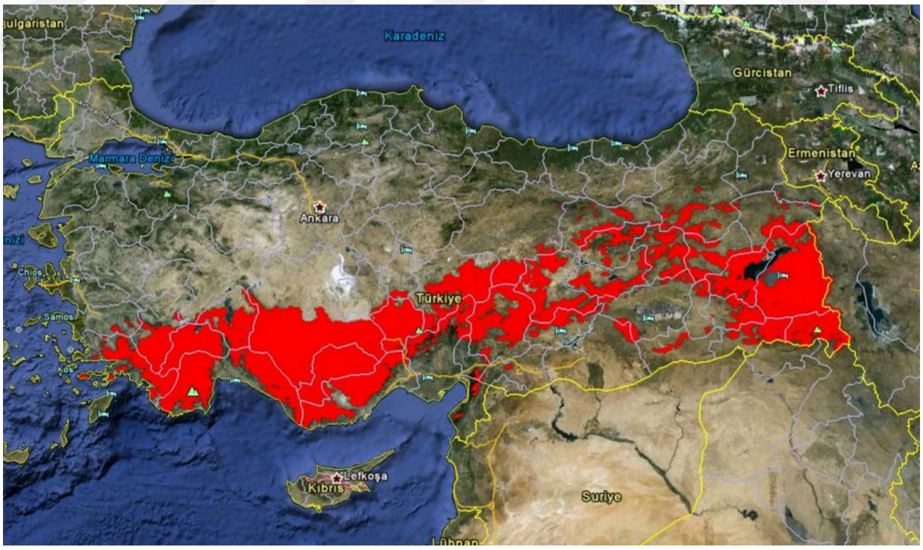


Figure 1-21 Permitted Regions for Solar Energy (PV) System Implementation [29]

These regions mostly have the solar radiation potential of more than 1,500 kWh/kWp-year. 37 cities, 121 transformer stations for the PV Power Plant grid connection and 600 MW total capacities were allowed for non-licensed PV Power Plant Investments. [30]

Table 1: Total Allowed Non-Licensed Solar Energy Plants by Regions [30]

City/Region	# of Transformer	Total Allowed Capacity (MW)
Konya-1	8	46
Konya-2	5	46
Van Ağrı	5	77
Antalya-1	6	29
Antalya-2	8	29
Karaman	3	38
Mersin	7	35
Kahramanmaraş Adıyaman	9	27
Burdur	3	26
Niğde Nevşehir Aksaray	4	26
Kayseri	6	25
Malatya Adıyaman	6	22
Hakkari	2	21
Muğla Aydın	8	20
Isparta Afyon	7	18
Denizli	3	18
Bitlis	2	16
Bingöl Tunceli	4	11
Şırnak	3	11
Adana Osmaniye	4	9
Muş	1	9
Siirt Batman Mardin	5	9
Sivas	1	9
Elazığ	5	8
Şanlıurfa Diyarbakır	1	7
Erzurum	3	5
Erzincan	2	3
	121	**600 MW**

The most important part of the law was the unlicensed Solar Energy Plants, which were boosted the market in a short time. From December 2015 to October 2016, the total installed power reached to 660 MW from 203 MW [31]. For the first year of the regulation, it was allowed to install PV Power Plant up to 500 kWp with just basic application process and approval period. These unlicensed systems were also allowed to sell the produced energy to the grid (to local utility) according to the fixed unit pricing within the regulation.

The first version of regulation and manifest contains:

- Limited region and capacity for licensed Solar Energy Plants
- 500kWp upper limit for unlicensed systems (must subscribe to the local energy utility and get the approval from the Central Energy Distribution Department)
- Application process and documents (forms attached on Appendix A)
- Grid connection details (LV, MV, HV connections)
- Energy selling models (feed-in-tariff)
- Unit prices and Domestic Component Initiative

The most important parts of the regulation for the unlicensed investors were upper limit for the plant capacity, application process and energy selling models. The main structure of energy selling model was based on daily net metering which means net settlement of energy used/produced for 24 hours total. In monthly basis, all of the daily net settlement aggregated separately after converting energy into money, then if consumer is indebted, he pays or vice versa.

The details of the implementation of this regulation were examined within the manifest released on October 2013, which means that all the market has been actuated after this date.

Up to now, Turkish Solar Energy Market has been encountered several serious updates on regulations and manifests in which the latest one, before this thesis ends, was in 22th January 2018. [32]

The major changes are given below although all of the allowed capacity limits were exceeded (most of them approved but not implemented yet) and the agency authorized by law has not accepted any application from since October 2016 both for licensed or unlicensed systems.

- Capacity Limitations for licensed Solar Energy Power Plants remains same
- Upper limit for the unlicensed Solar Energy Power Plants increased to 1MW
- Application procedures improved and simplified
- Domestic product certification procedures updated

Investors should follow several steps in order to start to produce and sell solar energy into the grid.

1. Pre-Application: In this part you provide your intention to invest on Solar Energy System. The applicant should provide the location to be installed, system capacity and rough drawings and some critical approvals from government units. All the documents should be submitted to the local utility.
2. Main Application: Main application is submitted directly to the Regional Electricity Distributor (Utility) Detailed electricity technical report including calculations, datasheets, single line diagrams and construction reports including static calculations on mechanical structure.
3. Temporary Admission: Detailed reports from the installed plant, given on table below
4. Main Admission: After limited time period over on-site commissioning by authorized government unit, applicant gets the main admission.

Table 2: Documents Needed for The Solar System Application Procedures [33]

Procedures	Documents needed for the Solar System Procedures		
	#	Root Top System	Field System
Pre Application	1	Registry of Deeds (If rental area, then rental agreement with authorized signature list)	
	2	Receipt of Application Fee (if it is lower than 250kWe, free; otherwise 536,41 TL for 2017)	
	3	Application Form	
	4	Technical Drawings (Single Line Diagram)	
	5	Subscription to Local Utility	
	6	System Settlement Plan (Approved by YEGM (1))	
	7	Construction Permit	Document for land usage (no agricultural land allowed) (Approved by GTHB (2))
	8		ÇED (3) Document (from ÇŞB (4))
Main Application	9	Technical Drawing, Electricity Calculations and Datasheets	
	10	Mechanical static calculations, wind and snow load calculations	
Temporary Admission	11	License of Electrical and Mechanical Engineers for technical documents	
	12	Approved Project of the Solar Energy Power Plant	
	13	Grid Connection Agreement	
	14	Agreement btw Plant Owner and Sub-Contractor (EPC Company)	
	15	License of Authorization for the responsible Electrical Engineer	
	16	Bill of Quantities	
	17	Tax Certificate	
	18	Communication Info for Owner and Sub-Contractor	
	19	Testing Reports for the Equipment used	
	20	Grounding Measurement Report	
	21	Photos from the Power Plant	
	22	Technical Evaluation form (Approved by YEGM)	
	23	Fire Department Report	
	24	Site Agent Authorization Report	
	25	Field Test Results (On-site measurements)	
	26	System Compatibility Report	
	27	Protection Relay Set Values	
	28	Other Consent Certificates for Land Settlement	

YEGM: Renewable Energy General Directorate
GTHM: Ministry of Food, Agriculture and Husbandry
ÇED: Environmental Evaluation Report
ÇŞB: Ministry of Environment and City Planning

Since the release of the new update on Photovoltaic Energy Regulations on 28th of December 2017, the application procedures for the on-site power plants up to 10 kWp-installed-power was made easier. If it is lower than 3 kWp, the applicant may get the approval directly from local energy distributor's office around 15-to-30 day time. If it is between 3-10kWp capacity, the applicant firstly gets the pre-approval from the local office then gets the approval letter from the HQ of local energy distributor in first 20 days of next month.

1.3.4 Incentive Mechanism (Net metering, Feed-in-tariff)

The supportive mechanisms to develop renewable energy market in Turkey may be divided into 3 different topics. These incentives are valid till the end of 2016 for whole non-licensed PV projects, which are up to 1 MWp capacity. After that, they started to get application only from the projects covering own consumption not for investment.

- Purchasing Guarantee
    - 10-year guarantee with $ 13.3 cent/kWh
    - 5-year additional guarantee based on the domestic product usage from $ 0.5 cent/kWh to $ 6.7 cent/kWh
- Tax Incentives
    - VAT and Custom Tariff Exception
    - Discount on Income Tax Withholding and Social Security Contribution
- Financial Support
    - Special Credits/Debts

Around 2018, all these capacities would be put into practice and started operation with Net-Metering model with different pricing for electricity sell and purchase. Turkish regulatory structure is based on Net-Metering with bi-directional single meter if solar system and consumption are on the same location or with two different meters in different locations for production and consumption.

All the netting is on daily basis according to your consumption and production in kWh. If the one get electricity tariff as Three-Time Tariff then, the netting period is adjusted accordingly. If the one produced more than consumption in that specific period, then it's written as receivable on his side after multiplied with the USD based constant selling price. If the production is under your consumption, that means you have to pay for the remaining energy drawn from the grid according to your existing electricity tariff.

Solar energy selling prices are defined in Renewable Energy Law with purchasing guarantee for 10 years. Even it is $ 13.30 cent/kWh, there is additional incentives for domestic component usage in PV power plant. All the purchasing prices are given on Table 3.

Table 3: Purchasing Prices by Power Plant Types according to the Renewable Energy Law [34]

Number I Table **(Article of law numbered as 6094 and dated as 29/12/2010)**	
Type of Power Plant based on Renewable Energy Resources	Purchasing Prices (USD cent/kWh)
a. Hydro Electricity Power Plant	7.3
b. Wind Energy Power Plant	7.3
c. Geothermal Energy Power Plant	10.5
d. Biomass Power Plant	13.3
e. Solar Energy Power Plant	**13.3**

Photovoltaic has the highest purchasing price with biomass and converting it into the TL with the exchange rate of 2010, which is around 1.55 TL/USD; it was 30% higher than the average electricity costs. Considering the additional incentives based on domestic component usage the highest purchasing price may reach to $ 15.40 cent/kWh as there is no solar cell and invertor manufacturer with domestic product certificate in Turkey. Table 4 provides the additional prices by domestic components below.

Table 4: Additional Incentives for Solar Energy Plants [34]

Number II Table (Article of law numbered as 6094 and dated as 29/12/2010)		
Plant Type	Domestic Components	Additional Incentive (USD cent/kWh)
C- Photovoltaic Power Plants	1- Mounting and Construction Equipment	0.8
	2- PV Modules	1.3
	3- Solar Cells of PV Modules	3.5
	4- Solar Invertor	0.6
	5- Materials Focusing Radiation onto PV Modules	0.5
D- Concentrated Solar Power Plants	1- Radiation Gathering Tube	2.4
	2- Reflective Surface Equipment	0.6
	3- Solar Tracking System	0.6
	4- Equipment of Thermal Energy Storage	1.3
	5- Equipment of Steam Generator from Solar Tower	2.4
	6- Sterling Engine	1.3
	7- Solar Panel Structural Mechanism	0.6

Besides these incentives, there are some legal payments for the application process except from the engineering costs; annual operational costs and distribution system usage cost for energy sell, which increases the capex and opex of investment.

These expenses, given on the Table 5, are relatively high for the plants under 250kWp capacity.

Table 5: Legal Expenses of Application and Operation Progress for 2017 [35]

Cost Type	Capacity Category	Cost
Application Cost (TL)	<= 250 kWp	-
	> 250 kWp	536.41 TL
Annual Operational Cost (TL/year)	<=10 kWp	-
	10 < x <= 250 kWp	750.00 TL/YIL
	> 250 kW	1,500.00 TL/YIL

Giving an example on 100 kWp PV Power Plant application on an industrial facility, the monthly Net-Metering mechanism for both single rate tariff and three-time tariff are shown below.

Considering the detailed production and consumption scenarios of facility below, it would be clearer to get the mechanism. No matter if the power plant and facility connected to the grid from the same point or not.

Table 6: Example of 100 kWp PV Power Plant for Incentive Mechanism in 2016

TL/USD	3.00		
Power Plant Capacity	100 kWp		
	Day - I	**Day - II**	**Unit Prices (TL/kWh)**
Hours of Sunshine	7	3	
Total Radiation (Wh/kWp)	6,000.00	2,000.00	
Total Production (kWh)	600.00	200.00	0.399
22:00 - 06:00	-	-	0.399
06:00 - 17:00	500.00	180.00	0.399
17:00 - 22:00	100.00	20.00	0.399
Total Consumption (kWh)	500.00	500.00	0.291
22:00 - 06:00	50.00	100.00	0.175
06:00 - 17:00	300.00	350.00	0.289
17:00 - 22:00	150.00	50.00	0.449
Netting (kWh)	100.00	-300.00	
22:00 - 06:00	-50.00	-100.00	
06:00 - 17:00	200.00	-170.00	
17:00 - 22:00	-50.00	-30.00	
Savings (TL)	**Day - I**	**Day - II**	**In Total**
Single Rate Tariff (without PV)	-145.35	-145.35	-290.70
Single Rate Tariff (with PV)	39.90	-87.21	-47.31
Three-Rate Tariff (without PV)	-162.79	-141.13	-303.92
Three-Rate Tariff (with PV)	48.65	-80.09	-31.44
22:00 - 06:00	-8.73	-17.45	
06:00 - 17:00	79.80	-49.18	
17:00 - 22:00	-22.43	-13.46	

These are the savings excluding Distribution System Usage Charge and taxes. It is also clear that investment return depends on the electricity tariff and energy consumption period. When the facility saved 185.25 TL in single rate tariff, it was 211.44 TL in three-rate tariff in day I; however the difference is not that much high between different rates for day II. It was only from 58.14 TL to 61.04 TL because of the consumption trend of facility.

There are also another financial support mechanisms for renewable energy investments.

- TURSEFF and MIDSEFF: They provide renewable-specific credits/debts from EBRD and European Bank with low interest rates and attractive payment plans over some of the Turkish banks.
- Turkey Ministry of Development: They provide grants for your investments after some application process over their Development Agencies around Turkey.
- Leasing: Some of the banks and European funds may provide leasing for the equipment purchasing
- Tax Incentives: Most of them depend on the location and size of investment. To benefit these incentives, investor has to get 'Investment Support Certificate'

In 2nd half of 2017, the situation in the market was politically changed. As the value of Turkish Liras dramatically decreases within last 2 years, all the guaranteed incentives created huge pressure on the government since the purchasing guarantee covers 10 year time with USD based fixed cost. Then, the regulations did not extended after December 2016 and they stopped to get new appointments. Three more important moves came from the government. Firstly, they pushed all the investors having approval to finish all the construction and make all the commissioning till the end of 2017, which is not such long for more than 100 MWp capacities. Then, they announced giant PV projects, which was 1.000 MWp, biddings to lower the purchasing guarantee cost from

USD 13.3 cent/kWh and Kanyon and Hanwha Consortium got the project with a price of USD 6.99 cent/kWh. Lastly, the government manipulated the electricity prices by increasing YEKDEM price, which has added on utility bills as a result of renewable purchasing guarantee couple of years ago, to 34.41 TL/kWh annual average in 2017 while it was 24.36 TL/kWh in 2016 and 8.73 TL/kWh in 2017. This manipulation directs affected to the energy providers in free market negatively and some of them has bankrupted.

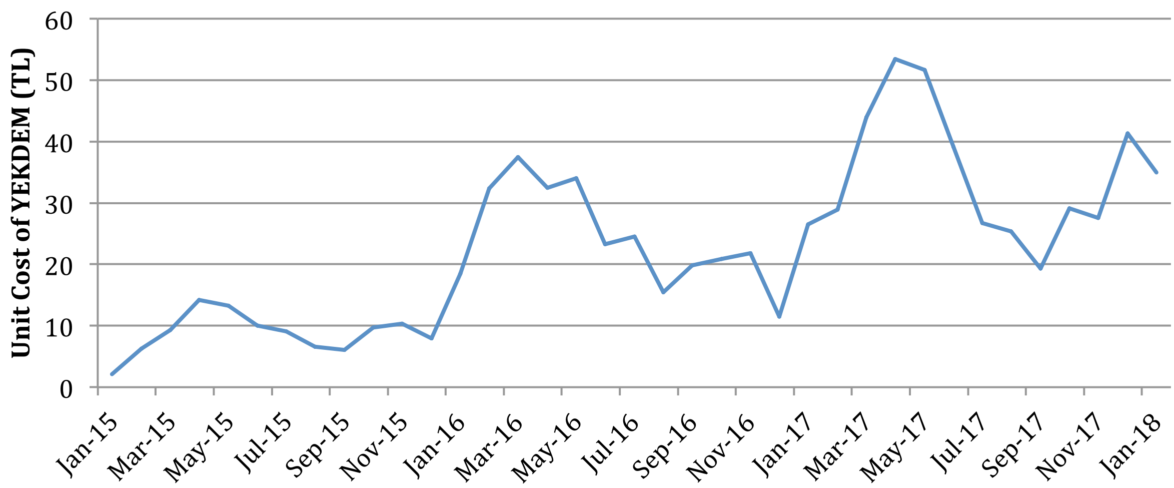


Figure 1-22 Change of YEKDEM pricing 2015-2017 [36]

1.3.5 Today's Conditions and Solar Energy Potential in Turkey

Turkey has reached its projected installed capacity of 600MWp non-licensed Power Plants defined on the Renewable Energy Law just before the end of 2016 according to the number of approved applications. The application period was over especially for the investments except from the ones that cover it's own consumptions.

By February 2017, there are 1,090 active PV power plants with 14 licensed and 1.076 non-licensed. Their overall capacity is 848 MWp with 1,08% share over total installed capacity of Turkey and the largest plant has 50 MWp in Kayseri.

Now, the government of Turkey changes the strategy and is betting for the largest renewable power plants with capacity of 1,000 MWp. The tendering process of the first one called 'Solar YEKA' was held on March 2017 and won by the partnership of Kalyon Construction Group and Hanwha Solar.

The development of investments on PV power plants for last 2 years is shown on the Figure 1-26 below.

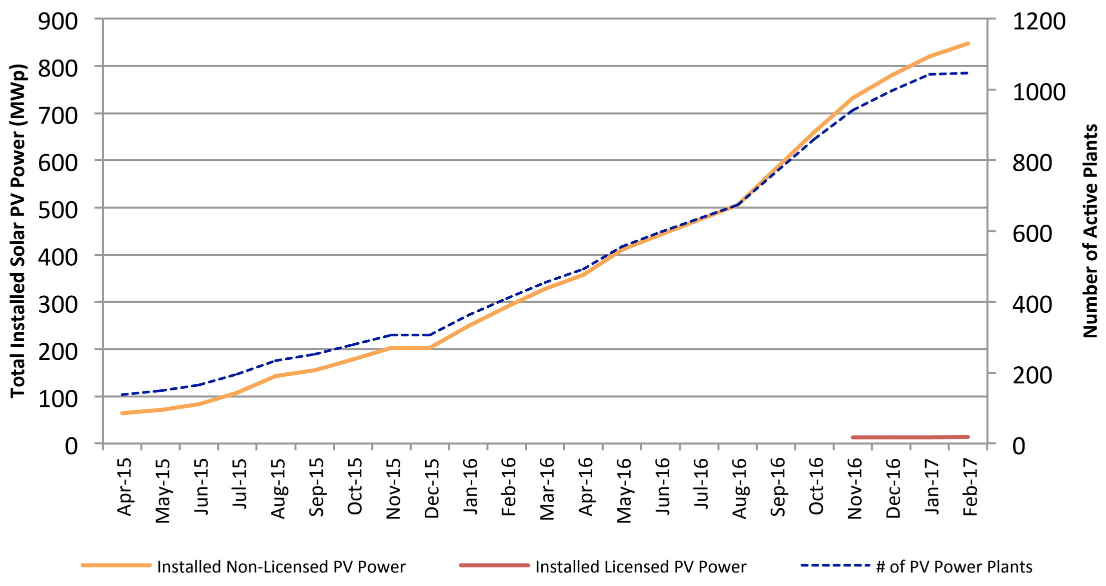


Figure 1-23 Development of Solar Energy Market for 2015-2017 [37]

While the government stopped the applications of new investments, they also announced that the 'Distribution System Usage Charge' will increase by 300% from 2.50 TL/kWh to 10.25 TL/kWh and be applied for the power plants installed in 2018. This announcement increased the urgency for the investors who already have approval but haven't started construction yet.

Considering these developments, the investments seem like to slow down in 2018 while the installations of existing approvals speed up till the end of 2017. The installed PV Power Plant capacity may reach to 1,500 MWp in December 2017 with this progress.

1.4 Methodology

A case-study approach has been followed within this thesis in order to cover whole process of project development and system operation analysis of a commercialized photovoltaic system in Turkey. The entire thesis provides information about photovoltaic technology and all details from project design, construction and operation. By those investigations, the main aims of the thesis are providing all details about procedures followed for the real case of photovoltaic investment in Turkey and information about system performance over 4-year energy production data while creating the operational performance KPI for the photovoltaic market. The analysis on the results answers the most important question about the real system operation, the way of improving the system performance, the realization of ROI, and suggestion for the future implementations.

All system data are realized numbers taken from the experts within the project and monitoring infrastructure. The system outputs from daily measurements of monitoring system of RefuSOL, inverter manufacturer, provide information about inverter-level energy production and failures with reasons. The comparison methods were used for performance measurements with the data from the simulation tools, PV*SOL, PVInsight and Turkey Solar Energy Potential Map. 4-year of sampling period were used to detect different environmental impact on system performance.

At the end, we provide information about inverter and sub-plant system performance, the most common failures, the way to improve system performance and OPI as an operational KPI for system performance of operation.

CHAPTER II

2 Photovoltaic Technology

'Photovoltaic' is term that contains 'photo' and 'voltaic' words which conceptually mean light and volt successively. Since 1849, it has been in used in English. And this is a technology converting sun energy into direct current by using semi-conductor materials. The technology has three basic operational fundamentals:

1. Electron-hole pairs or excitons are generated by the effect of absorbed sun light
2. Charge carriers of opposite types are separated
3. And these carriers are exported to the circuit

2.1 History

The discovery of the photovoltaic effect is dated back to more than 150 years ago. In 1839, French scientist Edmond Becquerel realized that electricity generation has been increased while experimenting on electrolytic cells made up of two metal electrodes placed in electricity-conducting solution. In 1950, Albert Einstein proved the underlying mechanism of carrier extraction, which is also called photoelectric effect then, was awarded with Nobel Prize in Physics. Just after these developments, the inventors Daryl Chapin, Calvin Souther Fuller and Gerald Pearson publicly launched the first practical solar cell with 6% efficiency on April 1954 in Bell Laboratories [38].

Figure 2-1 Daryl Chapin, Calvin Souther Fuller and Gerald Pearson are investigating on solar cell testing [38]

In following 20 years, the improvements on the technology significantly increased. The most common usage area is the space application in order to meet the power need of spacecraft because their best power-to-weight ratio. They were choosing the most efficient and robust type of solar cell for the proper operation of spacecraft and this increased the price level of PV technology in the beginning. However, the developments in semi-conductor technologies with Fairchild, Intel, Texas Instrument etc. affected the cost of solar cell to lower down to $100 per watt in 1971. Then, there were two things in front of the researchers; lowering the cost and increasing the efficiency. Elliot Berman was working on organic solar cells in late 1969 and started to research on PV technology of 30 years later with his team when he joined to Exxon. Their studies gave result and cost of solar cells declined to $20 per watt. The first improvement made was making the solar cell manufacturing process ideal. They eliminated the polishing and anti-reflective coating while replacing the expensive materials and hand wiring with printed-circuit board at the back. And journey to today dramatically increased in 1973 by oil companies using their high profits to initiate solar firms because of the oil crisis. As it mentioned in section 1.1 Energy Outlook Today, the in annual increase in photovoltaic energy capacity of the world has reached to 40% in average.

2.2 System Components

Photovoltaic system is bunch of different technologies including solar modules, solar invertor, mounting equipment, cables and other electricity components. While main system component solar module remains same, other components may vary according to the system topology and customer need. The most common implementation topology, grid-tie PV systems or grid-connected PV system, is directly connected to the utility grid through grid-tie invertor and smart meter as shown below. The detailed investigation will be made in the remaining sections for each component.

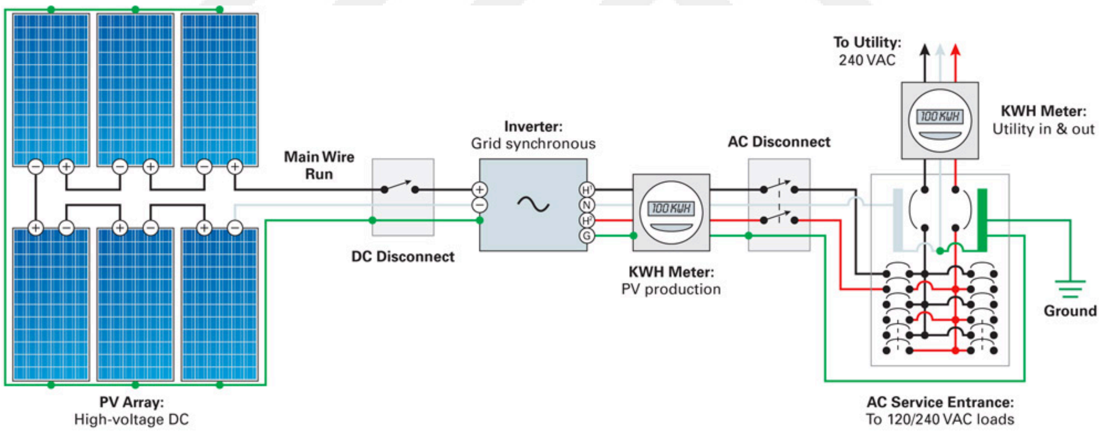


Figure 2-2 Typical grid-connected system topology [39]

2.2.1 Solar Cell and Modules

Solar Cell is the unit component of the solar modules while solar module, which may also be called as solar panel, is a form of connected solar cells of commercialized solar energy components depending on the technology used.

Solar Cell technologies are divided into 5 main groups according to the NREL (National Renewable Energy Lab) [40]:

i. Multi-Junction Cells
   a. Three-Junction (Concentrator)
   b. Three-Junction (Not Concentrator)
   c. Two-Junction (Concentrator)
   d. Two-Junction (Not Concentrator)
   e. Four-Junction or more (Concentrator)
   f. Four-Junction or more (Not Concentrator)

ii. Single Junction GaAs (Gallium Arsenide)
   a. Single Crystal
   b. Concentrator
   c. Thin-film Crystal

iii. Crystalline Silicon Cells
   a. Single Crystal (Concentrator)
   b. Single Crystal (Not Concentrator)
   c. Multicrystalline
   d. Thick Si Film
   e. Silicon Heterostructure (HIT)
   f. Thin-film crystal

iv. Thin Film Technologies
   a. CIGS (Concentrator)
   b. CIGS
   c. CdTe
   d. Amorphous Si:H (Stabilized)
   e. Nano-, mikro-, poly-Si

v. Emerging PV Techs

a. Dye-sensitized cells
b. Perovskite cells (not stabilized)
c. Organic cells (various types)
d. Organic tandem cells
e. Inorganic cells (CZTSSe)
f. Quantum Dot cells

The most common technology is based on silicon with symbol Si, atomic number 14, 3rd period element, divided into three different methodologies.

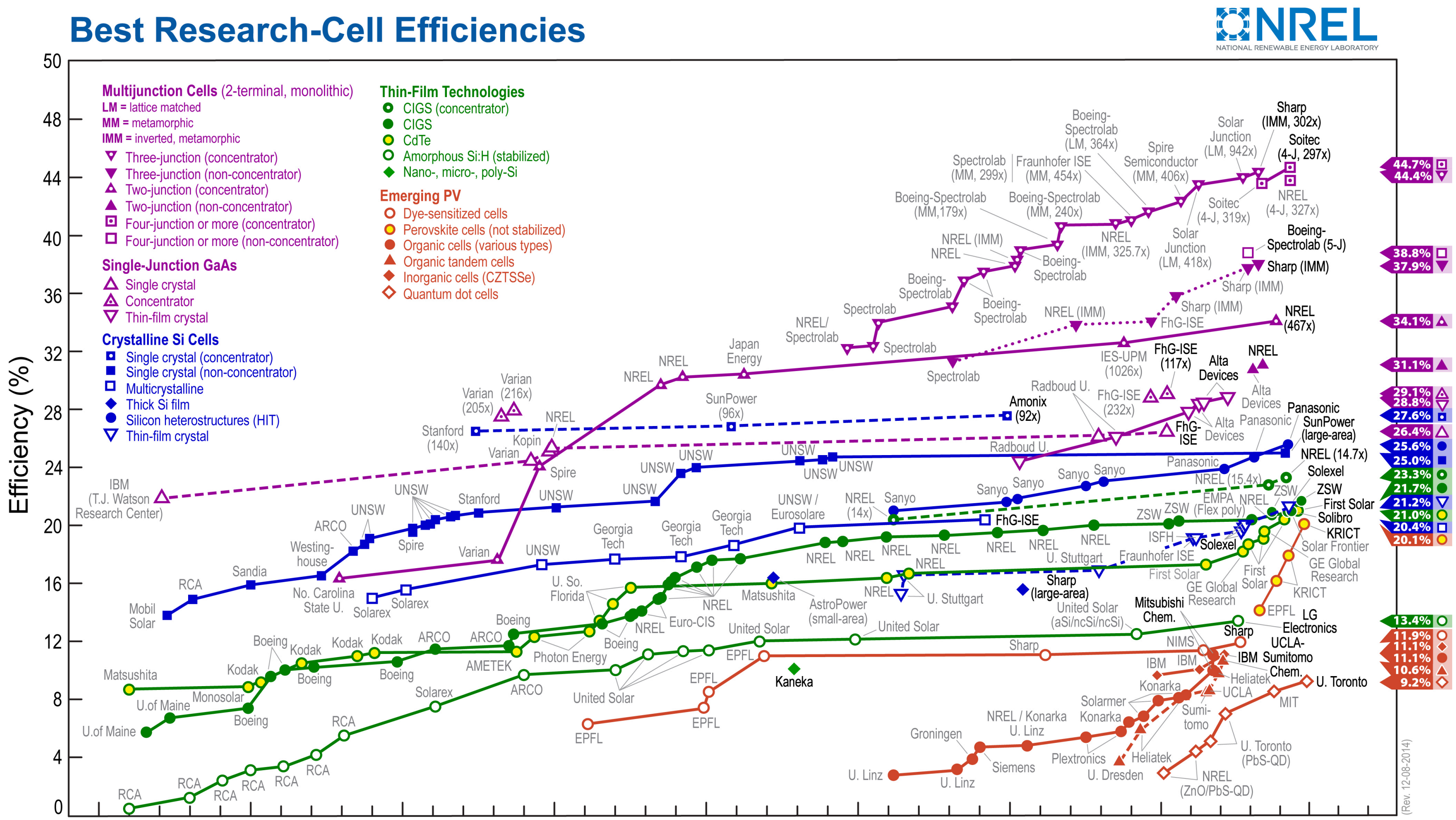


Figure 2-3: Best Research-Cell Efficiencies by NREL [40]

2.2.2 Solar Inverters

Solar inverter, PV inverter or Solar Converter is critical component for PV systems, which converts direct current (DC) produced by PV modules into alternating current (AC) with a utility frequency. These inverters can feed the utility by synchronizing the output electricity with the grid frequency or can convert DC into AC for the direct usage in off-grid systems. According to their specific usage, they may have different characteristics features for use with PV systems such as maximum power point tracker, anti-islanding protection etc.

Although general usage is mostly similar for all solar inverters, they may have different topologies for different manufacturers in order to increase the usability and efficiency. Common components of solar inverters are [41]:

1. DC – DC Converter (regulator)
2. MPPT (Maximum power point tracker): It has control algorithms with different methods. Most popular MPPT algorithms are Perturbation and Observation and Incremental Conductance
3. DC – AC Inverter
4. Frequency Synchronization Module

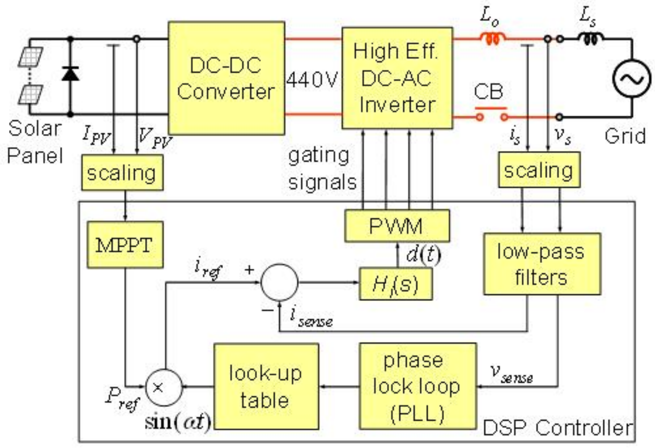


Figure 2-4 Sample Solar Inverter Topology [42]

According to design and usage, there are several types of solar inverters.

1. Off-Grid (Stand-alone) Inverters

These inverters are manufactured for the stand-alone (not connected to grid) PV systems. For these isolated system, it draws the DC energy from batteries charged by PV modules through solar-chargers or directly from PV modules and feeds the AC loads directly without any grid connection. Once there is no interaction with utility, these inverters do not need to have anti-islanding protection, which provides secure grid connection when the grid is off.

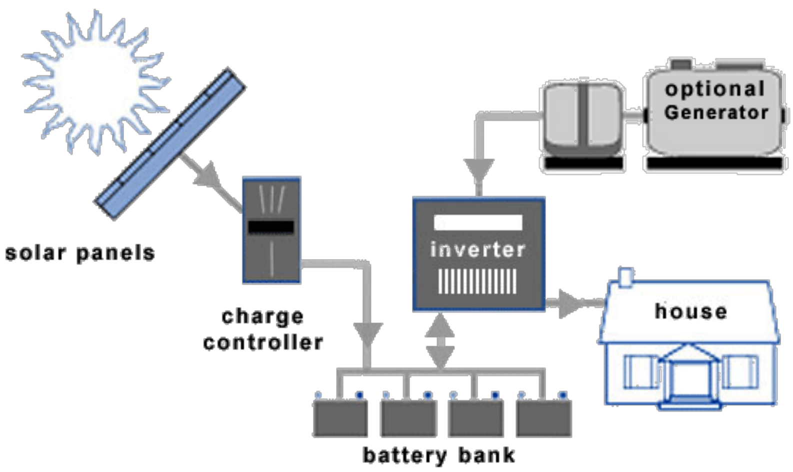


Figure 2-5 Off-grid PV System Topology [43]

2. Grid-tie (On-Grid) Inverters

The most common application of PV systems are grid connected systems, which means the PV system feeds utility as it produces electricity and user gathers electricity from the grid as it needs. On-grid inverters have direct connection to the grid and must be synchronized with the grid and must have anti-islanding protection in case of failure on grid. There are 3 types of grid-tie inverters according to their capacities [44].

a. Micro Inverters

As it is clear with its name, micro-inverter is used for 1 or 2 PV modules to convert DC electricity to AC with grid frequency. Outputs of micro inverters are gathered in one AC box and connected to the grid. Micro inverters have many advantages over conventional ones. They increase the maximum power point tracking capability of the system, simplicity in design and stock management while decrease the shading effect. However, the primary disadvantage is higher initial cost and increase on the failure rate of the system because of the number of inverters and O&M cost. The biggest micro-inverter specialist manufacturers are Enphase, Enecys, Petra Solar, Chilicon Power, SPARQ Systems etc. Beside them, there are another players, which manufactures both string inverter and solar panel, ABB/Power-One, SMA, APsystems, Advanced Energy etc. according to the EnergySage. [45] On cost perspective, their price levels are almost twice of string inverters in recent years.

Figure 2-6 Micro Inverter Installation under each PV Modules [46]

b. String Inverters

String inverter covers group of PV modules up to 100kWp. Several PV arrays, a group of PV modules connected each other in serial, with different capacity can be connected in parallel to the string inverter. It may have 1, 2 or 3 MPPT tracker which tracks each parallel connected arrays or group of them in order to draw maximum power and converts DC electricity to AC as all grid-connected inverters do. String inverters have cost and modularity advantage over micro and central inverters. Their market share is around 36% by 2017 according to the Solar Inverter Market Research Report [47] and they cover the highest efficiency inverter range.

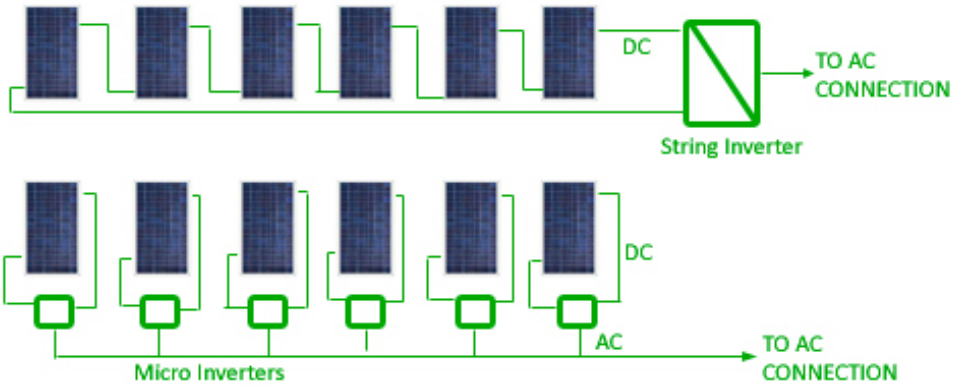


Figure 2-7 String Inverters vs Micro Inverters Connection Diagram [48]

c. Central Inverters

They are the most cost effective and most efficient inverters. Central inverters cover the system or group of modules with + 100 kWp capacity. They are formed as a combination of extendable modular racks – kind of string inverter – and embedded connection infrastructure.

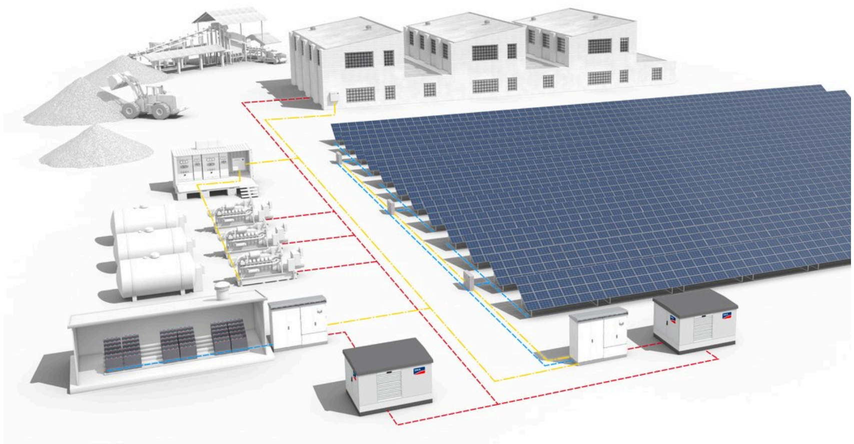


Figure 2-8 Central Inverter for Whole PV Power Plant [49]

3. Battery Back Up Inverters

These inverters are combination of on-grid and off-grid inverters with additional features. They draw power from PV modules or batteries and feed grid or AC loads according the specific operation defined for the usage. It can manage PV production, battery charging, generator (if connected), loads and grid connection.

Around the world the most used type of inverters are three-phase string inverters according to the report 'The Global Solar PV Inverter and MLPE Landscape: H2 2017' by Scott Moskowitz [50]. The global PV inverter shipment in 2017 reached a record of 88.4 GWac, up from 80.4 GWac in 2015. China, the United States and Japan were the largest inverter provider countries. Report also provides the market changes from 2015 to 2022E as shown in Figure 2-9.

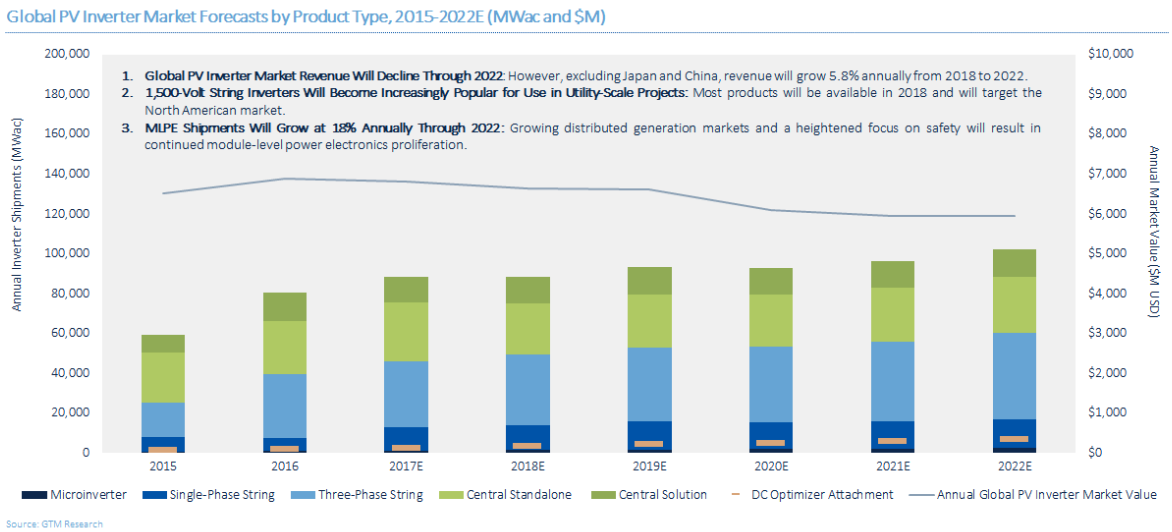


Figure 2-9 Global PV Inverter Market Forecast by Product Type, 2015 - 2022E (MWac and $M) [51]

2.2.3 Solar Cables

If we define PV modules as the heart of human body and inverters as the brain of a system, then we can define solar cables as the vessels. The importance of the solar cable is because of the Direct Current (DC) and direct sun exposure for a long time. It should be designed to be UV resistant and weather resistant. They should generally be resistant for outdoor usage between -40 ^{o}C and +90 ^{o}C. The allowable max voltage is around 1.8kV, max technical loss should be around 1% for common applications. The common current ranges of the solar cables are 1.5, 2.5, 4,6 and 10 mm^2 according to the cross-section area of cables. For the field applications, it is suggested that the color of cables should be used as follows: red for positive (+DC), black or dark blue for negative (-DC). In Figure 2-10, the structure of the solar cable is defined, as there are tinned electrolytic copper wire inside the cable rounded with XLPE Insulation and halogen-free and UV resistant outer sheath. The copper should be finely stranded according to the DIN VDE 2095 Class 5 and IEC 60228. Flame retardant and fire resistant cables should also be considered. Double insulation can extend the resistance up to 200^{o}C for short-circuits.

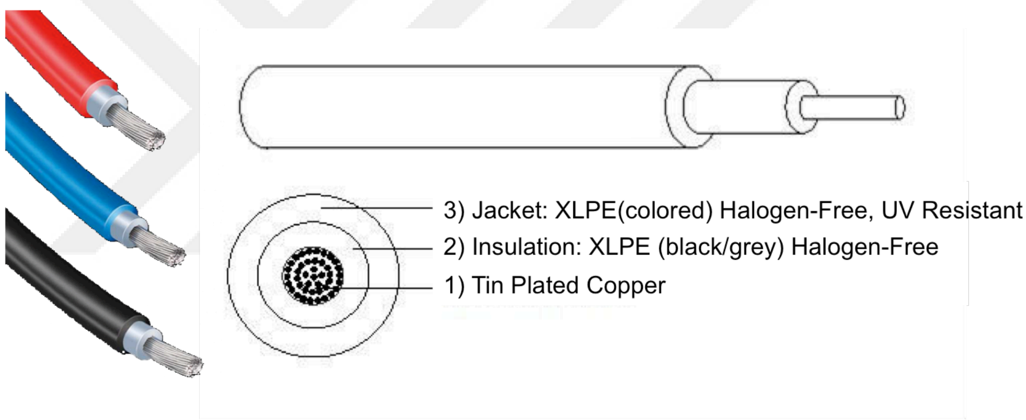


Figure 2-10 Solar Cables and Inner Structure [52]

2.2.4 Solar Mounting

To continue with the analogy of human body, here is the skeleton system of solar plants. As the solar energy investments are long-time investments, stability and robustness are very important. Considering the outside weather effect and min. 25 years lifetime, the material selection of such system should be resistant to any external effects. Common materials used as a mounting structure are aluminum and galvanized steel.

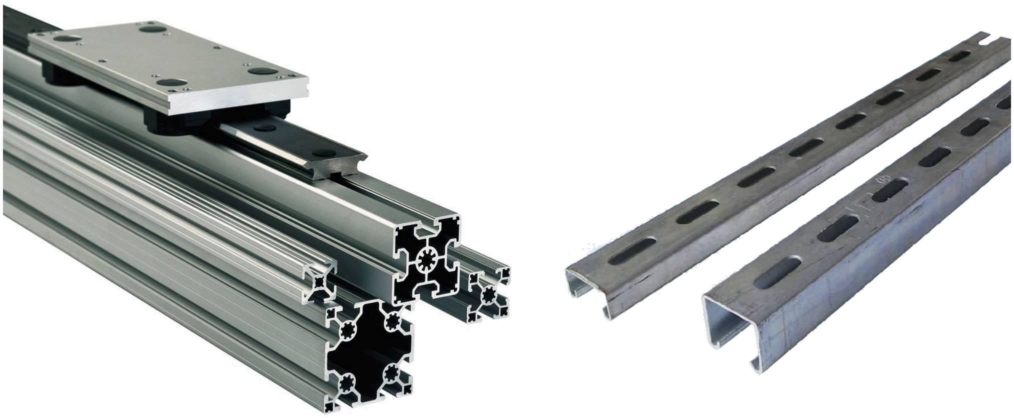


Figure 2-11 Aluminum and Galvanized Steel Mounting Equipment [53]

Aluminum and Steel has several advantageous and disadvantageous according to their cost, manufacturing and transportation processes, physical and chemical properties and installation.

Table 7: Aluminum vs. Galvanized Steel As Solar Mounting Equipment [54]

Aluminum (Al)	**Galvanized Steel**
- Designers receive limited, if any, exposure to aluminum and the extrusion process.	- Steel is widely understood by engineers and designers
- High strength-to-weight ratio	- Low strength-to-weight ratio
- High corrosion resistance and formability	- Need for very well galvanization for the reliable corrosion resistance
- Extruded aluminum designs require more design effort.	- Steel possesses approximately three times the modulus of elasticity (E) of aluminum.
- Aluminum's properties do not degrade when recycled. Once produced, it can be recycled repeatedly without any loss in quality.	- Cost effective design and manufacturing process. Due to the high weight, transportation costs are high.

Considering the type of applications: Rooftop, Field, and BIPV etc., each system has specific components for mounting infrastructure. For rooftops, while roofs with tiles have different components, shingled roofs have other specific components. For some of the flat roofs, some of the systems need drilling into the roof surface; some of them use weights for stabilizing the structure without any disturbance on water isolation. For ground installations; some of the systems need concrete around the metal foots, some of them have driven pile into the ground.

There are several local and international manufacturers with different designs. Then the important points are cost and ease of installation.

Components for roof applications [55]:

- Roof Rail
- Thin Film Mid Clamp
- Thin Film End Clamp
- Mid Clamp
- End Clamp
- Splice
- Roof Hook
- Earthing Lug
- Earthing Clip
- Cable Clip

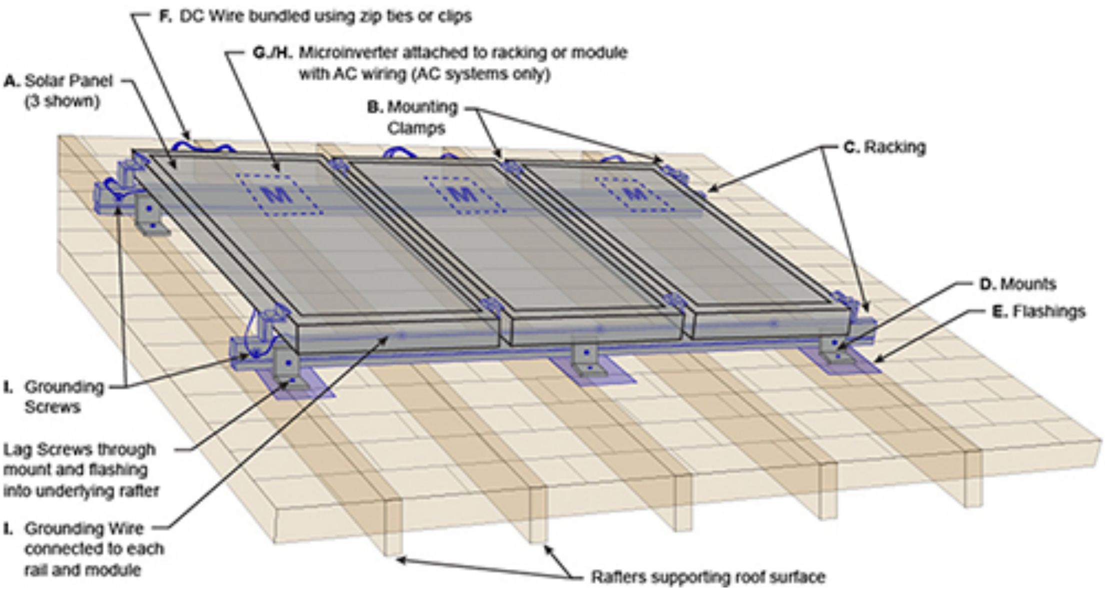


Figure 2-12 Rooftop Installation Diagram [56]

Components for ground applications:

- Pole
- Beam
- Purlin
- Rail and Rail Clamp
- Adjustable Bar and Accessories

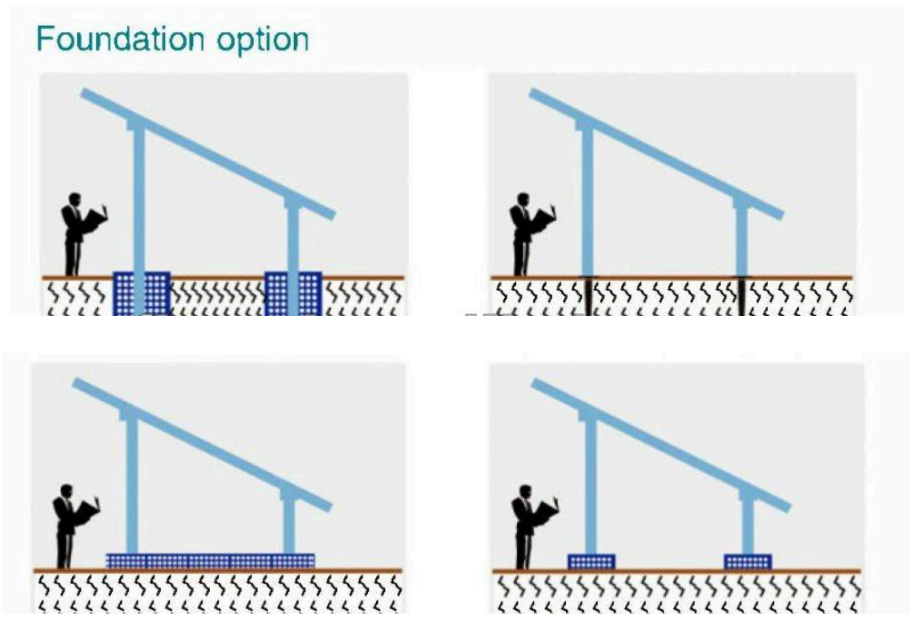


Figure 2-13 Different Type of Ground Installations: 1) Separate Filled Concrete, 2) Driven Pile, 3) Whole Surface Concrete, 4) Separate Concrete for Feet [57]

2.2.5 Standards on Photovoltaic Systems

International Electrotechnical Committee (IEC with more than 29 member countries) has established a Technical Committee, TC82, for photovoltaic applications in 1981. TC82 includes different working groups:

- Glossary
- Non-concentrating modules
- Systems
- BOS Components (Balance of System)
- Concentrator modules
- PV Cells

Their aim is, as said on website of IEC, *'to prepare international standards for systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system.'* [58]

In addition, ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources was formed in 1978. The sub-committee E44.09 is addressing the specific segment related with Photovoltaic Electric Power Conversion.

The categories of standards based on IEC are given in Table 8 below.

Table 8: Application Standards on Solar Energy Market [58]

Categories	Standards	Explanation
Terminology	IEC 61836 ISO 9488 ASTM E772-5	Standards referring to basic terminology of solar electric systems.
Solar Radiation	IEC 61725 ISO 9845-1, 9846, 9847, 9059, 9060, TR9901 ASTM E490, G173	Standards referring to solar radiation measurement process, measurement instrument calibration and the like can be found.
Solar cells and modules	IEC 60904-1-2-3-4-7-8-10 IEC 61277 IEC 612011 IEC 61215 IEC 61345 IEC 61701 IEC 61721 IEC 61829 JRC-ISPRA 503 IEEE 929, 1262	Standards from this category regulate solar cells (modules) characteristic measurement, solar cells (modules) tests and other standards referring to solar cells (modules) production and testing - production procedure, mechanic or electric photovoltaic module testing, I-U module characteristics measurement etc.
Solar Simulators		Standards regulating solar simulators and testing methods are presented.
PV systems	IEC 60364-7-712 IEC 61194 IEC 61724 IEC 61727 IEC 61683 IEC/TR2 61836 IEC 62124 IEEE 928, 1373, 1374	Standards regulating modes of photovoltaic system functioning supervision or standards advising planning and implementation of such systems can be found. The category includes safety regulations, which have to be considered upon photovoltaic systems implementation.
Balance of System	IEC 61173 IEC 61683 IEC 61427 IEEE 937, 1144, 1145, 1361	Standards for other parts/components of photovoltaic systems - standards within this category refer to batteries, over-voltage protection components and other system components not included in the categories mentioned above.
Solar Glazing		Standards in this section refer to BIPV applications
Monitoring		Standards referring to remote control of photovoltaic power plants.

Other standardizations [59]:

- International Electrotechnical Committee, IEC.
- European Committee for Electrotechnical Standardization, CENELEC.
- SEMI International Standards Program, SEMI.

- American Society for Testing and Materials, ASTM.
- European Committee for Standardization, CEN.
- Institute of Electrical and Electronic Engineers, IEEE.
- American National Standards Institute, ANSI.
- Underwriter Laboratories Inc., UL Standards.
- International Organisation for Standardization, ISO.
- Other national standards of Germany, France, Spain and Japan

Standards defined by Turkish Standard Institute (TSI) are only related with the design, testing and manufacturing therefore there are many missing part considering whole process of PV technologies. Here are the standards of TSI [60]:

- TS EN 61215 – c-Si PV modules, Design Evaluation and Acceptance
- TS EN 61646 – Thin Film PV modules, Design Evaluation and Acceptance
- TS EN 61730-1 – Safety Sufficiency of PV modules, Manufacturing
- TS EN 61730-2 – Safety Sufficiency of PV modules, Testing
- TS EN 61345 – Ultraviolet Testing for PV modules
- TS EN 61701 – Salt Water Corrosion Test for PV modules

2.2.6 Business / Financial Models for Solar Investments

The key word is sustainability of market and investments and it require aligning the interest of investors, customers, technology providers, utilities and solar companies. All the business models that may be applied into the market should take care of this concern. At the end, this concern leads to two major points:

- Maximize the value of the system by decreasing the cost and increasing the benefits from the system

- Create new business models enabling and incent solar companies, utilities and customers capture the win-win-win opportunities.

For the conventional investment model, customer has / finds money, makes the investment and starts to gain by producing electricity within the frame of applied regulations. However, most applicable and common model is third party solar-financing including different type [61].

- Solar Lease: A customer signs a traditional lease and pays for solar system
- Power Purchase Agreement (PPA): A customer signs a PPA to pay a specific rate for the electricity that is generated each month with system provider. System provider installs all the system to the customer's property with no cost and sells the generated electricity to a customer with a fixed rate, which is lower than the local utility tariffs. At the end, installer owns the system and customer can continue to purchase electricity with a new agreement or buys whole system. "Nearly 75% of homeowners who went solar in 2012 chose third-party-owned, compared to 56% in 2011" said Stephen Torres, founder and managing director of PV Solar Report [62]. SolarCity, SunGevity, SunRun, SunPower, Real Goods Solar are the biggest players who offers PPA to its customers.

Figure 2-14 shows the participants of solar power purchase agreement process. Solar Services Providers are mainly project coordinators. They have expertise on financial issues, system design, equipment supply, installation etc directly on indirectly with their network. Utilities are in the middle of it by having the electricity infrastructure and providing net metering if it is available. A host owns the PV system at all or rents their place for system installation and receives power from PV system, grid or purchase from other producers. They work with Solar Service Providers for project installation.

Equipment Manufacturers, Installers and Investors are the second layer players, which plays role in the project indirectly.

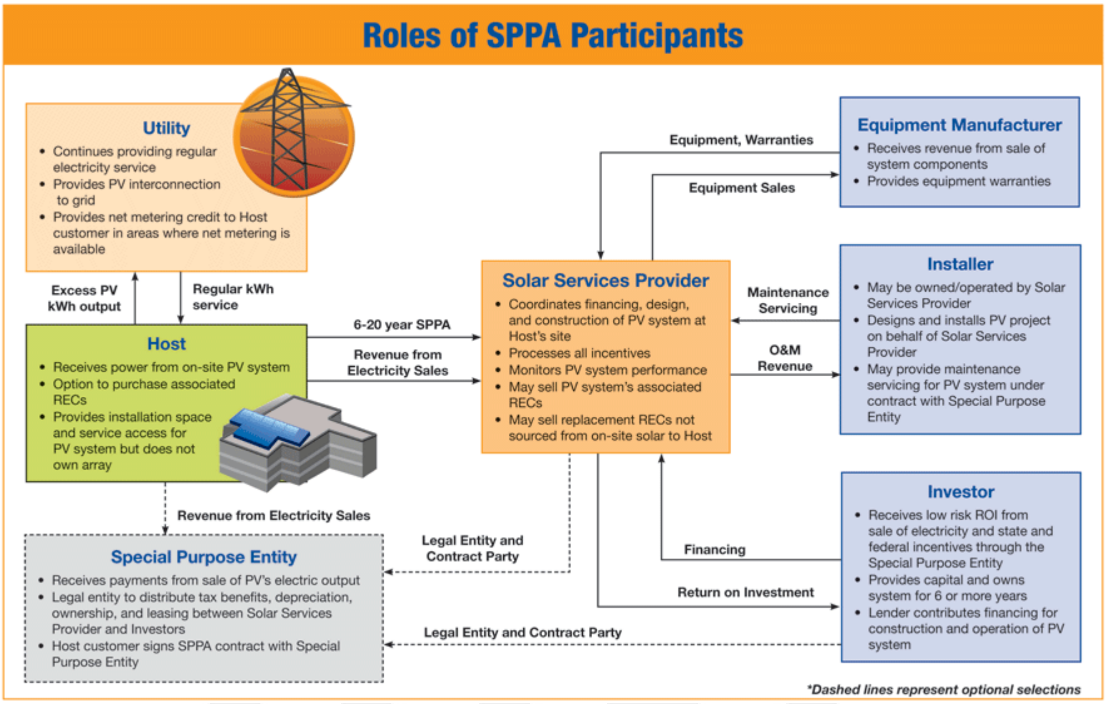


Figure 2-14 Roles of Solar Power Purchase Agreement Participants [63]

- Loan: It is defined as a new trend in US. Loan is the combination of benefits of solar lease including energy production guarantee, system warranty, performance monitoring with financial upside of solar ownership.
- Crowdsourcing: It is a common model for different sectors. For the solar investments, specific amount of money is gathered by several investors and used for large PV plants in order to decrease the unit cost. Then, investors share the gained money according to their investment level.

Business models designed to optimize Distributed PV deployment and capture the additional value created will increase the likelihood of positive outcomes for all, producing the win-win-wins that this report outlines and enabling a robust and sustainable market for DPV. These outcomes will not only benefit utilities, solar companies, and customers, but society as well—providing communities with economic development opportunities, cleaner air, and enhanced resiliency.

PV systems can be empowered by integrating demand response programs, battery storage and advanced inverter system to stabilize the grid quality.

2.2.7 Insurance of PV Power Plants

Underwriters as quite risky for two main reasons often view investments in PV: the technologies are newer and there are fewer installations relative to other technology deployments.

The insurance issue should gain currency with the installation of the project because insurance during installation and insurance on operation have the critical importance. [64]

- Insurance During Installation: This insurance is protects the installer company from any risk such as broken components, injury/death of field teams, fire or site related installation failures. The cost of this insurance depends on the project budget and technical ability of the field teams. This insurance should start with the first purchase of goods and their transportation. Operating all risks – electrical and mechanical breakdowns -, time delay and general liability are also important for this insurance.
- Insurance on Operation of Power Plant: The model of the insurance may change according to the business model of the investment. Once it is conventional project, then General Liability, property Risk Insurance, Environmental Risk Insurance and Business Interruption Insurance occur. When it is a third-party ownership model, System owner and Land owner

and customized risk assessment under third-party ownership, long-term and short-term PPAs.

2.2.8 Monitoring Platforms

The lifetime of PV power plants is relatively long and the return of investment is directly depends on the regulatory pricing and produced energy. The main handicap of PV systems is highly dynamic and hard to predict energy production because of a weather dependent structure although there is measured statistical data for many appropriate sites. In addition, all of the system equipment from modules to inverters and cables is directly exposed outdoor conditions, which increases the risk of failure. Real-time monitoring and performance analysis help the PV power plant operators manage their system and track the return of investment.

As the brain of the system is solar inverter, most of them are equipped with communication ports such as Ethernet (RJ-45), Modbus (RS-485), Serial Comm (RS-232) or Bluetooth. If the system uses Modbus or serial port, Data Logger or Gateway (Router) is also needed in order to convert the data read through Modbus into TCP/IP via Ethernet or GRPS. Each inverters has its own ID or IP address and most of them provides the data below:

- Instantaneous DC Voltage, Current, Power
- DC Energy Produced
- Instantaneous AC Voltage, Current for Phases
- Active, Reactive and Apparent Power
- AC Energy Produced
- Frequency and Phase Angles

- Sensor data if connected to the inverter (Radiation, Ambient Temperature, Panel Surface Temp, etc.)
- Inverter and System Status

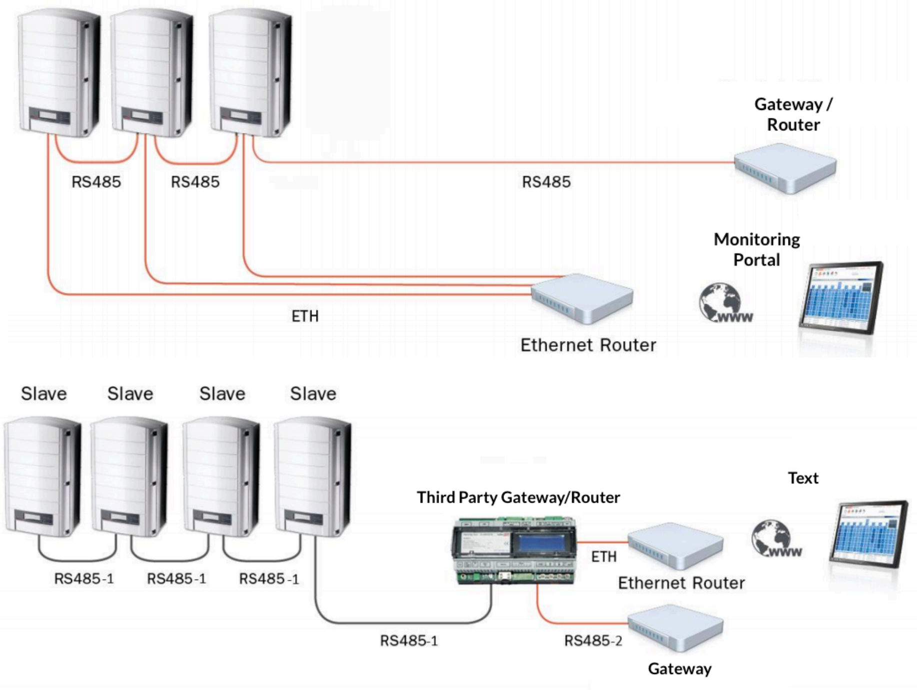


Figure 2-15 Typical Connection Diagram of Communication Infrastructure [65]

Market needs have created two types of companies providing monitoring solutions to the customers:

- Inverter Manufacturers and Their Specific Monitoring Portal

Most of the inverter manufacturers provides also monitoring portal customized for only their own inverters with no cost. SMA, PowerOne, ABB, Advanced Energy, Danfoss, SolarEdge, Enphase and so on.

- Third-Party Solar Monitoring Companies

Their prior business is developing monitoring solutions adoptable for every inverter type directly of by using their own gateways/dataloggers. Meteocontrol, Solax Power, SolarLog, Rbee Solar, BenQ Solar etc.

In addition, companies providing comprehensive solutions to the PV system owners or operators have been started to appear recently. They provides not only monitoring but also analytics for the performance of system and equipment including the financial part and production forecast. These platforms gather data not only from PV system but also from weather forecast/sensors, utility pricing and energy consumption if there is net metering, feed-in-tariff or other regulatory energy selling mechanism. Energy IoT Platform developed by Reengen is one of the best examples for such platforms.

2.3 On-Site Applications

Increasing the incentives on renewables and decreasing the initial cost of the PV systems attracts both investors and people who wants to decrease their electricity cost. As it mentioned on the section *1.2 Solar Energy Market in the World*, countries has started form new regulations specific for photovoltaic systems, provides initiatives and purchasing guarantee with high unit prices since the end of 1990s. For example, although some strategies have been discussed, some regulations have been released and some researched studies have been supported from 1974 to 1990s in US, the most effective initiative announced by President Clinton as Millions Solar Roofs Initiative in June 1997 [66]. While the technology is developing, the application areas for PV systems, started with space implementations, have been tremendously extended into our life.

2.3.1 Type of Applications

Since the electricity is everywhere in our life and our life is fully dependent to energy, solar energy may be applicable for every part of our life from large power plants to small mobile charger units. However, the only limitation is because of the equipment that should be used to convert solar energy into electricity. The size of solar modules, their electrical characteristics, need for enough free space, inverters and cables are all the criteria that limit the applications areas. Although there are so many variables to apply such technology, people have achieved to bring this technology into our lives with more than 15 different applications. They may be categorized as follows:

- On-Grid Systems [67]
    - PV Power Plants – Field Applications
    - Rooftop Applications for Buildings
    - Building Integrated PV Systems – On façade or different part of buildings (Commercials and Homes)
    - Solar Irrigation Systems
- Off-Grid Systems [67]
    - Stand-Alone Home Systems
    - Solar Pumps
    - Solar Cars
    - GSM Stations
    - Space Stations
    - Charger Units
    - Solar Benches / Bus Stations
    - Outdoor Lighting (small to large applications with LED)
    - Swimming Pools for Heating and Cooling
    - Calculators
    - Solar Ships/Yachts
    - Solar Powered Recycling Compactors
    - Solar Powered Airplanes

- Flexible Solar Panels for Military Usage
- Weather Stations

Although most of them are not that much common because of the ease of usage and initial cost, using solar energy in a wide applications create much more benefits for the investors.

Figure 2-16 Samples for Solar Energy Applications [68]

2.3.2 A General Project Design Methodology

Considering the solar sector development in different countries, the main influencer is the regulative infrastructure in order to boost the solar energy investments. Therefore, if there is no regulation on solar energy or renewables, it is hard to find a good example of solar investment in that region. If all the incentive mechanism is settled down and investors fell the trustyworth market for a long-term investments, then the next step is starting an investment with a project design.

Project design priciples depends on the type of the system planned. In the study, grid-connected systems withing a capacity range of +100 kWp will be investigated in terms of project design process. The project design starts with understanding of regulative details in that region. Then, the investor should plan the applicable installation areas, capacity of the system. Considering the regulations in Turkey, investors are allowed to use non-agricultural fields or buildings with technically available areas for solar panel installation. Important points while choosing the correct investment area:

- Regulative availability of the area: non-agricultural, geological features, statical requirements, environmental effect of the investment for necessary permissions from various government departments.
- Technical availability of the area: geolocial features, future development plans of government on that area, statical availability of the buildings, transportation and ease of installation, distance to the electricity connection point, security of the region.

After choosing the investment area, then right direction, right angle and right placement of solar modules. This process needs a kind of iteration according to your design, inverter and module selection, placement of transformer etc. The orientation and tilt angle of the system should firstly be designed by the engineering team considering the module type planning to be used. If the most common c-Si based modules, which have almost same dimensions, are used, then the design considerations are applied accordingly. In Figure 2-17, module placement, orientation to the south direction and inverter connections is shown. The modules are placed according to the available area in the installation place. All the shading effect, cabling, maximization are taken into account.

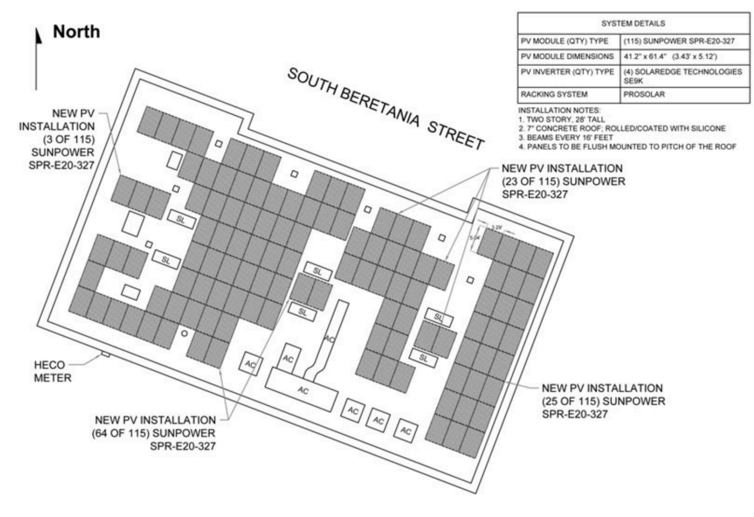


Figure 2-17 Sample Design of Rooftop System [69]

The iteration starts with the strings connected to the inverter(s) and number of modules fit. While designing, engineer should care about the optimized cable length, string connections and distribution board connection if needed. The project design does not only cover engineering part of the whole investment but also includes project planning. Project should make preparations for regulative procedures, which may take up to 6 months according to a type of system, region or spontaneous problems. The permissions from government departments, availability reports from authorized engineering offices, certifications of the goods, financial projections effecting the investment, bank credit/loan models and statistical weather conditions on that region. The detailed information about the preparation for the project is given in section 1.3.2 according to the Turkey conditions and technical project design procedure is also explained in details in section 2.2.

2.3.3 Preparation for Installation

Engineering, Procurement and Construction are key elements for the end-to-end solutions. While engineering covers the theoretical infrastructure, construction converts it into the practical field implementation. While starting a field part of the project, creating a correct team is the thing saving your bacon. The core team to do a good job may include:

- Project Manager: To manage all operations from government procedures to financials (For financials, Accounting Officer may be needed)
- Field Operations Coordinator: To manage the field operations from receiving the goods and commissioning of the field operations.
- Electrical Engineer: Electricity project design, selection of equipment, control and commissioning
- Mechanical Engineer: Mechanical project design, control of installation

- Geological/Civil Engineer: Analyzing the ground type and design the construction
- Head of Technicians: To manage the field team (electrical and mechanical)
- Electricity Technicians: qualified and certificated
- Mechanical Technicians: qualified and certificated

After forming a correct team and having a project design, the next steps are project planning and purchasing. For PV modules, technical specification sheets and illumination test reports and I-V curve measurements are important parameters to be followed. Then, construction part starts with a strict schedule and ends with a commissioning. In general, all of the process may take 1 to 6 months according to the solar plant capacity. (for 100kWp to 1MWp systems) After construction, the most important part, operations and maintenance, begins.

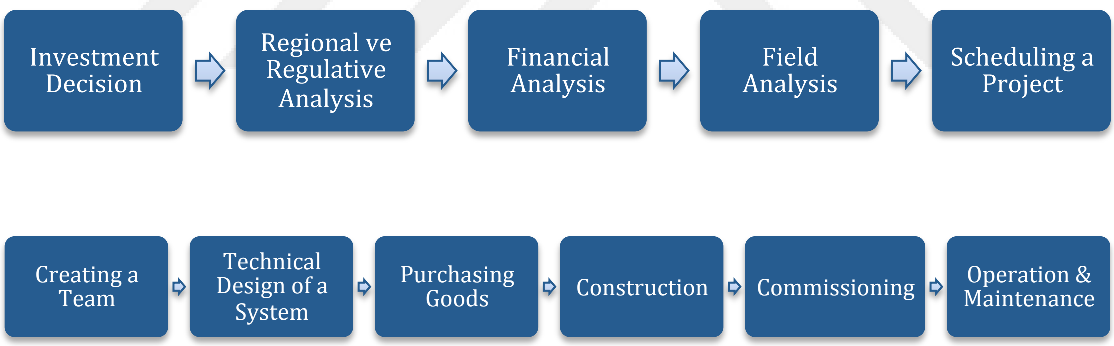


Figure 2-18 Process of Solar Investment

2.3.4 Construction Process

It starts with proving the field equipment and vehicles in order to landscape the field. After landscaping according to the project design, type of mounting equipment and regional conditions; the main metal stands of the mounting structure is installed.

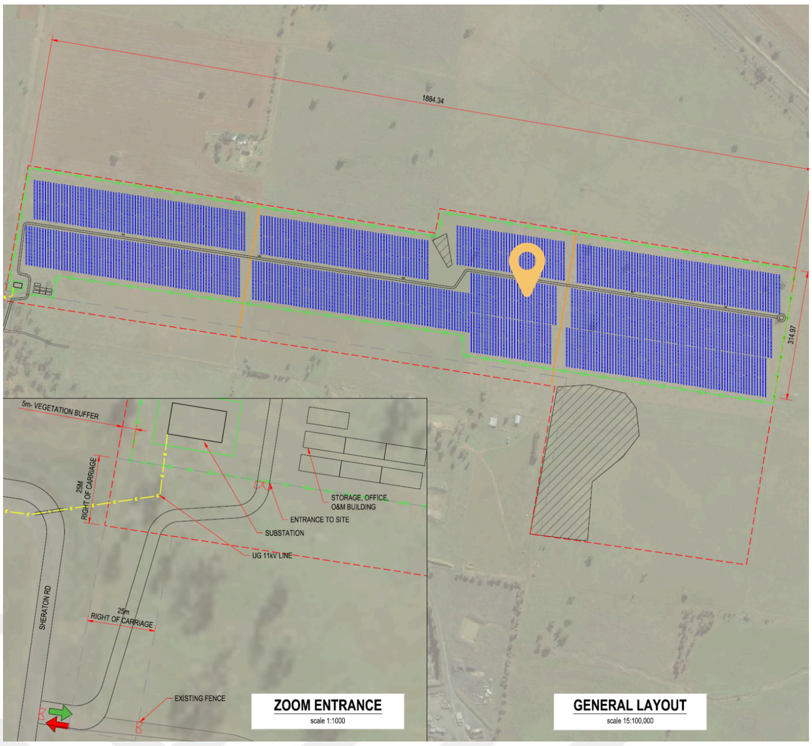


Figure 2-19 Sample from a PV Power Plant Construction Field [70]

The geological field conditions have huge effect on the project design and field landscaping. You may need to use separate areas for one system in order to use the existing field more efficiently as a sample PV Power Plant Construction Field is given in Figure 2-19.

The metal stands may directly be piled into the ground as it is shown or need concrete support according to the type of ground as it is given in Figure 2-20. For the rooftop system, you may have no permission even driving one nail into the roof surface. Balance and alignment between main stands are crucial for the sustainability of the system, so they should be controlled before the installation of horizontal supporter metals and PV modules on top of them.

Figure 2-20 Horizontal Metal Bars and PV Modules Installation [71]

Tightening the screws, aligning the module positions and connecting the module cables in proper way continue with inverter installation and cabling. According to the type of inverters (micro, string, central), placement of the inverters may change. While micro inverters should be placed at the back of each panel taking into account the AC cabling, central inverters should be place in the center of whole site as it is possible. Central inverter position should also be optimized considering the grid connection. Placement of the string inverters may change depending to the system designer. However, the most common approaches are grouping some of them and installing most appropriate area or spreading each of them to the separately according to the string arrays in order to minimize the length of DC cabling. The important point that must be taking into account is to avoid from the direct sunlight exposure, which affects the efficiency and lifetime negatively. Therefore most of the system designer prefers back of the modules to place inverters in order to use the natural shadow of modules and natural air circulation to cool them. Figure 2-21 shows two different options for inverter placement.

Figure 2-21 Placement of Central Inverters and String Inverters [72]

DC and AC electrification and security of the system would be the next big step for the sustainability of the system. Choosing correct sizing for the cables and optimum cable lines (on the cable tray or under the ground) affect the system reliability. When data cabling becomes an issue for that plant, the importance of the cabling doubled. Because of the electromagnetic effect around the energy cables, data monitoring system may faced with data transfer problem. Therefore, data cables and energy cable must be separated with appropriate distance and placed properly for a long-term lifetime as shown in Figure 2-22.

Figure 2-22 Cabling of PV Systems [73]

The last step is grid connection before the commissioning. The capacity of the power plant and the location of the PV plant are the identifiers of the grid connection point. System may be connected directly from the low voltage level or medium voltage level through a step-up transformer according to the decision of national electricity grid authority after detailed technical analysis.

Figure 2-23 Installation of Main Electricity Distribution Board [74]

Low voltage cabling, electricity security equipment (circuit breakers, surge arrestors, etc.) and distribution boards, grounding infrastructure, busbars, step-up transformers, MV power cells and approved electricity meters are the main components of the electricity part of the power plant.

The commissioning and testing part should be include the details below:

- Mechanical control: Screws, Modules, Alignment,
- Electricity control: DC voltage levels of strings, Inverter connections, AC production and grid synchronization, Circuit breakers and other security equipment tests, etc.
- Data Monitoring: Field measurement vs. Monitoring system, sensor values.
- Security System: Security Cameras and alarms

Before the first start you need to check [75]:

- Array configuration and proper number and model of PV modules are used
- The array conductor are arranged and supported in a neat and Code-compliant manner
- All grounding is done and resistance measurement is under the limit of 1 ohm.
- All the conduit equipment is connected to the common grounding system.
- All junction boxes, conduit bodies and disconnect switches are accessible and suitable for outside installation.
- The array is securely fastened directly to the mounting rack with the manufacturer's supplied or specified hardware. All roof penetrations are flashed correctly and the foundations and mounting structures are strong enough to support array in high wind and snowy conditions.
- The conductor insulations are suitable for wet conditions.
- The size of conductors will adequately carry the supplied current and keep the voltage drop to an acceptable level.
- All inverter connections are correct, tight and all operating parameters are correct.
- The positions of the breakers, switches and surge arresters on distribution panels and MV side are correct
- Follow inverter manufacturer instructions for start-up procedure

2.3.5 Operation and Maintenance Strategies

Considering the min. 25 years lifetime of PV systems, sustaining the system performance as its' first day needs almost 10 times extra effort than project design and construction. The main goal of proper operation and maintenance strategy should be to reduce the Levelized Cost of Energy (LCOE) of PV generation. When we separate the words Operations and Maintenance, they stands for different meaning according to the responsibilities that they cover.

PV Operations includes the following five areas:

- Administrative Operations: manages the O&M activities, keeps records of performance measurements, prepares scope of work and selection criteria for service providers, secures funding and contingency plans for O&M activities.
- Conducting Operations: provides efficient, safe and reliable operations
- Directions for the Performance of Work: specifies the rules and provisions to ensure that maintenance is performed safely and efficiently.
- Monitoring: maintains the monitoring system and analyze the resulting data
- Operator knowledge, Protocols and Documentation:

PV Maintenance includes the following four types of maintenance procedures:

- Administrative Maintenance
- Preventive Maintenance: Scheduled maintenance according to the equipment type, weather conditions, etc.
- Corrective Maintenance: Repairing/replacing the damaged equipment, it can be reduced by preventive maintenance.
- Condition-based Maintenance: using real-time information data form system and alarm management infrastructure for some pre-defined conditions.

The choices for resourcing O&M [76]:

- Use the Engineering, Procurement and Construction (EPC) Company or the installer who built and warrants the system
- Bring the O&M service in-house
- Outsource the service to a specialized third-party O&M service provider.

The O&M companies must have an experience on PV systems especially on DC electricity and medium voltage. They must also be experienced on financial analysis and insurance of the system.

All O&M management strategies and systems must achieve the following:

1. Document archive for complete plant documentation upkeep and reference
2. Customer/plant interaction tracking logs
3. System/portfolio analysis
4. Budget tracking
5. Trouble ticket or incident tracking
6. Mobile work order flow management and documentation systems

An O&M company should provide a documented PV system O&M plan include the followings [77]:

- List of responsible party contact information
- System descriptions with as built drawings, specifications, site plans, photo records and any special safety considerations.
- Performance estimates and insolation studies including description of nominal conditions to make it easier to see malfunctions and deviations
- Chronological O&M log: work order, task tracking, and reports.
- Description of operational indicators, meters and error messages and procedures.
- List of preventive maintenance measures that need to be performed to maintain warranties and to optimize the system delivery.
- Procedure for responding the alerts, error messages or complaints.
- Troubleshooting guide with common problems and sequence to approach solving each problem.

- Criteria to decide to repair or replace a component (or cannibalize a string of modules).
- List of the equipment with make, model and serial numbers and map of placement in system.
- Inventory of spare parts kept onsite and easily accessible maintenance crew.
- Operator manuals of the system equipment.
- All warranties from system installer and equipment manufacturers.
- Contracts for preventative maintenance, service and other operations documents
- Budget for O&M program including costs for monitoring and diagnostics, preventative maintenance and corrective maintenance.

For the proper O&M strategy all the components of the system should be monitored in real-time. IEC 61724 classifies the monitoring systems. An O&M company should give the performance guarantee the to PV plant owner. As every component within PV system has a standard definition, PV performance ratio is described in IEC 61724 [78]. Performance Ratio (PR) and temperature-corrected PR based on standard test conditions (STC) data or performance test condition data. Performance Ratio, as a definition, is actual energy delivery divided by the energy delivery estimated based on environmental conditions and exclusions such as clipping (when DC output exceeds AC output). In other words, PR is the measured electrical yield divided by POA irradiance, divided by nameplate rating, and multiplied by the reference irradiation value (e.g. 1000 W/m^2) corresponding to the nameplate rating, where the electrical yield and POA irradiance are integrated over the same time period.

$$PR = \frac{Y_f}{Y_r} = \frac{E}{P_n} * \frac{I_{STC}}{H_m}$$

Where:

Y_f= # of the production equivalent hours recorded at STC

Y_r= # of the irradiation equivalent hours at the STC

E= actual energy output (kWh) plus that number of kWh based on Operator's good faith calculation lost during the contract year due to force majeure event(s) and/or by any action or inaction of Owner, Utility, or Host.

P_n= nominal peak power of the PV plant (kWp) equal to XXXX.00 kWp

I_{STC}= Standard Condition of the irradiation equal to 1 kWh/m^2

H_m= actual irradiance during the Performance Period recorded through a pyronometer (kWh/m^2). The performance ratio is usually defined relative to the place of array irradiance. Global horizontal is fed into a model to correct for PV module orientation.

The O&M operator should try to achieve the expected performance ratio for selected period. For the corrective calculations, the equations should also include annual degradation of the system, availability ratio and corrective factor depending on the axial type of the system.

$$PR_{expected} = PR * K * \left(1 - Y_{degradation}\right) * (Y_{availability})$$

Where:

$Y_{degradation}$ is 0,5% from the previous year

$Y_{availability}$ is 98% (for the first year) and 99% (for the second and subsequent years)

K is the corrective factor equal to 1.3 for mono axial based systems and 1 for fixed systems

There are different performance calculation methodologies commonly used in the market. The SunSpec Alliance has published a report called 'PV System Performance Assessment' in June 2014 and defines all the common performance metric as shown in Table 9.

Table 9: Commonly Used Performance Metrics (* developed within thesis) [79]

Metric	Calculation	Reference
Yield*	kWh / $kW_{DC\ STC}$	NREL/CP-520-37358
Performance Ratio	(kWh/ $kW_{DC\ STC}$) / (H/G_{STC})	IEC61724
Performance Ratio*	kWh / (sunhours × area × efficiency)	SMA
Performance Ratio	(E_{Actual} / E_{Ideal}) * 100% E_{Ideal} is temp. and irrad. compensated	SolarPro, Taylor and Williams
Specific Production*	MWh_{AC} / $MW_{DC\ STC}$	SolarPro, Taylor and Williams
Performance Ratio	(100 * Net production / total incident solar radiation) / rated PV module eff.	NREL/TP-550-38603
Performance Factor	$I_{SC,G}*R_{SC}*FF_R*R_{OC}*V_{OC,T}$	Sutterlueti
Performance Index	$kW_{measured}$ / $kW_{expected}$	SolarPro, Sun Light and Power
Performance Index	Actual Power / (Rated power * irrad adj. * temp adj * degradation adj * soiling adj * BOS adj)	Towsend
Output Power Ratio	$kW_{measured}$ / $kW_{predicted}$	SolarPro, Sun Light and Power
Output Power	kW > CF-6R-PV Table	CEC Commissioning
Output Power	kW > 95% expected	SRP Arizona Utility
Specific Production	MWh_{AC} / MW_{DC-STC}	SolarPro, Taylor and Williams
Acceptance Ratio	kW_{actual} / $kW_{expected}$	Literature
Inverter Comparison*	kWh of multiple similar inverters	Qualitative
String Comparison	I_{mp}, V_{mp} of multiple parallel strings	Qualitative
Utility Billing*	Monthly Comparison	Qualitative
Performance Ratio, temp. comp. (CPR)	(kWh/ kW_{DC} *K_{Temp}) / (H/ G_{STC})	Proposed in referenced report
Energy Performance Index (EPI)	kWh AC actual / SAM (System Advisor Model) AC Expected using actual weather data	Proposed in referenced report
Power Performance Index (PPI)	kW_{AC} / (kW_{DC} *K_{Irrad}*K_{Temp}*K_{Derate})	Proposed in referenced report
Operational Performance Index (OPI)*	Total Hours of Failure / Total Operation Hours	Developed by this thesis

All the data gathered from the project site shows how important the operation of PV system to get high performance. As failures of grid, inverters, cabling infrastructure etc. have significant effect on system performance, it is needed to calculate system performance by taking Operational Performance Index (OPI) into account. OPI provides information about the system real performance except from the infrastructure failure and operational performance of system operator. According to the data resolution that the operator has the OPI can be interpreted by the formulas below:

$$OPI\ (Hourly) = \frac{Total\ Hours\ of\ Failure\ within\ Day - Time\ of\ Desired\ Period}{Total\ Sun\ Hour\ of\ Desired\ Period}$$

This equation can be used if you have hourly data for your system. The failure hours should be calculated for the daytime from sunrise to sunset. Since it depends on the sun hour, the OPI rate fluctuates seasonally. The reasonable periods for OPI calculation are month, quarter, season or year. Once you do not have hourly data of your system, then you may revise the equation as follows:

$$OPI\ (Daily) = \frac{\#\ of\ Days\ with\ Zero\ Production\ for\ Desired\ Period}{Total\ \#\ of\ Days\ for\ Desired\ Period}$$

For both OPI rate the planned maintenance periods must be omitted from the calculation. There may be different level of OPI according to the system production rate for daily OPI index. The second equation provides OPI rate for the zero-production (0% efficiency) days and it is also possible to calculate OPI index for >10%, <%30, >90% etc. system performance periods. Instead of using zero-production day; you may choose the days with a performance rate lower than %20 for a year then, OPI (Daily, <20%, Annual) can be calculated.

The components of maintenance strategy, preventive and corrective maintenance need routine procedures. Gathering them under specific title brings us 5 inspection groups.

- General Site Annual Inspection
- Detailed Visual Inspection
- Manufacturer Specific Inverter Inspection
- Manufacturer Specific Tracker Inspection (If the system has tracker unit)
- Manufacturer Specific Data Acquisition System Inspection

As the most critical and complex components of PV systems, inverters have detailed troubleshooting methods. The most common inverter errors are given in table 10.

Table 10: Inverter Troubleshooting - Common Inverter Errors [80]

Inverter Error	Actions
DC Undervoltage	Steps to diagnosis underperforming systems
DC Overvoltage	Voc string testing
DC Ground Fault	Ground fault detection procedure
Gating Fault	Check connections – Contact manufacturer
AC Undervoltage	Confirm all breakers are on > Check AC voltage with voltmeter > If within range, perform a manual restart > If outside of range, contact utility
AC Overvoltage	Check AC voltage with voltmeter > If within range, perform a manual restart > If outside of range, contact utility
Low Power	System is likely just shutting down because of lack of sun, if it is sunny, perform steps to diagnose underperforming systems
Over temperature – fan not operating	Check power supply to fan – if good, replace fan; if bad, replace power supply
Over temperature – fan is operating	Check to confirm sensor readings – if bad, replace sensor; if good, investigate further
Over temperature – fan & sensors are accurate	Check intake and exhaust filters for excessive buildup and clean or replace if necessary
Software Fault	Contact manufacturer

As new technics I-V curve measurements and Fill Factor measurements may give better idea about the performance of the PV system as shunt/series losses and aging and defects on arrays although it takes some time to test all the arrays in the system.

Beside these methods, the most common tests to identify the defects on PV modules are thermography (thermal camera measurements) and selective shading. Thermal camera measurements can easily indicate the failure, which cannot be detected under visible light, on the solar cells. As shown in Figure 2-24, it is impossible to detect the failure of two solar cells under visible light.

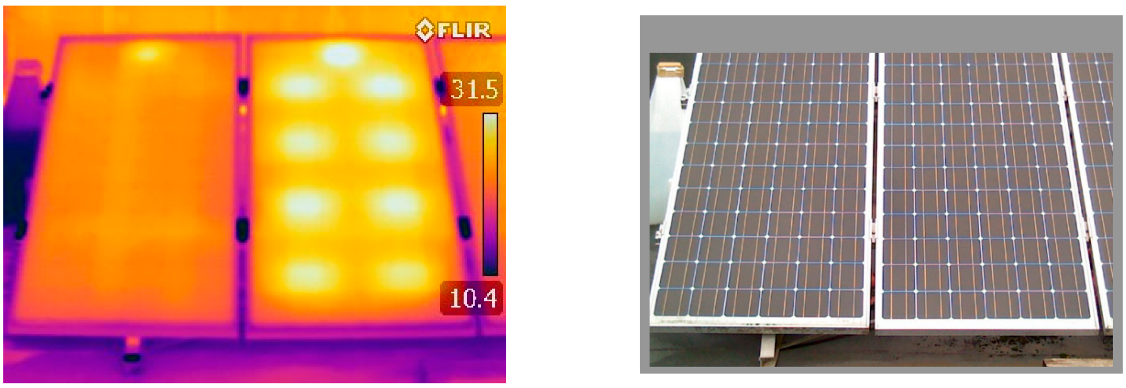


Figure 2-24 Thermal Camera Image vs. Visible Light Image [81]

Selective (partial) shading method indicates the operation of by-pass diodes of the modules. Shading small part of the module and measuring the I-V curve characteristic can gives an insight about the operation of diodes as shown in Figure 2-25.

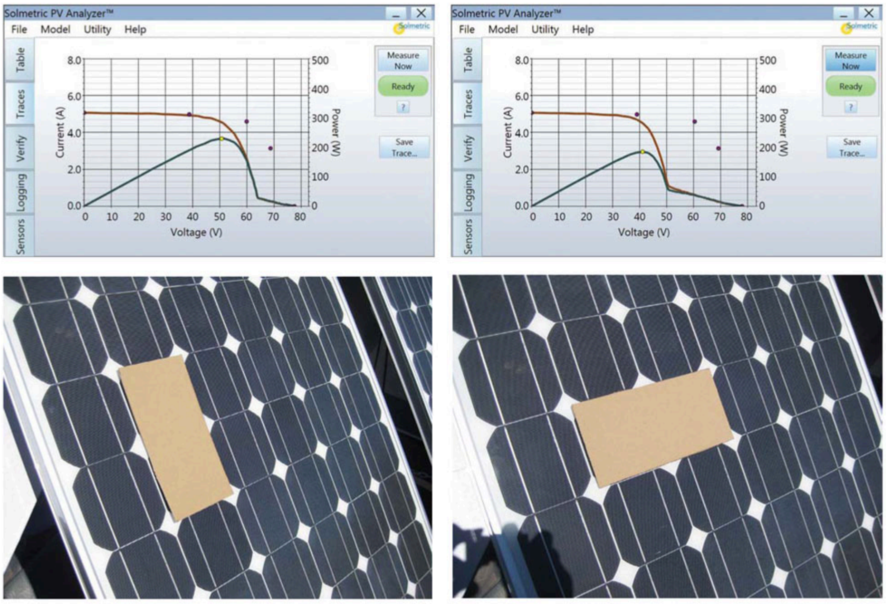


Figure 2-25 Selective Shading Methods and I-V Curve Output [82]

The troubleshooting methods for the PV arrays are given in Table 11. They are the most common control points for high performance PV module and system operation.

Table 11: PV Array Troubleshooting [83]

Checks	Actions
I-V Curve is useful?	Are the test leads connected? Are PV modules interconnected? No I-V Curve? – Check for a missing or blown fuse and for an open circuit in external string conductors. Replacement may be needed. Dropouts in I-V curve? – Intermittent electrical connections in the PV source may be causing narrow vertical dropouts.
PF > 90% and normal shape?	Follow the steps below
Shading?	Remove obstructions
Random soiling, debris or snow?	Clear modules and retest
Mismatch modules?	A string of modules with significantly mismatch currents will show slight steps along the I-V curve.
Cracked Cells?	May not be visible to the eye Use selective shading or thermal camera monitoring
Burn marks?	Replace module
Low Isc?	Check irradiance sensor position Check the measured test module Dirt, strip shade? – Clean modules
Low Voc?	Possibly shorted by-pass diodes. Find affected modules by selective shading.

CHAPTER III

3 ÖZYEĞİN UNIVERSITY SOLAR ENERGY SYSTEM INSTALLATION AND ANALYSIS

University campus has many different green features according to its global and environmental-friendly vision. From the mechanical systems to paints on the walls, from the usage of daylight to natural energy resources; these features brought 3 green certificated buildings and one over-certification building out. Engineering Faculty, Business Administration and Student Center has been awarded with LEED Gold certificate. In addition, The School of Foreign Language building constructed within the EU FP7 Project called NEED4B (New Energy Efficient Demonstrations for Buildings) has so many energy efficient applications and is over the certification limits. The main issue and shared feature are solar energy installations on the rooftops of these buildings with the additional Energy Distribution Center.

This campus wide solar energy application is first and the biggest building integrated plant over the universities around Turkey. From the idea to implementation, it was designed with completely scientific background. Theoretical calculations and paper based design methodologies were put into practice with many unique properties.

3.1 Design

Solar energy systems should have a customized design for each project although the system equipment has simple structure, because both mechanical and electrical design depends on the site where you install. From the beginning of the project idea – from the beginning of the architectural design of the building, if it is possible – each detail should be considered as a system specification. The main and extended projects steps are given on Figure 3-1.

Figure 3-1 Solar Energy Project Steps from Idea to Operation

Whole process for the solar energy projects took almost 2 months for engineering and documentations and additionally installation period. All the process was held by the collaboration of FİNA Energy Company and Center for Energy, Environment and Economy in OzU. The project coordinator was Orçun Başlak.

3.1.1 Site Visit

The correct site visit is the key step in order to create a completely successful project. Engineer or project manager have to visit the site and get the necessary information for detailed project design, correct cost analysis and healthy processes. The site visitor should have some common measurement devices and consider about the issues below.

Main measurement devices for site visit were deemed to be:

- Compass
- Checklist
- Clinometer
- Photographer
- Notebook, tablet or something to take notes
- Company or product documentations for client (optional)

Main issues that should be considered while/after site visit:

- Total useable area should be measured considering the south direction (for north hemisphere) and shading possibility for string design
- Options for installation area of the inverter and electricity boxes
- Rough calculation for the length of the cabling both for DC and AC power system
- Roof or field floor structure for mechanical construction
- Possible communication type for real-time monitoring
- As-built electrical and architectural projects (consider about the differences between site and as-built projects)
- Availability of the building or the field according to the local regulations
- Transformer/Electricity Panel capacities where the system may be connected to the grid (there could be limitations because of the regulations. In Turkey, the capacity of the photovoltaic systems have to be less than 30% of the transformer on which it is connected unless there is capacity increase. For each applicant, only 10% of the transformer is allowed to use in a lump for a year.

- For the electricity box availability, check circuit breakers nominal current values and cable size for max current ratings.

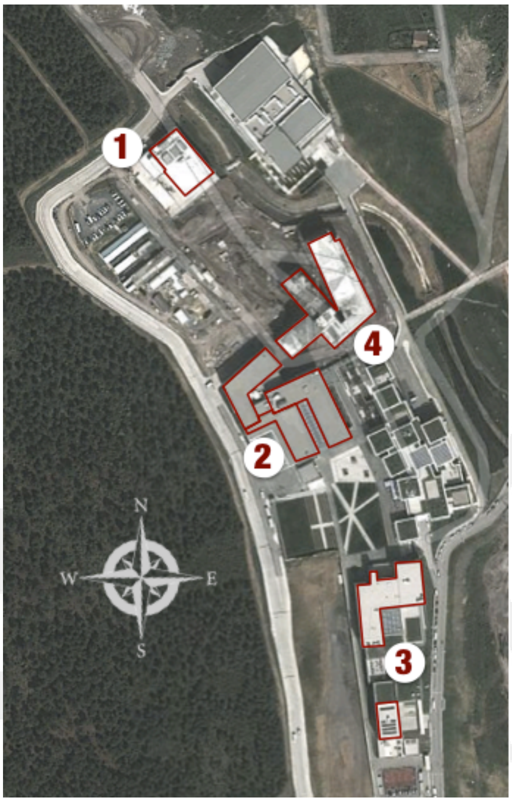


Figure 3-2 Available Buildings and Rooftop Plans

While doing site visit at Ozyegin University campus buildings, the process took a little long because there were still constructions and some buildings did not exist yet. One has green roofs, one has so many mechanical systems and shades on roof, one has perfect roof but it was not statically available for ~15kg/m^2. At the end there were 4 buildings available for installation and one had not been built yet.

The final selection of the installation sites is shown on the Figure 3-2. The main aim is maximizing the appropriate area on the rooftops and 4 buildings were available for that. Those framed with red lines are different-grade rooftops on each building. There are several grades on each rooftop and several mechanical systems such as chimneys, air handling units, etc. however, the pebbled roof structure was same for all the buildings.

The buildings can be listed below according to the installation schedule:

1) Energy Distribution Center (EDM)

   Total area: 1,161 m^2

2) Academic Building – 2 (AB2)

   Total area: 4,961 m^2

3) Engineering Faculty (MF)

   Total area: 5,225 m^2

4) ScOLa (School of Foreign Language)

   Total area: 3,317 m^2

Besides the total available area, it is must to measure the detailed length of each side considering the orientation of the building and obstacles on the roof for correct design. As-built projects make that process easier and enable you to design your system on the project in 2D and 3D format. The sample from the project design is given as Figure2-3. AutoCAD is used for 2D project schematics; Google SketchUp is used for 3D rendered models. Although 3D models are not mandatory for legal applications procedure it gives and insight about the how the system will look like before it is installed. 2D design is critical about optimum design, module selection, array orientations, cabling, placement of components, shading effect etc.

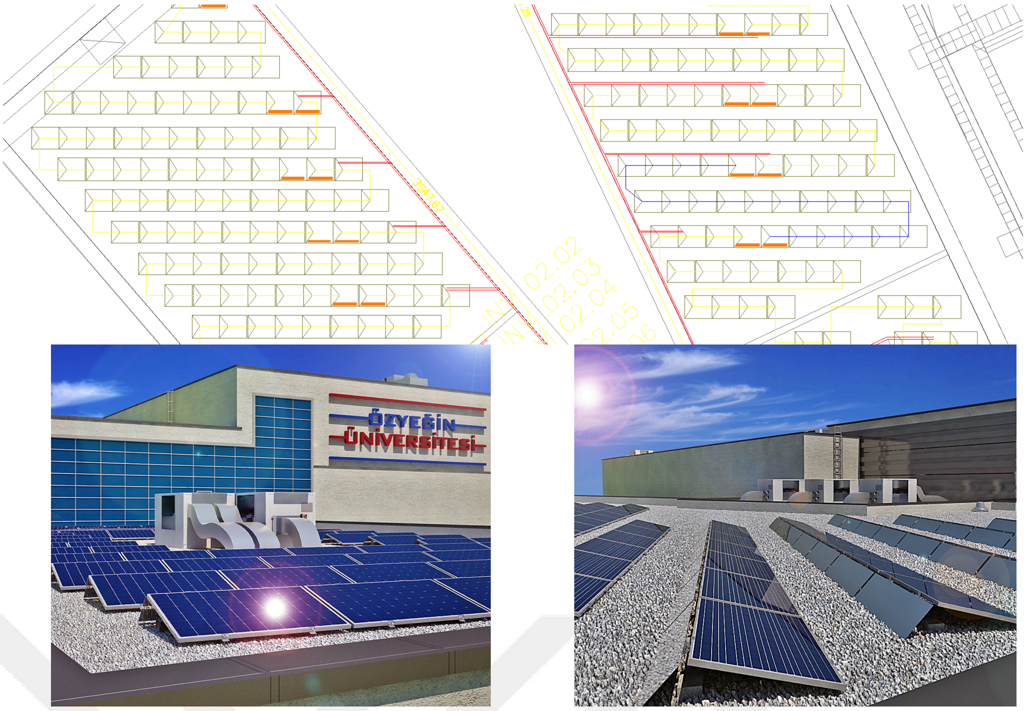


Figure 3-3 3D and 2D Designs of the Project

Each building has electricity and IT room on the upper floor, which seemed to have enough capacity for system connection; therefore we made a rough calculation for the length of DC cables, AC cables and data cables. The placement of the inverters would be seemed to be on the roof to optimize the cable length and use space efficiently. Besides electrical side, some issues raised for mechanical construction installation such that it was not allowed to dig into the roof floor for stable mounting and there were so many pebbles on the floor which are seemed becloud installation process

Finally, we got the client needs. The system should not have been seen from the ground level, there should not have been any intervention into the roof floor, which could damage the water resistant isolation system.

3.1.2 Equipment Selections

System design starts with equipment selection, which depends on several criteria as follows:

- The availability of equipment: number of stocks, delivery date
- Customer needs: cheaper, qualified, non-Chinese, EU branded etc.
- Technical info: equipment efficiency, resistant to humidity, IP54 or 65, Outdoor usage, design of the solar cell connections etc.
- Agreement conditions of the company with providers: system capacity lower limit
- Making process wait for gathering all request in order to decrease the unit cost of shipping/product
- Ease of installation and usage

In Ozyegin University case, FINA Energy Project Managers started negotiations with product supplier mainly for solar modules and inverters, which cover the 70% of project budget. Yingli Solar is the key supplier because they were new in Turkish market with globally well-known products and need best practices in Turkey. Therefore, negotiation ended with a reasonable cost and conditions in a very short time for the high-performed poly c-Si solar module, YL250P-29b. The detailed datasheet and cost structure is given in Appendix B. The main considerations were measured field performance of modules and cost.

Selection of the inverter is the most critical part of the whole system because it is the component where dynamic and continuous operation is occurred. Inverters are also the central hubs for all system because it connects modules to grid by converting the electricity signal type, it is the main communication point for produced energy measurements and it is also the point, which provides the electrical security to the whole system. That's why, main considerations while selecting inverters are the safety, reliability and ease of installation just before cost level. Considering these issues RefuSOL, formerly Advanced Energy, was selected as an inverter provider. Distributed system design and desire to create modular system led us to select string inverters with 10kW and 20kW capacity. The technical datasheet for the selected inverter types - RefuSOL 020K, RefuSOL 010K - is given in Appendix B.

The mounting structure, which shapes the system stability and robustness because of the high operation life (at least 25 year) of the system, is very important component of PV installation. Outdoor conditions are difficult to predict in most of the time and no way to take precautions for the system safety, therefore the system designer (commonly mechanical engineer) should consider all possible scenarios from maximum snow depth to highest wind speed and direction, from the humidity level to future planned construction around system, from the existing building structure to limitation for construction. For the campus, there were several additional difficulties including;

- No permission for any drilling or pounding process on the rooftop
- All the roof surface was covered with 3cm-depth of pebbles
- Modules should not be on the sight of view from ground level because of esthetical concerns
- No permission to exceed 30kg/m2 additional weight on rooftop
- High wind speed because of the rooftop application

Considering these issues, the system had to be designed separately from the roof surface. The distances to the edge of the roof were relatively long, tilt angles were decreased for the esthetical concerns and construction material had to be relatively lightweight. Aluminum framework was the strongest elements, the tilt angle was taken as 15^{o}, the distance to the edge of the roof was set to 1-2m and the mounting of the was provided by the additional weight blocks on the aluminum structure without any drilling. For the high wind speed, sheet metal was used at backside of the structure to avoid parachute effect. Details of the design are given Appendix C and Figure 3-4 shows the structure of the system. The line from point 1-to-5 shows the surface of PV module so the reactions on joint-2 refer to the snow and wind forces towards the middle of module. The line from point 3-to-5 shows the surface of wind barrier at the back.

Table 18: Joint Reactions

Table 18: Joint Reactions

Joint	OutputCase	CaseType	F1	F2	F3	M1	M2	M3
			Kgf	Kgf	Kgf	Kgf-m	Kgf-m	Kgf-m
2	G	LinStatic	9,87	0,00	8,57	0,00	0,00	0,00
2	Kar	LinStatic	23,22	0,00	37,15	0,00	0,00	0,00
2	Ruz(+)	LinStatic	-6,18	0,00	-4,83	0,00	0,00	0,00
2	Ruz(-)	LinStatic	3,45	0,00	-13,29	0,00	0,00	0,00
3	G	LinStatic	-9,87	0,00	11,54	0,00	0,00	0,00
3	Kar	LinStatic	-23,22	0,00	24,85	0,00	0,00	0,00
3	Ruz(+)	LinStatic	5,786E-02	0,00	-7,59	0,00	0,00	0,00
3	Ruz(-)	LinStatic	13,80	0,00	-5,17	0,00	0,00	0,00

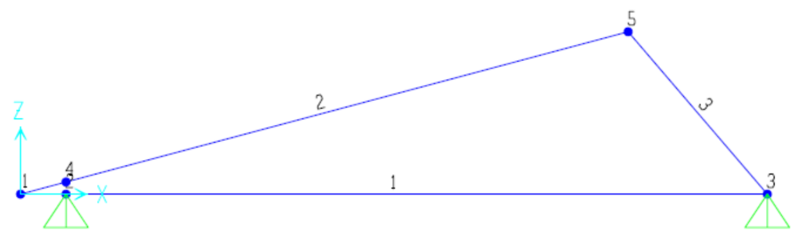


Figure 3-4 Joint Reactions on PV Mounting System Design

DC / AC and Communication cables are another crucial equipment. Cabling is directly related with the system safety and technical loss. Once the cable sizing and selection are designed with detailed engineering then, the system performance and lifetime increases. DC cabling from solar modules to inverters - since the system did not include DC boxes because of the integrated circuit breakers in inverters – is installed outdoor under direct sunlight. Therefore DC cables should be resistant to UV lights and outdoor conditions. AC cabling is directly related with the nominal AC current level from the inverter outputs. We choose 2x6mm^2 Solar Cables (TECSUN PV-1) with black and red colors for DC part, 4x6+6mm^2 YVV/NYY AC Cables for the connection between inverter and AC distribution boxes and 4x50+25mm^2 and 4x70+35mm^2 according to the max current and length of the cable for the grid connection. For the communication part, inverter was allowed us to use both Ethernet and RS485 then we planned to use both of them as back-up infrastructure and selected CAT6 UTF cable for outdoor usage with shielding and LI2Y(st)CY-PIMF 0,75mm^2. Details of the cable and safety equipment selection are given Appendix B.

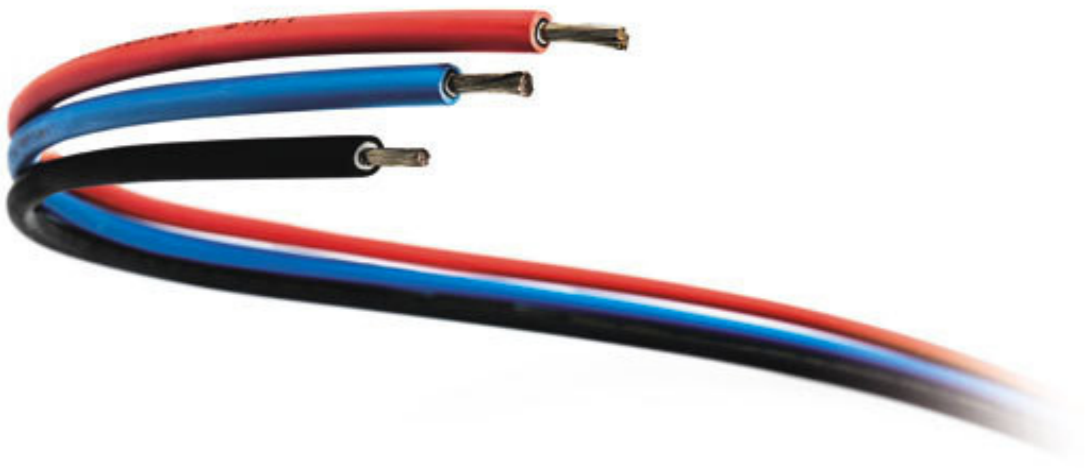


Figure 3-5 Solar DC Cables with Different Colors [84]

Last but not least, the critical part was the company, which would make the installation of whole system. It must have had experience on PV system installation for DC and AC electrical systems, mechanical mounting systems and components technical properties. Then, Reengen was the company who owns the all installation and commissioning process after Sunnova, which was selected at first, gave up all the installation process before it reached to half.

3.1.3 System Calculations

Replacement of the modules is prerequisite for the starting mechanical and electrical calculations. Material selection of mounting structure, the path of cables and the size selection were all affected by system design.

3.1.3.1 Mechanical Design

Alkor Aluminyum A.Ş., which was the mounting equipment provider designed the entire system component according to our needs and made static analysis with SAP 2000 software. They use aluminum as a main material with specifications below:

Solar module dimensions: 1650mm x 990(~1000) mm x 40mm

- Aluminum: 6063 – T6
  - E = 69 kN/mm^2
  - G = 26.2 kN/mm^2 (Self-weight)
  - Unit weight = 2.66E-08 kN/mm^3
  - $\sigma_a = 0.172\ kN/mm^2$
- Load Analysis
  - Equipment weight
    - Panel Load = Pt = 19.1 kg
    - Panel Load per Module = 19.1 kg /2 =~ 9.5 kg/m
    - Panel Load per Point = 9.5 kg/m /2 =~ 5 kg
    - Sheet Metal Weight = 1.65m x 0.0015m x 0.42m x 7,850 kg/m^3 /2 = 8.3 kg
  - Wind Load
    - V = 130 km/h (0.8 m/h)
    - q = 80 km/m^2 (According to the TS498 – Table-5)

- Wind (+) = (1.2 x sin15^o – 0.4) x 80 kg/m^2 x 1.65 kg /2 =~6 kg (Vacuum)
    - 0.4 x 80 kg/m^2 x 1.65 kg /2 = 27kg
- Wind (-) = (1.2 x sin50^o – 0.4) x 80 kg/m^2 x 1.65 kg /2 =~35 kg (Pressure)
    - 0.4 x v = 27kg

- Snow Load
    - P_k = 75 kg/m^2 (According to the TS498 – Table-4)
    - Snow Load = 75 kg/m^2 x 1.65m x 1m /2 = 31kg

The overall system was designed with 15^o tilt angle, metal sheet at the back part and additional concrete weights at the bottom to stick them to the surface. The Figure 3-6 below shows the 3D drawings of the system.

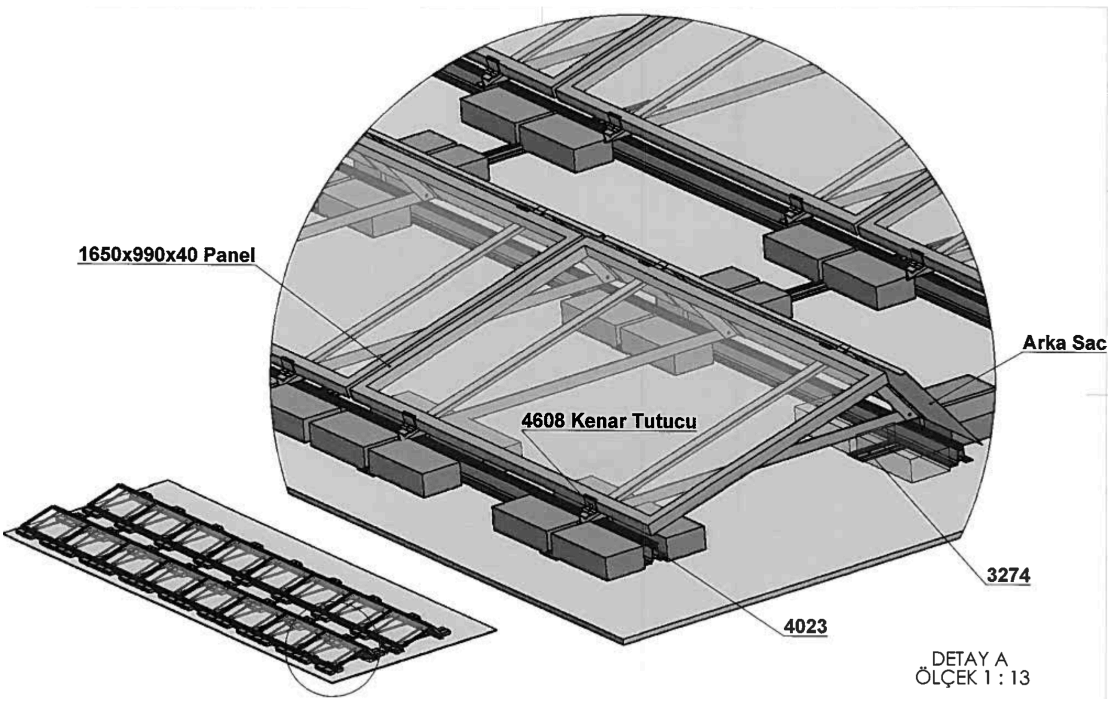


Figure 3-6 3D Design of PV System Placement with the Components

Panel = Solar Module

Kenar Tutucu = Edge Holder

Arka Sac = Metal Back Sheet

Detay A Ölçek = Detail A Scale

Detailed static analysis report including point based load calculations is given Appendix C.

The general placement of all modules was designed for each array individually because of the non-identical shape of the roofs. For example, in ScOLa Building

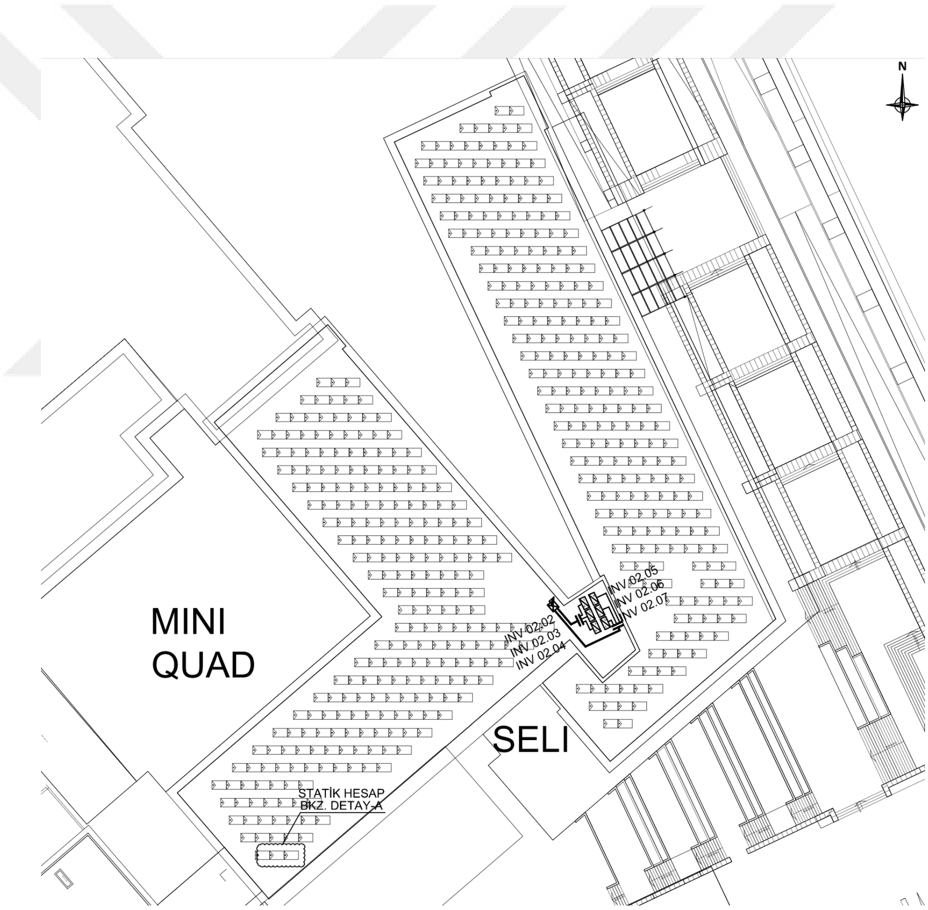
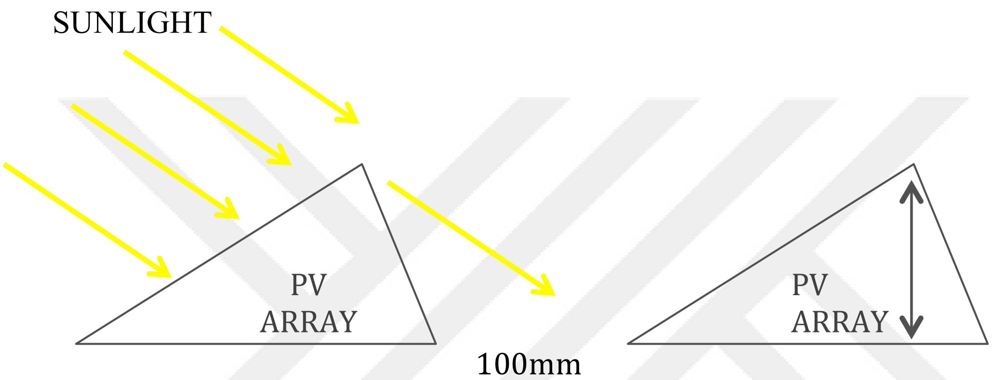


Figure 3-7 2D Placement Plan for PV Modules on SELI (ScOLA) Building

The length of the arrays and number of modules per array differ for most of part. The placement of the arrays was arranged according to the south facing and shading of arrays on each other. While calculating the appropriate distance between each array because of the back shading, we took into account the sunlight with a highest zenith angle, which means 21st December. Istanbul latitude is 41N and the solar noon zenith angle is around 64,5°.

21st June Sun Angle = 90 –Zenith Angle [=Latitude + (-23.5)] = 72.5°

21st Dec Sun Angle = 90 – Zenith Angle [=Latitude – (23.5)] = 25.5°



While sun angle is around 25.5°, the shading distance behind the each array can reach 100mm.

PV Modules Tilt Angle = 15°

Height of the PV array (h) = 1650 x sin(15) = 42mm

Sun Angle = 25.5°

Shading Distance = 42 / sin (25) = 100mm

After finalizing the module installation type then we need to place all the modules as efficiency as possible to maximize installed power. Each building has different geometrical shape with different shading effects and heights. By using AutoCAD drawing tool all the system placement were designed and exact number of PV modules were calculated.

- Energy Distribution Center (EDM)
    - Installed Power: 21 kWp
    - # of Module: 84 pcs.
    - Inverters: 1 pcs. of RefuSOL 008K-020
- Academic Building – 2 (AB2)
    - Installed Power: 136.5 kWp
    - # of Module: 546 pcs.
    - Inverters: 6 pcs. of RefuSOL 008K-020, 1 pcs. of RefuSOL 008K-010
- Engineering Faculty (MF)
    - Installed Power: 94.5 kWp
    - # of Module: 378 pcs.
    - Inverters: 3 pcs. of RefuSOL 008K-020, 1 pcs. of RefuSOL 008K-010
- ScOLa (School of Foreign Language)
    - Installed Power: 126 kWp
    - # of Module: 504 pcs.
    - Inverters: 4 pcs. of RefuSOL 008K-020

The placement of PV modules and inverters on each building is given on the Figure 3-8, Figure 3-9 and Figure 3-10.

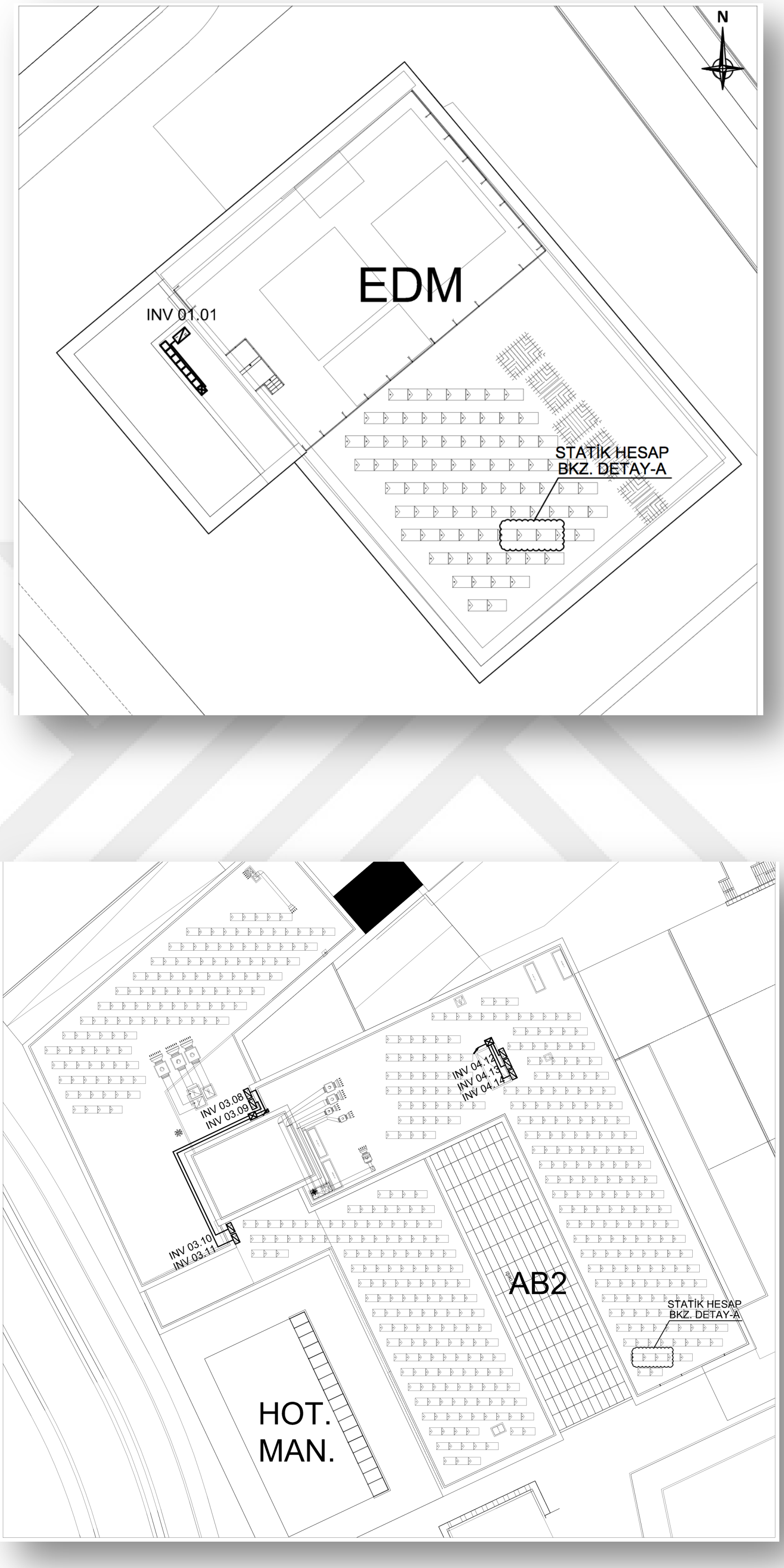


Figure 3-8 AutoCAD Designs for the Placement of PV Modules and Inverters

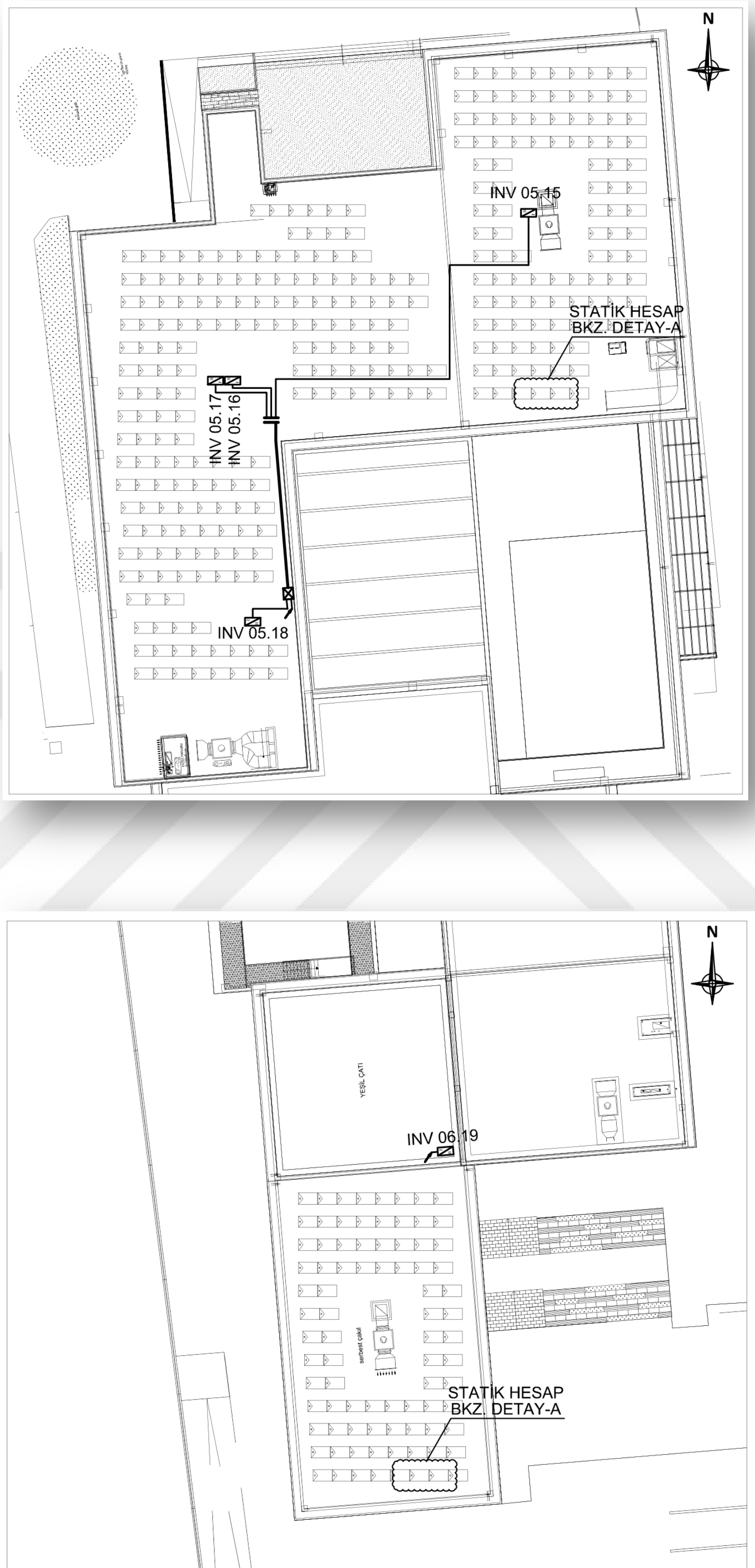


Figure 3-9 AutoCAD Designs for the Placement of PV Modules and Inverters

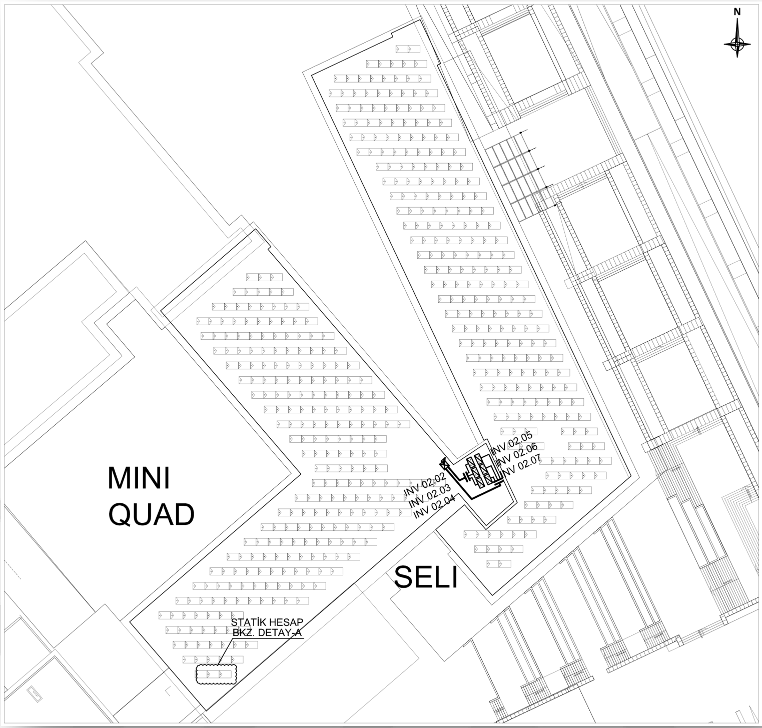


Figure 3-10 AutoCAD Designs for the Placements of PV Modules and Inverters

3.1.3.2 Electrical Design

Electrical design starts with the module selection. Module providers generally have different type of modules with a range of power capacity. The common PV module power capacity varies between 240-260Wp and the investor or project manager chooses the most appropriate one. In our case, the leading product of the Yingli Solar is 250Wp multi-crystalline PV module in terms of reliability, availability and price comparing with thin-film and mono-crystalline Si modules. Then, YL250P-29b was selected. The main technical specifications, which should be taken into account while designing electrical structure, are as shown in Table 12.

Table 12: PV Module - Yingli Solar YL250P-29b - Technical Specifications [85]

Specification	Value
Power Output (Pmax)	250 Wp
Voltage at Pmax	30.4 V
Current at Pmax	8.24 A
Open Circuit Voltage	38.4 V
Short Circuit Current	8.79 A
Module Efficiency	15.3%
Thermal Coefficient of Voc	-0.33 (%/^{o}C)
Dimension (W/H/D) ,mm	990/1650/40

As a second main component, technical specifications of inverters are shown in Table 13.

Table 13: Solar Invertor - RefuSOL-020K and 010K - Technical Specifications [78]

Specification	020K	010K
Max PV Power	11.2 kWp	21.6 kWp
MPP Voltage Range	410 – 850 V	480 – 850 V
Max DC Voltage	1000 V	1000 V
Max DC Current	25 A	41 A
MPP Tracker / DC Connector	1 / 3 x MC4	1 / 6 x MC4
Rated AC Power	10 kWh	19.2 kWh
Max Eff. / Euro. Eff.	98% / 97.4%	98.2 % / 97.8 %
Communication	Ethernet and RS485	Ethernet and RS485
Type of Protection	IP 65	IP65
Dimension (W/H/D) ,mm	535/601/225	535/601/227

As the system has distributed roof top design, central inverters are not applicable. Considering the system design and the capacity of the systems on each roof area, string inverters with around 20 kWe capacity are the most optimal solution. Here are the primary concerns for choosing RefuSOL-020K

- The smallest of PV system is located on EDM building and its capacity is around 21 kWp
- As we decrease the capacity to 10 kWe or 15 kWe then, the number of inverters increases which refers to increasing the risk of maintenance
- RefuSOL is high quality, German brand with huge experience on different fields.

After deciding these two main components, we have started engineering design for the number of modules for each inverter and each string, cable lengths, cable types, grid connection point and possible technical losses, etc.

There some critical criteria that has to be taken into account while designing the electrical infrastructure:

- According to the engineering design, our main aim is minimize the length of DC cabling and grouping the inverters for placement
- We have 84 pcs of PV modules with 4 different strings for each inverter and 100cm distance between each row.
- For placement of inverters, it has to be close to the grid connection point and optimize the length communication (CAT6) cabling towards to the IT room.
- Grid connection point has to be the closest distribution panel, which has enough electrical load capacity higher than PV system.

Beside those criteria, the most important part is labeling of all system components from modules to inverters. All the system components have unique codes (i.e. D 02.05.03, INV 02.05) in order to identify them on the project designs and ease the construction process.

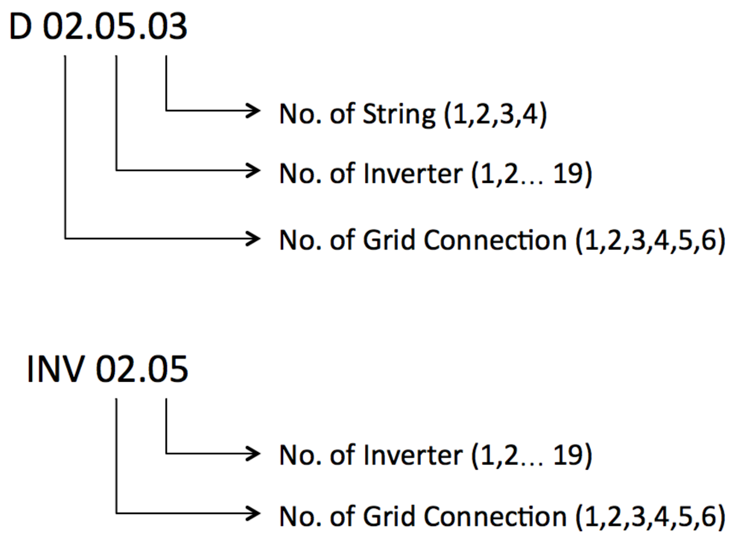


Figure 3-11 Logic behind the Notation of System Components

All those led us to the design consisting of inverter location, DC and AC cabling shown in Figure 3-12.

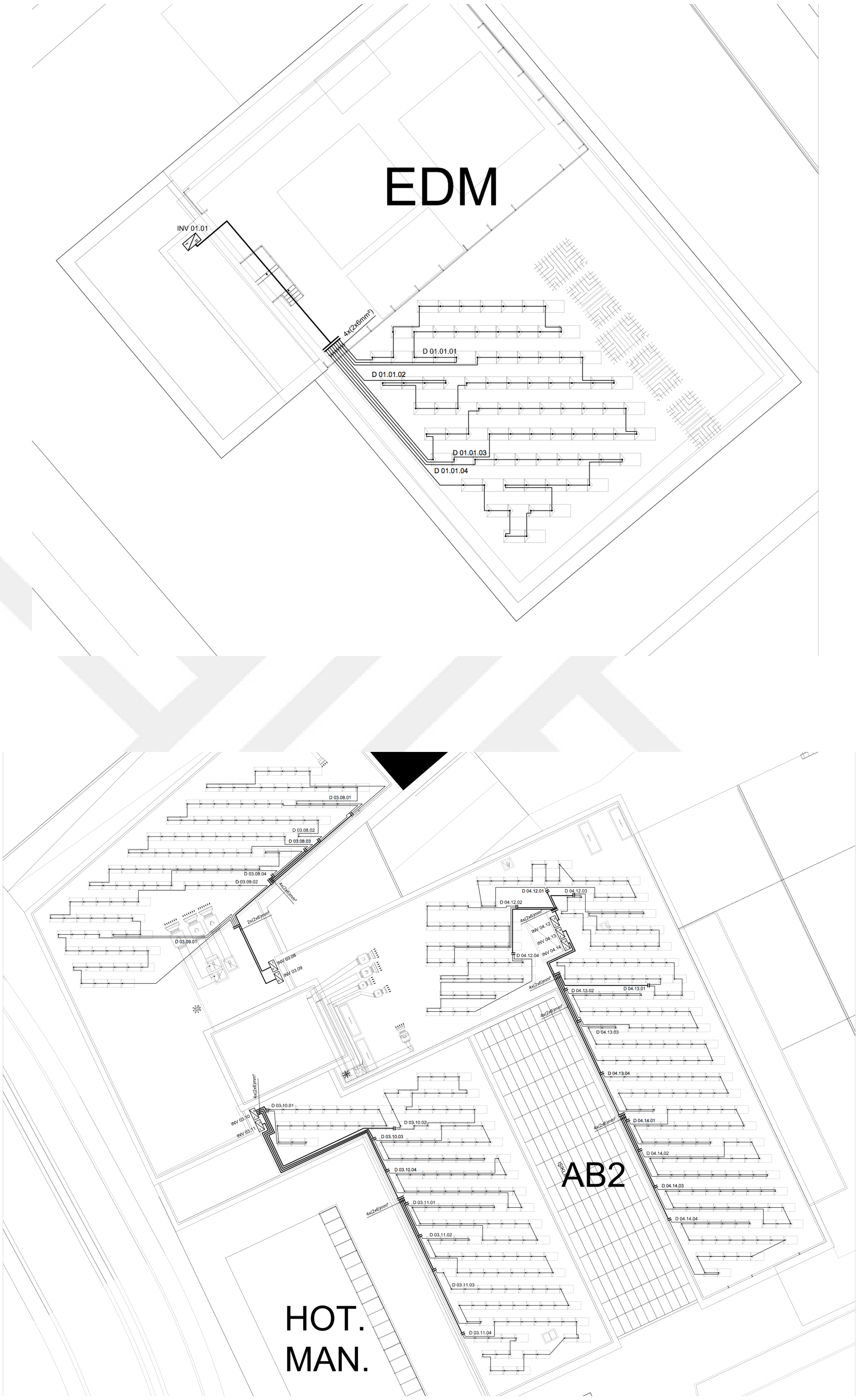
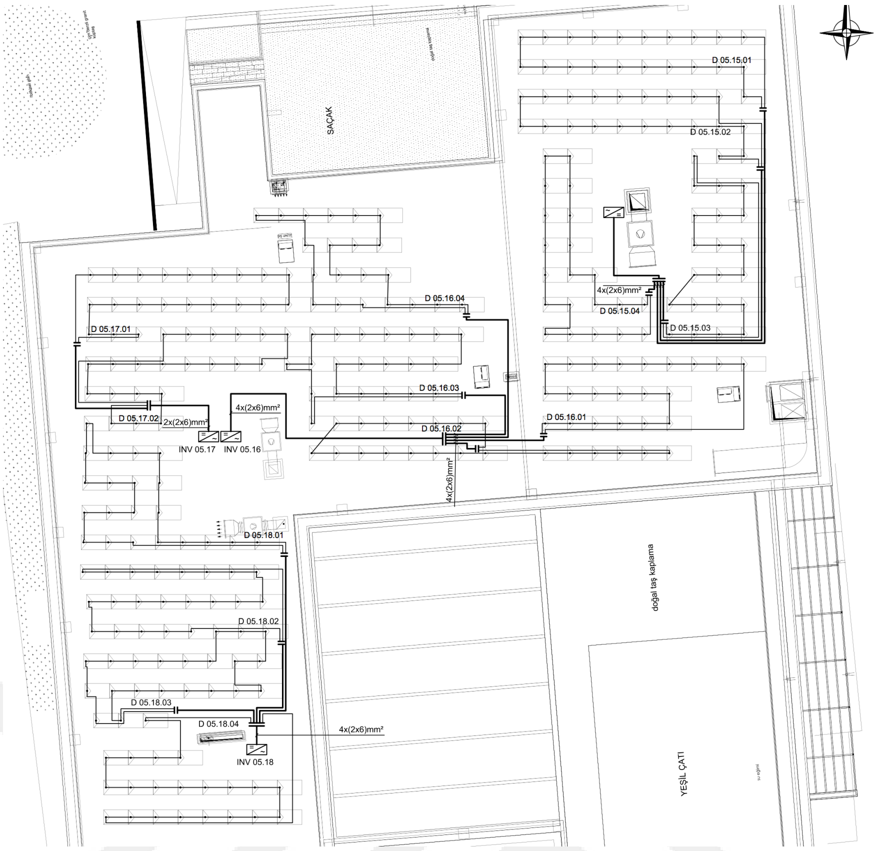


Figure 3-12 String Connections, PV Module Placement, AC and DC Cabling Routes of EDM and Engineering Building



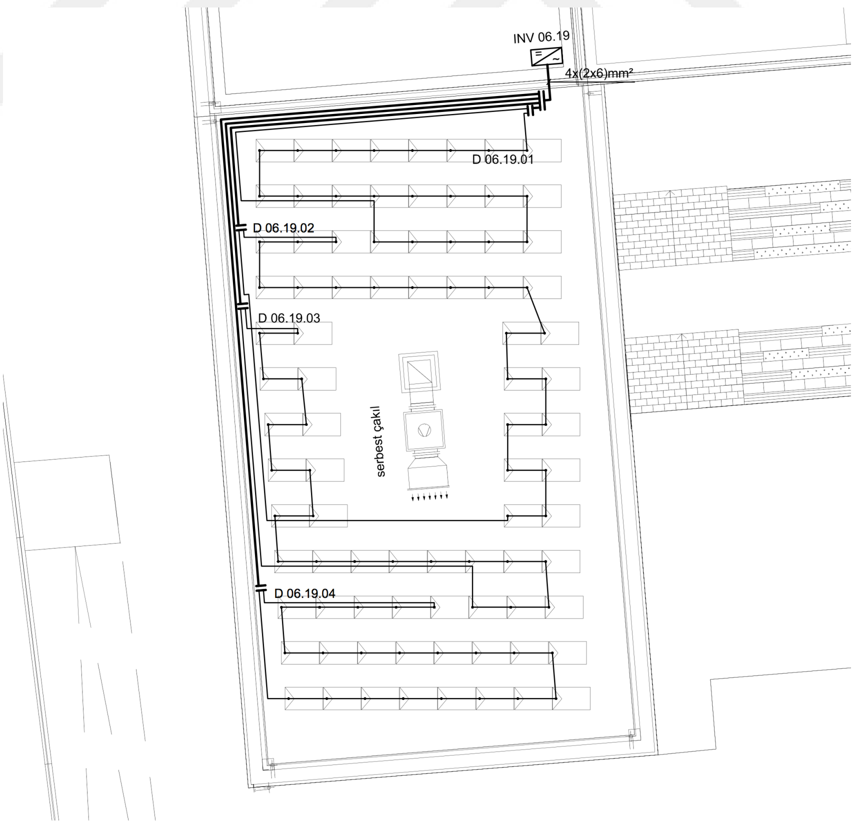


Figure 3-13 String Connections, PV Module Placement, AC and DC Cabling Routes for AB1 Building

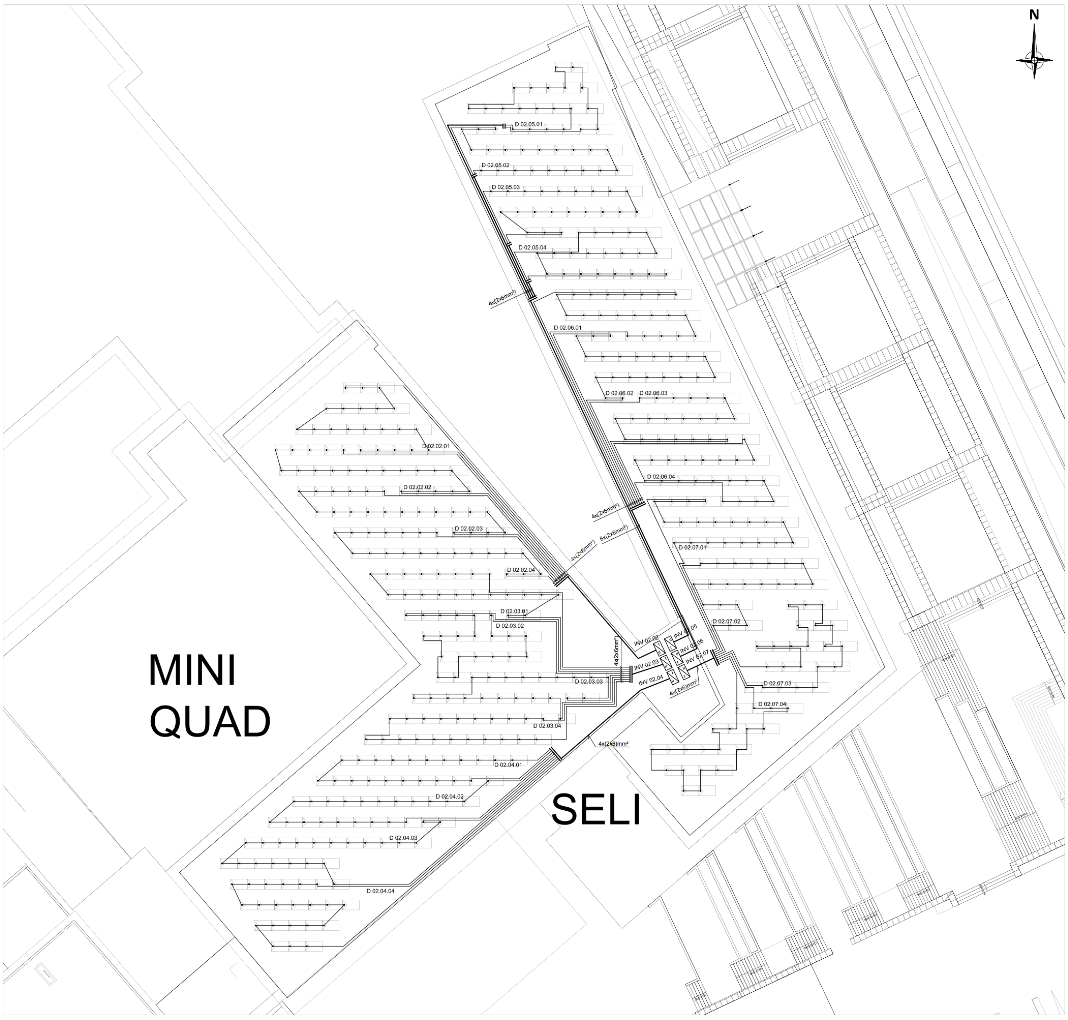


Figure 3-14 String Connections and AC and DC Cabling of Second Part of ScOLA Building

DC cabling is the most important part because all the connections and route must be very clear in order to connect all the modules, which are 1512 pcs. in our case, without any missing part. The total length of the DC cable from modules to inverter may exceed 300 m for some of the strings so, we decided on 6-mm^2 TEC-PV1-F cables with red and black colors in order to clarify the connections easily while constructing or maintenance.

Table 14: DC Cable Specifications and Selection of Cable [87]

Cable Type	Cable Cross Section (mm^2)	Outer Diameter (mm)	Current Flow Capacity (A)	Nominal Voltage (V_{dc})	Operating Temperature (°C)
TECSUN PV1-F	2.5 mm^2	5.1	41	1000	-40 / 90
	4 mm^2	5.6	55	1000	-40 / 90
	6 mm^2	6.1	70	1000	-40 / 90
	10 mm^2	7.2	98	1000	-40 / 90

The total length of the additional DC cables:

- EDM Building: 2 x 219 = 438 m (589.2 m with module-integrated cables)
- AB2 Building: 2 x 1,446 = 2,892 m (3,874.8 m)
- Engineering Faculty Building: 2 x 924 = 1,848 m (2,528.4 m)
- ScOLA: 2 x 1,348 = 2,696 m (3,603.2 m)

Since the main aim is optimizing the length of DC cabling, there is no DC combiner box used in this project. However; we have AC combiner box for the group of inverters on rooftop.

We have used 4 x 6 + 6 mm^2 YVV/NYY AC cables from inverter to AC combiner boxes. The average length of AC cabling from inverter to AC combiner boxes is around 15,8 m while the longest one is 49 m, the shortest one is 6 m. Except from EDM Building and front roof of Engineering Faculty, 4 different AC combiner boxes used. As the inverter groups have maximum capacity of 115.2 kWe power, grid connections directly made through the floor distribution panels. The cables used to connect AC combiner boxes to the floor distribution panels are 4 x 25 / 16 mm^2, 4 x 35 / 16 mm^2 and 4 x 70 / 35 mm^2 YVV/NYY with a length of 38m, 32m, 10m successively.

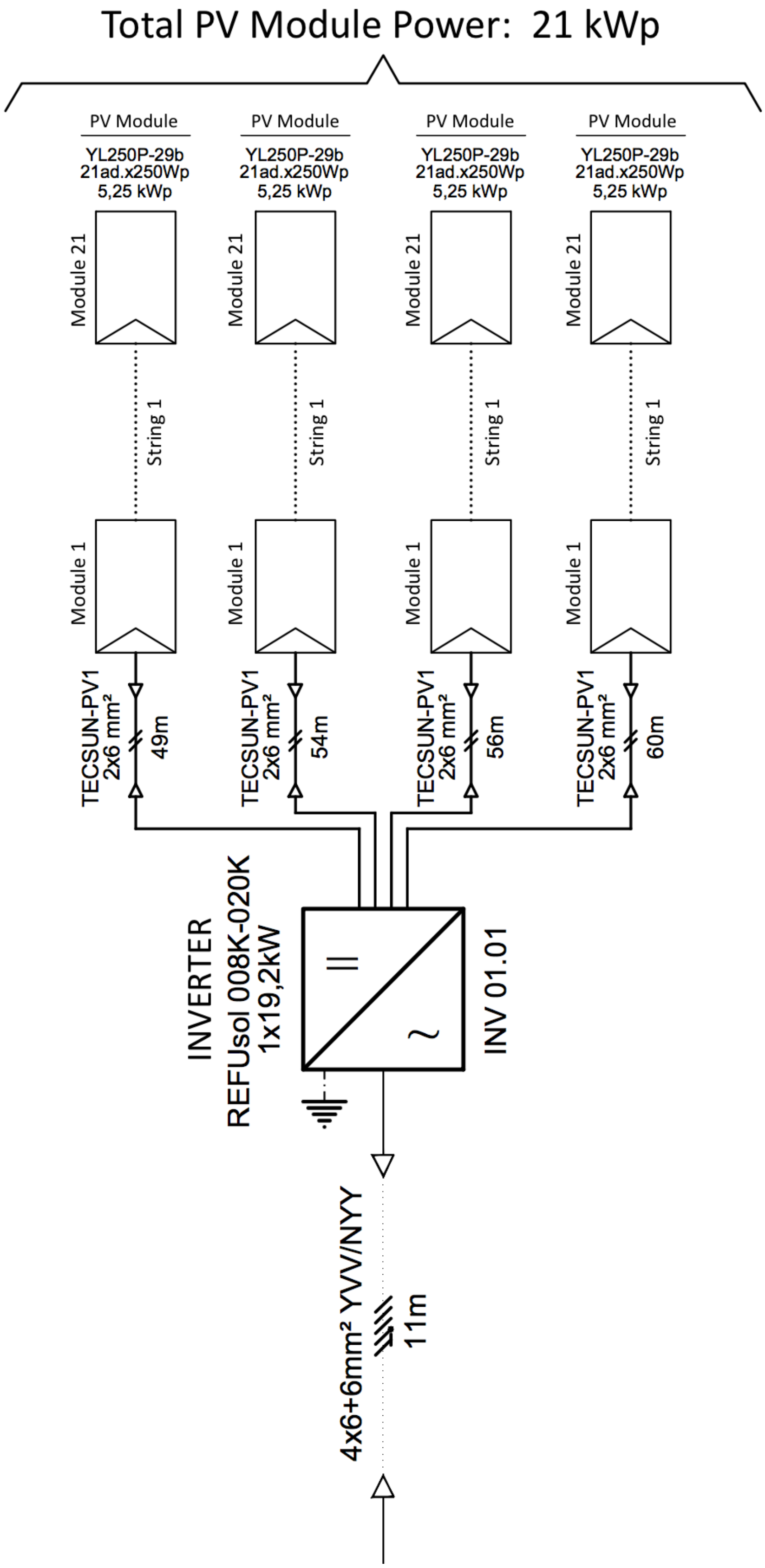


Figure 3-15 Sample Design of PV Module and Inverter Cabling for 21 kWp System

(i.e. EDM Building)

In electrical systems, you have to use protection equipment on specific place of wiring system. We used the high level internal protection equipment of inverters for DC wiring and inverter outputs; however we need additional circuit breakers and protection relays on AC combiner box for each input and output feeder lines. Figure 3-16 shows the AC combiner box and grid connection point for ScOLA Building. 6 inverter outputs are combined on the 20x3mm Copper bus bar in the combiner box through Miniature Circuit Breaker (AOS) and Residual Current Relay (KAKR). In the box, we have spare feeder (YEDEK) and plug output in case of any need. On the output feeder, there is Surge Arrester Type II and Circuit Breaker, Energy Meter and Protection Relay on the grid connection point of same feeder. The whole single line diagram of the project is given on Appendix D.

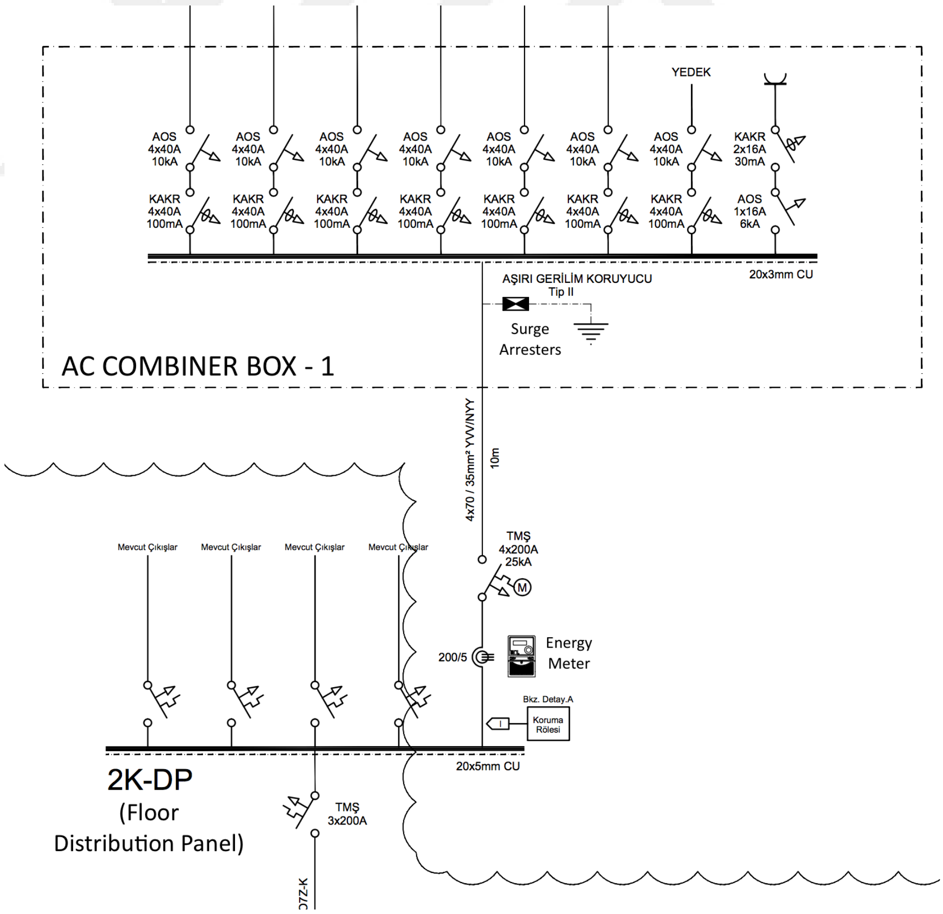


Figure 3-16 AC Combiner Box and Grid Connection Point of PV System

3.2 Operations

Whole year simulation with statistical weather values for the implementation area is the only key to validate the PV system feasibility from economic angle of view. As the project is one of the biggest projects on 2013, it was hard to find a whole year data for such system with similar location and capacity. Then, we used PV*SOL Solar Simulation Tool in order to get the whole year monthly production data for the feasibility reports of investment. System gets many parameters to make the analysis: location, PV system capacity, Manufacturer/Model of PV modules, Manufacturer of PV Inverters, Inclination of modules and direction of the modules.

From the report of PV*SOL, we got the data below.

- Annual PV Energy: 424,460 kWh
- Specific Annual Yield: 1,122.91 kWh/kWp
- Performance Ratio: 81.7 %

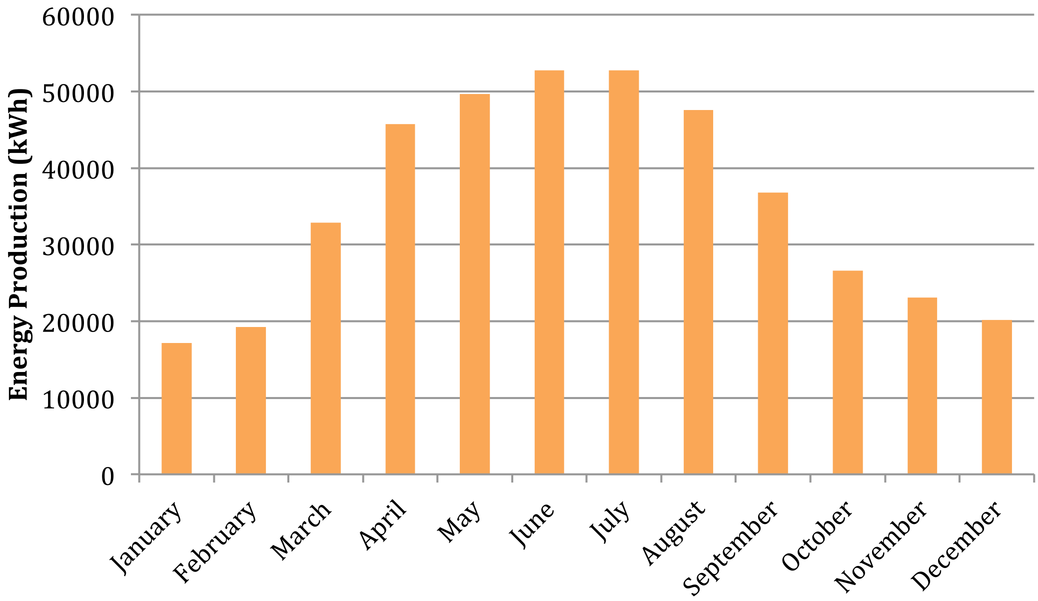


Figure 3-17 Simulation Results for Monthly Energy Production of Whole System

According to the simulation results, annual PV energy is around 424,460 kWh. The degradation rate of PV system is another important parameter that should be taken into account while calculating 10-year, 20-year or lifetime PV energy production. It gives the rate of decrease on the system production performance, which is because of mostly the material properties of Si or other solar cell materials and climate differences. In Photovoltaic Degradation Rates — An Analytical Review written by Dirk C. Jordan and Sarah R. Kurtz at NREL, the average degradation rate of PV modules is around 0.6% and of PV whole system is around 0.8 %/year [88].

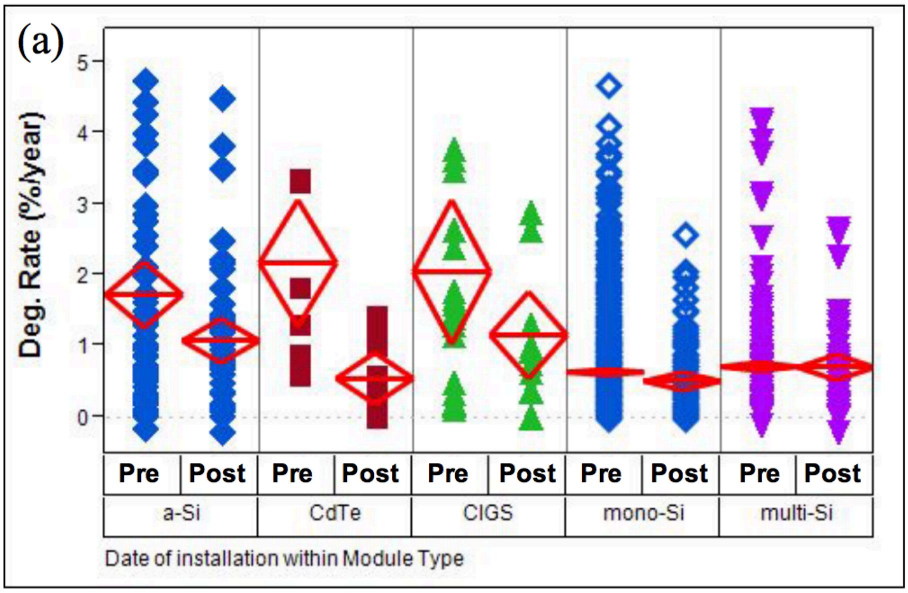


Figure 3-18 Degradation rates partitioned by technology for all the system. Dates of installation prior to the year 2000 and after 2000 and indicated by 'pre' and 'post' respectively. The crossbars denote the mean for each category; diamond, 95% confidence interval [88]

Taking into account that degradation rate, the total energy production of 10-year time is expected to be around 4,095,019 kWh and 25 year-time energy production projections are given Figure 3-19 below.

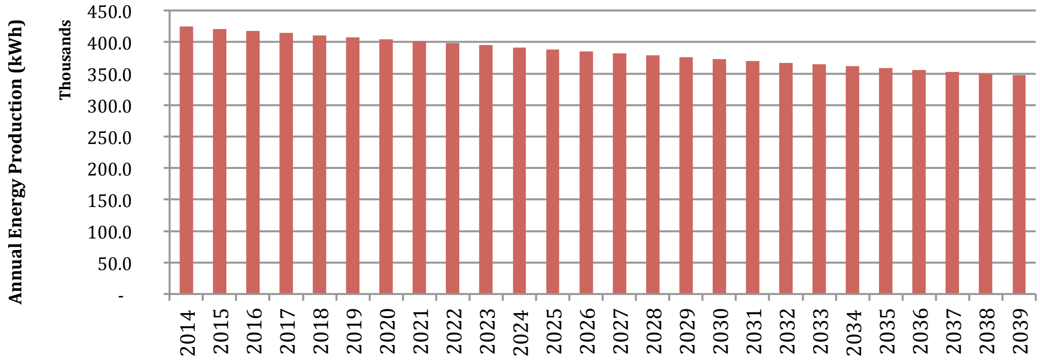


Figure 3-19 Annual PV energy production based on the degradation rates

3.2.1 Regulatory Processes

According to the Turkish statute of Renewable Energy Law and regulations and notices connected to that law, all system owners have to apply and proceed the application procedure for non-licensed PV energy systems, which must be under 1,000 kWh system capacity. This is around 3-to-6 month process and more than 5 different government unit included for the permissions. Therefore, it takes time, effort and costs even if it is such a big deal. These bureaucratic procedures are collected under 3 main steps:

1. Pre-Application Process
   1.1. It is the application must be done when the investor is willing to do the project in order to reserve the grid connection transformer
   1.2. Before it is applied, the PV system capacity, location, estimated grid connection point and potential products that will be used in the project have to be decided.
   1.3. The applications are accepted by the local energy utility.
   1.4. Once the approval, which is called 'Connection Contract', is got from that pre-application process then, you are ready to go further on project progress and have to prepare for the main application

2. Main Application Process
    2.1. You need more documents and permissions from different governmental organizations such as Turkey Energy Distribution Department, Ministry of Environment and City Planning, Local Municipality, Ministry of Energy and Natural Resources
    2.2. Static calculations and reports approved by Municipality
    2.3. Detailed electricity projects and calculations made by certificated electrical engineer and approved by Turkey Energy Distribution Department
    2.4. Letter of Environmentally Conformity from Ministry of Environment and City Planning
    2.5. Grounding System Report approved by certified engineering companies
    2.6. Technical Evaluation Form approved by Ministry of Energy and Natural Resources
    2.7. After getting approval of main application then, this means ready to start construction.
3. Commissioning Process
    3.1. After construction is ended and all test are done then, commissioning process, crosscheck visit by government responsible unit, starts. You need to announce that you are ready for commissioning with and application letter to Turkey Energy Distribution Department.
    3.2. The visit of group of people; one from Turkey Energy Distribution Department, one from local Energy Distribution Company, one from Engineering Company and one from Power Plant Owner Company
    3.3. Investment numbers and serial numbers of Inverters are needed
    3.4. Field Test and Measurement Reports

3.5. Approval from local Fire Department and safety signs on the field.

3.6. Announcement to the district governorship

Total list of application documents, which were delivered to the interested authority, are given below.

Table 15: The Document List of Main Application Process

CONTENT OF MAIN APPLICATION PROCESS
DOCUMENTS
1) Letter of Call for Connection Contract (as Pre-Application Approval)
2) Conformity Letter for Static Analysis and Solar System Availability
3) System General Information Form
4) System Designer / Engineer Information
5) Certificate of Consulting Engineer and Office Registration
6) Trade Registry Gazette
7) Authorized Signature List (only valid for Turkey)
8) Tax Registration Form
9) Site Assessment Report (List of all equipment expected to be used)
10) Justification Report/Note
11) Letter of Attorney
CALCULATIONS/ENGINEERING
1) Calculations for Power Loss, Voltage Drop, Current Flow Capacity of DC Cabling
2) Calculations for PV Module Selection, Minimum and Maximum DC Input Voltage Control for Inverters
3) Calculations for Voltage Drop, Current Flow Capacity and Short Circuit Current of LV and MV AC Cabling
4) Short Circuit Current Calculations from Module to Grid Connection Point
5) Grounding and Lightning Rod Calculations
PLAN and PROJECTS
1) System Construction Plan and Schematic
2) Single Line Diagram of Electrical Systems
3) PV String and Array Diagrams and Electrical Details
4) Grounding and Surge Protectors
5) Measurement, Monitoring and Communication Systems
6) AC Electricity Connection Details

ADDITIONAL
1) Datasheets and Brochures of PV Modules, Invertors, DC Cables
2) Monthly Statistical Meteorological Data
3) Protection Relay Details and Datasheet
4) Communication System Documents
5) Digital copy of all documents on CD

Table 16: The Document List of Commissioning Process

CONTENT OF COMMISSIONING PROCESS
1) Certificate of Provisional Acceptance
2) Letter of Project Approval (as Main Application Approval)
3) Assignment Letter for the Commissioning
4) Letter of Connection Contract (as Pre-Application Approval)
5) System Use Agreement
6) Power and Commissioning Protocol
7) Technical Delivery Report
8) Announcement Report
9) Announcement Report of District Governorship
10) Grounding Measurement Report (from certified engineering company)
11) Fire Department Report
12) Field Test Reports (including Measurements)
13) Compliance Report
14) Protect Relay Set Values Report
15) Single Line Diagram and Layout Plan

These entire documents were all set with 5 different copies and signed by the visiting committee. Then, general acceptance letter has arrived in 2-3 weeks after visiting.

3.2.2 Financial Analysis and Forecast

No matter if it is photovoltaic power plant or any other type of investments, the main issue is the feasibility of the project and ROI. All investments start with financial analysis so for our system with 378kWp capacity and 4 sub-plants, the total investment was 0.92 €/Wp, which was a quite good cost for those days.

- PV Module (Yingli Solar): 0.42 €/Wp
- Solar Inverter (Refusol): 0.11 €/Wp
- Mounting/Constructing Eqp: 0.7 €/Wp
- Construction: 0.1 €/Wp
- Engineering, Communication and Electrical Inf.: 0.22 €/Wp

While deciding on product suppliers, the main criteria are quality, cost and return due to the domestic product incentives. There were 3 different equipment groups (PV module, Mounting Equipment and Electricity Infrastructure) that we could find domestic manufacturer and get that incentive however, they were not that much competitive for the cost.

Table 17: Cost of PV Equipment for 3 Different Incentives Scenarios

Cost Of Equipment	1st Scenario with no Additional Incentives	2nd Scenario with Mounting Eqp. Incentive	3rd Scenario with Module and Mounting Eqp. Incentive
PV Module	0.42 €/Wp	0.42 €/Wp	0.50 €/Wp
Solar Inverter	0.11 €/Wp	0.11 €/Wp	0.11 €/Wp
Mounting Equipment	0.05 €/Wp	0.07 €/Wp	0.07 €/Wp
Construction	0.10 €/Wp	0.10 €/Wp	0.10 €/Wp
Engineering, Communication and Electricity Inf.	0.19 €/Wp	0.22 €/Wp	0.22 €/Wp
TOTAL	**0.87 €/Wp**	**0.92 €/Wp**	**1.00 €/Wp**

Table 18: Incentive Rates in Euro for Different Product Units

Incentives for Energy Purchasing	**Price (€/MWh)**
Base Incentive (10 years)	€ 100.00
Domestic PV Module (5 years)	€ 10.00
Domestic Construction Eqp. (5 years)	€ 6.00
Domestic Solar Cell (5 years)	€ 26.00
Deductions over Monthly Bill	
Loss/Theft	€ 17.06
Transmission Line Usage	€ 2.80
Distribution Line Usage	€ 8.50

Taking into account the simulation results with 1,123kWh/kWp annual radiation value and 0.8% annual degradation rate, the 9-year period financial ROI results for 3 different scenarios was investigated. As it is shown in table 18 below, first 2 scenario has very close return with € 41,156 and € 34,788.

Table 19: Return on Investment for 3 Different Scenarios

	1st Scenario	**2nd Scenario**	**3rd Scenario**
Total Investment	€ 328,860	€ 347,760	€ 378,000
Incentive (1-5)	€ 100 /MWh	€ 106/MWh	€ 116 /MWh
Incentive (after 5)	€ 100/ MWh	€ 100 /MWh	€ 100 /MWh
Total Return	**€ 370,016**	**€ 382,548**	**€ 403,434**
Year 1	€ 42,446	€ 44,993	€ 49,237
Year 2	€ 42,107	€ 44,633	€ 48,844
Year 3	€ 41,770	€ 44,276	€ 48,453

	1st Scenario	2nd Scenario	3rd Scenario
Year 4	€ 41,436	€ 43,922	€ 48,065
Year 5	€ 41,104	€ 43,570	€ 47,681
Year 6	€ 40,775	€ 40,775	€ 40,775
Year 7	€ 40,449	€ 40,449	€ 40,449
Year 8	€ 40,125	€ 40,125	€ 40,125
Year 9	€ 39,804	€ 39,804	€ 39,804
Profit	**€ 41,156**	**€ 34,788**	**€ 25,434**

One of the main aims in the project is creating a success story around Turkey, as it was the first rooftop application with such capacity on those days. Therefore, 2nd scenario was chosen to optimize cost. In addition, except from some specific days in a year it is really hard to push produced energy to grid (selling the energy over incentive price) because the total energy need in university campus rarely goes down to the energy production. Most of the energy produced uses internally. For recent years, 2014, 2015, 2016 and 2017 average energy purchasing price is around 0.33 TL/kWh without VAT. In Figure 3-20, investment and maintenance cost and production income will match at the end of 7th year. The first 3 years has just been realized and total earning is around 1,380,567 TL.

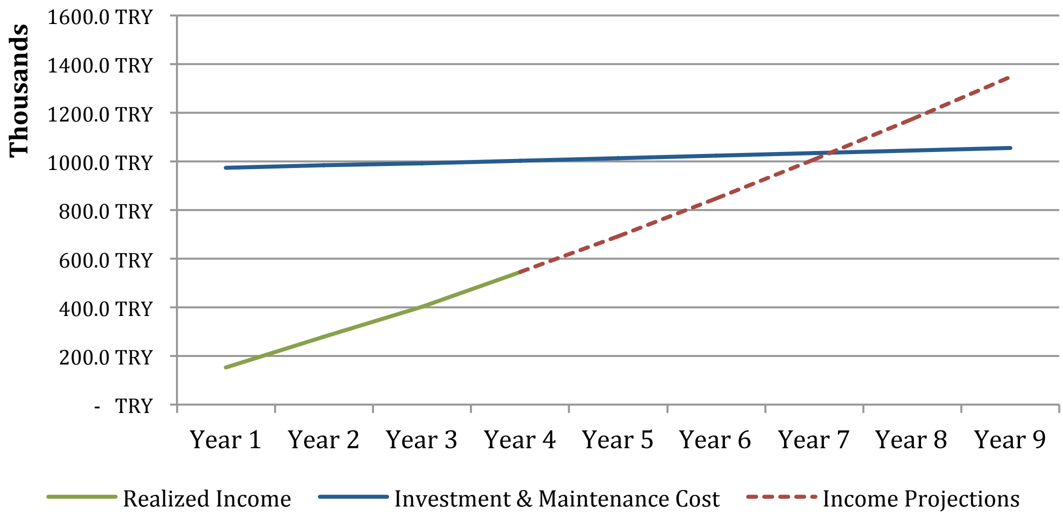


Figure 3-20 PV System Production Income vs. Investment

3.3 System Outputs

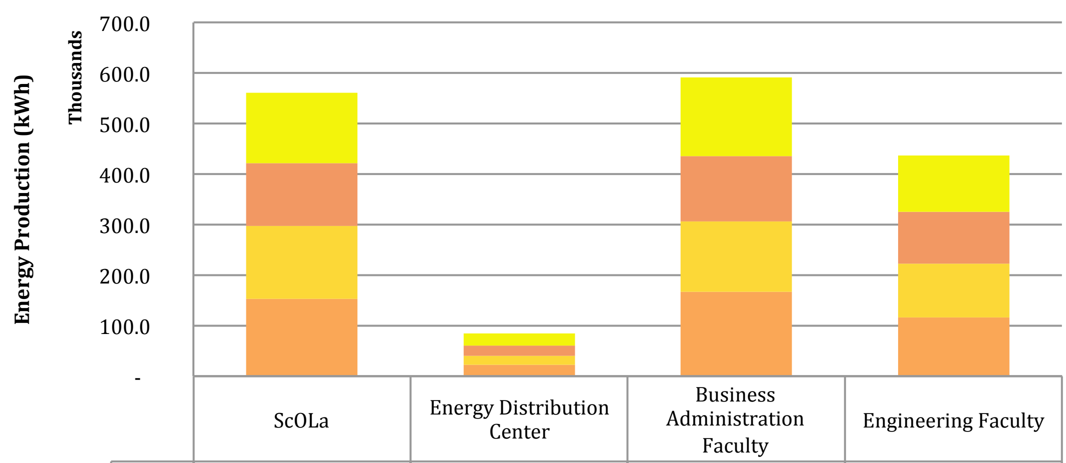
There are several key performance indicators globally accepted for the photovoltaic systems. Since the system performance is mostly dependent to weather conditions and maintenance they all are related to those differentiators.

Most commons KPIs are:

- Availability (Up time of System) (hours): There may be different type of availability explanation. It could be grid shut down, planned maintenance on grid, partially down of system etc. We will consider the whole system, sub plant and inverter level shutdowns.
- Energy Performance Index (%): This shows the percentage between simulated or expected energy production and realized production.
- Capacity Factor / Specific Yield (kWh/kWp-year): It is the energy delivery divided by the rated energy capacity of system.
- Power Performance Index: It provides the ratio between realized maximum power and expected power on that weather conditions.

Since July 2013, when the system partially started to operate and produce energy, the total produced energy is 1,845,400 kWh. This covers the time period from July 2013 to December 2017. Considering the realized energy production from 2014 to 2017, full 4-year period, it reached to 1.656.088 kWh. The simulation result for these 4 years is 1,677,577 kWh, which means that the accuracy of energy production forecast is around 98.7%. Maximum annual energy production was occurred in 2014 with 458,944 kWh. The annual radiation was 1,214 kWh/kWp, which is 8% higher than the simulation value of 1,122 kWh/kWp.

The whole production consists of the sub plants on the rooftop of 4 buildings. These sub plants are also have different PV production performance through 4-year period. As the system on the rooftop of ScOLA Building was the last sub plant constructed and started to fully operate in the beginning of 2014, the comparisons on the following parts only contains data from January 2014 to December 2017.



	ScOLa	Energy Distribution Center	Business Administration Faculty	Engineering Faculty
2017	138465.0	23489.0	155531.0	111705.0
2016	125081.0	20239.0	128575.0	102461.0
2015	143989.0	17659.0	139457.0	106728.0
2014	152812.0	23120.0	167187.0	115826.0

Figure 3-21 Annual PV Energy Production by Sub Plants

It is clear that the realized energy production is changing every year. 2014 is the most efficient year comparing with the following years. Once we investigate on it global radiation for the years from 2014 to 2017, the predicted energy production would have been 1,943,165 kWh in total while realized production was 1,656,088 kWh. The annual deviations of realized energy production from the simulation result was given in the Figure 3-22 below. This prediction is based on the measured real solar energy radiation for those years, not a simulation result according to the statistical value of decades. Although, the system seems to have a performance rate of 98.7% according to the simulation results based on historical radiation data for that region; the realistic performance rate is 85.2% according to the energy generation predictions. The performance rate fluctuated seasonally between 55% and 95% for 4 years time.

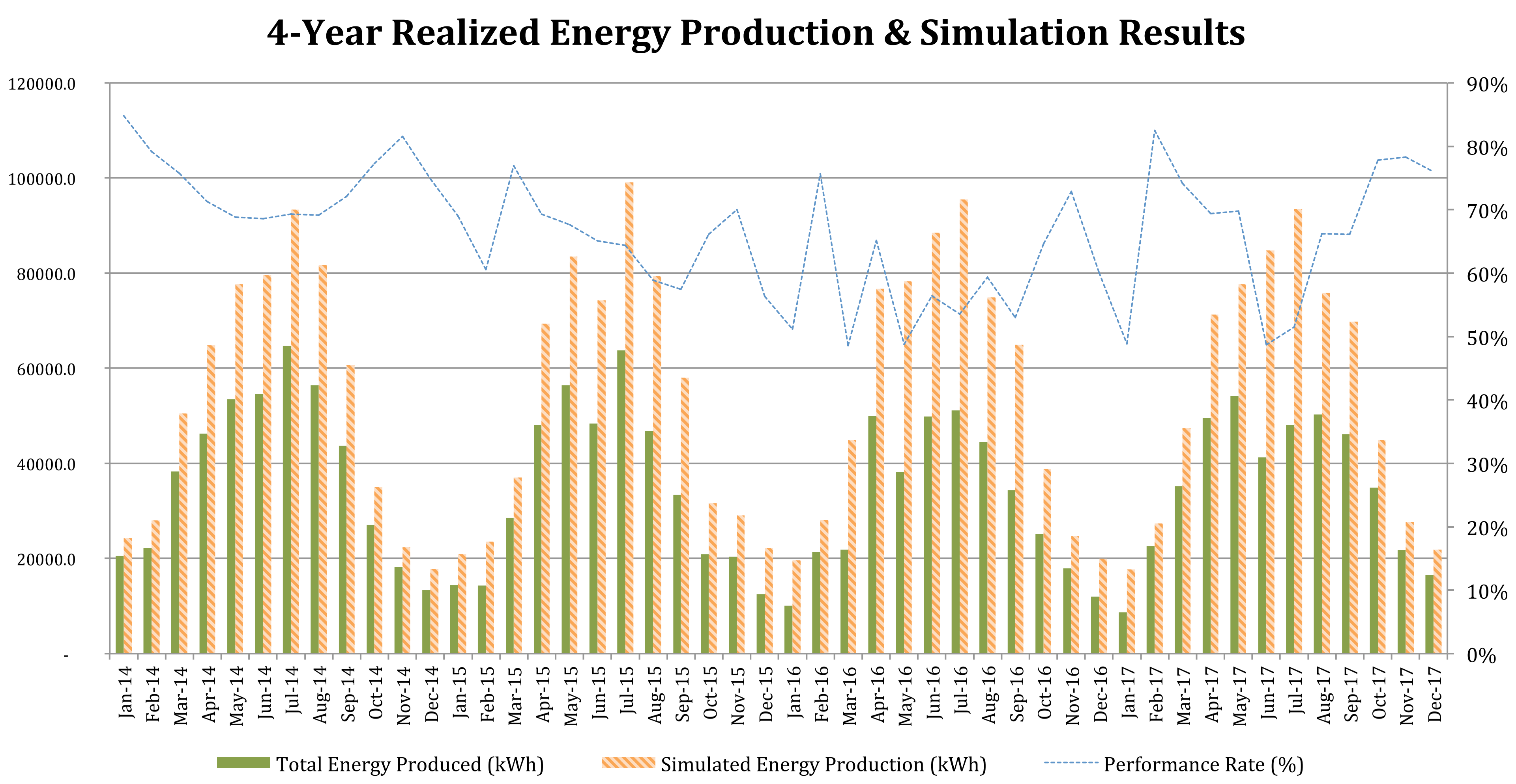


Figure 3-22 Realized Production and Simulation Results for 2014-2017

The main problem behind that low availability is the system operational failures. Most of the failures are because of

- Grid quality (voltage levels, frequency fluctuations, etc.)
- Errors, failures or old firmware versions on inverters
- Dust and pollution on the module surfaces
- Shading (occurred after system installation) and hot spots on PV modules
- Cracks and breaks on module surface
- Switching of circuit breakers on

These are all possible reasons that we have faced with during 4-year period. This cost us to almost 287,077 kWh equal to 100,500 TL losses theoretically.

As the system DC capacity is 378 kWp, the highest system performance days are the ones below.

Table 20: First 5 Days of Maximum Daily Energy Production for 2014-2017

Rank	**Date**	**Daily Energy Production**	**Specific Daily Yield kWh/kWp-day**
1	23th June 2014	2,562.60 kWh	6.779
2	18th May 2014	2,526.90 kWh	6.686
3	24th June 2014	2,522.50 kWh	6.673
4	12th July 2015	2,519.60 kWh	6.666
5	6th July 2014	2,514.20 kWh	6.651

For annual basis, overall system specific yield had dramatic change by the years. While it was 1,214 kWh/kWp in 2014, it decreased 8% and reached 995 kWh/kWp in 2016. The main reason of that decrease was the grid problems and accompanying inverter failures. According to the measurements till the end of October 2017, this rate has already exceeded the whole year value of 2016 and 2015 separately.

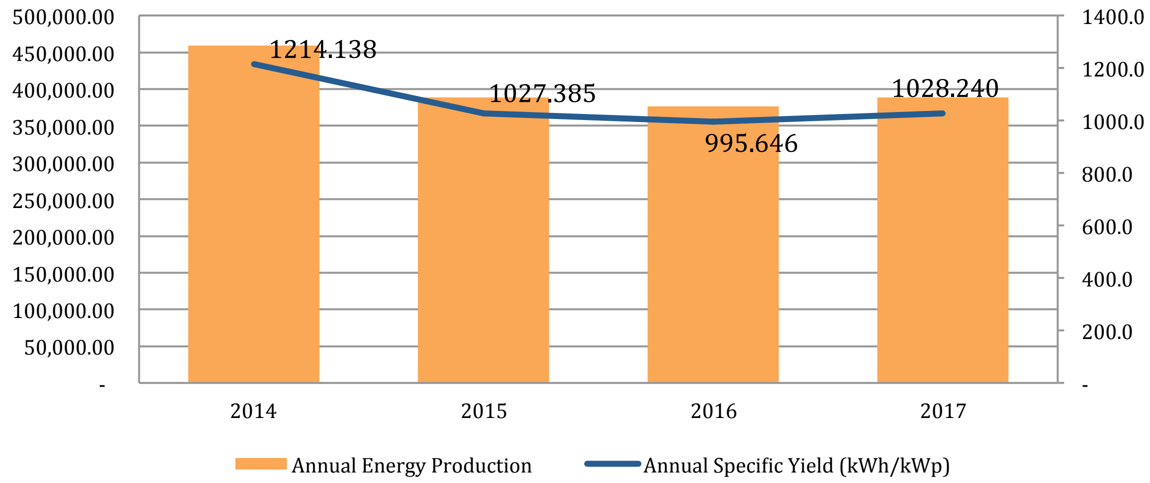


Figure 3-23 Annual Energy Production (kWh) and Capacity Factor (kWh/kWp) of Whole PV System

Beside plant or sub plant energy production performance, the inverter performance, error rates, and operation details should be investigated. As it is mentioned before, there are 19 inverters consisting of 17 pcs of 21kWp-capacity ones and 2 pcs of 10.5kWp-capacity ones. The overall energy production for each 21kWp-inverters is around 90-100MWh while INV 01.01, INV 03.11 and INV 04.12 are lower than this. In addition, INV 03.09 has energy production lower than the half of other 10.5kWp-inverter as shown in Figure 3-24.

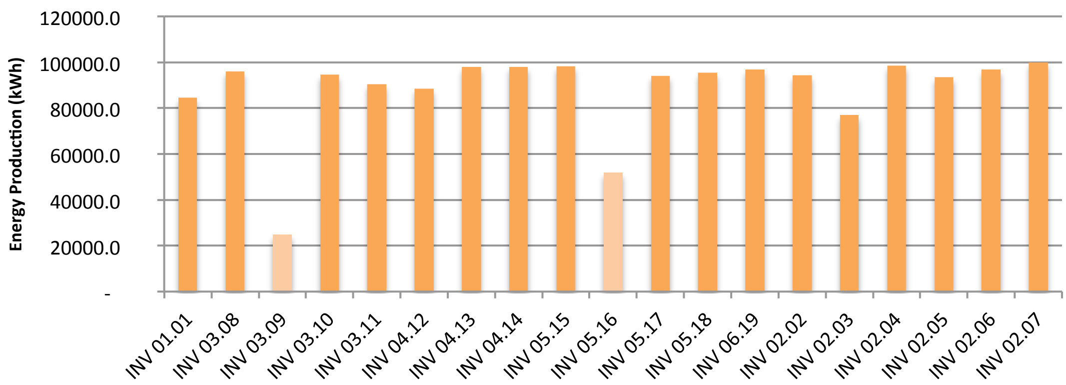


Figure 3-24 Lifetime (Jan 2014 - Dec 2017) Energy Production by Inverters

YIELD	INV 01.01	INV 03.08	INV 03.09	INV 03.10	INV 03.11	INV 04.12	INV 04.13	INV 04.14	INV 05.15	INV 05.16	INV 05.17	INV 05.18	INV 06.19	INV 02.02	INV 02.03	INV 02.04	INV 02.05	INV 02.06	INV 02.07
Q1 2014	44,74	57,93	55,90	59,23	59,90	56,83	61,12	57,76	56,96	61,62	56,31	57,29	59,44	51,91	59,66	60,29	2,04	60,07	61,12
	51,21	64,76	62,67	66,58	65,93	63,50	67,73	63,53	68,25	70,97	65,60	66,56	69,64	62,16	63,39	12,13	-	72,19	67,38
	96,30	108,57	104,94	108,37	105,19	103,72	110,20	106,91	107,51	109,44	102,69	104,16	97,81	97,45	98,79	103,36	79,96	82,48	101,69
Q2 2014	102,08	134,76	119,03	133,42	127,96	128,07	135,68	132,82	131,97	134,37	126,54	129,08	131,46	129,79	132,72	134,69	133,29	-	131,11
	110,20	153,60	115,18	145,26	142,12	147,04	155,70	153,11	152,28	154,46	145,77	148,53	97,11	144,70	145,30	154,56	153,10	107,45	154,27
	139,20	144,49	137,44	142,26	132,74	144,10	154,17	152,20	135,29	136,90	129,25	133,92	146,53	143,02	151,57	154,90	151,74	154,37	153,13
Q3 2014	163,30	174,70	126,32	167,99	161,99	166,60	178,88	176,92	174,94	177,17	168,29	174,83	170,60	166,97	170,86	181,13	175,12	178,75	177,48
	142,07	148,90	69,83	147,49	140,47	145,24	158,28	155,83	150,40	153,47	145,55	150,22	151,39	153,34	156,26	160,08	155,49	159,19	157,60
	109,10	116,24	104,18	116,88	112,50	107,87	120,49	117,74	115,17	118,36	110,46	113,49	115,12	117,19	118,77	121,90	117,77	120,73	120,43
Q4 2014	71,79	60,47	55,67	62,00	60,18	67,92	78,41	75,48	71,61	75,40	68,38	69,87	71,71	75,09	77,37	79,60	76,37	78,97	79,17
	38,36	47,97	37,72	49,39	48,75	43,90	51,56	48,46	47,62	51,43	45,71	46,75	49,17	48,31	50,45	52,42	49,99	51,88	52,41
	32,60	32,29	-	34,51	34,62	33,45	39,99	35,27	35,67	39,84	34,62	34,59	37,68	35,42	36,78	40,30	37,29	39,48	40,64
Q1 2015	39,67	17,00	-	17,68	17,34	40,09	48,02	43,92	41,91	45,85	39,57	40,73	44,86	40,47	46,04	47,67	44,86	47,20	47,68
	2,70	29,55	-	27,15	24,33	41,95	50,39	47,97	41,88	43,73	38,86	41,57	39,65	44,30	43,27	46,93	44,43	46,80	45,86
	64,02	79,91	14,45	80,81	76,88	69,46	81,49	79,45	77,00	79,79	72,31	73,86	76,39	78,73	77,72	82,24	76,50	81,50	81,68
Q2 2015	109,50	110,93	-	109,64	105,35	126,12	142,27	139,67	136,95	141,01	129,71	132,24	136,40	138,26	139,50	143,19	135,44	143,03	141,37
	143,67	130,50	76,05	128,80	121,15	147,16	165,01	163,71	158,66	162,53	151,33	155,57	138,55	149,51	162,49	166,93	155,38	166,36	164,05
	-	141,85	114,24	139,31	128,09	129,98	147,36	146,30	136,39	140,38	130,04	134,48	133,26	107,75	145,61	118,57	140,92	148,88	147,05
Q3 2015	153,12	161,85	107,02	157,26	146,99	161,41	180,52	179,30	173,87	176,82	165,59	174,89	169,55	173,10	177,75	182,55	174,90	182,48	179,33
	87,14	109,97	11,37	107,95	102,64	132,23	150,59	148,05	124,46	129,17	118,59	119,01	140,43	133,77	135,49	139,20	131,62	138,28	137,30
	84,02	97,76	0,01	96,57	92,93	97,59	113,28	110,55	92,28	96,56	87,75	90,37	91,88	87,37	43,70	90,60	85,00	89,98	89,17
Q4 2015	57,67	52,79	-	53,90	51,68	57,85	70,53	67,95	58,13	62,29	54,59	56,17	58,55	64,06	-	66,77	62,96	66,53	66,15
	57,62	53,17	-	54,28	53,79	55,30	68,53	61,99	59,41	66,19	57,03	58,17	61,82	55,37	-	60,68	57,42	61,08	61,70
	41,76	0,01	-	0,01	0,01	39,90	49,95	43,57	42,90	49,31	41,46	41,11	45,27	35,44	32,80	39,45	36,40	39,62	40,48
Q1 2016	17,26	31,02	-	25,50	23,88	29,81	38,30	36,20	27,05	29,28	25,51	27,40	25,30	29,62	2,02	30,60	30,20	31,77	31,73
	34,84	65,01	-	65,03	64,45	54,67	67,17	63,96	61,10	65,71	57,04	58,50	61,21	63,22	-	66,33	64,03	67,64	67,44
	51,58	95,95	-	95,55	90,95	80,27	96,34	94,14	45,73	47,59	42,19	42,90	44,29	43,74	-	47,72	46,19	48,74	48,43
Q2 2016	122,80	150,94	-	147,17	139,37	104,55	121,20	119,55	143,13	147,62	133,69	134,48	137,50	147,13	107,67	149,93	144,57	152,78	151,00
	139,90	127,80	-	124,50	115,38	-	-	-	123,52	127,36	115,33	116,29	117,90	127,05	127,62	130,21	125,80	132,37	130,20
	99,70	151,51	-	146,89	134,82	85,04	96,54	95,68	151,94	158,52	144,51	146,46	146,49	155,75	103,47	160,99	155,59	162,10	159,89
Q3 2016	151,12	172,92	-	166,07	152,75	57,33	65,05	64,46	166,01	175,19	160,07	162,66	162,65	166,46	-	178,19	170,00	176,95	175,07
	81,64	129,56	-	125,54	117,28	123,14	142,55	140,15	129,16	138,87	125,44	126,19	130,00	126,68	-	141,38	132,68	139,96	137,95
	104,16	117,93	-	114,52	109,34	107,93	126,44	123,21	114,45	122,78	110,00	109,46	115,61	60,51	-	66,80	63,43	66,76	66,35
Q4 2016	76,98	73,90	-	74,66	72,37	70,07	84,11	80,74	68,78	75,20	65,99	65,81	69,85	61,43	37,92	58,87	63,02	66,97	67,00
	49,86	46,71	25,55	48,58	47,88	45,48	56,36	51,47	42,71	48,29	41,10	40,76	44,19	50,22	48,87	42,03	51,23	55,84	56,05
	33,90	30,71	31,03	31,27	32,78	33,36	42,05	36,52	28,09	32,78	27,93	27,78	30,38	27,08	29,76	31,76	30,38	32,77	32,33
Q1 2017	23,50	25,89	25,93	25,99	26,10	23,60	28,76	26,74	22,98	26,14	21,70	21,73	23,97	18,70	17,90	19,91	19,12	20,35	20,44
	51,99	54,98	55,62	56,14	55,63	54,79	66,91	63,24	58,38	65,31	56,11	55,86	60,88	62,04	57,01	65,43	62,88	66,47	66,11
	69,18	100,05	99,90	99,91	96,73	85,30	101,72	98,07	89,97	99,39	87,42	87,03	92,59	96,19	79,70	98,80	95,16	100,34	99,37
Q2 2017	132,48	138,50	110,45	129,45	129,81	123,13	143,26	139,32	130,56	140,13	125,68	125,04	131,66	131,37	106,93	136,78	132,73	139,20	136,89
	144,29	152,72	112,60	150,18	140,21	133,14	153,78	149,59	142,02	150,67	136,00	136,41	140,62	148,40	118,77	151,11	146,71	153,95	150,96
	145,69	83,04	68,29	81,33	75,25	134,79	154,94	150,55	144,17	153,31	137,56	138,55	140,28	77,84	65,31	81,75	78,87	83,25	81,91
Q3 2017	155,81	122,09	107,47	118,98	110,94	150,34	17,24	166,20	161,79	171,21	155,03	155,94	157,23	116,23	92,39	118,36	114,27	120,01	117,56
	131,06	142,17	122,14	137,56	128,49	124,02	143,97	138,26	132,47	141,39	127,23	124,38	131,15	136,56	113,09	139,67	133,69	140,02	136,99
	121,69	130,10	95,31	126,71	122,68	114,16	132,10	126,32	121,58	129,93	117,03	113,93	121,79	125,55	106,12	128,07	123,46	128,87	126,22
Q4 2017	65,72	97,13	95,00	96,18	96,97	85,71	101,61	95,20	91,12	99,94	88,07	86,93	92,95	93,23	84,94	97,75	94,52	99,75	98,16
	36,19	59,81	60,84	61,56	61,38	52,54	63,92	58,00	55,41	62,86	54,00	53,40	57,99	56,79	57,34	61,14	58,03	62,39	61,56
	40,94	44,50	46,28	47,66	48,51	39,53	48,43	41,86	41,84	48,95	41,43	40,14	44,67	40,20	43,38	45,42	41,61	45,67	45,94

Table 21 System Monthly Performance Comparing with Solar Energy by Inverters

The heat map in Table 21, refers to the monthly energy production (kWh) of each inverters divided by kW_{DC-STC}. This performance metric is called 'Yield' and gives the highest and lowest performed inverters and its time period. It is clearly seen that low-performed months have important affects on each inverter and act crucial role for revenue loss. There are 30 full-months of non-operation period in total of 8 different inverters. Although the loss of whole system low performance cost around 900.000 kWh according to the expected energy production based on the calculations with sun-hour data, full-month non-operated inverters cost directly 49.500 kWh equals to 17,244 TL.

Another realistic calculation based on the monthly maximum produced energy shows that if all the inverters' energy production is equal to the highest one then, total energy production would have been 1,957,657 kWh instead of 1,672,324 kWh. The difference of 285,333 kWh equals to 99,867 TL losses. Operation and maintenance procedures of the system may be improved to decrease those losses for the lifetime of PV system.

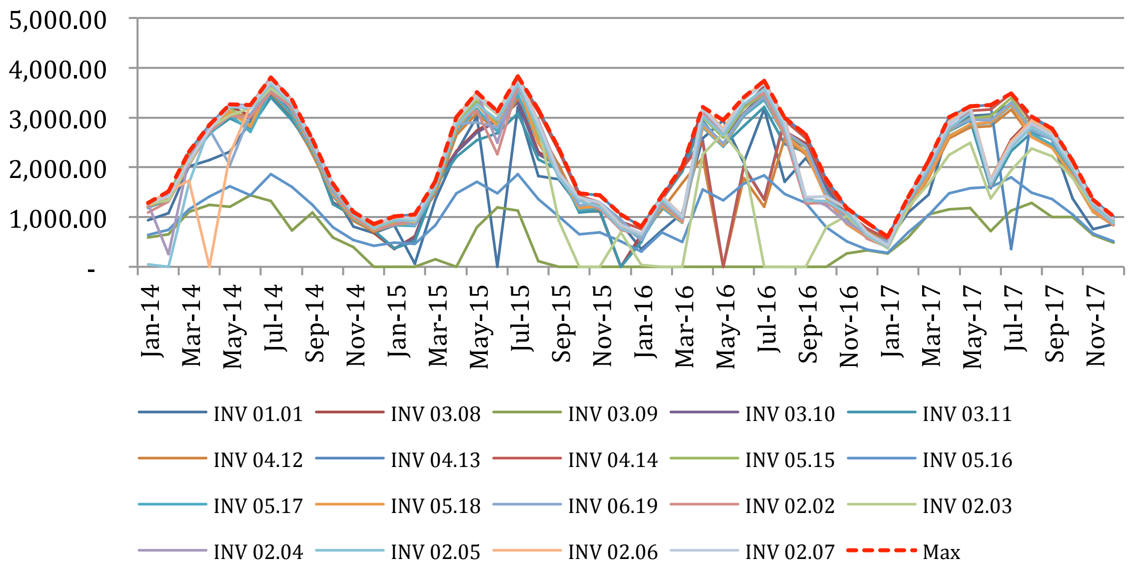


Figure 3-25 Monthly Energy Production (kWh) of Each Inverters and Their Max Production Line

In addition; investing on daily energy production of each Sub Plant (Energy Distribution Center, Engineering Faculty, Business Administration Faculty and ScOLa) for 4-year (2014, 2015, 2016, 2017) of operation provides data emphasizing deeply the importance of system monitoring and need for maintenance. In 4-year-time, equals to 1,461 days, the maximum loss occurred in Energy Distribution Center as shown in Table 22. The Low-Performed Days, can be accepted as zero-production day, provides the operational performance index, OPI (Daily, <1%, Annual) for each sub-plant. While the lowest OPI is 1.50% for Business Administration Faculty, Energy Distribution Center has the highest OPI with 15.74%. For entire system OPI rate, it should be calculated with weighted average according to the installed power of each sub-plant. Average Low-Performance Days for entire system are 75 days and the OPI rate is around 5.14%.

Table 22: Sub Plant based Number of Low-Performed Days (<1%) for 2015-2017

	ScOLa	**Energy Distribution Center**	**Business Administration Faculty**	**Engineering Faculty**
2014	3	36	2	3
2015	25	93	7	16
2016	51	67	12	41
2017	33	34	1	8
Total	**112**	**230**	**22**	**68**
	7.66%	15.74%	1.50%	4.65%

All those under performed days were because of grid quality, grid faults and etc. The most frequent alarms gathered from the system are:

- Grid Undervoltage, means one or more phases of the grid have voltage value under limits
- Under/Over frequency, means grid frequency is under/above the limits (less than 49.8Hz – 50.2Hz)
- Regulator Undervoltage, means that negatively boosted DC link has dropped below the mains peak value.
- Grid Fault, means grid is not available for running the system
- Connection Check, means communication network disabled

Table 23: Annual Energy Production of Sub Plant

Annual Production (kWh)	**ScOLa**	**Energy Distribution Center**	**Business Administration Faculty**	**Engineering Faculty**
2014	152,812	23,120	167,187	115,826
2015	143,989	17,659	139,457	106,728
2016	125,081	20,239	128,575	102,461
2017	138,465	23,489	155,531	111,705
Total	**560,347**	**84,507**	**590,750**	**436,720**
Total Non-Zero Operation Days	1,348	1,230	1,438	1,392

Table 24: Daily Average Energy Performance Rate for Non-Zero Operation Days

Daily Average Energy Performance Rate kWh/(Days-kWp)	ScOLa	Energy Distribution Center	Business Administration Faculty	Engineering Faculty
2014	3.35	3.35	3.37	3.39
2015	3.36	3.09	2.85	3.24
2016	3.16	3.23	2.67	3.35
2017	3.31	3.38	3.13	3.31
Average	**3.30**	**3.26**	**3.01**	**3.32**

According to the daily average energy performance rates, Engineering Faculty has the lead although Business Adm. Fac. has the least zero performance days. These performance rates are 3.05, 2.76, 2.96, and 3.17 successively while considering whole days of year.

Table 25: Performance Rate on Non-Zero Days (Actual/Simulated)

Production Performance on Non-Zero Days	ScOLa	Energy Distribution Center	Business Administration Faculty	Engineering Faculty
2014	72%	70%	73%	73%
2015	72%	69%	62%	70%
2016	65%	67%	56%	67%
2017	71%	68%	65%	68%
Average	**70%**	**69%**	**64%**	**70%**
For Entire Days of Year	63%	57%	61%	66%

There is also dramatic change on sub-plant energy production performance while taking non-zero days into account. There are different types of system performance parameters as shown on Table 9, however; performance rates should be divided into two; production based performance parameters and operation based performance parameters.

Additionally, the non-zero operation days have different performance rate according to the sun energy. More than 80% of entire system life has production performance rate between 60%-80%. This rate even changes according to the sub-plants as shown on Table 25.

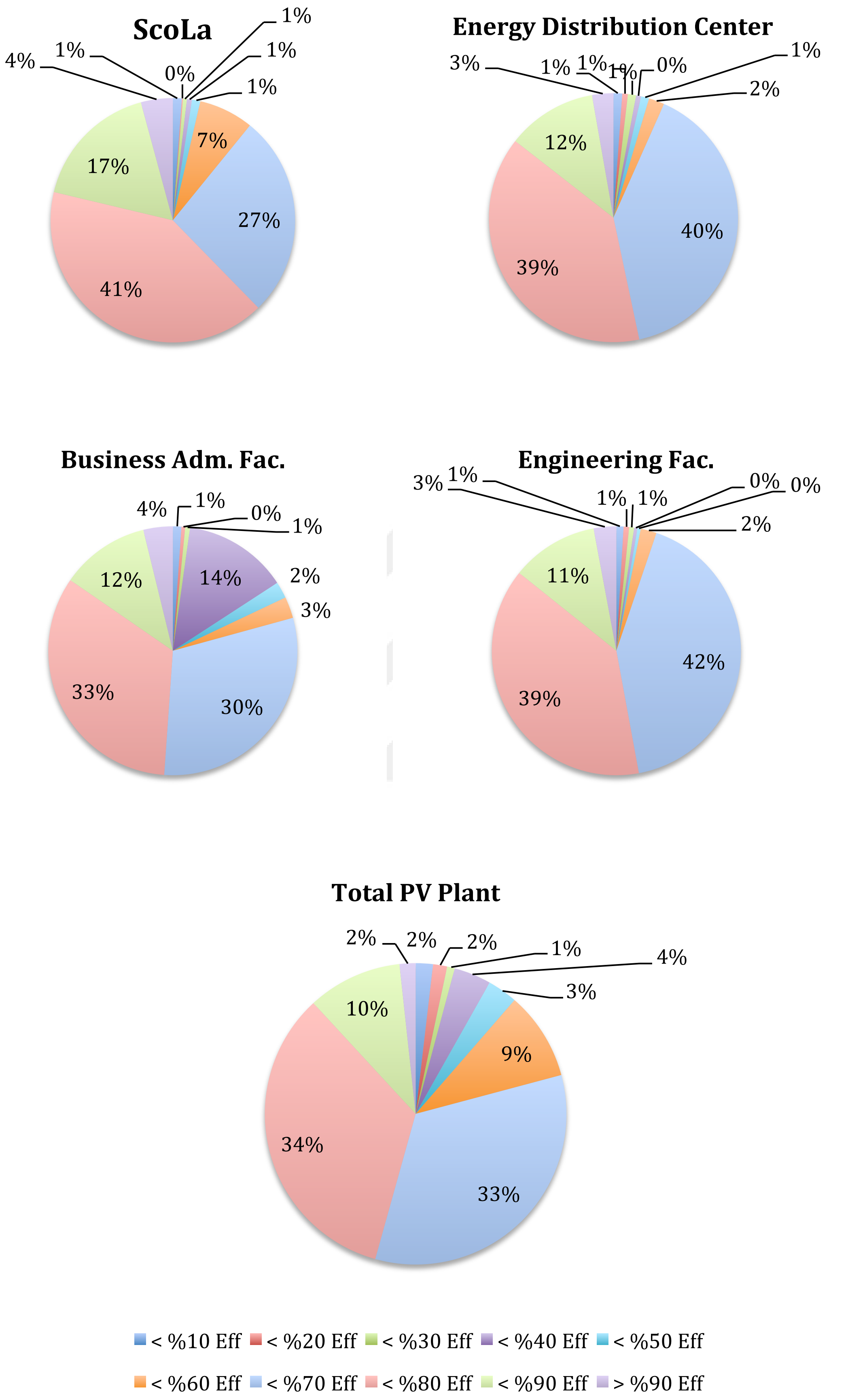


Figure 3-26 Percentage of Operation Life-Time according to the Daily Performance Rate

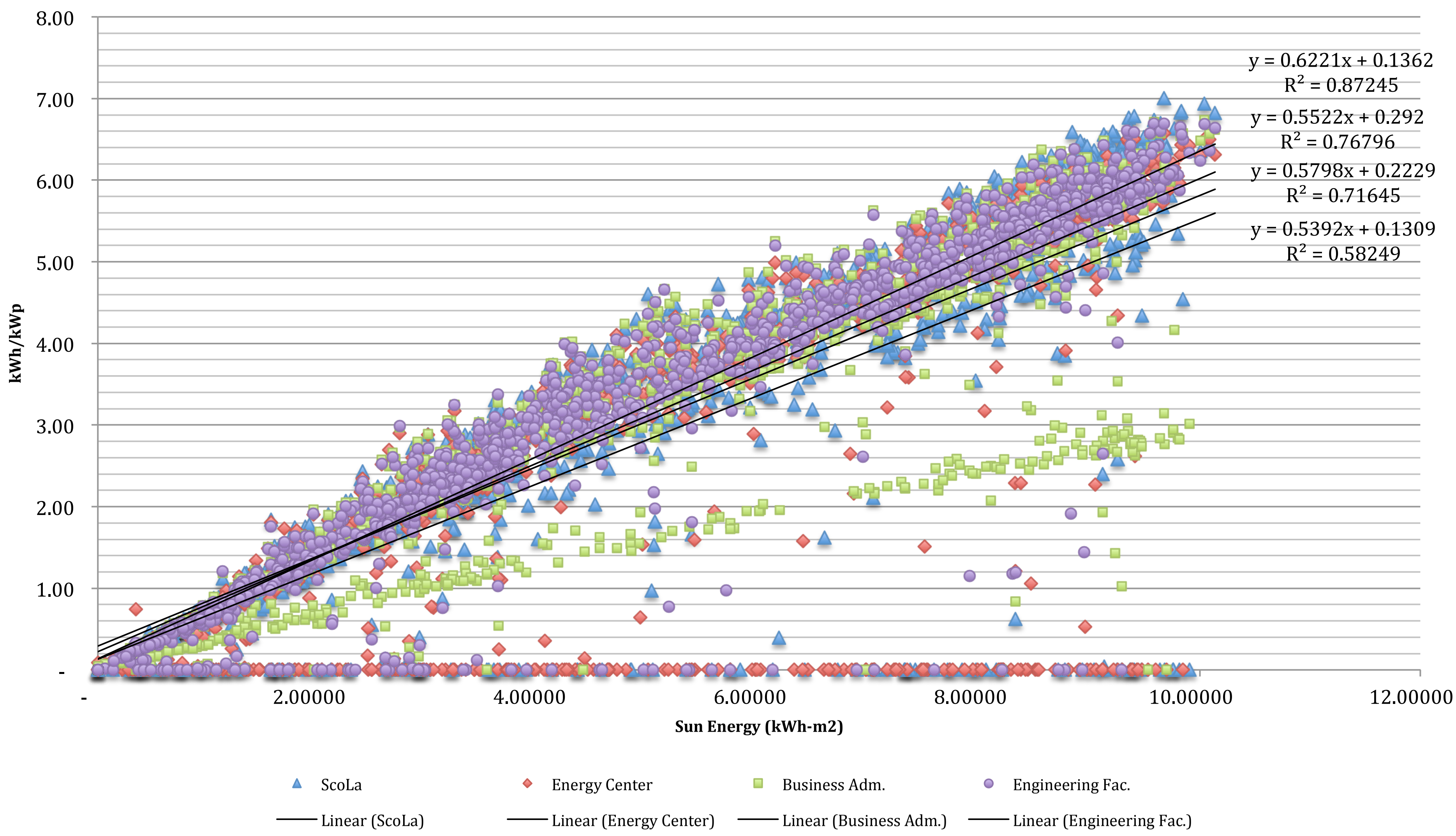


Figure 3-27 Comparison of Sub-Plant Performance by solar energy (kWh-m2)

4-year operation time of each sub-plant has been identified by daily energy production values compared with the solar-energy in Figure 3-27. The scatter graph and linearity function provide insights about the daily performance distribution of each sub-plant for 1.460 days.

- Engineering Faculty: y=0.6221x + 0.1362, R^2= 0.87245
- Business Administration Faculty: y=0.552x + 0.292, R^2= 0.76796
- ScoLa: y=0.5798x + 0.2229, R^2= 0.71645
- Energy Distribution Center: y=0.5392x + 0.1309, R^2= 0.58249

As it is seen on the graph, Engineering Faculty is the best performing sub-plant while Business Administration Faculty has half performing days, which has high impact on the low performance. ScoLa has the largest range of performance rate especially for the higher sun energy days. It is clear that the points below the linear lines refer to the low-performance days. There is even second lower line path for Business Administration sub-plant, which shows a long-lasting failure on the system operation, which affect some of the inverters under the sub-plant. All these energy daily production data by sub-plants is given on Appendix E.

The availability of each inverter is the most important reason behind that fluctuating energy production. The availability has been calculated according to the best operating inverter in monthly basis. Considering the operation lifetime from January 2014 to October 2017, the best operating inverter is INV 05.16 having 10.5kW capacity with 94.8% availability while the worst one is INV 03.09 having 10,5kW capacity with 44.3% availability. Availability of each inverter is given in Figure 3-28. Monthly availability of each inverter is given on Appendix F.

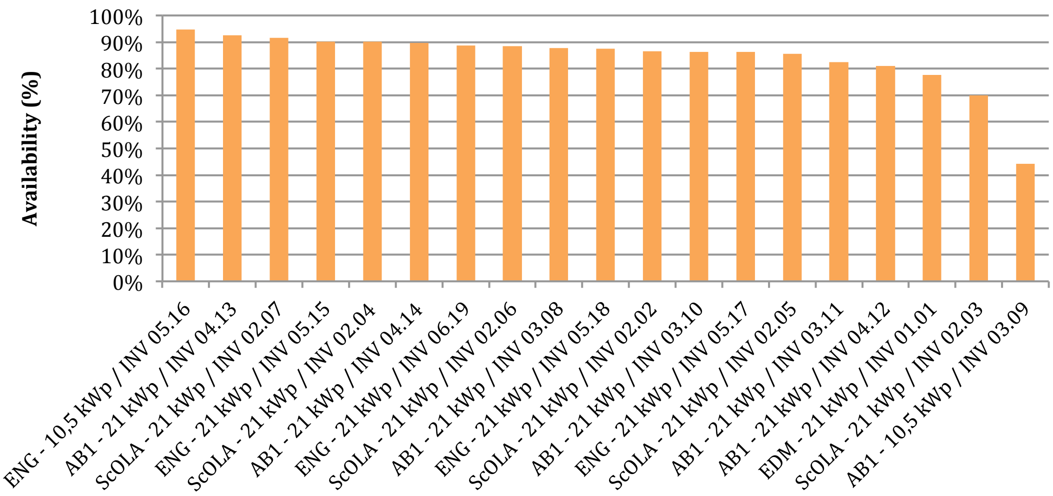


Figure 3-28 Availability of Each Inverters

If the availability of each inverter were 100%, then overall energy production would have been 1,916,941 kWh with an increase of 15.7% equal to 260,850 kWh. This extra potential refers to 91,300 TL and it is only possible with detailed monitoring and maintenance procedures to fix those failures. Hiring one qualified technician for the system operation may be the best solution for increasing the availability of the system. The cost of such solution would be around 40,000 – 50,000 TL/year according to the average conditions in 2018.

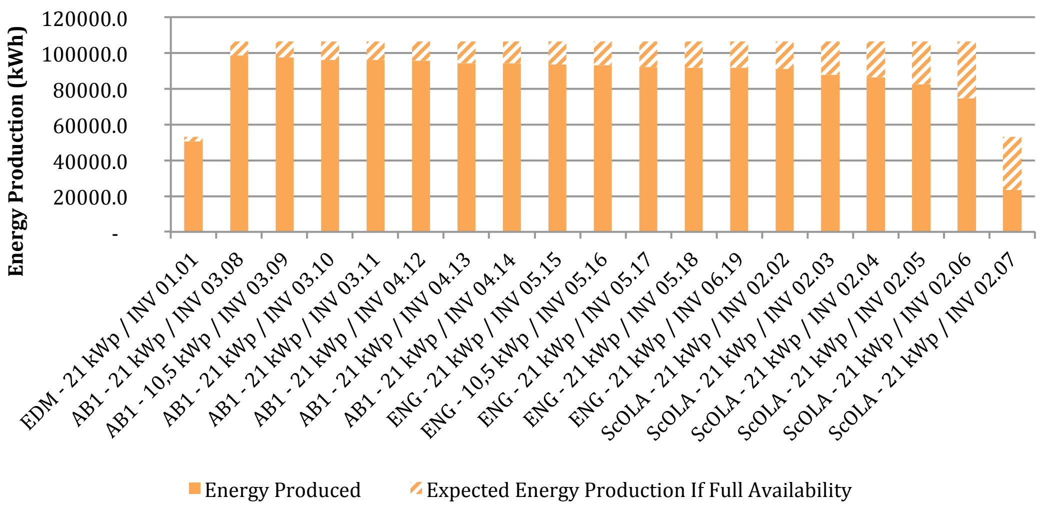


Figure 3-29 Realized Production and Expected Production if Full Availability

The operation period from January 2104 to January 2017 is 35,040 hours for each inverter and the system loss was 5,270 hours for one inverter on average. This results in 84.9% Operational Performance Index (OPI) for 48-month operation of PV system. This rate also shows the quality of operation and maintenance over the years.

In addition, taking into account those system losses and non-operating periods, the highest Power Performance Rate of 93.2% was reached with 335,399 kW instantaneous AC power on 23th May 2017.

CHAPTER IV

4 CONCLUSIONS

4.1 Conclusions

Photovoltaic system investments are long-term energy investment and although it seems simple and easy to maintain, there are lots of differentiators, which affects the energy production performance of system, from the idea to operation.

The whole operation starts with an idea of solar powered green campus and then all the project process begun. Every detail was taken into account according to the condition of those days. The project brought investors, operators, technical teams, academic research center, product suppliers and installation teams together; which eased the progress starting from legal applications to installations and commissioning. Since it was 2013 and early times for the regulatory procedures in Turkey, each party learnt the progress on the job and found the gaps of the system as well. It was the first campus-wide project, first order for the PV module supplier and the biggest project for the inverter manufacturer in Turkey. Although those 'first's created some obstacles for the process, these are the small variables depending on the design and application procedures considering whole lifetime of PV system.

While this thesis focused on photovoltaic technology and life cycle of building integrated PV projects in Turkey with a sample of Ozyegin University application; it deeply investigates the performance parameters of system operation. There are lots of well-accepted KPIs as PV system performance measurement however, the production results and performance parameters of Ozyegin University system strongly shows that one of the most important reason of low-performed PV systems is ineffective system operation and maintenance. Behind this problem there are even lots of reasons from grid quality to inverter compatibility.

Since the beginning of 2014, in which the whole PV system started energy production, 1,656,088 kWh energy was generated and it made campus save around 580,000 TL. It is made by 378 kWp including 19 pcs of inverter over the top of the 4 different campus building. Additionally, 4-year time provided some striking results about the performance of inverters and system. The average availability rate of each inverter was around 85% according to the operation time and this resulted in 260,a850 kWh losses only because of lack of operational efficiency.

In today's digital world, this system loss may easily be solved with different methods. Even if, using manpower would be conventional solution; it is clear that it would be worth to dedicate a technician for the system operation to save two times more than the cost of it. However, the key is the technology in order to save 5 times more than the cost of solution. Energy analytics software platforms powered by machine learning algorithms are the most promising solution for the long lifetime of the power plant. As they have a learning structure behind, adaptive data aggregator for any kind of system and analytics libraries to create relations among different type of data; they can serve fastest and easiest solution for operational efficiency and PV power plant management.

4.2 Suggestions for Future Work

After these investigations, the next steps may be smart grid integration of photovoltaic system with digitalization and their impacts on grid as well as the most promising business models applicable for Turkey in order to increase the technology penetration.

Smart grid integration should cover details of ICT infrastructure, communication/control standards, utility engagement and demand side management (DSM) technologies. As DSM is the critical milestone for the energy market transformation, photovoltaic system will act a critical role for instantaneously energy supply management, which requires energy market integration.

Strategy, government support and business models are the key for implementing new technologies into countries. Considering the solar energy expansion, which is highly regulative issue for each country, all the strategies for the market penetration have been based on governmental initiatives. However, all those strategies depend on the development of country, its economical vision, its technology infrastructure and its regulations.

As it is know, Turkey is a developing country and the biggest obstacle to go through a phase is almost 70% of foreign-source dependency on energy market. Therefore, solar energy becomes the most important and promising technology for Turkey, which has two times more solar energy potential than Germany. The Renewable Energy Law and its additional packs starting from 2010, might have had great infrastructure beyond however, the critical and more important part was implementation of those regulatory infrastructure. In the end, the system may have worked but it crashed in 2017 and no more additional approval is being accepted. This solar energy expansion should be fast but careful because time is money on the other hand, there is no transmission or distribution infrastructure, which has a capability to handle such fast penetration.

Considering all those technical details done, business model and strategy comes second.

If energy consumed and produced with renewables in a same place without any dependence to others then, this would be an ideal energy distribution. Countries should take into account those steps:

- Strengthen electricity infrastructure available to solar energy fluctuations
- Lighten procedures for on site PV systems for internal energy usage
- Tax Exemptions, Bank Credit Models, Purchasing Guarantee, P2P Energy Trade should be defined and implemented strictly
- The procedure should differ by system capacity and type.

CHAPTER V

5 APPENDICES

5.1 APPENDIX A – Application Documents

Grid Connection Application Form:

EK-1

LİSANSSIZ ÜRETİM BAĞLANTI BAŞVURU FORMU

Başvuru Sahibinin Bilgileri			
Adı-Soyadı/Ünvanı			
Adresi			
Telefonu			
Faks Numarası			
E-Posta Adresi			
T.C. Vergi/ T.C. Kimlik Numarası			
Banka Hesap Numarası			
Üretim Tesisinin Bilgileri			
Adresi			
Coğrafi Koordinatları (UTM 6-ED50)			
Kurulu Gücü			
Bağlantı İçin Talep Edilen Tarih			
Sistem Kullanımına Başlaması İçin Öngörülen Tarih			
Türü / Kullanılan Kaynak			
Bağlantı Şekli	☐ **AG Tek Faz**	☐ **AG Üç Faz**	☐ **YG**
Bağlantı Transformatörü Bilgileri			
Diğer Bilgiler			
Bu formda verilen tüm bilgiler tarafımca doğru bir şekilde doldurulmuştur. Başvurumun kabul edilmesi durumunda; üretim tesisini bu formda belirtilen özelliklere uygun olarak tesis etmeyi, tesis aşamasında, İlgili Şebeke İşletmecisinden gerekli izinleri almadan, bu formda belirtilen bilgilere aykırı bir işlem tesis etmeyeceğimi, bu formda verilen bilgilere aykırı bir durum tespit edilmesi halinde başvurumun her aşamada İlgili Şebeke İşletmecisi tarafından iptal edilmesini kabul ve taahhüt ederim.			
Adı-Soyadı/Ünvanı	**İmza**	**Tarih**	

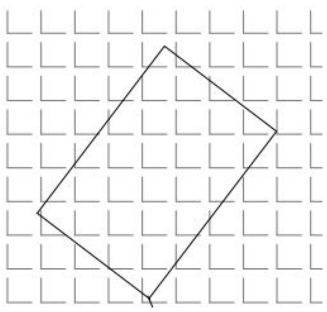
Sample for PV System Application Project:

CITY:	İSTANBUL	OZYEGIN UNIVERSITY PV SYSTEM PROJECT
DISTRICT:	BÜYÜKÇEKMECE	
STREET/AVE:	AKÇABURGAZ MAH.	
MAP SECTION:	F21D18D1D	

BLOCK NO:	LAYOUT NO:	AREA OF DEED:	OWNER:
224	10	92.470,00 m2	HAKAN YALÇIN

Coordinates 6 degree UTM ED 50

K1	634733.00	4546958.00
K2	634721.00	4546957.00
K3	634721.00	4546983.00
K4	634726.00	4546983.00
K1	634730.00	4546988.00
K2	634725.00	4546988.00
K3	634721.00	4547002.00
K4	634726.00	4547000.00



	PREPARED and APPROVED by
NAME SURNAME	
TITLE	
DATE	
SIGNATURE	

Technical Assessment Form:

GÜNEŞ ENERJİSİNE DAYALI ÜRETİM TESİSİNE İLİŞKİN TEKNİK DEĞERLENDİRME FORMU

BAŞVURU SAHİBİNİN ADI ve İLETİŞİM BİLGİLERİ			
TESİS ADI			
DAĞITIM ŞİRKETİNE BAŞVURU TARİHİ			
ÜRETİM TESİSİNİN YERİ	**İLİ**		
	İLÇESİ		
	KÖY/MAHALLE		
	ADA / PARSEL NO		
TEKNOLOJİ TÜRÜ	**FOTOVOLTAİK SİSTEMLER;** ☐ Optimum açıda sabitlenmiş fotovoltaik sistemler ☐ Tek eksende güneşi takip eden fotovoltaik sistemler ☐ Çift eksende güneşi takip eden fotovoltaik sistemler **TERMAL SİSTEMLER;** ☐ Parabolik oluklu doğrusal odaklayıcılı sistem (ısı depolama ünitesi kullanılan) ☐ Parabolik oluklu doğrusal odaklayıcılı sistem (ısı depolama ünitesi kullanılmayan) ☐ Doğrusal odaklayıcılı düzlemsel aynalar kullanılan sistemler (Fresnel) ☐ Kule ve üzerinde buhar üreten reaktör hücresi bulunan merkezi odaklayıcılı sistemler ☐ Stirling motoru kullanan merkezi odaklayıcılı çanak tipi sistemler **DİĞER SİSTEMLER;** ☐ Hibrit (…………………….....……kaynağı ile)		
UYGULAMA YERİ	☐ Çatı ☐ Arazi		
FOTOVOLTAİK SİSTEMLERDE KULLANILACAK HÜCRE TÜRÜ	☐ İnce film veya organik yapılı ☐ Çok Kristalli yapı ☐ Tek Kristalli yapı ☐ Çok katmanlı yapı		
Ünite/Modül gücü (Wp)			
Ünite/Modül sayısı (adet)			
Evirici gücü (W)			
Evirici sayısı (adet)			
Tesis toplam kurulu gücü DC (kWp)			
Tesis toplam kurulu gücü AC (kWe)			
Tercih edilen trafo merkezinin (bağlantı noktası) adı			
Santral Sahası Alanı (m^2)			
Projeksiyon Sistemi			
TESİSİN KURULACAĞI ALANIN KÖŞE NUMARASI	**Doğu (sağa değer)**	**Kuzey (yukarı değer)**	**Dilim Orta Boylamı**
K1			
K2			
K3			
K4			
…			
Kn			

Not: Santral sahası alanının dış çizgileri boyunca oluşan köşe noktalarına ait koordinatlar (K1, K2,.., Kn) birbirini takip eden sırada olacak şekilde forma doldurulmalıdır.

Application Letter:

BOĞAZİÇİ ELEKTRİK DAĞITIM A.Ş. GENEL MÜDÜRLÜĞÜ
YATIRIM PLANLAMA YÖNETMENLİĞİ' NE

Tarih: .… / .… / 201..

BAĞLI BULUNDUĞU BÖLGE MÜDÜRLÜĞÜ/ İŞLETME MÜDÜRLÜĞÜ:……….……………………………

TÜZEL / GERÇEK KİŞİNİN ADI–ÜNVANI:…………………………………………………..…………..
……………………………………………………..………

LİSANSSIZ ÜRETİM İSTENEN YERİN;

Adresi :……………………………………………………………….……………………….…..…
……………………………………………………………………………………………..………………...

Tesisat No :………………………………

Mevcut Dağıtım Bağlantı Gücü :……………………………...

Üretim Talep Edilen Güç :…….……………………..

Üretim Kaynak Türü :……………………………... (Güneş/Rüzgar/Kojenerasyon vb.)

AÇIKLAMA: .... nolu tesisata aboneyim, ……………….….……………………... …………………………………………………………… adresinde elektrik kullanıyorum. Yukarıda belirttiğim üretim adresinde ….…….. kW …..…..……. (Güneş / Rüzgar / Kojenerasyon) tesisi kurarak Lisanssız Elektrik Üretimi yapmak için bağlantı görüşünün verilmesi ve gerekli yasal işlemlerin yapılmasını arz ederim.

Başvuru Sahibinin veya Vekilinin

Adı Soyadı :……………………………………..….

İmzası :

Başvuru Sahibinin veya Vekilinin İletişim Bilgileri:

Tel/Faks :….………………………………

Mail Adresi :….……………@…………………

Adresi :….………………………………
….………………………………
….………………………………

EKLER:

-Lisanssız Elektrik Bağlantı Başvuru Formu (Ek-1)
-Yenilenebilir Enerji Genel Müdürlüğü Teknik Değerlendirme Formu (Ek-2)
-Koordinatlı ve Onaylı Aplikasyon Krokisi (6 derece – ED 50) (Ek-3)
-Öngörülen Bağlantı Tek Hat Şeması (OG ve AG) (Ek-4)
-Tapu Senedi ve Başvuru Yapılan Parselin Takyidatlı Tapu Kayıt Örneği
-Kira Sözleşmesi (var ise-Üretim Cihaz ömrü kadar)
-Üretim Santral Yerleşim Planı ve Proje Bilgi Notu
-Üretim Santral Teknik Dokümanları
-BEDAŞ Abonelik Fatura Fotokopisi
-Vekaletname (Vekil ise)
-Çoklu Ortaklık Yapısına Sahip Parseldeki Maliklerden Muvafakatname Alınması
-Lisanssız Üretim Başvuru Ücret Makbuzu* **(2017 yılı 0-250 kW ücretsiz/ 250 kW üstü 536,41 TL+KDV)**

* Başvuru Bedeli dosya teslimi sırasında BEDAŞ veznesine yatırılmış olmalıdır.

5.2 *APPENDIX B – Product Datasheets*

Photovoltaic Module:

YGE 60 Cell 40mm SERIES

ELECTRICAL PERFORMANCE

Module type			YL250P-29b	YL245P-29b	YL240P-29b	YL235P-29b	YL230P-29b
Power output	P_{max}	W	250	245	240	235	230
Power output tolerances	ΔP_{max}	W	-0 / +5				
Module efficiency	η_m	%	15.3	15.0	14.7	14.4	14.1
Voltage at P_{max}	V_{mpp}	V	30.4	30.2	29.5	29.5	29.5
Current at P_{max}	I_{mpp}	A	8.24	8.11	8.14	7.97	7.80
Open-circuit voltage	V_{oc}	V	38.4	37.8	37.5	37.0	37.0
Short-circuit current	I_{sc}	A	8.79	8.63	8.65	8.54	8.40

STC: 1000W/m² irradiance, 25°C cell temperature, AM1.5g spectrum according to EN 60904-3.
Average relative efficiency reduction of 5% at 200W/m² according to EN 60904-1.

Power output	P_{max}	W	181.1	177.9	174.3	170.7	167.0
Voltage at P_{max}	V_{mpp}	V	27.6	27.2	26.6	26.6	26.6
Current at P_{max}	I_{mpp}	A	6.56	6.54	6.56	6.42	6.29
Open-circuit voltage	V_{oc}	V	35.4	34.5	34.2	33.8	33.8
Short-circuit current	I_{sc}	A	7.12	6.99	7.01	6.92	6.81

NOCT: open-circuit module operation temperature at 800W/m² irradiance, 20°C ambient temperature, 1m/s wind speed.

THERMAL CHARACTERISTICS

Nominal operating cell temperature	NOCT	°C	46 +/- 2
Temperature coefficient of P_{max}	γ	%/°C	-0.45
Temperature coefficient of V_{oc}	β_{Voc}	%/°C	-0.33
Temperature coefficient of I_{sc}	α_{Isc}	%/°C	0.06
Temperature coefficient of V_{mpp}	β_{Vmpp}	%/°C	-0.45

OPERATING CONDITIONS

Max. system voltage	1000V_{DC}
Max. series fuse rating	15A
Limiting reverse current	15A
Operating temperature range	-40 to 85°C
Max. static load, front (e.g., snow and wind)	5400Pa
Max. static load, back (e.g., wind)	2400Pa
Max. hailstone impact (diameter / velocity)	25mm / 23m/s

CONSTRUCTION MATERIALS

Front cover (material / thickness)	low-iron tempered glass / 3.2mm
Cell (quantity / material / dimensions / # of busbars)	60 / multicrystalline silicon / 156mm x 156mm / 2 or 3
Encapsulant (material)	ethylene vinyl acetate (EVA)
Frame (material / color / anodization color / edge sealing)	anodized aluminum alloy / silver / clear / silicone or tape
Junction box (protection degree)	≥ IP65
Cable (length / cross-sectional area)	1100mm / 4mm²
Plug connector (type / protection degree)	MC4 / IP67 or Amphenol H4 / IP68

- Due to continuous innovation, research and product improvement, the specifications in this product information sheet are subject to change without prior notice. The specifications may deviate slightly and are not guaranteed.
- The data do not refer to a single module and they are not part of the offer, they only serve for comparison to different module types.

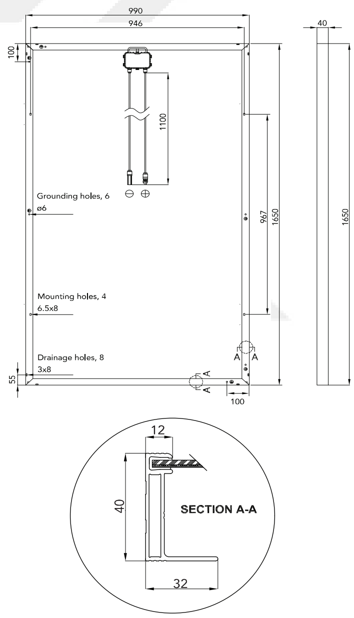
GENERAL CHARACTERISTICS

Dimensions (L / W / H)	1650mm / 990mm / 40mm
Weight	19.1kg

PACKAGING SPECIFICATIONS

Number of modules per pallet	26
Number of pallets per 40' container	28
Packaging box dimensions (L / W / H)	1700mm / 1150mm / 1190mm
Box weight	534kg

Unit: mm



Warning: Read the Installation and User manual in its entirety before handling, installing, and operating Yingli Solar modules.

Our Partners:

Yingli Green Energy Holding Co. Ltd.
service@yinglisolar.com
Tel: 0086-312-8929802

YINGLISOLAR.COM

Solar Inverter:

TECHNICAL DATA	REFU*sol* 008K	REFU*sol* 010K	REFU*sol* 013K	REFU*sol* 017K	REFU*sol* 020K
Art. No.	803R008	803R010	802R013	802R017	802R020
DC DATA					
Recommended max. PV power, kWp	9.3	11.2	13.9	18.5	21.6
MPPT range, V	370 … 850	410 … 850	420 … 850	445 … 850	480 … 850
DC start voltage, V	350				
Max. DC voltage, V	1000				
Max. DC current, A	23	25	30	38.5	41
MPP tracker	1				
Number of DC connections	3 x MC4	3 x MC4	4 x MC4	6 x MC4	6 x MC4
DC disconnection switch	Yes				
AC DATA					
Rated AC power, kVA	8.25	10.0	12.4	16.5	19.2
Max. AC active power, kW	8.25	10.0	12.4	16.5	19.2
AC grid connection	3AC 400 V + N, 50–60 Hz				
Rated power factor	1				
Adjustable displacement factor	0.9i …1… 0.9c				
Max. AC current, A	3 x 12	3 x 18	3 x 18	3 x 29	3 x 29
Distortion factor THD, %	< 2.5	< 1.8	< 1.8	< 1.8	< 1.8
Max. efficiency, %	98.0	98.0	98.0	98.2	98.2
European efficiency, %	97.3	97.4	97.5	97.8	97.8
Feed-in starting power, W	20				
Nighttime power consumption, W	< 0.5				
COOLING, AMBIENT CONDITIONS, EMC					
Cooling	Natural convection				
Ambient temperature, °C	-25 … +55				
Elevation	Up to 2000 m above sea level				
Noise, dBA	< 45				
Emitted interference	EN 61000-6-4:2007				
Interference immunity	EN 61000-6-2:2005				
Internal overvoltage protection, type	3 (acc. to EN 61643-11)				
Protection class	I (acc. to IEC 62103)				
Overvoltage category	DC: II, AC: III (acc. To IEC 60664-1)				
Environment classification	4K4H acc. to DIN IEC 721-3-4				
Certification	Current certificates can be found at http://europe.refusol.com/certifications.pdf				
SZS or grid protection	Acc. to VDE 0126-1-1				
Interfaces	Ethernet & RS485				
GENERAL DATA					
Type of protection	IP65 as per EN 60529				
Dimensions Width/Height/Depth, mm	535/601/225	535/601/225	535/601/277	535/601/277	535/601/277
Weight, kg	28.5	28.5	35.5	41.5	41.5

Subject to modification. Technical specifications are subject to change without notice.

REFU*sol* GmbH | Uracher Straße 91 | 72555 Metzingen | Germany | Tel. +49 7123 969-0 | Fax +49 7123 969-165 | info@refusol.com

5.3 APPENDIX C – Mechanical Design Report

1. Model geometry

This section provides model geometry information, including items such as joint coordinates, joint restraints, and element connectivity.

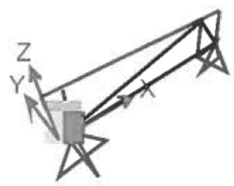


Figure 1: Finite element model

1.1. Joint coordinates

Table 1: Joint Coordinates, Part 1 of 2

Table 1: Joint Coordinates, Part 1 of 2

Joint	CoordSys	CoordType	XorR	Y	Z	SpecialJt	GlobalX
			m	m	m		m
1	GLOBAL	Cartesian	0,00000	0,00000	0,00000	No	0,00000
2	GLOBAL	Cartesian	0,08000	0,00000	0,00000	Yes	0,08000
3	GLOBAL	Cartesian	1,31500	0,00000	0,00000	No	1,31500
4	GLOBAL	Cartesian	0,08000	0,00000	0,02138	Yes	0,08000
5	GLOBAL	Cartesian	1,07000	0,00000	0,28600	No	1,07000

Table 1: Joint Coordinates, Part 2 of 2

Table 1: Joint Coordinates, Part 2 of 2

Joint	GlobalY	GlobalZ	GUID
	m	m	
1	0,00000	0,00000	
2	0,00000	0,00000	
3	0,00000	0,00000	
4	0,00000	0,02138	
5	0,00000	0,28600	

1.2. Joint restraints

Table 2: Joint Restraint Assignments

Table 2: Joint Restraint Assignments

Joint	U1	U2	U3	R1	R2	R3
2	Yes	Yes	Yes	No	No	No
3	Yes	Yes	Yes	No	No	No

H.K.

1.3. *Element connectivity*

Table 3: Connectivity - Frame, Part 1 of 2

Table 3: Connectivity - Frame, Part 1 of 2

Frame	JointI	JointJ	IsCurved	Length	CentroidX	CentroidY	CentroidZ
				m	m	m	m
1	1	3	No	1,31500	0,65750	0,00000	0,00000
2	1	5	No	1,10756	0,53500	0,00000	0,14300
3	5	3	No	0,37659	1,19250	0,00000	0,14300

Table 3: Connectivity - Frame, Part 2 of 2

Table 3: Connectivity - Frame, Part 2 of 2

Frame	GUID
1	
2	
3	

Table 4: Frame Section Assignments

Table 4: Frame Section Assignments

Frame	SectionType	AutoSelect	AnalSect	DesignSect	MatProp
1	Angle	N.A.	L40x3.1	L40x3.1	Default
2	Angle	N.A.	L40x3.1	L40x3.1	Default
3	Angle	N.A.	L40x3.1	L40x3.1	Default

Table 5: Frame Release Assignments 1 - General, Part 1 of 2

Table 5: Frame Release Assignments 1 - General, Part 1 of 2

Frame	PI	V2I	V3I	TI	M2I	M3I	PJ	V2J
2	No	No	No	No	Yes	Yes	No	No
3	No	No	No	No	Yes	Yes	No	No

Table 5: Frame Release Assignments 1 - General, Part 2 of 2

Table 5: Frame Release Assignments 1 - General, Part 2 of 2

Frame	V3J	TJ	M2J	M3J	PartialFix
2	No	No	Yes	Yes	No
3	No	No	Yes	Yes	No

H.K.

2. Material properties

This section provides material property information for materials used in the model.

Table 6: Material Properties 02 - Basic Mechanical Properties

Table 6: Material Properties 02 - Basic Mechanical Properties

Material	UnitWeight	UnitMass	E1	G12	U12	A1
	Kgf/m3	Kgf-s2/m4	Kgf/m2	Kgf/m2		1/C
6063T6	2,7126E+03	2,7680E+02	7101003224	2669550084	0,330000	2,3580E-05
S275	7,8490E+03	8,0038E+02	2,141E+10	8236169245	0,300000	1,1700E-05

Table 7: Material Properties 03a - Steel Data, Part 1 of 2

Table 7: Material Properties 03a - Steel Data, Part 1 of 2

Material	Fy	Fu	EffFy	EffFu	SSCurveOpt	SSHysType	SHard	SMax
	Kgf/m2	Kgf/m2	Kgf/m2	Kgf/m2				
S275	28042195,29	43847796,27	30846414,81	48232575,89	Simple	Kinematic	0,015000	0,110000

Table 7: Material Properties 03a - Steel Data, Part 2 of 2

Table 7: Material Properties 03a - Steel Data, Part 2 of 2

Material	SRup	FinalSlope
S275	0,170000	-0,100000

Table 8: Material Properties 03c - Aluminum Data

Table 8: Material Properties 03c - Aluminum Data

Material	AlumType	Alloy	Fcy	Fty	Ftu	Fsu	SSHysType
			Kgf/m2	Kgf/m2	Kgf/m2	Kgf/m2	
6063T6	Wrought	6063-T6	17576740,65	17576740,65	21092088,78	13358322,90	Kinematic

3. Section properties

This section provides section property information for objects used in the model.

3.1. Frames

Table 9: Frame Section Properties 01 - General, Part 1 of 6

Table 9: Frame Section Properties 01 - General, Part 1 of 6

SectionName	Material	Shape	t3	t2	tf	tw
			m	m	m	m
L40x3.1	6063T6	Angle	0,040000	0,040000	0,003100	0,003100

H.K.

Table 9: Frame Section Properties 01 - General, Part 2 of 6

Table 9: Frame Section Properties 01 - General, Part 2 of 6

SectionName	Area	TorsConst	I33	I22	AS2	AS3	S33
	m2	m4	m4	m4	m2	m2	m3
L40x3.1	0,000238	7,410E-10	3,688E-08	3,688E-08	0,000124	0,000124	1,278E-06

Table 9: Frame Section Properties 01 - General, Part 3 of 6

Table 9: Frame Section Properties 01 - General, Part 3 of 6

SectionName	S22	Z33	Z22	R33	R22	ConcCol	ConcBeam
	m3	m3	m3	m	m		
L40x3.1	1,278E-06	2,302E-06	2,302E-06	0,012438	0,012438	No	No

Table 9: Frame Section Properties 01 - General, Part 4 of 6

Table 9: Frame Section Properties 01 - General, Part 4 of 6

SectionName	Color	TotalWt	TotalMass	FromFile	AMod	A2Mod	A3Mod
		Kgf	Kgf-s2/m				
L40x3.1	White	1,81	0,18	No	1,000000	1,000000	1,000000

Table 9: Frame Section Properties 01 - General, Part 5 of 6

Table 9: Frame Section Properties 01 - General, Part 5 of 6

SectionName	JMod	I2Mod	I3Mod	MMod	WMod	GUID
L40x3.1	1,000000	1,000000	1,000000	1,000000	1,000000	

Table 9: Frame Section Properties 01 - General, Part 6 of 6

Table 9: Frame Section Properties 01 - General, Part 6 of 6

SectionName	Notes
L40x3.1	Added 27/03/13 17:08:11

4. Load patterns

This section provides loading information as applied to the model.

4.1. Definitions

Table 10: Load Pattern Definitions

Table 10: Load Pattern Definitions

LoadPat	DesignType	SelfWtMult	AutoLoad	GUID	Notes
G	DEAD	1,000000			
Kar	LIVE	0,000000			
Ruz(+)	WIND	0,000000	None		
Ruz(-)	WIND	0,000000	None		

H.K.

5. Load cases

This section provides load case information.

5.1. Definitions

Table 11: Load Case Definitions, Part 1 of 3

Table 11: Load Case Definitions, Part 1 of 3

Case	Type	InitialCond	ModalCase	BaseCase	DesTypeOpt	DesignType	DesActOpt
G	LinStatic	Zero			Prog Det	DEAD	Prog Det
Kar	LinStatic	Zero			Prog Det	LIVE	Prog Det
Ruz(+)	LinStatic	Zero			Prog Det	WIND	Prog Det
Ruz(-)	LinStatic	Zero			Prog Det	WIND	Prog Det

Table 11: Load Case Definitions, Part 2 of 3

Table 11: Load Case Definitions, Part 2 of 3

Case	DesignAct	AutoType	RunCase	CaseStatus	GUID
G	Non-Compos ite	None	Yes	Finished	
Kar	Short-Term Composite	None	Yes	Finished	
Ruz(+)	Short-Term Composite	None	Yes	Finished	
Ruz(-)	Short-Term Composite	None	Yes	Finished	

Table 11: Load Case Definitions, Part 3 of 3

Table 11: Load Case Definitions, Part 3 of 3

Case	Notes
G	
Kar	
Ruz(+)	
Ruz(-)	

5.2. Static case load assignments

Table 12: Case - Static 1 - Load Assignments

Table 12: Case - Static 1 - Load Assignments

Case	LoadType	LoadName	LoadSF
G	Load pattern	G	1,000000
Kar	Load pattern	Kar	1,000000
Ruz(+)	Load pattern	Ruz(+)	1,000000
Ruz(-)	Load pattern	Ruz(-)	1,000000

H.K.

5.3. Response spectrum case load assignments

Table 13: Function - Response Spectrum - User

Table 13: Function - Response Spectrum - User

Name	Period Sec	Accel	FuncDamp
UNIFRS	0,000000	1,000000	0,050000
UNIFRS	1,000000	1,000000	

6. Load combinations

This section provides load combination information.

Table 14: Combination Definitions, Part 1 of 3

Table 14: Combination Definitions, Part 1 of 3

ComboName	ComboType	AutoDesign	CaseType	CaseName	ScaleFactor	SteelDesign
G+Kar	Linear Add	No	Linear Static	G	1,000000	None
G+Kar			Linear Static	Kar	1,000000	
G+Ruz(+)	Linear Add	No	Linear Static	G	1,000000	None
G+Ruz(+)			Linear Static	Ruz(+)	1,000000	
G+Ruz(-)	Linear Add	No	Linear Static	G	1,000000	None
G+Ruz(-)			Linear Static	Ruz(-)	1,000000	

Table 14: Combination Definitions, Part 2 of 3

Table 14: Combination Definitions, Part 2 of 3

ComboName	CaseName	ConcDesign	AlumDesign	ColdDesign
G+Kar	G	None	Strength	None
G+Kar	Kar			
G+Ruz(+)	G	None	Strength	None
G+Ruz(+)	Ruz(+)			
G+Ruz(-)	G	None	Strength	None
G+Ruz(-)	Ruz(-)			

Table 14: Combination Definitions, Part 3 of 3

Table 14: Combination Definitions, Part 3 of 3

ComboName	CaseName	GUID	Notes
G+Kar	G		
G+Kar	Kar		
G+Ruz(+)	G		
G+Ruz(+)	Ruz(+)		
G+Ruz(-)	G		
G+Ruz(-)	Ruz(-)		

H.K.

7. Structure results

This section provides structure results, including items such as structural periods and base reactions.

7.1. *Mass summary*

Table 15: Assembled Joint Masses

Table 15: Assembled Joint Masses

Joint	U1	U2	U3	R1	R2	R3
	Kgf-s2/m	Kgf-s2/m	Kgf-s2/m	Kgf-m-s2	Kgf-m-s2	Kgf-m-s2
1	5,372E-03	5,372E-03	5,372E-03	0,00	0,00	0,00
2	4,339E-02	4,339E-02	4,339E-02	0,00	0,00	0,00
3	5,317E-02	5,317E-02	5,317E-02	0,00	0,00	0,00
4	3,654E-02	3,654E-02	3,654E-02	0,00	0,00	0,00
5	4,623E-02	4,623E-02	4,623E-02	0,00	0,00	0,00

7.2. *Base reactions*

Table 16: Base Reactions, Part 1 of 3

Table 16: Base Reactions, Part 1 of 3

OutputCase	CaseType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ	GlobalX
		Kgf	Kgf	Kgf	Kgf-m	Kgf-m	Kgf-m	m
G	LinStatic	-8,882E-14	0,00	20,11	0,00	-15,86	0,00	0,00000
Kar	LinStatic	-4,441E-13	0,00	62,00	0,00	-35,65	0,00	0,00000
Ruz(+)	LinStatic	-6,12	0,00	-12,42	0,00	10,37	0,00	0,00000
Ruz(-)	LinStatic	17,25	0,00	-18,47	0,00	7,87	0,00	0,00000

Table 16: Base Reactions, Part 2 of 3

Table 16: Base Reactions, Part 2 of 3

OutputCase	GlobalY	GlobalZ	XCentroidFX	YCentroidFX	ZCentroidFX	XCentroidFY	YCentroidFY	ZCentroidFY
	m	m	m	m	m	m	m	m
G	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
Kar	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
Ruz(+)	0,00000	0,00000	0,06833	0,00000	0,00000	0,00000	0,00000	0,00000
Ruz(-)	0,00000	0,00000	1,06817	0,00000	0,00000	0,00000	0,00000	0,00000

Table 16: Base Reactions, Part 3 of 3

Table 16: Base Reactions, Part 3 of 3

OutputCase	XCentroidFZ	YCentroidFZ	ZCentroidFZ
	m	m	m
G	0,78884	0,00000	0,00000
Kar	0,57500	0,00000	0,00000
Ruz(+)	0,83488	0,00000	0,00000
Ruz(-)	0,42602	0,00000	0,00000

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8. Joint results

This section provides joint results, including items such as displacements and reactions.

Table 17: Joint Displacements

Table 17: Joint Displacements

Joint	OutputCase	CaseType	U1	U2	U3	R1	R2	R3
			m	m	m	Radians	Radians	Radians
1	G	LinStatic	-4,662E-07	0,000000	-0,000068	0,000000	-0,000863	0,000000
1	Kar	LinStatic	-1,098E-06	0,000000	-0,000383	0,000000	-0,004821	0,000000
1	Ruz(+)	LinStatic	2,921E-07	0,000000	0,000050	0,000000	0,000626	0,000000
1	Ruz(-)	LinStatic	-1,629E-07	0,000000	0,000137	0,000000	0,001725	0,000000
2	G	LinStatic	0,000000	0,000000	0,000000	0,000000	-0,000769	0,000000
2	Kar	LinStatic	0,000000	0,000000	0,000000	0,000000	-0,004394	0,000000
2	Ruz(+)	LinStatic	0,000000	0,000000	0,000000	0,000000	0,000571	0,000000
2	Ruz(-)	LinStatic	0,000000	0,000000	0,000000	0,000000	0,001572	0,000000
3	G	LinStatic	0,000000	0,000000	0,000000	0,000000	0,000286	0,000000
3	Kar	LinStatic	0,000000	0,000000	0,000000	0,000000	0,002187	0,000000
3	Ruz(+)	LinStatic	0,000000	0,000000	0,000000	0,000000	-0,000284	0,000000
3	Ruz(-)	LinStatic	0,000000	0,000000	0,000000	0,000000	-0,000782	0,000000
4	G	LinStatic	0,000012	0,000000	-0,000115	0,000000	0,000529	0,000000
4	Kar	LinStatic	0,000057	0,000000	-0,000607	0,000000	0,002476	0,000000
4	Ruz(+)	LinStatic	-5,246E-06	0,000000	0,000072	0,000000	-0,000242	0,000000
4	Ruz(-)	LinStatic	-0,000029	0,000000	0,000244	0,000000	-0,001184	0,000000
5	G	LinStatic	-0,000020	0,000000	-0,000021	0,000000	0,000000	0,000000
5	Kar	LinStatic	-0,000095	0,000000	-0,000092	0,000000	0,000000	0,000000
5	Ruz(+)	LinStatic	0,000015	0,000000	0,000014	0,000000	0,000000	0,000000
5	Ruz(-)	LinStatic	0,000029	0,000000	0,000029	0,000000	0,000000	0,000000

Table 18: Joint Reactions

Table 18: Joint Reactions

Joint	OutputCase	CaseType	F1	F2	F3	M1	M2	M3
			Kgf	Kgf	Kgf	Kgf-m	Kgf-m	Kgf-m
2	G	LinStatic	9,87	0,00	8,57	0,00	0,00	0,00
2	Kar	LinStatic	23,22	0,00	37,15	0,00	0,00	0,00
2	Ruz(+)	LinStatic	-6,18	0,00	-4,83	0,00	0,00	0,00
2	Ruz(-)	LinStatic	3,45	0,00	-13,29	0,00	0,00	0,00
3	G	LinStatic	-9,87	0,00	11,54	0,00	0,00	0,00
3	Kar	LinStatic	-23,22	0,00	24,85	0,00	0,00	0,00
3	Ruz(+)	LinStatic	5,786E-02	0,00	-7,59	0,00	0,00	0,00
3	Ruz(-)	LinStatic	13,80	0,00	-5,17	0,00	0,00	0,00

9. Frame results

This section provides frame force results.

Table 19: Element Forces - Frames, Part 1 of 3

Table 19: Element Forces - Frames, Part 1 of 3

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2
	m			Kgf	Kgf	Kgf	Kgf-m	Kgf-m
1	0,00000	G	LinStatic	9,87	7,62	0,00	0,00	0,00
1	0,08000	G	LinStatic	9,87	7,67	0,00	0,00	0,00
1	0,08000	G	LinStatic	0,00	-0,89	0,00	0,00	0,00
1	0,49167	G	LinStatic	0,00	-0,63	0,00	0,00	0,00

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Table 19: Element Forces - Frames, Part 1 of 3

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2
	m			Kgf	Kgf	Kgf	Kgf-m	Kgf-m
1	0,90333	G	LinStatic	0,00	-0,36	0,00	0,00	0,00
1	1,31500	G	LinStatic	0,00	-9,605E-02	0,00	0,00	0,00
1	0,00000	Kar	LinStatic	23,22	34,89	0,00	0,00	0,00
1	0,08000	Kar	LinStatic	23,22	34,89	0,00	0,00	0,00
1	0,08000	Kar	LinStatic	0,00	-2,26	0,00	0,00	0,00
1	0,49167	Kar	LinStatic	0,00	-2,26	0,00	0,00	0,00
1	0,90333	Kar	LinStatic	0,00	-2,26	0,00	0,00	0,00
1	1,31500	Kar	LinStatic	0,00	-2,26	0,00	0,00	0,00
1	0,00000	Ruz(+)	LinStatic	-6,18	-4,53	0,00	0,00	0,00
1	0,08000	Ruz(+)	LinStatic	-6,18	-4,53	0,00	0,00	0,00
1	0,08000	Ruz(+)	LinStatic	0,00	0,29	0,00	0,00	0,00
1	0,49167	Ruz(+)	LinStatic	0,00	0,29	0,00	0,00	0,00
1	0,90333	Ruz(+)	LinStatic	0,00	0,29	0,00	0,00	0,00
1	1,31500	Ruz(+)	LinStatic	0,00	0,29	0,00	0,00	0,00
1	0,00000	Ruz(-)	LinStatic	3,45	-12,48	0,00	0,00	0,00
1	0,08000	Ruz(-)	LinStatic	3,45	-12,48	0,00	0,00	0,00
1	0,08000	Ruz(-)	LinStatic	0,00	0,81	0,00	0,00	0,00
1	0,49167	Ruz(-)	LinStatic	0,00	0,81	0,00	0,00	0,00
1	0,90333	Ruz(-)	LinStatic	0,00	0,81	0,00	0,00	0,00
1	1,31500	Ruz(-)	LinStatic	0,00	0,81	0,00	0,00	0,00
2	0,00000	G	LinStatic	-11,50	-4,82	0,00	0,00	0,00
2	0,08281	G	LinStatic	-11,49	-4,76	0,00	0,00	0,00
2	0,08281	G	LinStatic	-10,19	6,692E-02	0,00	0,00	0,00
2	0,55378	G	LinStatic	-10,12	0,36	0,00	0,00	0,00
2	1,10756	G	LinStatic	-10,02	0,71	0,00	0,00	0,00
2	0,00000	Kar	LinStatic	-31,45	-27,71	0,00	0,00	0,00
2	0,08281	Kar	LinStatic	-31,45	-27,71	0,00	0,00	0,00
2	0,08281	Kar	LinStatic	-23,44	2,24	0,00	0,00	0,00
2	0,55378	Kar	LinStatic	-23,44	2,24	0,00	0,00	0,00
2	1,10756	Kar	LinStatic	-23,44	2,24	0,00	0,00	0,00
2	0,00000	Ruz(+)	LinStatic	7,14	2,78	0,00	0,00	0,00
2	0,08281	Ruz(+)	LinStatic	7,14	2,78	0,00	0,00	0,00
2	0,08281	Ruz(+)	LinStatic	7,16	-0,22	0,00	0,00	0,00
2	0,55378	Ruz(+)	LinStatic	7,16	-0,22	0,00	0,00	0,00
2	1,10756	Ruz(+)	LinStatic	7,16	-0,22	0,00	0,00	0,00
2	0,00000	Ruz(-)	LinStatic	-0,11	12,95	0,00	0,00	0,00
2	0,08281	Ruz(-)	LinStatic	-0,11	12,95	0,00	0,00	0,00
2	0,08281	Ruz(-)	LinStatic	-0,10	-1,05	0,00	0,00	0,00
2	0,55378	Ruz(-)	LinStatic	-0,10	-1,05	0,00	0,00	0,00
2	1,10756	Ruz(-)	LinStatic	-0,10	-1,05	0,00	0,00	0,00
3	0,00000	G	LinStatic	-15,07	-7,922E-02	0,00	0,00	0,00
3	0,18830	G	LinStatic	-15,16	2,776E-17	0,00	0,00	0,00
3	0,37659	G	LinStatic	-15,26	7,922E-02	0,00	0,00	0,00
3	0,00000	Kar	LinStatic	-35,70	0,00	0,00	0,00	0,00
3	0,18830	Kar	LinStatic	-35,70	0,00	0,00	0,00	0,00
3	0,37659	Kar	LinStatic	-35,70	0,00	0,00	0,00	0,00
3	0,00000	Ruz(+)	LinStatic	6,02	5,08	0,00	0,00	0,00
3	0,18830	Ruz(+)	LinStatic	6,02	-8,882E-16	0,00	0,00	0,00
3	0,37659	Ruz(+)	LinStatic	6,02	-5,08	0,00	0,00	0,00
3	0,00000	Ruz(-)	LinStatic	13,52	-6,59	0,00	0,00	0,00
3	0,18830	Ruz(-)	LinStatic	13,52	-2,665E-15	0,00	0,00	0,00
3	0,37659	Ruz(-)	LinStatic	13,52	6,59	0,00	0,00	0,00

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Table 19: Element Forces - Frames, Part 2 of 3

Table 19: Element Forces - Frames, Part 2 of 3

Frame	Station	OutputCase	M3	S11Max	PtS11Max	x2S11Max	x3S11Max	S11Min
	m		Kgf-m	Kgf/m2		m	m	Kgf/m2
1	0,00000	G	3,331E-16	41384,74	1	-0,011147	-0,028853	41384,74
1	0,08000	G	-0,61	520016,84	3	0,028853	-0,028853	-143526,08
1	0,08000	G	-0,61	478632,10	3	0,028853	-0,028853	-184910,82
1	0,49167	G	-0,30	233348,26	3	0,028853	-0,028853	-90149,86
1	0,90333	G	-9,433E-02	73804,23	3	0,028853	-0,028853	-28512,92
1	1,31500	G	-5,690E-16	4,452E-10	3	0,028853	-0,028853	-1,720E-10
1	0,00000	Kar	1,332E-15	97419,48	1	-0,011147	-0,028853	97419,48
1	0,08000	Kar	-2,79	2281154,80	3	0,028853	-0,028853	-746226,99
1	0,08000	Kar	-2,79	2183735,32	3	0,028853	-0,028853	-843646,47
1	0,49167	Kar	-1,86	1455823,55	3	0,028853	-0,028853	-562430,98
1	0,90333	Kar	-0,93	727911,77	3	0,028853	-0,028853	-281215,49
1	1,31500	Kar	-7,772E-16	6,080E-10	3	0,028853	-0,028853	-2,349E-10
1	0,00000	Ruz(+)	2,220E-16	-25923,31	1	-0,011147	-0,028853	-25923,31
1	0,08000	Ruz(+)	0,36	83682,27	1	-0,011147	-0,028853	-309631,69
1	0,08000	Ruz(+)	0,36	109605,58	1	-0,011147	-0,028853	-283708,39
1	0,49167	Ruz(+)	0,24	73070,39	1	-0,011147	-0,028853	-189138,93
1	0,90333	Ruz(+)	0,12	36535,19	1	-0,011147	-0,028853	-94569,46
1	1,31500	Ruz(+)	1,527E-16	4,614E-11	1	-0,011147	-0,028853	-1,194E-10
1	0,00000	Ruz(-)	-2,220E-16	14462,06	3	0,028853	-0,028853	14462,06
1	0,08000	Ruz(-)	1,00	316302,98	1	-0,011147	-0,028853	-766837,57
1	0,08000	Ruz(-)	1,00	301840,92	1	-0,011147	-0,028853	-781299,63
1	0,49167	Ruz(-)	0,67	201227,28	1	-0,011147	-0,028853	-520866,42
1	0,90333	Ruz(-)	0,33	100613,64	1	-0,011147	-0,028853	-260433,21
1	1,31500	Ruz(-)	2,776E-16	8,389E-11	1	-0,011147	-0,028853	-2,172E-10
2	0,00000	G	0,00	-48236,56	0	0,000000	0,000000	-48236,56
2	0,08281	G	0,40	71695,70	1	-0,011147	-0,028853	-358466,88
2	0,08281	G	0,40	77111,71	1	-0,011147	-0,028853	-353050,87
2	0,55378	G	0,30	46972,62	1	-0,011147	-0,028853	-273853,55
2	1,10756	G	1,110E-16	-42044,74	1	-0,011147	-0,028853	-42044,74
2	0,00000	Kar	0,00	-131908,12	0	0,000000	0,000000	-131908,12
2	0,08281	Kar	2,29	561638,95	1	-0,011147	-0,028853	-1927118,93
2	0,08281	Kar	2,29	595218,22	1	-0,011147	-0,028853	-1893539,66
2	0,55378	Kar	1,24	276466,79	1	-0,011147	-0,028853	-1068468,03
2	1,10756	Kar	-2,220E-16	-98328,86	3	0,028853	-0,028853	-98328,86
2	0,00000	Ruz(+)	0,00	29954,09	0	0,000000	0,000000	29954,09
2	0,08281	Ruz(+)	-0,23	210276,17	3	0,028853	-0,028853	-39710,07
2	0,08281	Ruz(+)	-0,23	210376,92	3	0,028853	-0,028853	-39609,32
2	0,55378	Ruz(+)	-0,12	127501,62	3	0,028853	-0,028853	-7591,96
2	1,10756	Ruz(+)	5,551E-17	30054,84	1	-0,011147	-0,028853	30054,84
2	0,00000	Ruz(-)	0,00	-450,08	0	0,000000	0,000000	-450,08
2	0,08281	Ruz(-)	-1,07	838526,56	3	0,028853	-0,028853	-324573,46
2	0,08281	Ruz(-)	-1,07	838551,86	3	0,028853	-0,028853	-324548,16
2	0,55378	Ruz(-)	-0,58	452961,59	3	0,028853	-0,028853	-175582,36
2	1,10756	Ruz(-)	1,110E-16	-424,78	1	-0,011147	-0,028853	-424,78
3	0,00000	G	0,00	-63224,88	0	0,000000	0,000000	-63224,88
3	0,18830	G	7,458E-03	-61358,56	1	-0,011147	-0,028853	-69447,74
3	0,37659	G	-1,041E-17	-64000,69	3	0,028853	-0,028853	-64000,69
3	0,00000	Kar	0,00	-149744,19	0	0,000000	0,000000	-149744,19
3	0,18830	Kar	0,00	-149744,19	0	0,000000	0,000000	-149744,19
3	0,37659	Kar	0,00	-149744,19	0	0,000000	0,000000	-149744,19
3	0,00000	Ruz(+)	0,00	25268,27	0	0,000000	0,000000	25268,27
3	0,18830	Ruz(+)	-0,48	399746,59	3	0,028853	-0,028853	-119404,62
3	0,37659	Ruz(+)	3,886E-16	25268,27	1	-0,011147	-0,028853	25268,27
3	0,00000	Ruz(-)	0,00	56724,41	0	0,000000	0,000000	56724,41
3	0,18830	Ruz(-)	0,62	244263,35	1	-0,011147	-0,028853	-428710,44
3	0,37659	Ruz(-)	1,221E-15	56724,41	1	-0,011147	-0,028853	56724,41

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Table 19: Element Forces - Frames, Part 3 of 3

Table 19: Element Forces - Frames, Part 3 of 3

Frame	Station	OutputCase	PtS11Min	x2S11Min	x3S11Min	FrameElem	ElemStation
	m			m	m		m
1	0,00000	G	3	0,028853	-0,028853	1-1	0,00000
1	0,08000	G	1	-0,011147	-0,028853	1-1	0,08000
1	0,08000	G	1	-0,011147	-0,028853	1-2	0,00000
1	0,49167	G	1	-0,011147	-0,028853	1-2	0,41167
1	0,90333	G	1	-0,011147	-0,028853	1-2	0,82333
1	1,31500	G	1	-0,011147	-0,028853	1-2	1,23500
1	0,00000	Kar	3	0,028853	-0,028853	1-1	0,00000
1	0,08000	Kar	1	-0,011147	-0,028853	1-1	0,08000
1	0,08000	Kar	1	-0,011147	-0,028853	1-2	0,00000
1	0,49167	Kar	1	-0,011147	-0,028853	1-2	0,41167
1	0,90333	Kar	1	-0,011147	-0,028853	1-2	0,82333
1	1,31500	Kar	1	-0,011147	-0,028853	1-2	1,23500
1	0,00000	Ruz(+)	3	0,028853	-0,028853	1-1	0,00000
1	0,08000	Ruz(+)	3	0,028853	-0,028853	1-1	0,08000
1	0,08000	Ruz(+)	3	0,028853	-0,028853	1-2	0,00000
1	0,49167	Ruz(+)	3	0,028853	-0,028853	1-2	0,41167
1	0,90333	Ruz(+)	3	0,028853	-0,028853	1-2	0,82333
1	1,31500	Ruz(+)	3	0,028853	-0,028853	1-2	1,23500
1	0,00000	Ruz(-)	1	-0,011147	-0,028853	1-1	0,00000
1	0,08000	Ruz(-)	3	0,028853	-0,028853	1-1	0,08000
1	0,08000	Ruz(-)	3	0,028853	-0,028853	1-2	0,00000
1	0,49167	Ruz(-)	3	0,028853	-0,028853	1-2	0,41167
1	0,90333	Ruz(-)	3	0,028853	-0,028853	1-2	0,82333
1	1,31500	Ruz(-)	3	0,028853	-0,028853	1-2	1,23500
2	0,00000	G	0	0,000000	0,000000	2-1	0,00000
2	0,08281	G	3	0,028853	-0,028853	2-1	0,08281
2	0,08281	G	3	0,028853	-0,028853	2-2	0,00000
2	0,55378	G	3	0,028853	-0,028853	2-2	0,47097
2	1,10756	G	3	0,028853	-0,028853	2-2	1,02475
2	0,00000	Kar	0	0,000000	0,000000	2-1	0,00000
2	0,08281	Kar	3	0,028853	-0,028853	2-1	0,08281
2	0,08281	Kar	3	0,028853	-0,028853	2-2	0,00000
2	0,55378	Kar	3	0,028853	-0,028853	2-2	0,47097
2	1,10756	Kar	1	-0,011147	-0,028853	2-2	1,02475
2	0,00000	Ruz(+)	0	0,000000	0,000000	2-1	0,00000
2	0,08281	Ruz(+)	1	-0,011147	-0,028853	2-1	0,08281
2	0,08281	Ruz(+)	1	-0,011147	-0,028853	2-2	0,00000
2	0,55378	Ruz(+)	1	-0,011147	-0,028853	2-2	0,47097
2	1,10756	Ruz(+)	3	0,028853	-0,028853	2-2	1,02475
2	0,00000	Ruz(-)	0	0,000000	0,000000	2-1	0,00000
2	0,08281	Ruz(-)	1	-0,011147	-0,028853	2-1	0,08281
2	0,08281	Ruz(-)	1	-0,011147	-0,028853	2-2	0,00000
2	0,55378	Ruz(-)	1	-0,011147	-0,028853	2-2	0,47097
2	1,10756	Ruz(-)	3	0,028853	-0,028853	2-2	1,02475
3	0,00000	G	0	0,000000	0,000000	3-1	0,00000
3	0,18830	G	3	0,028853	-0,028853	3-1	0,18830
3	0,37659	G	0	0,000000	0,000000	3-1	0,37659
3	0,00000	Kar	0	0,000000	0,000000	3-1	0,00000
3	0,18830	Kar	0	0,000000	0,000000	3-1	0,18830
3	0,37659	Kar	0	0,000000	0,000000	3-1	0,37659
3	0,00000	Ruz(+)	0	0,000000	0,000000	3-1	0,00000
3	0,18830	Ruz(+)	1	-0,011147	-0,028853	3-1	0,18830
3	0,37659	Ruz(+)	3	0,028853	-0,028853	3-1	0,37659
3	0,00000	Ruz(-)	0	0,000000	0,000000	3-1	0,00000
3	0,18830	Ruz(-)	3	0,028853	-0,028853	3-1	0,18830
3	0,37659	Ruz(-)	3	0,028853	-0,028853	3-1	0,37659

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10. Material take-off

This section provides a material take-off.

Table 20: Material List 2 - By Section Property

Table 20: Material List 2 - By Section Property

Section	ObjectType	NumPieces	TotalLength	TotalWeight
			m	Kgf
L40x3.1	Frame	3	2,79915	1,81

11. Design preferences

This section provides the design preferences for each type of design, which typically include material reduction factors, framing type, stress ratio limit, deflection limits, and other code specific items.

11.1. Aluminum design

Table 21: Preferences - Aluminum Design - AA-ASD 2000

Table 23: Preferences - Aluminum Design - AA-ASD 2000

THDesign	FrameType	SRatioLimit	MaxIter	LatFact	UseLatFact	Bridge
Envelopes	Moment Frame	1,000000	1	1,333333	No	No

12. Design overwrites

This section provides the design overwrites for each type of design, which are assigned to individual members of the structure.

12.1. Aluminum design

Table 22: Overwrites - Aluminum Design - AA-ASD 2000, Part 1 of 4

Table 25: Overwrites - Aluminum Design - AA-ASD 2000, Part 1 of 4

Frame	DesignSect	FrameType	RLLF	XLMajor	XLMinor	Fy
						Kgf/m2
2	Program Determined	Program Determined	0,000000	0,000000	0,000000	0,00
3	Program Determined	Program Determined	0,000000	0,000000	0,000000	0,00
1	Program Determined	Program Determined	0,000000	0,000000	0,000000	0,00

Table 22: Overwrites - Aluminum Design - AA-ASD 2000, Part 2 of 4

Table 25: Overwrites - Aluminum Design - AA-ASD 2000, Part 2 of 4

Frame	XKMajor	XKMinor	CmMajor	CmMinor	Cb	K1Comp	K2Comp
2	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
3	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000

H.K.

Table 25: Overwrites - Aluminum Design - AA-ASD 2000, Part 2 of 4

Frame	XKMajor	XKMinor	CmMajor	CmMinor	Cb	K1Comp	K2Comp
1	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000

Table 22: Overwrites - Aluminum Design - AA-ASD 2000, Part 3 of 4

Table 25: Overwrites - Aluminum Design - AA-ASD 2000, Part 3 of 4

Frame	K1Bend	K2Bend	KT	C1	C2	Fa Kgf/m2	Ft Kgf/m2
2	0,000000	0,000000	0,000000	0,000000	0,000000	0,00	0,00
3	0,000000	0,000000	0,000000	0,000000	0,000000	0,00	0,00
1	0,000000	0,000000	0,000000	0,000000	0,000000	0,00	0,00

Table 22: Overwrites - Aluminum Design - AA-ASD 2000, Part 4 of 4

Table 25: Overwrites - Aluminum Design - AA-ASD 2000, Part 4 of 4

Frame	Fb3 Kgf/m2	Fb2 Kgf/m2	Fs2 Kgf/m2	Fs3 Kgf/m2
2	0,00	0,00	0,00	0,00
3	0,00	0,00	0,00	0,00
1	0,00	0,00	0,00	0,00

13. Design summary

This section provides the design summary for each type of design, which highlights the controlling demand/capacity ratio and it's associated combination and location in each member.

13.1. Aluminum design

Table 23: Aluminum Design 1 - Summary Data - AA-ASD 2000, Part 1 of 2

Table 26: Aluminum Design 1 - Summary Data - AA-ASD 2000, Part 1 of 2

Frame	DesignSect	DesignType	Status	Ratio	RatioType
2	L40x3.1	Brace	No Messages	0,579976	PMM
3	L40x3.1	Brace	No Messages	0,073582	PMM
1	L40x3.1	Beam	No Messages	0,761036	PMM

Table 23: Aluminum Design 1 - Summary Data - AA-ASD 2000, Part 2 of 2

Table 26: Aluminum Design 1 - Summary Data - AA-ASD 2000, Part 2 of 2

Frame	Combo	Location m	ErrMsg	WarnMsg
2	G+Kar	0,08281	No Messages	No Messages
3	G+Ruz(-)	0,18830	No Messages	No Messages
1	G+Kar	0,08000	No Messages	No Messages

HK.

5.4 APPENDIX D – Electrical Project Diagrams

5.4.1 Placement and Cabling Design

5.4.2 Single Line Diagram

Placement and Cabling Design is provided as an attachment

Single Line Diagram is provided as an attachment

5.5 *APPENDIX E – Daily Energy Production Data by Sub-Plants*

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
1/1/14	59,60	9,10	62,50	42,50	173,70	0,5851
1/2/14	141,40		152,30	102,60	396,30	1,3072
1/3/14	118,20	20,80	137,80	93,20	370,00	1,2407
1/4/14	198,10	36,60	253,10	174,00	661,80	2,2238
1/5/14	217,30	41,90	280,70	191,80	731,70	2,5025
1/6/14	214,20	41,60	279,90	189,50	725,20	2,3294
1/7/14	256,50	-	340,50	232,00	829,00	2,7942
1/8/14	281,20	-	366,40	247,70	895,30	2,8741
1/9/14	270,80	-	353,10	236,70	860,60	2,6970
1/10/14	317,80	-	413,70	284,40	1.015,90	3,4579
1/11/14	282,50	51,20	361,80	250,80	946,30	3,1601
1/12/14	260,90	47,50	334,10	229,20	871,70	3,0156
1/13/14	292,00	54,80	353,10	261,90	961,80	3,2752
1/14/14	140,30	26,40	178,50	121,40	466,60	1,6168
1/15/14	273,00	50,00	348,80	239,30	911,10	3,0486
1/16/14	114,70	21,70	146,20	98,80	381,40	1,2781
1/17/14	203,80	39,90	268,00	180,90	692,60	1,9547
1/18/14	303,00	56,60	387,80	267,00	1.014,40	3,2804
1/19/14	317,70	60,40	416,10	282,20	1.076,40	3,2028
1/20/14	291,50	55,80	381,10	256,30	984,70	2,9000
1/21/14	283,40	53,90	364,70	249,10	951,10	3,1064
1/22/14	248,50	57,00	393,50	273,60	972,60	3,2448
1/23/14	160,20	31,20	205,50	140,00	536,90	1,5437
1/24/14	309,80	57,70	401,10	276,30	1.044,90	3,2309
1/25/14	221,80	42,60	288,90	197,30	750,60	2,4177
1/26/14	89,80	16,50	111,00	75,40	292,70	1,0487
1/27/14	19,30	3,40	23,80	15,70	62,20	0,2000
1/28/14	128,40	24,30	163,70	113,80	430,20	1,4423
1/29/14	85,00	16,00	107,90	73,80	282,70	0,9508
1/30/14	62,50	-	77,90	51,90	192,30	0,6959
1/31/14	33,60	-	41,70	27,80	103,10	0,3744
2/1/14	40,50	-	50,50	34,30	125,30	0,4620
2/2/14	422,80	-	547,50	377,00	1.347,30	4,2361
2/3/14	343,80	63,10	447,60	318,70	1.173,20	3,6304
2/4/14	143,50	27,10	180,60	122,20	473,40	1,5715
2/5/14	375,80	78,40	533,30	367,90	1.355,40	4,2904
2/6/14	225,80	54,20	363,50	246,20	889,70	2,6745
2/7/14	255,40	61,50	417,30	284,60	1.018,80	3,1702
2/8/14	218,20	52,90	351,30	238,70	861,10	2,5762
2/9/14	253,60	60,30	408,60	278,60	1.001,10	3,9070
2/10/14	273,60	66,70	442,80	306,60	1.089,70	3,2354
2/11/14	270,00	65,70	400,30	296,60	1.032,60	3,7324
2/12/14	232,10	56,20	375,50	258,40	922,20	3,6519
2/13/14	316,60	75,70	512,50	351,40	1.256,20	4,1086
2/14/14	277,90	48,10	319,90	217,70	863,60	3,0041
2/15/14	59,70	7,20	50,40	34,50	151,80	0,4657
2/16/14	249,80	60,90	406,00	282,40	999,10	2,7368
2/17/14	379,10	90,30	615,80	425,80	1.511,00	5,0601
2/18/14	323,10	76,90	524,00	361,50	1.285,50	4,3814
2/19/14	336,40	56,80	549,20	372,80	1.315,20	4,3028
2/20/14	365,00	-	637,10	440,40	1.442,50	5,1387
2/21/14	190,40	-	324,30	221,00	735,70	3,0202
2/22/14	42,30	-	70,70	47,30	160,30	0,6728
2/23/14	93,70	-	158,30	106,60	358,60	1,4692
2/24/14	41,10	-	69,00	46,20	156,30	0,6291
2/25/14	51,80	-	71,80	49,60	173,20	0,6909
2/26/14	40,00	1,50	62,80	43,40	147,70	0,6099
2/27/14	-	15,60	-	31,10	46,70	0,3463
2/28/14	-	56,30	-	254,60	310,90	3,5281
3/1/14	142,30	27,00	180,50	121,20	471,00	1,6533
3/2/14	232,00	44,50	299,70	202,50	778,70	2,8607
3/3/14	373,90	74,00	491,40	335,40	1.274,70	4,0674
3/4/14	291,30	56,60	378,40	258,00	984,30	3,6721
3/5/14	278,30	52,50	354,90	243,70	929,40	2,9028
3/6/14	491,60	104,70	716,80	490,90	1.804,00	6,1433
3/7/14	386,60	76,50	527,90	356,50	1.347,50	5,1008
3/8/14	54,00	9,70	67,30	45,70	176,70	0,6443

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
3/9/14	60,30	11,10	75,20	50,10	196,70	0,7136
3/10/14	55,80	10,30	69,80	46,70	182,60	0,6560
3/11/14	128,50	22,00	147,00	98,30	395,80	1,3592
3/12/14	375,30	59,20	404,20	278,60	1.117,30	3,5437
3/13/14	312,50	49,40	338,20	230,80	930,90	3,1869
3/14/14	604,70	100,80	684,90	467,80	1.858,20	6,2449
3/15/14	265,60	-	768,80	526,70	1.561,10	7,0334
3/16/14	72,90	1,70	75,50	54,20	204,30	0,7665
3/17/14	456,30	73,40	496,10	333,00	1.358,80	4,5427
3/18/14	623,80	101,60	681,40	466,80	1.873,60	6,4044
3/19/14	649,90	106,50	764,10	527,20	2.047,70	7,5707
3/20/14	517,90	81,00	566,80	385,60	1.551,30	5,3912
3/21/14	691,00	115,90	797,00	546,10	2.150,00	7,8825
3/22/14	713,10	110,10	770,60	526,30	2.120,10	7,7962
3/23/14	500,10	81,00	548,80	382,40	1.512,30	5,8041
3/24/14	592,70	94,80	642,30	439,80	1.769,60	6,3313
3/25/14	265,70	41,30	281,00	189,70	777,70	2,6660
3/26/14	405,40	63,60	434,50	295,50	1.199,00	4,2064
3/27/14	570,90	99,50	672,00	458,70	1.801,10	6,5163
3/28/14	214,30	39,80	273,50	186,70	714,30	2,6209
3/29/14	201,80	63,90	393,70	289,60	949,00	3,9924
3/30/14	672,90	127,60	870,40	524,40	2.195,30	8,5604
3/31/14	636,80	122,20	831,20	445,90	2.036,10	8,3700
4/1/14	535,30	101,10	697,60	478,60	1.812,60	6,7121
4/2/14	528,80	-	688,00	465,70	1.682,50	6,4435
4/3/14	540,30	-	702,90	481,10	1.724,30	6,7687
4/4/14	562,90	-	679,70	504,80	1.747,40	7,3424
4/5/14	375,80	-	484,20	327,20	1.187,20	4,6437
4/6/14	447,40	-	576,90	393,40	1.417,70	5,4180
4/7/14	263,10	15,90	331,20	221,60	831,80	3,0465
4/8/14	523,80	99,80	630,00	466,50	1.720,10	6,6846
4/9/14	629,80	120,30	832,50	570,30	2.152,90	8,4617
4/10/14	577,30	110,60	751,30	512,30	1.951,50	7,6646
4/11/14	207,20	39,70	263,70	174,20	684,80	2,3769
4/12/14	235,80	44,70	302,40	209,40	792,30	2,8381
4/13/14	654,60	125,70	855,10	584,90	2.220,30	8,4855
4/14/14	464,00	89,60	610,10	440,50	1.604,20	6,5552
4/15/14	660,90	125,50	867,70	596,90	2.251,00	8,7359
4/16/14	534,50	101,70	695,30	473,90	1.805,40	6,9188
4/17/14	611,60	115,30	801,10	549,30	2.077,30	8,0631
4/18/14	364,40	69,10	470,60	320,80	1.224,90	4,4686
4/19/14	566,70	108,00	742,10	507,90	1.924,70	7,2931
4/20/14	578,90	110,00	754,60	519,50	1.963,00	7,5548
4/21/14	656,20	125,50	850,80	579,10	2.211,60	8,6704
4/22/14	577,40	112,60	727,50	490,80	1.908,30	7,9862
4/23/14	489,70	92,40	637,50	433,20	1.652,80	6,5592
4/24/14	137,90	26,20	176,70	118,70	459,50	1,8559
4/25/14	591,00	115,20	765,80	522,50	1.994,50	7,8317
4/26/14	172,10	32,80	214,10	141,10	560,10	2,0040
4/27/14	276,00	51,90	349,80	241,00	918,70	3,3870
4/28/14	229,00	43,70	289,20	193,50	755,40	2,8342
4/29/14	552,90	99,90	705,70	492,50	1.851,00	6,9987
4/30/14	348,20	66,40	442,60	299,70	1.156,90	4,2304
5/1/14	631,60	120,10	813,50	557,60	2.122,80	8,2505
5/2/14	676,50	128,10	871,50	602,90	2.279,00	8,8601
5/3/14	621,10	118,10	813,00	563,60	2.115,80	8,7850
5/4/14	428,70	78,90	543,80	305,40	1.356,80	5,3308
5/5/14	408,70	79,70	485,30	279,80	1.253,50	5,3873
5/6/14	383,20	68,20	487,00	265,90	1.204,30	4,5784
5/7/14	313,50	57,00	361,50	214,00	946,00	3,8622
5/8/14	289,40	53,40	363,90	191,80	898,50	3,5199
5/9/14	96,80	17,60	112,80	64,60	291,80	1,2231
5/10/14	102,30	19,10	118,70	68,20	308,30	1,2465
5/11/14	272,90	7,50	417,90	225,00	923,30	4,0535
5/12/14	648,10	-	855,20	456,60	1.959,90	8,8060
5/13/14	754,20	-	741,10	431,10	1.926,40	8,1729
5/14/14	529,90	82,30	562,90	299,70	1.474,80	5,7499
5/15/14	799,30	11,10	812,90	416,70	2.040,00	8,9571
5/16/14	798,20	-	794,20	459,30	2.051,70	9,1224
5/17/14	700,10	-	832,10	563,00	2.095,20	9,3899
5/18/14	848,50	129,60	916,10	632,70	2.526,90	9,5815
5/19/14	654,90	98,90	594,40	487,20	1.835,40	7,5466

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
5/20/14	825,20	128,40	895,00	621,10	2.469,70	9,5448
5/21/14	826,50	125,90	885,40	607,70	2.445,50	9,1261
5/22/14	694,60	105,10	741,00	510,60	2.051,30	7,6074
5/23/14	604,40	91,20	593,60	442,30	1.731,50	6,7614
5/24/14	498,60	74,30	528,80	381,50	1.483,20	5,7371
5/25/14	611,50	93,70	590,70	430,40	1.726,30	6,6571
5/26/14	738,00	113,90	785,40	535,80	2.173,10	8,4070
5/27/14	710,70	110,20	758,20	524,50	2.103,60	8,2255
5/28/14	760,60	118,10	817,80	561,90	2.258,40	9,1286
5/29/14	708,10	109,80	763,10	523,70	2.104,70	8,2919
5/30/14	569,90	92,10	620,00	429,80	1.711,80	6,7470
5/31/14	541,00	81,90	565,90	385,00	1.573,80	5,3369
6/1/14	483,40	75,40	503,60	343,70	1.406,10	4,9204
6/2/14	418,10	65,50	437,70	302,10	1.223,40	4,3452
6/3/14	490,90	75,00	515,80	363,00	1.444,70	5,3366
6/4/14	547,00	85,90	577,40	92,00	1.302,30	5,6993
6/5/14	320,90	49,20	333,10	227,70	930,90	3,2089
6/6/14	204,50	30,90	211,20	141,70	588,30	2,0227
6/7/14	431,40	66,10	442,90	298,30	1.238,70	4,2920
6/8/14	747,00	112,90	792,50	544,10	2.196,50	8,1978
6/9/14	830,50	128,20	808,50	590,60	2.357,80	8,8418
6/10/14	810,10	123,50	857,10	136,20	1.926,90	8,9472
6/11/14	775,20	115,60	824,10	180,90	1.895,80	8,8277
6/12/14	695,00	104,70	734,90	512,50	2.047,10	8,0505
6/13/14	750,40	113,40	798,60	550,20	2.212,60	8,8165
6/14/14	744,00	113,60	796,90	551,80	2.206,30	8,9570
6/15/14	751,80	113,70	801,60	557,60	2.224,70	8,5953
6/16/14	431,80	77,00	492,40	327,40	1.328,60	6,0122
6/17/14	710,20	113,70	434,40	523,30	1.781,60	8,4672
6/18/14	629,10	96,90	651,70	458,50	1.836,20	7,1053
6/19/14	637,00	104,50	695,90	486,40	1.923,80	8,1654
6/20/14	456,80	70,00	475,90	322,40	1.325,10	4,8766
6/21/14	622,80	97,10	667,40	460,00	1.847,30	7,1093
6/22/14	798,70	125,00	834,80	566,90	2.325,40	8,9523
6/23/14	874,30	136,60	919,70	632,00	2.562,60	10,0414
6/24/14	859,30	132,60	903,50	627,10	2.522,50	10,1362
6/25/14	802,90	124,30	854,80	591,80	2.373,80	9,4700
6/26/14	797,00	122,40	849,60	591,50	2.360,50	9,4317
6/27/14	605,30	55,60	501,90	431,10	1.593,90	6,8283
6/28/14	668,70	97,20	696,10	498,00	1.960,00	7,5854
6/29/14	615,60	92,80	659,80	474,70	1.842,90	7,5128
6/30/14	573,70	104,00	638,20	498,70	1.814,60	8,6849
7/1/14	747,40	112,30	788,90	553,00	2.201,60	8,6997
7/2/14	825,70	125,80	873,40	607,10	2.432,00	9,6241
7/3/14	687,90	110,70	748,80	532,10	2.079,50	9,0751
7/4/14	561,40	88,80	580,80	411,30	1.642,30	6,3216
7/5/14	730,60	111,90	709,60	531,80	2.083,90	8,1281
7/6/14	860,30	132,50	892,80	628,60	2.514,20	9,8223
7/7/14	843,80	131,30	897,60	624,10	2.496,80	9,6398
7/8/14	805,80	123,20	789,30	598,30	2.316,60	9,3640
7/9/14	812,10	124,50	789,00	596,20	2.321,80	9,4809
7/10/14	805,20	123,90	850,00	589,90	2.369,00	9,4621
7/11/14	737,10	116,80	797,40	564,60	2.215,90	9,3274
7/12/14	759,90	117,50	686,40	564,90	2.128,70	9,0537
7/13/14	796,70	119,70	838,80	587,30	2.342,50	9,2146
7/14/14	785,70	119,10	833,20	581,60	2.319,60	9,4489
7/15/14	716,30	110,50	762,10	541,90	2.130,80	8,5107
7/16/14	500,20	92,60	630,10	433,00	1.655,90	6,4387
7/17/14	608,70	92,90	630,10	439,90	1.771,60	6,6694
7/18/14	576,80	88,30	587,30	401,80	1.654,20	6,0958
7/19/14	299,80	16,30	285,60	210,20	811,90	3,0270
7/20/14	595,10	114,70	701,30	520,80	1.931,90	8,0483
7/21/14	773,90	121,10	750,70	562,40	2.208,10	8,7778
7/22/14	829,30	129,40	872,90	605,30	2.436,90	9,5830
7/23/14	767,40	119,90	784,90	551,20	2.223,40	8,8636
7/24/14	533,60	81,20	549,30	378,90	1.543,00	5,7634
7/25/14	504,00	85,70	554,60	392,40	1.536,70	6,4208
7/26/14	762,40	117,00	802,10	554,00	2.235,50	8,6530
7/27/14	763,40	119,80	807,50	550,20	2.240,90	8,6993
7/28/14	755,30	120,40	739,30	547,90	2.162,90	8,7772
7/29/14	761,80	120,70	735,10	540,30	2.157,90	8,5624
7/30/14	770,60	120,40	800,10	543,60	2.234,70	8,5438

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
7/31/14	778,40	120,30	825,90	577,60	2.302,20	9,2078
8/1/14	761,60	119,20	807,40	558,70	2.246,90	8,7092
8/2/14	460,10	66,20	460,80	347,30	1.334,40	5,5209
8/3/14	340,10	28,60	353,00	241,70	963,40	3,6139
8/4/14	738,00	114,60	713,00	530,30	2.095,90	8,3327
8/5/14	743,40	111,50	740,90	529,00	2.124,80	8,3300
8/6/14	783,10	121,10	778,50	569,50	2.252,20	8,8745
8/7/14	396,90	65,20	504,60	296,60	1.263,30	5,0325
8/8/14	494,70	77,20	474,90	355,10	1.401,90	5,5219
8/9/14	500,30	75,20	475,20	353,70	1.404,40	5,2329
8/10/14	738,50	114,70	710,20	525,40	2.088,80	8,2070
8/11/14	743,00	82,20	626,00	419,60	1.870,80	8,7798
8/12/14	773,50	117,80	816,30	560,90	2.268,50	8,8380
8/13/14	796,90	122,30	583,30	576,30	2.078,80	9,1970
8/14/14	750,30	116,00	656,30	538,80	2.061,40	8,6255
8/15/14	713,00	110,80	692,40	511,40	2.027,60	8,3711
8/16/14	738,40	113,90	734,90	527,40	2.114,60	8,4199
8/17/14	650,50	100,60	648,70	477,70	1.877,50	7,5869
8/18/14	293,50	46,20	310,40	205,60	855,70	3,0249
8/19/14	802,00	122,70	775,70	575,00	2.275,40	9,0398
8/20/14	649,70	101,60	618,80	451,80	1.821,90	7,0437
8/21/14	689,80	105,70	723,20	508,70	2.027,40	8,1905
8/22/14	728,80	112,30	706,10	524,50	2.071,70	8,3937
8/23/14	750,90	114,40	791,70	541,10	2.198,10	8,5357
8/24/14	710,80	110,50	694,70	514,90	2.030,90	8,2837
8/25/14	562,30	81,80	590,00	408,10	1.642,20	6,1164
8/26/14	724,60	110,70	702,80	525,10	2.063,20	8,2264
8/27/14	676,70	103,90	701,20	487,30	1.969,10	7,8029
8/28/14	519,20	79,70	551,90	378,40	1.529,20	6,0332
8/29/14	616,30	93,80	654,60	454,70	1.819,40	7,0359
8/30/14	359,20	55,10	351,50	254,80	1.020,60	3,8629
8/31/14	575,00	88,00	604,30	410,90	1.678,20	6,3398
9/1/14	302,00	46,60	320,30	216,70	885,60	3,4272
9/2/14	515,50	79,60	493,50	366,20	1.454,80	5,7407
9/3/14	548,10	86,30	582,60	392,90	1.609,90	6,4570
9/4/14	600,10	93,40	622,90	425,00	1.741,40	6,6247
9/5/14	536,40	81,40	561,40	384,20	1.563,40	5,8293
9/6/14	399,50	61,60	414,40	276,20	1.151,70	4,1382
9/7/14	433,90	67,40	446,70	298,40	1.246,40	4,5380
9/8/14	439,60	68,40	459,00	311,50	1.278,50	4,7186
9/9/14	638,30	98,90	664,10	448,40	1.849,70	7,0602
9/10/14	688,80	105,80	715,20	490,90	2.000,70	7,7280
9/11/14	669,60	101,20	705,60	483,80	1.960,20	7,5888
9/12/14	586,50	88,20	600,50	420,50	1.695,70	6,6122
9/13/14	622,50	95,10	655,00	452,80	1.825,40	7,0939
9/14/14	562,50	83,60	595,00	414,60	1.655,70	6,4516
9/15/14	614,80	90,90	642,90	445,30	1.793,90	6,8914
9/16/14	587,10	87,90	615,40	413,40	1.703,80	6,4727
9/17/14	484,80	74,30	474,30	348,30	1.381,70	5,2984
9/18/14	175,80	27,40	168,80	120,60	492,60	1,8373
9/19/14	608,70	94,00	637,80	430,10	1.770,60	6,6373
9/20/14	580,20	88,70	609,70	421,80	1.700,40	6,5790
9/21/14	428,30	67,50	451,90	306,30	1.254,00	4,8670
9/22/14	638,30	96,70	669,80	460,00	1.864,80	7,1321
9/23/14	313,90	23,20	276,00	224,80	837,90	3,6603
9/24/14	658,40	102,00	696,50	478,30	1.935,20	7,3951
9/25/14	533,10	90,20	584,40	406,70	1.614,40	6,7171
9/26/14	375,10	57,00	395,30	267,70	1.095,10	4,2676
9/27/14	200,70	31,20	207,10	137,20	576,20	2,0150
9/28/14	112,10	17,50	107,50	77,40	314,50	1,1426
9/29/14	606,00	94,30	632,50	423,20	1.756,00	6,0274
9/30/14	592,20	90,90	614,00	438,60	1.735,70	6,2761
10/1/14	643,10	97,90	669,90	459,90	1.870,80	6,7076
10/2/14	471,80	73,00	488,40	333,40	1.366,60	4,5711
10/3/14	190,90	29,30	108,20	131,10	459,50	1,9517
10/4/14	161,90	25,30	75,30	107,40	369,90	1,6398
10/5/14	385,50	59,90	182,20	266,00	893,60	3,7820
10/6/14	304,40	47,30	142,30	205,00	699,00	2,8692
10/7/14	477,00	72,20	227,10	333,40	1.109,70	4,8314
10/8/14	296,70	45,80	139,20	207,40	689,10	3,0692
10/9/14	276,30	41,20	180,90	189,40	687,80	2,9716
10/10/14	272,90	49,90	330,00	241,70	894,50	4,1143

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
10/11/14	95,60	14,50	98,10	61,80	270,00	1,0244
10/12/14	134,20	20,50	128,10	90,60	373,40	1,4172
10/13/14	347,90	52,20	359,80	236,90	996,80	3,2382
10/14/14	274,50	41,80	259,50	193,40	769,20	2,7171
10/15/14	467,90	72,70	488,30	318,80	1.347,70	4,0969
10/16/14	274,70	41,80	285,70	192,20	794,40	2,8308
10/17/14	450,10	69,80	477,00	323,80	1.320,70	4,1672
10/18/14	267,50	40,80	254,70	183,70	746,70	2,6961
10/19/14	463,30	71,90	483,00	326,20	1.344,40	4,2797
10/20/14	548,30	83,20	573,80	391,00	1.596,30	5,2586
10/21/14	555,60	84,00	582,90	398,20	1.620,70	5,0726
10/22/14	541,40	81,30	567,00	387,40	1.577,10	4,8855
10/23/14	369,60	56,20	386,70	264,30	1.076,80	3,4760
10/24/14	353,50	53,20	366,40	246,40	1.019,50	3,3289
10/25/14	399,50	62,60	418,00	284,00	1.164,10	3,5950
10/26/14	271,10	42,70	283,90	190,00	787,70	2,7941
10/27/14	89,50	13,50	93,90	62,40	259,30	0,9548
10/28/14	68,90	10,40	72,10	47,60	199,00	0,7334
10/29/14	223,50	34,30	230,60	-	488,40	2,2718
10/30/14	70,80	10,80	73,30	-	154,90	0,7494
10/31/14	49,90	7,60	51,80	31,20	140,50	0,5308
11/1/14	261,40	41,20	271,70	183,60	757,90	2,4252
11/2/14	350,40	54,80	367,30	246,70	1.019,20	3,1567
11/3/14	348,50	50,50	358,30	244,20	1.001,50	3,2822
11/4/14	493,70	73,30	512,00	352,70	1.431,70	4,4861
11/5/14	478,60	70,40	497,70	341,40	1.388,10	4,3579
11/6/14	455,00	67,10	474,80	326,90	1.323,80	4,1345
11/7/14	373,00	55,30	387,60	265,40	1.081,30	3,5986
11/8/14	392,00	59,40	409,50	280,40	1.141,30	3,6061
11/9/14	235,40	34,80	244,10	165,00	679,30	2,5802
11/10/14	317,70	47,80	332,10	227,40	925,00	3,1494
11/11/14	314,90	48,30	328,40	226,10	917,70	2,9924
11/12/14	261,40	39,90	249,20	188,40	738,90	2,5040
11/13/14	146,70	-	151,20	99,60	397,50	1,5544
11/14/14	164,30	-	156,10	112,70	433,10	1,8207
11/15/14	62,30	-	65,00	42,70	170,00	0,6579
11/16/14	116,30	-	119,90	77,60	313,80	1,2004
11/17/14	221,30	34,50	225,70	155,20	636,70	1,8814
11/18/14	282,20	43,60	292,10	197,30	815,20	2,6185
11/19/14	173,50	27,40	178,40	121,00	500,30	1,7737
11/20/14	108,10	14,80	102,40	73,40	298,70	1,1236
11/21/14	89,70	14,00	84,00	58,80	246,50	0,8802
11/22/14	42,20	7,70	47,50	32,90	130,30	0,5259
11/23/14	27,00	4,10	26,50	18,00	75,60	0,2926
11/24/14	107,10	16,70	101,60	72,10	297,50	1,0955
11/25/14	55,80	-	53,00	36,90	145,70	0,5703
11/26/14	104,00	-	94,80	69,40	268,20	1,0408
11/27/14	105,50	-	48,90	70,50	224,90	1,0464
11/28/14	191,80	-	178,70	133,30	503,80	1,7859
11/29/14	105,40	-	100,80	74,20	280,40	1,1383
11/30/14	29,50	-	27,90	19,20	76,60	0,3091
12/1/14	31,70	-	30,30	21,20	83,20	0,3236
12/2/14	92,80	0,50	87,70	62,60	243,60	0,9410
12/3/14	200,70	32,10	192,00	141,10	565,90	1,7366
12/4/14	91,40	14,20	86,90	62,00	254,50	0,9554
12/5/14	41,30	6,30	40,30	29,10	117,00	0,5492
12/6/14	71,20	11,00	67,10	48,70	198,00	0,7653
12/7/14	235,60	40,90	270,10	201,80	748,40	2,8600
12/8/14	118,00	16,90	115,30	88,90	339,10	1,3310
12/9/14	130,90	20,40	123,80	89,60	364,70	1,2599
12/10/14	29,50	4,50	27,90	18,90	80,80	0,2942
12/11/14	126,20	19,30	119,90	87,00	352,40	1,2945
12/12/14	26,90	-	12,60	18,50	58,00	0,2825
12/13/14	147,60	21,50	68,20	106,70	344,00	1,3949
12/14/14	278,10	37,90	130,30	197,60	643,90	2,7904
12/15/14	211,20	35,80	200,00	141,40	588,40	1,8066
12/16/14	212,10	31,90	202,80	147,70	594,50	2,0580
12/17/14	88,20	13,80	83,70	59,40	245,10	0,9029
12/18/14	120,70	17,70	113,20	80,90	332,50	1,2250
12/19/14	326,70	45,80	306,10	223,40	902,00	3,2545
12/20/14	343,70	48,10	326,70	243,30	961,80	3,4055
12/21/14	103,60	14,50	98,00	71,20	287,30	1,1452

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
12/22/14	345,40	48,10	326,10	242,70	962,30	3,3776
12/23/14	342,50	46,20	323,80	242,60	955,10	3,3110
12/24/14	376,30	51,70	358,30	268,40	1.054,70	3,7497
12/25/14	370,10	50,80	351,90	263,10	1.035,90	3,7219
12/26/14	53,10	8,20	50,10	32,30	143,70	0,5355
12/27/14	24,60	3,60	23,40	15,80	67,40	0,2571
12/28/14	258,70	38,20	242,90	182,50	722,30	2,5767
12/29/14	25,70	2,80	24,30	16,80	69,60	0,2503
12/30/14	-	0,70	1,10	-	1,80	0,3984
12/31/14	4,00	1,30	8,10	6,70	20,10	0,3440
1/1/15	34,00	-	16,20	23,20	73,40	0,3508
1/2/15	149,90	-	70,50	102,40	322,80	1,3514
1/3/15	119,20	7,80	81,70	80,70	289,40	1,3464
1/4/15	90,20	13,80	86,20	60,00	250,20	0,8864
1/5/15	192,40	30,20	185,00	133,70	541,30	1,6504
1/6/15	60,60	10,90	61,50	42,60	175,60	0,7918
1/7/15	1,80	0,50	2,60	0,80	5,70	1,3320
1/8/15	-	-	-	-	-	0,7147
1/9/15	-	-	-	-	-	2,2717
1/10/15	7,40	-	16,70	11,30	35,40	0,4374
1/11/15	401,70	55,70	385,80	287,30	1.130,50	3,6535
1/12/15	10,90	1,60	10,60	1,60	24,70	0,0640
1/13/15	218,20	30,80	209,10	57,30	515,40	2,1292
1/14/15	343,20	54,60	332,60	239,90	970,30	2,8548
1/15/15	190,90	30,50	95,10	137,10	453,60	1,6024
1/16/15	69,50	10,80	32,50	46,40	159,20	0,6850
1/17/15	320,00	53,80	179,60	266,40	819,80	3,4962
1/18/15	333,60	45,00	158,60	234,00	771,20	3,3412
1/19/15	306,50	49,20	144,60	217,70	718,00	2,4015
1/20/15	242,40	38,00	114,30	171,00	565,70	2,1956
1/21/15	261,80	40,80	123,90	184,30	610,80	2,2959
1/22/15	380,30	55,20	181,80	271,50	888,80	3,4515
1/23/15	363,00	54,10	173,10	258,50	848,70	3,3295
1/24/15	232,20	37,90	110,10	166,10	546,30	1,5721
1/25/15	294,40	45,70	140,30	209,90	690,30	2,3842
1/26/15	78,00	11,90	37,00	52,60	179,50	0,8242
1/27/15	224,10	34,20	210,80	154,50	623,60	1,9197
1/28/15	54,60	8,40	52,60	36,10	151,70	0,5404
1/29/15	335,30	50,20	324,40	240,00	949,90	3,3190
1/30/15	297,00	40,70	261,80	208,90	808,40	3,1180
1/31/15	139,40	21,20	65,90	94,70	321,20	1,4358
2/1/15	258,00	27,20	122,30	179,10	586,60	2,5732
2/2/15	24,40	-	11,40	15,80	51,60	0,2237
2/3/15	219,80	-	103,60	154,90	478,30	1,7884
2/4/15	485,80	-	233,30	349,50	1.068,60	4,3282
2/5/15	433,20	-	208,50	308,30	950,00	4,0780
2/6/15	468,70	-	236,90	335,20	1.040,80	4,1322
2/7/15	87,10	-	83,50	58,60	229,20	0,8727
2/8/15	179,70	18,50	170,90	124,40	493,50	1,9177
2/9/15	59,50	11,00	68,80	47,80	187,10	0,6900
2/10/15	3,10	-	10,50	4,30	17,90	0,9963
2/11/15	1,10	-	-	0,80	1,90	1,2268
2/12/15	15,70	-	2,40	10,90	29,00	0,4076
2/13/15	132,80	-	123,30	89,80	345,90	1,3316
2/14/15	102,80	-	117,70	81,90	302,40	1,1838
2/15/15	175,00	-	150,80	96,90	422,70	1,7391
2/16/15	126,70	-	60,10	-	186,80	1,2464
2/17/15	145,90	-	77,40	-	223,30	1,9909
2/18/15	-	-	0,10	-	0,10	1,5739
2/19/15	-	-	-	-	-	-
2/20/15	0,10	-	0,40	-	0,50	1,0720
2/21/15	209,20	-	339,70	171,20	720,10	5,3874
2/22/15	467,60	-	464,50	326,30	1.258,40	5,2567
2/23/15	131,30	-	125,90	88,80	346,00	1,3264
2/24/15	456,30	-	450,70	328,60	1.235,60	4,4996
2/25/15	420,50	-	414,20	301,30	1.136,00	4,1210
2/26/15	493,60	-	483,80	356,20	1.333,60	4,6238
2/27/15	337,20	-	327,30	241,50	906,00	3,7056
2/28/15	268,20	-	260,00	188,30	716,50	2,6392
3/1/15	147,30	-	141,80	101,30	390,40	1,4634
3/2/15	580,20	-	565,50	412,60	1.558,30	4,9898
3/3/15	133,40	-	128,40	91,00	352,80	1,3668

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
3/4/15	595,10	-	580,60	427,70	1.603,40	5,6305
3/5/15	417,00	39,40	402,70	293,20	1.152,30	3,6015
3/6/15	372,90	59,00	398,50	268,10	1.098,50	3,9738
3/7/15	56,40	8,90	58,60	32,30	156,20	0,5541
3/8/15	73,80	11,50	77,80	50,30	213,40	0,7563
3/9/15	70,90	11,00	74,30	47,90	204,10	0,7153
3/10/15	88,50	13,90	92,20	59,50	254,10	0,8910
3/11/15	100,70	15,80	104,30	67,60	288,40	1,0094
3/12/15	420,90	65,20	441,20	292,90	1.220,20	3,8462
3/13/15	386,00	61,20	399,90	267,00	1.114,10	3,6114
3/14/15	236,40	45,10	277,50	200,40	759,40	2,9160
3/15/15	119,10	18,40	114,60	80,10	332,20	1,1694
3/16/15	180,00	29,10	174,30	121,80	505,20	1,7764
3/17/15	397,50	63,30	392,20	288,00	1.141,00	4,3221
3/18/15	534,30	87,50	511,50	362,00	1.495,30	4,9669
3/19/15	409,90	62,00	395,20	289,20	1.156,30	4,1512
3/20/15	272,90	43,60	264,70	184,00	765,20	2,6773
3/21/15	97,20	15,10	92,80	63,20	268,30	0,9722
3/22/15	742,40	116,90	726,20	536,60	2.122,10	7,8170
3/23/15	199,00	31,90	193,30	138,50	562,70	2,0658
3/24/15	428,90	65,00	408,20	295,30	1.197,40	4,0751
3/25/15	650,00	104,80	651,70	471,60	1.878,10	7,1410
3/26/15	587,40	95,50	592,80	423,80	1.699,50	6,4649
3/27/15	315,50	50,60	307,80	223,60	897,50	3,5330
3/28/15	364,80	56,50	348,00	253,70	1.023,00	3,6037
3/29/15	333,80	53,00	323,10	235,20	945,10	3,4038
3/30/15	535,00	84,80	524,60	391,00	1.535,40	5,8068
3/31/15	198,30	35,50	215,30	159,40	608,50	2,8551
4/1/15	736,80	117,30	723,90	534,70	2.112,70	7,8797
4/2/15	358,10	56,00	338,00	243,40	995,50	3,3771
4/3/15	677,00	109,30	671,30	493,60	1.951,20	7,3619
4/4/15	791,00	125,10	779,50	577,50	2.273,10	8,6980
4/5/15	510,40	82,60	498,40	362,40	1.453,80	5,2853
4/6/15	325,50	51,70	323,60	235,30	936,10	3,6833
4/7/15	169,90	27,50	165,00	118,70	481,10	1,7419
4/8/15	628,20	102,20	611,30	446,60	1.788,30	6,3353
4/9/15	78,10	12,00	75,70	51,50	217,30	0,7840
4/10/15	761,40	119,40	739,80	549,60	2.170,20	8,1332
4/11/15	784,30	124,70	768,80	570,40	2.248,20	8,3823
4/12/15	789,70	126,10	769,70	567,40	2.252,90	8,8532
4/13/15	731,80	116,70	719,40	533,00	2.100,90	8,0449
4/14/15	579,30	93,80	570,20	417,90	1.661,20	6,2764
4/15/15	691,90	110,70	674,20	497,00	1.973,80	7,3906
4/16/15	788,10	125,10	404,50	569,20	1.886,90	8,7484
4/17/15	793,70	124,10	386,70	576,20	1.880,70	8,6517
4/18/15	724,70	114,40	352,90	527,50	1.719,50	7,7916
4/19/15	80,00	8,30	64,40	48,10	200,80	0,8294
4/20/15	816,30	-	396,80	589,40	1.802,50	8,9117
4/21/15	326,80	-	152,80	225,00	704,60	3,1531
4/22/15	272,70	-	128,90	189,10	590,70	2,6690
4/23/15	509,50	64,90	440,80	357,10	1.372,30	5,3201
4/24/15	852,60	135,70	837,80	620,30	2.446,40	9,3507
4/25/15	590,90	95,00	583,30	431,60	1.700,80	6,6175
4/26/15	603,90	96,90	593,20	442,20	1.736,20	6,8343
4/27/15	797,50	126,90	781,90	578,50	2.284,80	8,8935
4/28/15	552,00	33,10	544,80	397,20	1.527,10	6,3962
4/29/15	725,30	-	717,40	534,30	1.977,00	8,2836
4/30/15	609,20	-	598,40	437,10	1.644,70	6,5875
5/1/15	454,60	61,90	436,60	325,60	1.278,70	4,7745
5/2/15	608,10	98,50	601,90	442,40	1.750,90	6,8695
5/3/15	307,10	48,00	292,90	212,30	860,30	3,0996
5/4/15	781,00	119,00	759,00	564,30	2.223,30	9,1090
5/5/15	795,60	126,80	776,20	572,00	2.270,60	9,2673
5/6/15	788,30	125,20	425,50	566,50	1.905,50	9,1080
5/7/15	695,80	112,20	341,20	501,50	1.650,70	8,1028
5/8/15	128,90	20,20	61,30	89,10	299,50	1,3206
5/9/15	795,60	124,50	383,50	575,00	1.878,60	8,5407
5/10/15	882,70	138,10	429,10	632,50	2.082,40	9,6722
5/11/15	726,70	136,50	420,60	624,40	1.908,20	9,3359
5/12/15	854,80	136,60	815,10	622,60	2.429,10	9,4031
5/13/15	824,40	130,10	802,20	592,60	2.349,30	9,2369
5/14/15	814,70	130,40	801,70	594,50	2.341,30	9,3770

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
5/15/15	790,30	125,30	790,00	581,30	2.286,90	9,0351
5/16/15	717,40	114,20	768,60	409,30	2.009,50	8,1765
5/17/15	763,20	122,70	811,20	431,40	2.128,50	8,6902
5/18/15	775,80	121,40	829,00	443,60	2.169,80	8,7811
5/19/15	778,50	104,00	834,90	558,60	2.276,00	8,9786
5/20/15	393,70	76,30	497,60	339,80	1.307,40	5,2202
5/21/15	349,70	56,70	366,30	244,20	1.016,90	3,8023
5/22/15	721,10	114,30	761,80	522,90	2.120,10	8,2946
5/23/15	783,80	124,80	830,20	568,50	2.307,30	9,2494
5/24/15	703,10	114,30	750,10	512,00	2.079,50	8,3072
5/25/15	720,70	115,80	761,70	525,30	2.123,50	8,3611
5/26/15	820,10	130,80	874,80	597,80	2.423,50	9,5571
5/27/15	185,50	29,40	179,10	128,40	522,40	1,9401
5/28/15	278,20	43,10	262,10	188,00	771,40	2,6192
5/29/15	677,70	75,30	702,70	482,10	1.937,80	7,3571
5/30/15	534,70	40,70	558,00	375,50	1.508,90	5,5909
5/31/15	808,60	-	856,70	569,00	2.234,30	8,9761
6/1/15	834,10	-	820,50	607,70	2.262,30	9,3679
6/2/15	464,00	-	432,80	306,00	1.202,80	4,4440
6/3/15	302,60	-	289,90	210,30	802,80	3,1234
6/4/15	792,10	-	771,40	569,10	2.132,60	9,0059
6/5/15	231,10	-	211,70	122,90	565,70	2,5520
6/6/15	495,10	-	239,30	-	734,40	5,3663
6/7/15	565,50	-	583,30	394,20	1.543,00	5,9629
6/8/15	265,90	-	255,30	184,10	705,30	2,7258
6/9/15	618,80	-	623,70	442,70	1.685,20	6,8736
6/10/15	451,40	-	477,10	329,20	1.257,70	5,3880
6/11/15	680,00	-	705,80	479,50	1.865,30	7,5284
6/12/15	547,70	-	690,80	481,80	1.720,30	7,5210
6/13/15	781,80	-	815,70	555,70	2.153,20	8,6853
6/14/15	819,50	-	863,90	585,90	2.269,30	9,4283
6/15/15	773,70	-	818,20	556,80	2.148,70	9,0580
6/16/15	565,20	-	598,80	410,90	1.574,90	6,6425
6/17/15	753,70	-	790,40	538,40	2.082,50	8,5069
6/18/15	380,10	-	434,20	297,90	1.112,20	4,7921
6/19/15	219,30	-	333,50	223,40	776,20	3,2341
6/20/15	546,70	-	854,30	585,70	1.986,70	9,4756
6/21/15	572,00	-	897,60	614,00	2.083,60	9,8460
6/22/15	354,50	-	564,90	380,00	1.299,40	6,0112
6/23/15	278,00	-	429,50	288,50	996,00	4,2749
6/24/15	409,30	-	631,90	418,20	1.459,40	6,3144
6/25/15	614,60	-	696,00	470,40	1.781,00	7,4710
6/26/15	781,00	-	827,50	567,70	2.176,20	8,9022
6/27/15	636,50	-	673,90	456,70	1.767,10	7,0225
6/28/15	732,00	-	762,90	521,20	2.016,10	8,0232
6/29/15	729,00	-	765,40	525,10	2.019,50	8,2136
6/30/15	789,00	-	829,90	567,60	2.186,50	9,1102
7/1/15	302,40	-	264,00	250,40	816,80	9,1157
7/2/15	743,50	-	774,80	522,40	2.040,70	8,3748
7/3/15	725,50	-	759,70	531,60	2.016,80	8,4373
7/4/15	617,60	78,00	622,40	422,60	1.740,60	8,1521
7/5/15	789,50	125,10	382,80	566,90	1.864,30	9,1203
7/6/15	765,00	116,60	387,10	562,20	1.830,90	9,2266
7/7/15	702,80	101,10	758,10	521,90	2.083,90	9,0640
7/8/15	785,60	123,10	829,80	568,90	2.307,40	9,6105
7/9/15	746,00	115,70	783,40	529,50	2.174,60	9,2116
7/10/15	762,10	115,90	816,80	554,10	2.248,90	9,1701
7/11/15	714,50	116,30	740,40	495,40	2.066,60	7,9335
7/12/15	862,60	135,00	902,20	619,80	2.519,60	9,8300
7/13/15	805,90	124,80	843,70	575,90	2.350,30	9,2100
7/14/15	763,00	120,10	806,40	545,90	2.235,40	8,9092
7/15/15	798,40	124,00	834,70	564,00	2.321,10	9,1353
7/16/15	812,80	130,60	836,80	593,20	2.373,40	9,6883
7/17/15	740,90	119,70	796,10	554,30	2.211,00	9,5442
7/18/15	732,40	129,10	816,70	579,00	2.257,20	9,7294
7/19/15	835,60	129,10	568,30	579,00	2.112,00	9,7688
7/20/15	741,60	116,70	771,50	531,70	2.161,50	8,9501
7/21/15	822,50	129,00	797,20	589,60	2.338,30	9,4919
7/22/15	732,80	112,50	710,50	532,50	2.088,30	8,5515
7/23/15	750,50	115,10	718,80	529,60	2.114,00	8,3177
7/24/15	552,60	83,60	533,50	390,80	1.560,50	6,2189
7/25/15	490,60	73,00	482,20	347,50	1.393,30	5,4802

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
7/26/15	727,10	114,70	767,00	530,40	2.139,20	9,0115
7/27/15	736,90	115,70	715,10	528,10	2.095,80	8,7845
7/28/15	719,60	112,80	700,20	518,30	2.050,90	8,7594
7/29/15	745,10	115,80	724,90	536,00	2.121,80	8,9087
7/30/15	732,60	113,10	714,70	527,40	2.087,80	8,8164
7/31/15	714,10	109,40	697,80	519,40	2.040,70	8,6672
8/1/15	404,20	63,90	398,00	290,00	1.156,10	4,8340
8/2/15	574,70	89,70	550,50	404,20	1.619,10	6,3249
8/3/15	641,90	95,10	623,90	466,70	1.827,60	7,4981
8/4/15	720,60	113,90	695,40	505,60	2.035,50	8,3098
8/5/15	660,10	101,20	640,90	474,00	1.876,20	7,6585
8/6/15	657,70	104,20	690,80	467,20	1.919,90	7,5504
8/7/15	457,50	13,50	263,90	257,10	992,00	4,9248
8/8/15	615,20	-	297,40	445,50	1.358,10	7,0429
8/9/15	683,90	-	327,90	476,10	1.487,90	7,7269
8/10/15	325,10	-	151,00	218,20	694,30	3,4160
8/11/15	433,10	-	203,80	297,00	933,90	4,7082
8/12/15	643,60	100,80	621,50	456,70	1.822,60	7,9751
8/13/15	623,80	98,90	612,00	462,30	1.797,00	8,5489
8/14/15	-	110,50	339,30	495,90	945,70	8,1534
8/15/15	-	105,10	328,40	483,10	916,60	7,9683
8/16/15	510,10	100,70	563,20	460,60	1.634,60	8,1695
8/17/15	686,40	107,30	673,00	490,30	1.957,00	8,2317
8/18/15	564,00	88,30	414,00	246,50	1.312,80	6,9397
8/19/15	629,80	101,50	476,70	108,50	1.316,50	7,9094
8/20/15	683,80	105,60	676,50	111,90	1.577,80	8,2995
8/21/15	424,70	65,90	420,20	72,70	983,50	5,1804
8/22/15	309,00	48,60	149,10	11,10	517,80	3,4377
8/23/15	296,20	5,30	298,40	209,60	809,50	3,6398
8/24/15	666,70	-	696,20	477,90	1.840,80	7,6774
8/25/15	706,60	-	685,40	507,10	1.899,10	8,2142
8/26/15	708,00	-	686,30	503,90	1.898,20	7,9827
8/27/15	705,40	-	680,60	498,00	1.884,00	7,9404
8/28/15	745,80	-	723,70	532,90	2.002,40	8,5247
8/29/15	710,20	-	698,90	507,50	1.916,60	8,1928
8/30/15	700,50	110,10	684,50	501,80	1.996,90	8,1969
8/31/15	640,20	99,80	628,20	469,50	1.837,70	7,6139
9/1/15	708,10	110,40	692,60	508,60	2.019,70	8,3686
9/2/15	682,40	107,30	668,20	485,80	1.943,70	8,0882
9/3/15	641,00	100,80	627,90	456,10	1.825,80	7,5702
9/4/15	612,40	96,60	600,00	439,60	1.748,60	7,4974
9/5/15	639,30	101,80	629,20	456,80	1.827,10	7,6703
9/6/15	-	98,00	613,60	447,90	1.159,50	7,4166
9/7/15	-	62,40	387,50	271,70	721,60	4,3527
9/8/15	186,20	46,90	283,80	198,90	715,80	3,3246
9/9/15	508,60	82,80	495,70	350,30	1.437,40	5,6258
9/10/15	590,40	93,40	577,60	411,50	1.672,90	6,6405
9/11/15	564,90	91,40	560,70	395,80	1.612,80	6,5873
9/12/15	124,50	8,00	121,00	82,70	336,20	1,3758
9/13/15	277,10	-	265,50	187,80	730,40	2,9478
9/14/15	193,20	36,70	219,40	153,80	603,10	2,4186
9/15/15	374,10	70,70	422,20	300,20	1.167,20	4,5650
9/16/15	464,20	86,80	533,80	379,80	1.464,60	5,8926
9/17/15	508,50	94,90	586,90	434,10	1.624,40	7,0601
9/18/15	425,90	81,10	503,80	379,30	1.390,10	6,0882
9/19/15	429,70	81,30	498,20	364,30	1.373,50	6,0337
9/20/15	414,60	79,60	483,00	348,10	1.325,30	5,5562
9/21/15	475,70	90,90	559,70	403,10	1.529,40	6,4854
9/22/15	419,70	78,30	493,90	361,20	1.353,10	5,7243
9/23/15	313,90	58,90	363,70	265,20	1.001,70	4,2322
9/24/15	-	-	245,60	-	245,60	5,7367
9/25/15	-	-	294,60	-	294,60	7,0450
9/26/15	-	-	294,60	-	294,60	6,8862
9/27/15	313,90	-	361,20	258,60	933,70	4,0477
9/28/15	142,70	-	165,00	116,80	424,50	1,9074
9/29/15	120,30	-	140,90	104,50	365,70	1,6768
9/30/15	70,70	5,40	92,50	59,10	227,70	1,2138
10/1/15	221,40	42,60	255,20	178,30	697,50	2,7336
10/2/15	143,40	22,10	147,70	92,40	405,60	1,7930
10/3/15	286,20	-	161,20	-	447,40	3,3413
10/4/15	397,40	-	222,00	-	619,40	4,5504
10/5/15	369,80	69,10	433,80	319,90	1.192,60	4,7097

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
10/6/15	112,80	20,70	131,50	92,70	357,70	1,4712
10/7/15	354,70	66,60	406,70	292,60	1.120,60	4,0784
10/8/15	170,40	32,40	195,60	141,00	539,40	1,8239
10/9/15	432,50	80,10	508,60	371,00	1.392,20	5,5666
10/10/15	435,20	82,10	513,20	373,20	1.403,70	5,1838
10/11/15	139,90	26,40	161,80	114,50	442,60	1,7193
10/12/15	374,80	70,90	437,40	318,50	1.201,60	4,2301
10/13/15	61,90	11,30	70,40	47,40	191,00	0,7690
10/14/15	-	59,20	178,00	263,40	500,60	3,6454
10/15/15	152,30	37,90	210,10	170,50	570,80	2,8197
10/16/15	298,70	54,30	344,60	248,70	946,30	3,8110
10/17/15	243,00	45,80	281,80	197,70	768,30	2,8445
10/18/15	131,10	24,80	150,30	103,60	409,80	1,6746
10/19/15	275,30	52,70	319,80	228,00	875,80	3,0175
10/20/15	376,80	71,30	444,80	321,50	1.214,40	4,2579
10/21/15	41,40	7,60	48,10	32,70	129,80	0,5338
10/22/15	70,80	13,30	81,70	55,50	221,30	0,9186
10/23/15	74,50	14,00	85,90	59,20	233,60	0,9785
10/24/15	70,30	13,10	81,80	55,70	220,90	0,8784
10/25/15	189,30	32,90	215,00	155,30	592,50	2,4075
10/26/15	377,60	69,00	436,80	318,20	1.201,60	4,4993
10/27/15	247,60	44,00	287,00	206,20	784,80	3,3422
10/28/15	361,00	65,00	384,60	308,50	1.119,10	4,1312
10/29/15	71,70	13,20	40,30	57,10	182,30	0,9528
10/30/15	178,80	33,90	101,00	146,30	460,00	2,0704
10/31/15	195,30	34,80	111,90	161,20	503,20	2,5373
11/1/15	169,50	32,80	95,20	139,20	436,70	2,0748
11/2/15	371,20	71,70	211,40	316,90	971,20	4,0376
11/3/15	394,10	73,40	430,50	338,20	1.236,20	4,4503
11/4/15	392,00	71,10	458,20	333,50	1.254,80	4,3998
11/5/15	373,40	68,50	440,00	321,40	1.203,30	4,2633
11/6/15	60,80	11,50	70,00	46,80	189,10	0,7894
11/7/15	40,00	7,40	46,20	31,20	124,80	0,5172
11/8/15	286,30	54,00	333,80	235,70	909,80	3,1137
11/9/15	163,00	31,10	193,80	143,70	531,60	1,6883
11/10/15	203,40	37,50	237,30	165,70	643,90	2,6158
11/11/15	247,50	26,40	291,90	209,80	775,60	2,8918
11/12/15	291,50	52,80	341,50	240,70	926,50	3,6678
11/13/15	230,90	44,30	270,30	188,20	733,70	2,6677
11/14/15	326,40	59,60	383,60	275,10	1.044,70	3,7373
11/15/15	256,60	47,00	299,00	209,60	812,20	2,9811
11/16/15	188,90	35,90	221,20	157,10	603,10	2,3344
11/17/15	322,90	60,00	380,00	273,00	1.035,90	3,6986
11/18/15	312,70	56,30	367,80	264,10	1.000,90	3,6907
11/19/15	262,90	49,30	308,70	221,60	842,50	3,0634
11/20/15	326,50	57,10	386,60	275,90	1.046,10	3,8316
11/21/15	213,20	36,20	247,30	173,50	670,20	2,8082
11/22/15	219,60	10,70	259,60	184,80	674,70	2,4535
11/23/15	186,40	34,70	216,90	153,30	591,30	2,1326
11/24/15	160,40	29,50	186,70	130,50	507,10	2,0825
11/25/15	221,10	40,90	259,70	183,60	705,30	2,5635
11/26/15	-	13,20	48,00	6,90	68,10	1,1619
11/27/15	-	29,20	87,30	125,90	242,40	1,9933
11/28/15	-	7,40	22,70	31,70	61,80	0,5228
11/29/15	-	12,00	35,10	47,40	94,50	0,7422
11/30/15	-	48,60	158,00	234,70	441,30	3,2204
12/1/15	-	25,90	83,80	121,30	231,00	1,8808
12/2/15	-	18,10	53,00	75,00	146,10	1,1426
12/3/15	-	46,60	150,10	222,10	418,80	3,2036
12/4/15	-	24,50	72,80	106,50	203,80	1,5838
12/5/15	-	50,00	166,80	245,90	462,70	3,5931
12/6/15	258,60	44,90	146,20	213,70	663,40	3,1609
12/7/15	266,50	46,50	150,90	219,60	683,50	3,2167
12/8/15	43,20	8,10	23,90	32,50	107,70	0,5421
12/9/15	50,60	9,50	28,80	39,80	128,70	0,6269
12/10/15	23,30	3,60	10,80	14,60	52,30	0,2223
12/11/15	82,10	12,60	38,60	53,80	187,10	0,8725
12/12/15	154,20	22,10	71,50	99,50	347,30	1,5859
12/13/15	190,80	30,90	91,10	143,20	456,00	1,9534
12/14/15	298,60	40,60	141,10	209,00	689,30	3,1779
12/15/15	146,80	20,50	68,80	100,10	336,20	1,6132
12/16/15	71,90	11,30	33,50	46,80	163,50	0,7292

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
12/17/15	77,00	12,00	36,00	51,80	176,80	0,8046
12/18/15	119,50	19,20	55,80	78,20	272,70	1,1697
12/19/15	331,20	46,50	159,20	238,60	775,50	3,5352
12/20/15	162,30	28,10	74,70	112,90	378,00	1,4371
12/21/15	293,60	43,80	137,80	205,40	680,60	2,9623
12/22/15	341,40	48,50	161,20	238,50	789,60	3,5278
12/23/15	305,10	44,10	143,50	210,60	703,30	3,1729
12/24/15	314,80	44,70	148,70	217,60	725,80	3,2918
12/25/15	197,50	29,70	92,40	135,20	454,80	2,0032
12/26/15	124,50	20,40	57,70	81,50	284,10	1,1644
12/27/15	324,20	46,30	153,10	224,30	747,90	3,3867
12/28/15	328,40	47,30	154,30	227,20	757,20	3,3853
12/29/15	89,80	11,60	42,30	60,30	204,00	1,0002
12/30/15	112,60	18,70	54,70	78,30	264,30	1,1309
12/31/15	-	-	-	-	-	-
1/1/16	-	-	-	-	-	-
1/2/16	-	-	-	-	-	0,5705
1/3/16	-	-	-	-	-	-
1/4/16	-	-	2,40	-	2,40	0,4026
1/5/16	11,50	0,80	13,30	8,70	34,30	0,2958
1/6/16	149,80	22,30	71,30	101,20	344,60	1,3314
1/7/16	109,40	16,00	51,60	73,10	250,10	1,1762
1/8/16	149,90	29,00	82,60	121,20	382,70	1,7837
1/9/16	286,20	48,50	331,40	238,90	905,00	3,5842
1/10/16	105,10	19,10	119,80	84,20	328,20	1,3733
1/11/16	303,90	52,70	356,80	258,40	971,80	3,6132
1/12/16	312,60	55,80	364,20	262,20	994,80	3,6204
1/13/16	137,50	25,30	159,30	111,30	433,40	1,7291
1/14/16	201,90	37,50	238,20	172,80	650,40	2,5451
1/15/16	193,10	33,80	221,50	158,20	606,60	2,2106
1/16/16	69,30	13,10	79,80	53,90	216,10	0,8679
1/17/16	65,10	8,50	72,70	51,70	198,00	0,9598
1/18/16	0,50	-	0,90	0,20	1,60	0,5982
1/19/16	-	-	0,70	0,50	1,20	1,7364
1/20/16	0,50	-	4,50	1,70	6,70	2,8526
1/21/16	17,50	-	72,50	14,30	104,30	2,6047
1/22/16	31,50	-	65,80	16,00	113,30	1,2595
1/23/16	69,30	-	137,80	35,40	242,50	2,4860
1/24/16	50,50	-	129,50	28,40	208,40	2,9174
1/25/16	107,70	-	186,00	53,60	347,30	2,1247
1/26/16	24,90	-	38,00	9,70	72,60	0,6215
1/27/16	174,40	-	267,60	97,10	539,10	3,6278
1/28/16	148,10	-	169,10	117,50	434,70	1,6286
1/29/16	232,40	-	270,50	189,50	692,40	2,2481
1/30/16	67,80	-	78,40	52,40	198,60	0,8580
1/31/16	254,30	-	292,80	205,90	753,00	2,4527
2/1/16	211,80	-	243,10	169,80	624,70	2,1790
2/2/16	381,30	-	443,40	318,10	1.142,80	4,1613
2/3/16	369,40	-	426,50	305,90	1.101,80	3,9725
2/4/16	171,30	-	196,70	135,90	503,90	2,1961
2/5/16	24,80	-	28,90	19,00	72,70	0,2779
2/6/16	72,90	-	83,50	56,00	212,40	0,8639
2/7/16	303,40	-	346,30	244,40	894,10	3,2971
2/8/16	428,70	-	498,00	358,70	1.285,40	4,6346
2/9/16	423,80	-	498,00	358,30	1.280,10	4,3737
2/10/16	357,50	-	416,60	298,70	1.072,80	4,2127
2/11/16	140,80	-	162,50	114,10	417,40	1,1342
2/12/16	116,30	-	133,00	90,70	340,00	1,4142
2/13/16	102,00	17,30	116,90	80,80	317,00	1,2136
2/14/16	370,60	69,40	435,20	317,50	1.192,70	3,9123
2/15/16	317,90	60,00	371,00	265,30	1.014,20	3,8079
2/16/16	292,10	54,60	337,70	241,20	925,60	3,4955
2/17/16	234,60	44,70	269,10	189,20	737,60	2,8284
2/18/16	136,60	24,00	159,90	119,80	440,30	1,8485
2/19/16	68,20	12,60	78,10	53,10	212,00	0,8320
2/20/16	77,00	14,10	88,40	60,80	240,30	0,9544
2/21/16	180,00	32,90	209,10	151,50	573,50	2,1775
2/22/16	452,40	86,20	532,90	382,60	1.454,10	4,7044
2/23/16	466,00	87,40	547,60	375,80	1.476,80	5,0487
2/24/16	89,50	16,90	102,20	69,00	277,60	1,1057
2/25/16	86,50	16,10	98,10	66,80	267,50	1,0585
2/26/16	243,40	46,00	280,50	195,40	765,30	3,0457

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
2/27/16	267,00	49,90	310,30	223,40	850,60	3,1084
2/28/16	115,60	21,80	108,00	91,10	336,50	1,4329
2/29/16	400,40	77,80	464,50	332,00	1.274,70	4,2976
3/1/16	364,00	70,80	423,60	305,10	1.163,50	4,1202
3/2/16	152,30	28,90	174,70	121,60	477,50	1,8866
3/3/16	-	25,60	156,70	-	182,30	1,6411
3/4/16	-	56,70	340,30	-	397,00	2,6437
3/5/16	-	36,90	221,00	-	257,90	2,2938
3/6/16	-	88,20	552,70	-	640,90	5,5694
3/7/16	-	70,30	433,80	-	504,10	4,5750
3/8/16	-	70,90	445,10	-	516,00	4,9523
3/9/16	-	75,70	465,40	-	541,10	5,0343
3/10/16	-	70,00	428,40	-	498,40	4,1187
3/11/16	-	100,80	613,40	-	714,20	6,1239
3/12/16	-	84,90	523,10	-	608,00	5,3401
3/13/16	-	16,00	93,30	-	109,30	0,9745
3/14/16	-	11,20	70,80	-	82,00	0,7476
3/15/16	-	24,80	150,10	-	174,90	1,5674
3/16/16	-	41,50	250,90	-	292,40	2,6132
3/17/16	-	33,70	202,30	-	236,00	2,1153
3/18/16	-	112,00	699,60	-	811,60	7,5865
3/19/16	-	25,00	153,90	-	178,90	1,6485
3/20/16	212,50	39,30	248,60	177,60	678,00	2,6544
3/21/16	535,40	-	627,20	455,00	1.617,60	6,9680
3/22/16	272,40	-	393,10	279,50	945,00	4,2516
3/23/16	280,30	-	326,10	231,70	838,10	3,7082
3/24/16	267,00	-	309,10	219,60	795,70	3,4185
3/25/16	120,80	-	138,80	94,00	353,60	1,4643
3/26/16	307,80	-	352,30	250,50	910,60	3,7250
3/27/16	500,00	-	578,60	417,60	1.496,20	6,3940
3/28/16	251,90	-	282,60	197,60	732,10	2,9530
3/29/16	551,50	-	646,50	467,10	1.665,10	7,2355
3/30/16	554,20	-	647,20	468,60	1.670,00	7,2708
3/31/16	561,20	-	667,80	491,30	1.720,30	8,1919
4/1/16	596,50	-	694,60	504,90	1.796,00	8,0188
4/2/16	307,50	-	350,60	242,50	900,60	3,7794
4/3/16	639,80	-	741,00	533,90	1.914,70	8,4150
4/4/16	623,80	48,00	721,50	519,70	1.913,00	8,3200
4/5/16	604,80	113,80	702,80	504,70	1.926,10	8,2271
4/6/16	579,70	108,90	673,20	483,10	1.844,90	8,0005
4/7/16	568,00	107,80	657,50	472,50	1.805,80	7,9685
4/8/16	271,40	50,20	307,80	216,70	846,10	3,3828
4/9/16	491,20	60,80	486,40	346,40	1.384,80	5,9493
4/10/16	619,90	96,70	601,70	430,40	1.748,70	6,6957
4/11/16	673,60	108,10	662,70	479,80	1.924,20	7,7662
4/12/16	457,60	69,90	430,70	304,60	1.262,80	4,7246
4/13/16	730,10	113,60	711,80	519,40	2.074,90	8,3200
4/14/16	488,10	76,80	475,50	339,50	1.379,90	5,4813
4/15/16	600,20	93,00	578,10	415,40	1.686,70	6,6846
4/16/16	717,90	113,20	702,00	505,00	2.038,10	8,4879
4/17/16	743,30	115,00	728,90	529,30	2.116,50	8,5943
4/18/16	687,30	108,00	673,10	485,00	1.953,40	8,0137
4/19/16	587,50	93,70	577,70	414,80	1.673,70	6,9644
4/20/16	598,20	96,00	583,70	411,80	1.689,70	6,7811
4/21/16	755,40	117,90	727,20	526,90	2.127,40	8,1692
4/22/16	808,40	127,50	780,70	566,00	2.282,60	9,2870
4/23/16	443,50	71,20	430,50	309,60	1.254,80	5,0275
4/24/16	538,00	85,60	523,10	379,00	1.525,70	6,1287
4/25/16	647,10	100,00	394,10	453,60	1.594,80	6,9663
4/26/16	368,80	59,30	179,60	257,90	865,60	4,1744
4/27/16	733,80	115,10	352,50	512,20	1.713,60	8,2193
4/28/16	663,60	107,50	324,70	466,90	1.562,70	7,7516
4/29/16	552,20	88,90	267,60	377,50	1.286,20	6,0146
4/30/16	817,50	132,20	397,20	565,70	1.912,60	9,1554
5/1/16	469,00	70,40	222,30	327,10	1.088,80	5,1127
5/2/16	543,10	87,30	265,80	372,10	1.268,30	5,9996
5/3/16	408,70	3,00	198,20	280,60	890,50	4,4170
5/4/16	618,40	45,30	298,70	436,90	1.399,30	6,8605
5/5/16	417,50	67,10	204,20	291,80	980,60	4,5501
5/6/16	583,40	90,90	277,60	400,40	1.352,30	6,0364
5/7/16	735,50	120,00	348,10	470,30	1.673,90	7,7193
5/8/16	810,90	127,60	390,70	565,90	1.895,10	9,2930

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
5/9/16	831,10	129,90	399,90	577,70	1.938,60	9,2086
5/10/16	684,20	108,50	336,90	474,90	1.604,50	7,6024
5/11/16	524,20	83,40	255,30	354,40	1.217,30	5,6378
5/12/16	469,40	75,20	231,90	327,40	1.103,90	5,2145
5/13/16	553,20	86,80	265,50	377,40	1.282,90	5,8845
5/14/16	820,40	128,00	399,90	576,40	1.924,70	9,3481
5/15/16	799,90	128,00	390,50	571,20	1.889,60	9,2884
5/16/16	814,90	129,30	394,30	571,40	1.909,90	9,3099
5/17/16	525,50	79,30	252,70	362,10	1.219,60	5,5689
5/18/16	716,80	112,50	342,70	497,60	1.669,60	7,8171
5/19/16	708,30	112,90	344,40	508,00	1.673,60	8,3676
5/20/16	676,70	108,80	283,30	476,00	1.544,80	8,1034
5/21/16	409,10	65,00	-	280,00	754,10	4,4030
5/22/16	191,90	30,50	-	122,50	344,90	1,9579
5/23/16	644,00	101,30	-	438,50	1.183,80	6,9633
5/24/16	687,90	109,00	332,70	483,70	1.613,30	7,9065
5/25/16	769,20	123,60	377,50	548,30	1.818,60	8,8777
5/26/16	625,60	99,40	304,30	444,60	1.473,90	6,9995
5/27/16	199,70	32,50	96,40	133,90	462,50	2,2239
5/28/16	-	113,50	-	-	113,50	8,2040
5/29/16	-	121,80	-	-	121,80	8,7705
5/30/16	-	126,30	139,70	-	266,00	9,2881
5/31/16	-	120,90	367,60	-	488,50	8,9320
6/1/16	-	116,10	350,40	-	466,50	8,7159
6/2/16	716,90	117,10	359,90	511,00	1.704,90	8,9315
6/3/16	547,70	87,70	267,60	370,80	1.273,80	6,1867
6/4/16	486,30	76,50	236,90	345,60	1.145,30	5,7729
6/5/16	768,80	121,10	365,50	534,00	1.789,40	8,7683
6/6/16	709,00	115,70	343,90	502,90	1.671,50	8,5846
6/7/16	333,50	23,60	73,60	227,10	657,80	3,6359
6/8/16	560,80	104,90	314,40	464,60	1.444,70	7,2886
6/9/16	739,80	117,50	440,60	517,00	1.814,90	8,4268
6/10/16	821,10	129,80	787,10	557,20	2.295,20	9,1541
6/11/16	805,40	-	-	567,30	1.372,70	9,6965
6/12/16	792,40	-	-	558,90	1.351,30	9,5261
6/13/16	636,50	31,80	494,60	451,30	1.614,20	7,5021
6/14/16	591,20	95,70	570,00	416,60	1.673,50	6,7282
6/15/16	760,80	119,70	734,00	539,70	2.154,20	8,7176
6/16/16	741,40	117,40	723,30	532,30	2.114,40	9,1140
6/17/16	764,10	119,80	738,90	534,00	2.156,80	9,4016
6/18/16	764,80	121,00	682,90	534,90	2.103,60	9,2410
6/19/16	743,80	117,20	374,80	518,00	1.753,80	9,0642
6/20/16	794,30	-	726,40	552,20	2.072,90	9,2927
6/21/16	688,10	-	789,10	572,40	2.049,60	9,5937
6/22/16	659,80	-	765,90	545,90	1.971,60	9,2520
6/23/16	613,00	-	709,90	507,00	1.829,90	8,3468
6/24/16	662,50	-	773,40	559,90	1.995,80	9,3853
6/25/16	647,60	-	753,80	546,30	1.947,70	9,2145
6/26/16	567,60	-	660,50	466,60	1.694,70	7,8642
6/27/16	540,60	101,30	311,60	454,40	1.407,90	7,4912
6/28/16	422,30	79,20	453,00	346,40	1.300,90	5,8202
6/29/16	541,20	101,70	629,30	456,10	1.728,30	7,5497
6/30/16	432,10	78,90	488,90	351,40	1.351,30	5,6342
7/1/16	629,20	119,80	730,10	530,20	2.009,30	9,0256
7/2/16	619,10	116,90	725,40	529,00	1.990,40	8,9638
7/3/16	521,70	98,00	300,10	448,30	1.368,10	7,6244
7/4/16	632,30	120,40	370,10	544,70	1.667,50	9,2058
7/5/16	369,30	68,60	211,60	306,30	955,80	4,9074
7/6/16	587,00	114,10	334,60	499,80	1.535,50	8,4452
7/7/16	532,60	103,60	310,80	450,60	1.397,60	7,6225
7/8/16	632,70	55,00	358,90	539,00	1.585,60	9,4118
7/9/16	674,60	-	384,70	565,40	1.624,70	9,4362
7/10/16	622,00	97,80	359,00	531,40	1.610,20	9,0589
7/11/16	610,20	116,10	347,70	508,70	1.582,70	8,4767
7/12/16	665,20	125,10	382,90	567,30	1.740,50	9,4567
7/13/16	621,40	116,20	357,50	510,20	1.605,30	8,6112
7/14/16	655,90	125,00	379,70	551,10	1.711,70	9,4634
7/15/16	673,00	127,10	388,20	572,90	1.761,20	9,8005
7/16/16	645,00	122,90	372,90	547,50	1.688,30	9,4152
7/17/16	587,20	110,80	335,90	484,90	1.518,80	8,1870
7/18/16	549,50	102,00	317,00	461,20	1.429,70	7,6687
7/19/16	608,30	112,30	408,70	525,30	1.654,60	8,6814

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
7/20/16	339,80	62,10	388,30	281,30	1.071,50	4,4451
7/21/16	632,40	119,50	732,20	534,50	2.018,60	8,9430
7/22/16	660,50	125,40	768,80	556,60	2.111,30	9,4858
7/23/16	624,60	116,10	364,90	533,10	1.638,70	9,3869
7/24/16	612,00	116,80	195,60	522,00	1.446,40	9,2315
7/25/16	637,80	47,70	699,60	539,10	1.924,20	9,0488
7/26/16	540,90	101,80	624,50	460,70	1.727,90	8,0612
7/27/16	490,20	91,90	577,20	432,30	1.591,60	7,2556
7/28/16	596,80	112,30	701,90	508,20	1.919,20	8,6002
7/29/16	488,30	114,60	483,90	513,30	1.600,10	8,7064
7/30/16	531,80	99,80	624,00	452,00	1.707,60	7,8217
7/31/16	608,50	113,80	713,50	511,80	1.947,60	8,8166
8/1/16	577,80	48,00	679,40	486,20	1.791,40	8,3749
8/2/16	542,70	-	635,90	458,00	1.636,60	8,1863
8/3/16	492,40	-	583,30	422,60	1.498,30	7,2230
8/4/16	483,00	67,50	567,10	409,10	1.526,70	7,1609
8/5/16	446,90	104,40	655,30	474,10	1.680,70	7,9623
8/6/16	525,90	66,70	620,30	455,20	1.668,10	8,0448
8/7/16	581,60	-	683,60	489,10	1.754,30	8,5354
8/8/16	528,50	-	624,40	446,30	1.599,20	7,4950
8/9/16	529,70	-	625,70	446,40	1.601,80	7,4861
8/10/16	402,40	-	465,50	329,60	1.197,50	5,3401
8/11/16	553,30	-	639,70	458,00	1.651,00	7,7535
8/12/16	391,80	-	234,40	326,10	952,30	5,5360
8/13/16	131,50	-	74,30	100,50	306,30	1,6771
8/14/16	534,40	-	307,50	442,30	1.284,20	7,1620
8/15/16	656,80	123,20	764,50	550,40	2.094,90	9,1847
8/16/16	551,50	102,40	646,70	465,20	1.765,80	7,8403
8/17/16	578,20	109,30	675,10	482,90	1.845,50	8,4266
8/18/16	485,60	113,40	713,00	515,40	1.827,40	8,7734
8/19/16	557,10	104,60	659,30	483,60	1.804,60	8,1708
8/20/16	422,40	78,20	503,70	366,80	1.371,10	6,1099
8/21/16	349,80	63,90	408,00	289,70	1.111,40	4,6375
8/22/16	503,80	91,90	601,50	432,30	1.629,50	7,4431
8/23/16	313,80	55,50	363,40	256,10	988,80	4,1576
8/24/16	131,20	24,00	154,10	104,80	414,10	1,7866
8/25/16	232,90	43,80	275,40	192,90	745,00	3,1905
8/26/16	386,30	71,70	451,20	324,90	1.234,10	5,2467
8/27/16	500,50	94,80	592,00	422,50	1.609,80	7,0481
8/28/16	518,50	100,30	604,10	423,60	1.646,50	7,1885
8/29/16	500,70	96,00	589,20	413,30	1.599,20	7,1721
8/30/16	435,00	81,20	511,90	371,60	1.399,70	6,3519
8/31/16	405,50	73,70	433,10	345,20	1.257,50	5,9180
9/1/16	370,20	-	549,70	401,90	1.321,80	6,6859
9/2/16	521,60	-	618,00	434,30	1.573,90	7,2415
9/3/16	344,80	32,20	405,20	291,70	1.073,90	4,9422
9/4/16	451,30	86,50	533,80	388,90	1.460,50	6,4531
9/5/16	504,10	97,40	591,30	422,70	1.615,50	7,1665
9/6/16	509,60	99,30	606,70	435,30	1.650,90	7,4586
9/7/16	401,80	85,80	506,00	354,20	1.347,80	6,4835
9/8/16	-	97,40	303,00	431,00	831,40	7,3241
9/9/16	-	103,00	603,80	456,70	1.163,50	7,7079
9/10/16	-	102,40	640,90	463,60	1.206,90	7,7331
9/11/16	-	80,50	520,60	381,60	982,70	6,4101
9/12/16	-	75,20	476,00	343,90	895,10	5,8274
9/13/16	-	89,80	565,50	404,20	1.059,50	6,7137
9/14/16	-	101,40	631,40	450,40	1.183,20	7,8413
9/15/16	-	92,30	605,00	437,30	1.134,60	7,4727
9/16/16	-	95,00	596,80	431,60	1.123,40	7,3719
9/17/16	-	93,80	591,20	428,50	1.113,50	7,3138
9/18/16	-	90,50	570,30	413,50	1.074,30	7,1551
9/19/16	49,90	79,70	504,80	365,10	999,50	6,1811
9/20/16	216,90	40,50	259,60	183,20	700,20	3,2253
9/21/16	85,20	16,10	98,20	65,50	265,00	1,0852
9/22/16	145,00	27,00	167,80	114,20	454,00	1,8431
9/23/16	340,30	63,10	395,90	282,90	1.082,20	4,3981
9/24/16	263,70	50,50	309,80	218,70	842,70	3,5170
9/25/16	412,90	77,60	480,70	337,80	1.309,00	5,3960
9/26/16	386,50	71,50	448,50	319,70	1.226,20	5,1747
9/27/16	426,80	81,60	498,30	337,80	1.344,50	5,3419
9/28/16	383,50	72,80	445,70	304,00	1.206,00	4,5981
9/29/16	503,10	94,10	591,90	421,20	1.610,30	6,5710

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
9/30/16	483,80	90,40	570,50	407,70	1.552,40	6,3229
10/1/16	488,80	91,70	576,20	413,60	1.570,30	6,3561
10/2/16	430,10	79,80	507,00	369,00	1.385,90	5,5350
10/3/16	450,30	84,20	532,70	379,60	1.446,80	5,8308
10/4/16	404,80	75,70	483,40	343,10	1.307,00	5,3551
10/5/16	97,70	23,30	141,20	95,90	358,10	1,5154
10/6/16	198,00	38,00	225,80	150,60	612,40	2,4169
10/7/16	228,90	82,30	388,80	187,00	887,00	5,0549
10/8/16	-	50,90	163,10	-	214,00	3,8880
10/9/16	-	48,70	142,90	-	191,60	2,9074
10/10/16	193,10	69,00	349,40	205,60	817,10	5,0454
10/11/16	408,90	64,00	412,80	292,40	1.178,10	4,5642
10/12/16	254,80	71,80	388,30	316,50	1.031,40	4,5095
10/13/16	122,60	72,40	469,60	344,90	1.009,50	5,0207
10/14/16	480,40	78,50	485,10	339,40	1.383,40	4,6954
10/15/16	310,40	49,50	309,70	221,90	891,50	2,8293
10/16/16	416,40	65,10	413,40	293,50	1.188,40	4,5191
10/17/16	82,60	12,80	81,10	54,70	231,20	0,9210
10/18/16	109,90	17,10	107,90	73,40	308,30	1,2082
10/19/16	311,80	51,00	310,00	217,50	890,30	3,0972
10/20/16	332,40	52,70	343,30	241,70	970,10	3,6896
10/21/16	-	63,20	409,80	297,40	770,40	4,3493
10/22/16	354,90	70,00	441,90	310,50	1.177,30	4,3482
10/23/16	169,00	26,40	164,30	113,80	473,50	1,8286
10/24/16	168,60	27,10	163,50	115,10	474,30	1,8722
10/25/16	176,30	28,40	170,80	118,10	493,60	1,8238
10/26/16	299,20	49,00	294,80	207,20	850,20	3,0306
10/27/16	128,30	20,40	124,90	86,00	359,60	1,3744
10/28/16	150,30	23,00	150,10	103,40	426,80	1,6440
10/29/16	156,60	29,50	180,40	119,50	486,00	1,8779
10/30/16	213,50	41,80	254,50	180,20	690,00	2,5630
10/31/16	320,70	59,20	386,30	277,10	1.043,30	3,4615
11/1/16	172,50	33,90	205,50	144,90	556,80	1,9428
11/2/16	383,50	73,40	469,20	334,80	1.260,90	4,3618
11/3/16	363,50	67,10	438,70	316,00	1.185,30	4,2279
11/4/16	29,90	5,60	34,80	22,50	92,80	0,3757
11/5/16	116,10	22,00	135,40	92,80	366,30	1,5053
11/6/16	201,20	36,80	234,30	165,40	637,70	2,5269
11/7/16	237,90	37,70	241,70	170,40	687,70	2,5168
11/8/16	240,00	38,50	235,20	165,70	679,40	2,5379
11/9/16	119,80	18,90	116,10	79,40	334,20	1,3339
11/10/16	271,60	44,80	273,30	196,50	786,20	2,7917
11/11/16	191,00	36,30	200,50	148,30	576,10	1,6921
11/12/16	309,80	48,70	149,00	-	507,50	3,3167
11/13/16	321,90	52,00	155,20	-	529,10	2,9683
11/14/16	194,50	38,30	149,30	-	382,10	2,3350
11/15/16	114,80	18,60	115,00	34,10	282,50	1,2017
11/16/16	232,00	31,60	239,40	157,40	660,40	2,5972
11/17/16	413,90	63,00	446,40	293,00	1.216,30	3,9847
11/18/16	406,60	60,90	436,20	287,80	1.191,50	3,9903
11/19/16	398,80	59,80	428,40	281,30	1.168,30	3,8933
11/20/16	378,30	56,40	403,80	264,70	1.103,20	3,7419
11/21/16	181,80	27,80	194,20	124,40	528,20	2,0198
11/22/16	91,70	14,50	96,30	60,10	262,60	0,9795
11/23/16	234,60	37,50	255,00	170,60	697,70	2,6527
11/24/16	177,80	28,00	188,80	122,10	516,70	1,8241
11/25/16	238,50	36,30	253,70	165,90	694,40	2,5267
11/26/16	105,70	16,90	112,10	70,30	305,00	1,1407
11/27/16	144,10	23,60	161,40	106,00	435,10	1,8116
11/28/16	22,20	3,40	23,50	14,20	63,30	0,2162
11/29/16	37,80	5,90	40,20	24,10	108,00	0,3949
11/30/16	57,30	8,90	61,40	38,20	165,80	0,6083
12/1/16	221,00	31,40	230,30	151,90	634,60	2,4130
12/2/16	160,50	25,30	171,80	111,00	468,60	1,7046
12/3/16	268,40	40,20	280,10	191,20	779,90	2,9670
12/4/16	298,70	44,70	319,00	211,70	874,10	3,2439
12/5/16	297,40	44,40	318,90	207,70	868,40	3,0484
12/6/16	357,20	51,30	381,00	251,30	1.040,80	3,6130
12/7/16	85,20	10,70	88,40	57,70	242,00	1,0638
12/8/16	318,80	50,70	348,50	223,60	941,60	3,0558
12/9/16	354,90	51,00	380,20	251,80	1.037,90	3,5936
12/10/16	306,40	46,60	328,80	215,30	897,10	3,1388

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
12/11/16	277,70	46,80	349,60	231,10	905,20	3,4886
12/12/16	62,30	9,70	65,90	41,00	178,90	0,6728
12/13/16	34,70	5,20	37,10	22,60	99,60	0,3646
12/14/16	183,80	34,50	199,30	139,50	557,10	3,1476
12/15/16	33,40	5,20	34,70	21,40	94,70	0,3229
12/16/16	105,00	16,30	110,60	70,00	301,90	1,0459
12/17/16	17,90	7,40	37,60	14,10	77,00	2,8257
12/18/16	109,30	23,40	204,60	72,00	409,30	3,1258
12/19/16	163,60	23,90	189,30	104,30	481,10	1,9906
12/20/16	107,80	15,70	114,50	69,90	307,90	1,1831
12/21/16	56,70	19,80	95,70	38,30	210,50	1,3995
12/22/16	-	5,40	16,80	-	22,20	0,3658
12/23/16	-	1,80	5,90	-	7,70	-
12/24/16	-	2,60	8,30	-	10,90	0,1378
12/25/16	-	30,30	86,20	-	116,50	1,7253
12/26/16	-	9,10	37,60	-	46,70	0,8957
12/27/16	-	38,00	135,50	-	173,50	2,9598
12/28/16	-	12,60	37,80	-	50,40	0,8090
12/29/16	16,10	0,30	8,10	10,40	34,90	0,1442
12/30/16	26,80	4,20	29,60	18,10	78,70	0,2942
12/31/16	-	4,00	14,80	16,30	35,10	0,2802
1/1/17	-	24,00	88,00	97,80	209,80	1,2804
1/2/17	-	53,60	216,00	251,30	520,90	3,5476
1/3/17	-	38,90	159,80	189,30	388,00	2,9279
1/4/17	262,70	40,40	284,30	184,30	771,70	2,6740
1/5/17	51,10	8,10	53,50	32,60	145,30	0,5002
1/6/17	74,00	10,90	77,30	48,70	210,90	0,7968
1/7/17	-	-	3,10	-	3,10	0,9385
1/8/17	-	-	0,40	-	0,40	0,4188
1/11/17	-	-	22,50	-	22,50	2,9118
1/12/17	-	-	76,80	-	76,80	2,0318
1/13/17	-	-	182,90	-	182,90	3,7503
1/14/17	-	0,10	143,40	-	143,50	2,7600
1/15/17	-	2,60	30,40	-	33,00	0,6350
1/16/17	36,60	5,50	40,50	26,80	109,40	0,4328
1/17/17	84,10	11,90	86,80	53,70	236,50	0,9298
1/18/17	46,70	7,00	48,80	29,20	131,70	0,4752
1/19/17	63,80	9,90	66,90	42,60	183,20	0,6442
1/20/17	77,90	12,00	81,90	50,80	222,60	0,7734
1/21/17	280,70	46,10	301,50	196,60	824,90	2,4532
1/22/17	62,10	9,60	64,10	39,10	174,90	0,6271
1/23/17	429,50	64,30	459,90	299,90	1.253,60	3,9354
1/24/17	135,70	21,90	141,00	87,60	386,20	1,3153
1/25/17	42,90	6,40	46,30	29,30	124,90	0,4552
1/26/17	3,50	1,00	6,00	1,70	12,20	0,9053
1/27/17	14,20	2,90	20,50	10,20	47,80	2,6900
1/28/17	1,60	0,60	7,00	0,30	9,50	0,4812
1/29/17	204,40	25,00	239,90	94,80	564,10	2,5259
1/30/17	101,90	16,10	107,20	67,00	292,20	1,0346
1/31/17	471,30	74,80	513,60	339,00	1.398,70	4,1293
2/1/17	438,20	65,90	471,10	308,50	1.283,70	4,1567
2/2/17	464,90	71,70	507,30	332,20	1.376,10	4,1533
2/3/17	159,30	25,80	166,00	104,40	455,50	1,4233
2/4/17	306,50	49,70	327,00	210,20	893,40	2,7545
2/5/17	77,70	12,30	82,10	42,60	214,70	0,7954
2/6/17	232,00	3,60	126,70	157,00	519,30	2,4476
2/7/17	131,20	-	61,50	85,60	278,30	1,3622
2/8/17	294,30	-	143,10	208,40	645,80	2,9814
2/9/17	45,90	-	21,90	29,50	97,30	0,4777
2/10/17	111,80	-	52,30	71,80	235,90	1,0948
2/11/17	91,80	-	42,90	58,70	193,40	0,9032
2/12/17	194,40	-	92,90	132,50	419,80	1,8892
2/13/17	61,20	-	35,00	34,40	130,60	0,8610
2/14/17	234,60	38,80	255,50	153,60	682,50	2,1234
2/15/17	36,30	5,70	31,50	22,50	96,00	0,3545
2/16/17	106,80	16,90	111,50	69,10	304,30	1,0565
2/17/17	547,00	87,10	600,40	391,40	1.625,90	5,0838
2/18/17	526,80	83,50	579,40	380,20	1.569,90	4,7784
2/19/17	435,30	69,40	472,20	306,80	1.283,70	4,5414
2/20/17	49,70	7,70	52,20	32,70	142,30	0,5301
2/21/17	551,20	89,20	608,30	396,80	1.645,50	5,0344
2/22/17	363,50	60,50	395,10	256,50	1.075,60	2,9950

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
2/23/17	556,60	88,40	612,90	397,50	1.655,40	5,1845
2/24/17	564,10	90,90	623,90	405,90	1.684,80	5,2416
2/25/17	246,90	39,00	262,20	165,90	714,00	2,5732
2/26/17	289,30	45,50	301,50	190,20	826,50	2,6550
2/27/17	331,70	53,60	351,30	222,50	959,10	2,9671
2/28/17	529,90	86,50	581,80	374,10	1.572,30	4,9841
3/1/17	518,70	84,80	575,40	366,40	1.545,30	4,9456
3/2/17	143,10	22,30	148,90	91,70	406,00	1,4615
3/3/17	407,20	66,80	442,40	281,70	1.198,10	4,3923
3/4/17	602,70	97,70	664,80	431,40	1.796,60	5,9029
3/5/17	601,10	97,00	666,00	431,00	1.795,10	6,0817
3/6/17	468,90	75,80	514,40	332,70	1.391,80	5,0699
3/7/17	561,90	90,90	618,30	400,60	1.671,70	5,9264
3/8/17	403,70	65,40	439,70	281,80	1.190,60	4,5157
3/9/17	151,10	23,40	159,90	101,90	436,30	1,6223
3/10/17	283,20	45,30	303,50	192,30	824,30	2,5392
3/11/17	0,60	12,60	82,60	48,50	144,30	0,7707
3/12/17	-	4,60	31,20	18,40	54,20	0,2718
3/13/17	90,80	15,90	106,90	66,40	280,00	1,0323
3/14/17	69,00	10,80	72,20	43,50	195,50	0,6890
3/15/17	339,70	54,50	360,80	232,50	987,50	3,2884
3/16/17	173,20	27,80	180,10	112,10	493,20	1,7136
3/17/17	129,50	20,20	136,80	85,00	371,50	1,2911
3/18/17	677,00	112,50	760,20	495,70	2.045,40	7,4630
3/19/17	149,60	23,80	156,50	97,50	427,40	1,5398
3/20/17	453,50	75,70	506,20	326,30	1.361,70	5,2329
3/21/17	393,40	64,40	420,30	265,90	1.144,00	4,2066
3/22/17	703,60	115,80	781,10	507,30	2.107,80	8,0489
3/23/17	656,10	75,40	729,00	466,30	1.926,80	7,3287
3/24/17	587,90	-	659,70	428,50	1.676,10	6,8404
3/25/17	586,00	-	644,40	416,50	1.646,90	6,6301
3/26/17	286,70	-	313,20	198,60	798,50	3,2219
3/27/17	188,50	-	196,50	120,70	505,70	1,8224
3/28/17	722,10	-	802,20	525,10	2.049,40	8,2161
3/29/17	727,50	22,30	810,20	531,50	2.091,50	8,4631
3/30/17	694,00	114,80	771,30	504,20	2.084,30	8,0911
3/31/17	190,30	32,20	211,50	138,80	572,80	2,2405
4/1/17	680,50	114,20	754,70	488,70	2.038,10	7,4229
4/2/17	700,30	116,20	781,40	508,60	2.106,50	7,8036
4/3/17	675,20	112,20	753,70	499,00	2.040,10	7,8879
4/4/17	279,10	53,20	354,30	227,50	914,10	3,4769
4/5/17	547,50	80,20	598,70	396,50	1.622,90	6,0776
4/6/17	390,30	41,90	417,60	269,70	1.119,50	4,2005
4/7/17	102,40	16,20	107,00	65,80	291,40	1,0776
4/8/17	315,40	49,90	342,00	228,80	936,10	3,5953
4/9/17	383,20	60,80	403,80	261,10	1.108,90	3,8548
4/10/17	627,00	104,20	696,20	443,80	1.871,20	7,1222
4/11/17	740,90	122,80	824,50	538,00	2.226,20	8,7452
4/12/17	419,70	67,40	444,50	284,30	1.215,90	4,3476
4/13/17	746,50	125,30	836,30	543,50	2.251,60	8,5542
4/14/17	682,80	112,70	760,20	497,10	2.052,80	8,0352
4/15/17	636,40	104,20	698,70	453,90	1.893,20	7,3793
4/16/17	618,10	103,90	673,50	449,50	1.845,00	7,5270
4/17/17	515,80	85,70	565,50	376,30	1.543,30	6,1425
4/18/17	201,90	31,60	207,70	129,90	571,10	1,9456
4/19/17	741,20	123,40	668,70	543,30	2.076,60	8,7600
4/20/17	521,90	87,70	553,90	383,50	1.547,00	6,3238
4/21/17	364,70	60,30	395,10	250,20	1.070,30	4,0133
4/22/17	204,40	95,20	406,60	408,90	1.115,10	6,5905
4/23/17	333,50	77,20	404,20	335,50	1.150,40	5,0830
4/24/17	541,40	88,10	562,60	390,60	1.582,70	6,0420
4/25/17	795,60	131,70	840,70	581,50	2.349,50	9,4328
4/26/17	754,70	124,70	778,10	548,50	2.206,00	9,1182
4/27/17	739,20	122,90	812,50	537,10	2.211,70	9,0011
4/28/17	737,20	123,00	776,10	539,10	2.175,40	9,1533
4/29/17	705,50	118,30	773,20	511,30	2.108,30	8,8446
4/30/17	759,50	127,00	840,80	551,60	2.278,90	9,0793
5/1/17	525,70	87,20	574,10	373,10	1.560,10	5,7759
5/2/17	730,10	121,90	786,50	527,30	2.165,80	8,6514
5/3/17	716,70	119,90	746,30	515,00	2.097,90	8,3396
5/4/17	732,70	121,30	807,90	533,40	2.195,30	8,8193
5/5/17	715,70	120,40	797,00	525,20	2.158,30	8,5810

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
5/6/17	316,40	50,70	332,90	218,50	918,50	3,5215
5/7/17	655,50	110,70	730,90	483,80	1.980,90	7,7496
5/8/17	621,00	104,70	652,20	459,70	1.837,60	7,6096
5/9/17	569,30	95,10	618,60	402,50	1.685,50	6,5343
5/10/17	301,10	46,10	313,70	206,00	866,90	3,1444
5/11/17	707,70	116,60	781,20	517,30	2.122,80	8,6914
5/12/17	501,10	82,80	526,40	355,20	1.465,50	5,9163
5/13/17	696,40	115,70	713,20	509,50	2.034,80	8,3645
5/14/17	698,40	117,80	738,20	509,90	2.064,30	8,4038
5/15/17	550,00	91,30	593,10	390,40	1.624,80	6,3128
5/16/17	559,40	91,50	604,20	401,30	1.656,40	6,2641
5/17/17	333,20	53,90	351,50	225,20	963,80	3,5269
5/18/17	493,50	81,40	525,70	356,50	1.457,10	5,5847
5/19/17	609,90	99,60	661,90	435,10	1.806,50	6,7167
5/20/17	653,00	110,40	702,10	486,10	1.951,60	7,9844
5/21/17	263,50	39,80	260,70	182,00	746,00	2,7518
5/22/17	622,90	105,40	680,90	458,50	1.867,70	7,5003
5/23/17	691,20	116,00	754,60	513,20	2.075,00	8,2693
5/24/17	712,20	117,60	787,90	536,20	2.153,90	8,7751
5/25/17	766,60	129,10	847,20	559,00	2.301,90	9,2986
5/26/17	627,70	102,30	651,00	450,60	1.831,60	7,1228
5/27/17	626,80	104,10	660,30	446,00	1.837,20	7,1599
5/28/17	626,40	103,20	660,40	453,30	1.843,30	7,1605
5/29/17	707,90	119,40	799,00	537,20	2.163,50	8,6610
5/30/17	233,50	36,10	243,00	155,90	668,50	2,4364
5/31/17	702,40	116,60	751,80	515,50	2.086,30	8,3642
6/1/17	749,70	125,40	819,90	552,10	2.247,10	9,1462
6/2/17	581,70	97,00	630,70	413,30	1.722,70	6,9371
6/3/17	654,40	107,70	698,70	477,90	1.938,70	8,1782
6/4/17	749,10	126,60	835,90	553,10	2.264,70	9,0817
6/5/17	418,20	67,40	426,50	288,20	1.200,30	4,5865
6/6/17	257,80	47,60	315,70	206,80	827,90	3,2600
6/7/17	712,70	118,00	736,20	524,60	2.091,50	9,2586
6/8/17	577,70	96,10	615,80	416,10	1.705,70	7,2796
6/9/17	248,50	39,40	258,60	168,20	714,70	2,6280
6/10/17	145,90	23,10	152,30	96,80	418,10	1,5853
6/11/17	78,80	25,50	114,80	112,60	331,70	8,3244
6/12/17	750,80	125,90	828,50	553,90	2.259,10	9,0657
6/13/17	812,50	136,40	896,80	601,20	2.446,90	10,0864
6/14/17	687,50	115,90	755,60	507,20	2.066,20	8,7651
6/15/17	618,80	101,50	674,30	443,70	1.838,30	7,5449
6/16/17	800,90	132,30	885,50	590,00	2.408,70	10,0034
6/17/17	692,00	117,20	740,60	506,60	2.056,40	8,9874
6/18/17	310,60	69,60	383,60	285,00	1.048,80	4,6334
6/19/17	-	57,90	172,20	241,50	471,60	3,8198
6/20/17	-	108,30	328,60	475,30	912,20	7,9346
6/21/17	-	100,20	305,40	436,00	841,60	7,3206
6/22/17	-	121,30	367,50	531,60	1.020,40	9,1324
6/23/17	-	124,40	377,60	545,90	1.047,90	9,6758
6/24/17	-	124,20	377,30	544,20	1.045,70	9,3635
6/25/17	-	128,70	396,50	572,50	1.097,70	9,7557
6/26/17	-	130,30	401,40	578,20	1.109,90	9,7547
6/27/17	-	125,60	380,60	544,10	1.050,30	9,3755
6/28/17	-	124,30	379,40	546,40	1.050,10	9,3992
6/29/17	-	119,20	364,50	527,90	1.011,60	9,2470
6/30/17	-	122,50	374,10	540,70	1.037,30	9,4698
7/1/17	-	125,30	385,80	555,40	1.066,50	9,8137
7/2/17	-	126,70	387,00	558,20	1.071,90	9,6381
7/3/17	-	121,60	367,60	532,20	1.021,40	9,0391
7/4/17	-	68,20	210,40	309,10	587,70	4,8309
7/5/17	-	134,90	411,70	598,50	1.145,10	9,9015
7/6/17	710,50	118,80	793,80	540,00	2.163,10	8,8823
7/7/17	716,00	118,60	797,70	536,50	2.168,80	9,0684
7/8/17	759,10	126,50	842,20	568,90	2.296,70	9,6758
7/9/17	725,20	121,20	790,50	539,80	2.176,70	9,4361
7/10/17	754,70	123,60	831,70	573,80	2.283,80	9,7224
7/11/17	727,60	120,30	815,20	556,50	2.219,60	9,4427
7/12/17	714,50	120,20	793,60	546,90	2.175,20	9,6590
7/13/17	5,10	116,00	362,20	520,30	1.003,60	9,1292
7/14/17	-	65,90	198,80	289,30	554,00	4,8430
7/15/17	-	112,00	339,80	491,90	943,70	8,0582
7/16/17	-	76,20	235,50	346,70	658,40	5,7371

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
7/17/17	250,80	47,60	288,50	203,90	790,80	3,3517
7/18/17	230,10	37,70	250,00	155,80	673,60	2,6147
7/19/17	729,60	125,10	810,00	537,80	2.202,50	9,0166
7/20/17	688,10	115,10	760,00	508,90	2.072,10	8,3760
7/21/17	691,90	114,20	762,10	519,30	2.087,50	8,6189
7/22/17	745,90	119,90	813,40	558,10	2.237,30	9,4488
7/23/17	720,70	120,90	795,10	530,70	2.167,40	9,1111
7/24/17	716,50	120,20	797,60	535,50	2.169,80	9,1619
7/25/17	661,70	113,00	725,80	495,20	1.995,70	9,0230
7/26/17	690,50	116,20	769,40	514,40	2.090,50	8,8069
7/27/17	635,00	108,30	705,20	475,40	1.923,90	8,2145
7/28/17	576,40	-	645,30	428,70	1.650,40	6,9721
7/29/17	325,30	91,20	482,30	379,30	1.278,10	9,2519
7/30/17	738,90	123,50	789,70	551,20	2.203,30	9,3637
7/31/17	740,90	123,90	820,30	569,30	2.254,40	9,4177
8/1/17	649,60	107,80	722,30	491,50	1.971,20	8,0715
8/2/17	542,80	90,20	604,50	402,70	1.640,20	6,6678
8/3/17	535,10	85,50	578,50	388,00	1.587,10	6,3412
8/4/17	558,70	92,90	619,50	416,60	1.687,70	7,1623
8/5/17	578,40	93,70	613,30	420,10	1.705,50	7,4186
8/6/17	646,70	108,20	719,30	479,60	1.953,80	8,2942
8/7/17	647,40	107,50	709,90	479,00	1.943,80	8,2658
8/8/17	234,80	37,70	249,00	158,60	680,10	2,6511
8/9/17	386,30	63,70	410,30	213,30	1.073,60	4,3306
8/10/17	597,30	99,20	620,50	450,00	1.767,00	7,6978
8/11/17	629,70	103,20	702,60	467,60	1.903,10	7,9853
8/12/17	674,90	112,70	758,00	503,40	2.049,00	8,7232
8/13/17	625,90	102,30	691,40	470,80	1.890,40	8,3008
8/14/17	507,50	82,10	542,30	371,60	1.503,50	6,1244
8/15/17	404,80	63,10	425,90	280,20	1.174,00	4,5568
8/16/17	454,10	76,60	499,10	330,10	1.359,90	5,5458
8/17/17	443,60	70,50	474,00	314,20	1.302,30	5,0954
8/18/17	653,60	109,90	727,80	481,50	1.972,80	8,2322
8/19/17	633,20	104,60	706,20	468,10	1.912,10	8,0144
8/20/17	606,50	101,20	672,10	444,60	1.824,40	7,4914
8/21/17	425,20	68,20	449,40	297,50	1.240,30	4,7626
8/22/17	245,30	39,10	261,50	170,00	715,90	2,8750
8/23/17	470,20	75,40	519,50	354,70	1.419,80	5,9474
8/24/17	603,00	103,30	623,40	439,90	1.769,60	7,4034
8/25/17	675,10	114,50	760,80	504,00	2.054,40	8,4129
8/26/17	628,80	86,70	691,30	475,40	1.882,20	7,9798
8/27/17	507,40	82,10	554,10	367,10	1.510,70	5,9964
8/28/17	659,80	108,80	738,50	489,50	1.996,60	8,2223
8/29/17	561,10	93,60	618,70	417,00	1.690,40	7,0808
8/30/17	532,10	87,20	590,50	392,30	1.602,10	6,2404
8/31/17	481,60	80,70	532,10	365,40	1.459,80	7,3254
9/1/17	668,00	111,80	748,40	502,50	2.030,70	8,5390
9/2/17	665,70	111,20	720,90	498,40	1.996,20	8,5619
9/3/17	648,20	108,80	723,50	488,20	1.968,70	8,5265
9/4/17	628,00	104,70	704,80	466,10	1.903,60	7,6717
9/5/17	552,90	92,60	612,50	411,10	1.669,10	6,9999
9/6/17	437,50	73,20	461,50	323,90	1.296,10	5,1923
9/7/17	621,10	105,50	692,10	469,40	1.888,10	8,0867
9/8/17	635,80	107,00	656,90	478,40	1.878,10	8,2139
9/9/17	592,90	100,60	629,50	446,50	1.769,50	7,7221
9/10/17	535,20	90,20	550,40	397,20	1.573,00	7,0747
9/11/17	561,80	93,30	596,50	414,90	1.666,50	7,2453
9/12/17	598,30	96,20	645,70	438,40	1.778,60	7,4396
9/13/17	618,00	99,70	675,50	452,50	1.845,70	7,7840
9/14/17	628,60	101,10	696,30	458,50	1.884,50	7,6867
9/15/17	556,10	94,40	625,20	411,00	1.686,70	7,0136
9/16/17	448,90	71,50	478,00	304,00	1.302,40	4,8755
9/17/17	497,40	79,70	518,60	357,90	1.453,60	6,0557
9/18/17	568,40	92,30	590,40	408,80	1.659,90	7,2260
9/19/17	579,20	94,10	639,80	420,00	1.733,10	7,1352
9/20/17	548,90	87,60	600,70	392,30	1.629,50	7,1174
9/21/17	507,10	80,20	553,00	369,10	1.509,40	6,3426
9/22/17	403,80	65,70	429,70	274,10	1.173,30	4,4527
9/23/17	612,40	100,10	662,60	449,70	1.824,80	7,5589
9/24/17	571,60	94,80	622,10	416,50	1.705,00	6,8564
9/25/17	512,40	84,50	563,40	373,90	1.534,20	5,8804
9/26/17	284,20	45,10	301,90	197,70	828,90	3,0431

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
9/27/17	337,00	59,80	344,90	238,00	979,70	4,5738
9/28/17	512,20	82,60	567,30	373,90	1.536,00	5,7499
9/29/17	60,80	9,60	64,50	32,00	166,90	0,6700
9/30/17	111,60	17,60	117,90	60,30	307,40	1,1801
10/1/17	93,40	14,50	99,70	55,50	263,10	1,0193
10/2/17	303,50	50,60	281,20	215,40	850,70	3,1378
10/3/17	458,90	73,50	504,90	330,10	1.367,40	5,2547
10/4/17	511,00	0,10	554,30	374,10	1.439,50	5,9731
10/5/17	554,60	-	609,10	404,60	1.568,30	5,9382
10/6/17	564,00	-	626,70	414,40	1.605,10	5,9816
10/7/17	314,80	-	344,60	223,70	883,10	3,7292
10/8/17	186,70	-	197,40	126,30	510,40	1,9178
10/9/17	421,70	-	476,00	318,70	1.216,40	5,1744
10/10/17	461,40	-	501,10	336,40	1.298,90	4,6285
10/11/17	541,70	33,40	596,10	393,50	1.564,70	5,4135
10/12/17	554,40	89,50	611,90	401,90	1.657,70	5,5357
10/13/17	533,30	85,50	585,30	384,50	1.588,60	5,3353
10/14/17	221,70	33,80	234,00	153,00	642,50	2,3941
10/15/17	481,90	79,90	525,60	346,60	1.434,00	4,6401
10/16/17	353,30	57,50	386,80	251,90	1.049,50	3,6250
10/17/17	534,00	85,70	587,70	388,90	1.596,30	5,2913
10/18/17	515,60	82,40	567,50	373,50	1.539,00	5,1972
10/19/17	477,20	76,30	521,60	342,40	1.417,50	4,9020
10/20/17	477,70	77,80	529,30	346,70	1.431,50	4,7344
10/21/17	470,80	76,20	514,90	335,90	1.397,80	4,6292
10/22/17	446,20	71,10	489,00	317,50	1.323,80	4,4292
10/23/17	428,90	68,10	466,20	304,40	1.267,60	4,3206
10/24/17	70,70	11,10	74,80	46,40	203,00	0,8012
10/25/17	112,50	17,80	120,00	75,90	326,20	1,2117
10/26/17	97,20	15,20	102,70	64,30	279,40	1,0122
10/27/17	457,10	72,50	499,20	328,40	1.357,20	4,5410
10/28/17	209,90	33,10	224,80	145,80	613,60	2,2933
10/29/17	258,70	43,20	279,00	182,40	763,30	2,5399
10/30/17	395,70	65,50	440,40	290,50	1.192,10	3,9573
10/31/17	427,00	65,90	474,30	316,20	1.283,40	4,2099
11/1/17	349,50	53,80	378,30	242,90	1.024,50	3,4675
11/2/17	451,60	71,40	493,00	329,10	1.345,10	4,4353
11/3/17	396,90	59,90	435,70	284,50	1.177,00	4,1450
11/4/17	158,50	25,20	170,60	108,40	462,70	1,6845
11/5/17	210,20	33,00	227,10	148,60	618,90	2,0485
11/6/17	336,60	51,40	365,40	239,80	993,20	3,7122
11/7/17	385,00	-	419,60	280,10	1.084,70	3,9585
11/8/17	407,30	-	443,70	292,30	1.143,30	3,9003
11/9/17	290,20	-	313,30	207,40	810,90	3,0448
11/10/17	264,60	-	286,20	186,20	737,00	2,6300
11/11/17	318,40	-	345,30	226,60	890,30	3,4720
11/12/17	277,00	-	302,30	197,70	777,00	2,8661
11/13/17	260,50	-	282,00	184,20	726,70	2,4868
11/14/17	381,00	-	415,80	274,10	1.070,90	3,7212
11/15/17	260,20	40,40	279,80	160,30	740,70	2,2484
11/16/17	52,30	8,20	56,30	35,50	152,30	0,6120
11/17/17	124,50	19,90	130,60	82,00	357,00	1,2927
11/18/17	302,30	48,20	332,80	215,40	898,70	3,1069
11/19/17	210,30	30,30	225,30	145,60	611,50	2,2104
11/20/17	63,00	9,70	67,70	42,60	183,00	0,6813
11/21/17	165,70	26,80	178,50	113,80	484,80	1,6518
11/22/17	96,20	15,40	102,40	65,10	279,10	1,0134
11/23/17	85,80	13,90	91,00	57,10	247,80	0,9187
11/24/17	303,10	49,90	331,70	214,00	898,70	2,8440
11/25/17	351,50	53,90	388,30	255,10	1.048,80	3,5818
11/26/17	251,70	34,40	268,10	178,30	732,50	2,8722
11/27/17	156,80	22,80	167,60	109,70	456,90	1,8195
11/28/17	174,50	28,30	188,30	127,90	519,00	1,6730
11/29/17	140,60	23,20	153,30	96,20	413,30	1,2891
11/30/17	276,30	40,70	300,10	196,10	813,20	3,0240
12/1/17	158,40	24,60	171,80	110,10	464,90	1,7050
12/2/17	279,50	41,40	305,00	201,00	826,90	3,2150
12/3/17	277,50	43,40	303,00	196,90	820,80	2,8056
12/4/17	33,20	5,30	35,80	22,00	96,30	0,2907
12/5/17	69,90	11,10	74,40	46,70	202,10	0,6538
12/6/17	240,20	38,50	258,80	166,50	704,00	2,0901
12/7/17	111,10	17,10	121,80	79,00	329,00	1,0523

Days	ScOLa - 126kWp	Energy Distribution Center - 21kWp	Business Administration Faculty - 136.5kWp	Engineering Faculty - 94.5kWp	Total PV System - 378kWp	Sun Energy - kWh/m2
12/8/17	313,60	47,30	339,60	226,40	926,90	2,8618
12/9/17	250,00	39,90	273,90	177,90	741,70	2,2091
12/10/17	74,90	11,60	80,20	50,40	217,10	0,7744
12/11/17	267,90	50,90	330,00	228,30	877,10	3,5708
12/12/17	224,10	27,90	234,40	153,80	640,20	2,6600
12/13/17	331,60	48,70	359,50	236,60	976,40	3,5413
12/14/17	210,50	34,50	231,70	148,80	625,50	2,0132
12/15/17	316,80	46,50	341,00	225,20	929,50	3,4447
12/16/17	294,40	41,10	316,10	208,20	859,80	3,2477
12/17/17	50,20	8,10	53,50	33,10	144,90	0,5571
12/18/17	49,20	7,90	52,00	31,40	140,50	0,5230
12/19/17	79,60	13,00	83,30	52,00	227,90	0,8235
12/20/17	88,90	14,30	94,40	58,70	256,30	0,9293
12/21/17	45,80	7,40	46,30	29,70	129,20	0,4687
12/22/17	23,30	3,60	25,30	15,50	67,70	0,2564
12/23/17	39,90	6,10	42,70	25,90	114,60	0,4312
12/24/17	318,50	44,90	334,10	220,00	917,50	3,2721
12/25/17	210,60	49,40	326,40	244,00	830,40	3,6030
12/26/17	247,00	49,40	376,50	228,10	901,00	3,3427
12/27/17	349,50	49,10	374,20	247,20	1.020,00	3,6054
12/28/17	296,20	40,40	314,70	210,80	862,10	3,3597
12/29/17	72,40	11,50	76,00	48,40	208,30	0,7770
12/30/17	137,60	18,30	143,00	92,70	391,60	1,5632
12/31/17	43,70	6,60	46,10	28,50	124,90	0,4708
TOTAL	**407.534,30**	**61.387,60**	**426.811,10**	**320.896,40**	**1.216.629**	**5.356**

5.6 APPENDIX F – Daily Energy Production by Inverter

Months	INV 01.01	INV 03.08	INV 03.09	INV 03.10	INV 03.11	INV 04.12	INV 04.13
Jan-14	940	1.217	587	1.244	1.258	1.193	1.284
Feb-14	1.075	1.360	658	1.398	1.385	1.333	1.422
Mar-14	2.022	2.280	1.102	2.276	2.209	2.178	2.314
Apr-14	2.144	2.830	1.250	2.802	2.687	2.690	2.849
May-14	2.314	3.226	1.209	3.051	2.985	3.088	3.270
Jun-14	2.923	3.034	1.443	2.987	2.788	3.026	3.238
Jul-14	3.429	3.669	1.326	3.528	3.402	3.499	3.757
Aug-14	2.984	3.127	733	3.097	2.950	3.050	3.324
Sep-14	2.291	2.441	1.094	2.455	2.363	2.265	2.530
Oct-14	1.508	1.270	585	1.302	1.264	1.426	1.647
Nov-14	806	1.007	396	1.037	1.024	922	1.083
Dec-14	685	678	-	725	727	702	840
Jan-15	833	357	-	371	364	842	1.008
Feb-15	57	621	-	570	511	881	1.058
Mar-15	1.345	1.678	152	1.697	1.614	1.459	1.711
Apr-15	2.300	2.330	-	2.302	2.212	2.649	2.988
May-15	3.017	2.741	799	2.705	2.544	3.090	3.465
Jun-15	-	2.979	1.200	2.926	2.690	2.730	3.095
Jul-15	3.216	3.399	1.124	3.303	3.087	3.390	3.791
Aug-15	1.830	2.309	119	2.267	2.155	2.777	3.162
Sep-15	1.764	2.053	0	2.028	1.952	2.049	2.379
Oct-15	1.211	1.109	-	1.132	1.085	1.215	1.481
Nov-15	1.210	1.117	-	1.140	1.130	1.161	1.439
Dec-15	877	0	-	0	0	838	1.049
Jan-16	362	651	-	535	501	626	804
Feb-16	732	1.365	-	1.366	1.354	1.148	1.411
Mar-16	1.083	2.015	-	2.007	1.910	1.686	2.023
Apr-16	2.579	3.170	-	3.091	2.927	2.196	2.545
May-16	2.938	2.684	-	2.615	2.423	-	-
Jun-16	2.094	3.182	-	3.085	2.831	1.786	2.027
Jul-16	3.174	3.631	-	3.487	3.208	1.204	1.366
Aug-16	1.715	2.721	-	2.636	2.463	2.586	2.994
Sep-16	2.187	2.477	-	2.405	2.296	2.267	2.655
Oct-16	1.617	1.552	-	1.568	1.520	1.472	1.766
Nov-16	1.047	981	268	1.020	1.006	955	1.184
Dec-16	712	645	326	657	688	701	883
Jan-17	494	544	272	546	548	496	604
Feb-17	1.092	1.155	584	1.179	1.168	1.151	1.405
Mar-17	1.453	2.101	1.049	2.098	2.031	1.791	2.136
Apr-17	2.782	2.909	1.160	2.719	2.726	2.586	3.009
May-17	3.030	3.207	1.182	3.154	2.944	2.796	3.229
Jun-17	3.060	1.744	717	1.708	1.580	2.831	3.254
Jul-17	3.272	2.564	1.128	2.499	2.330	3.157	362
Aug-17	2.752	2.986	1.283	2.889	2.698	2.605	3.023
Sep-17	2.556	2.732	1.001	2.661	2.576	2.397	2.774
Oct-17	1.380	2.040	998	2.020	2.036	1.800	2.134
Nov-17	760	1.256	639	1.293	1.289	1.103	1.342
Dec-17	860	935	486	1.001	1.019	830	1.017
TOTAL	**84.506,90**	**96.072,50**	**24.868,40**	**94.576,30**	**90.456,40**	**88.619,70**	**98.130,20**

Months	INV 04.14	INV 05.15	INV 05.16	INV 05.17	INV 05.18	INV 06.19	INV 02.02
Jan-14	1.213	1.196	647	1.183	1.203	1.248	1.090
Feb-14	1.334	1.433	745	1.378	1.398	1.463	1.305
Mar-14	2.245	2.258	1.149	2.156	2.187	2.054	2.046
Apr-14	2.789	2.771	1.411	2.657	2.711	2.761	2.726
May-14	3.215	3.198	1.622	3.061	3.119	2.039	3.039
Jun-14	3.196	2.841	1.437	2.714	2.812	3.077	3.004
Jul-14	3.715	3.674	1.860	3.534	3.671	3.583	3.506
Aug-14	3.272	3.159	1.611	3.057	3.155	3.179	3.220
Sep-14	2.473	2.419	1.243	2.320	2.383	2.418	2.461
Oct-14	1.585	1.504	792	1.436	1.467	1.506	1.577
Nov-14	1.018	1.000	540	960	982	1.033	1.015
Dec-14	741	749	418	727	726	791	744
Jan-15	922	880	481	831	855	942	850
Feb-15	1.007	879	459	816	873	833	930
Mar-15	1.669	1.617	838	1.519	1.551	1.604	1.653
Apr-15	2.933	2.876	1.481	2.724	2.777	2.864	2.903
May-15	3.438	3.332	1.707	3.178	3.267	2.910	3.140
Jun-15	3.072	2.864	1.474	2.731	2.824	2.799	2.263
Jul-15	3.765	3.651	1.857	3.477	3.673	3.561	3.635
Aug-15	3.109	2.614	1.356	2.490	2.499	2.949	2.809
Sep-15	2.322	1.938	1.014	1.843	1.898	1.930	1.835
Oct-15	1.427	1.221	654	1.146	1.180	1.230	1.345
Nov-15	1.302	1.248	695	1.198	1.222	1.298	1.163
Dec-15	915	901	518	871	863	951	744
Jan-16	760	568	307	536	575	531	622
Feb-16	1.343	1.283	690	1.198	1.229	1.285	1.328
Mar-16	1.977	960	500	886	901	930	919
Apr-16	2.511	3.006	1.550	2.808	2.824	2.887	3.090
May-16	-	2.594	1.337	2.422	2.442	2.476	2.668
Jun-16	2.009	3.191	1.665	3.035	3.076	3.076	3.271
Jul-16	1.354	3.486	1.840	3.362	3.416	3.416	3.496
Aug-16	2.943	2.712	1.458	2.634	2.650	2.730	2.660
Sep-16	2.588	2.403	1.289	2.310	2.299	2.428	1.271
Oct-16	1.696	1.444	790	1.386	1.382	1.467	1.290
Nov-16	1.081	897	507	863	856	928	1.055
Dec-16	767	590	344	587	583	638	569
Jan-17	562	483	275	456	456	503	393
Feb-17	1.328	1.226	686	1.178	1.173	1.278	1.303
Mar-17	2.059	1.889	1.044	1.836	1.828	1.944	2.020
Apr-17	2.926	2.742	1.471	2.639	2.626	2.765	2.759
May-17	3.141	2.983	1.582	2.856	2.865	2.953	3.116
Jun-17	3.162	3.028	1.610	2.889	2.910	2.946	1.635
Jul-17	3.490	3.398	1.798	3.256	3.275	3.302	2.441
Aug-17	2.904	2.782	1.485	2.672	2.612	2.754	2.868
Sep-17	2.653	2.553	1.364	2.458	2.393	2.558	2.637
Oct-17	1.999	1.914	1.049	1.849	1.826	1.952	1.958
Nov-17	1.218	1.164	660	1.134	1.122	1.218	1.193
Dec-17	879	879	514	870	843	938	844
TOTAL	**98.026,10**	**98.395,00**	**51.822,70**	**94.123,30**	**95.455,50**	**96.923,50**	**94.404,10**

Months	INV 02.03	INV 02.04	INV 02.05	INV 02.06	INV 02.07	Total
Jan-14	1.253	1.266	43	1.261	1.284	20.609
Feb-14	1.331	255	-	1.516	1.415	22.204
Mar-14	2.075	2.171	1.679	1.732	2.136	38.269
Apr-14	2.787	2.828	2.799	-	2.753	46.245
May-14	3.051	3.246	3.215	2.257	3.240	53.443
Jun-14	3.183	3.253	3.187	3.242	3.216	54.601
Jul-14	3.588	3.804	3.678	3.754	3.727	64.703
Aug-14	3.282	3.362	3.265	3.343	3.310	56.478
Sep-14	2.494	2.560	2.473	2.535	2.529	43.746
Oct-14	1.625	1.672	1.604	1.658	1.663	27.088
Nov-14	1.059	1.101	1.050	1.090	1.101	18.221
Dec-14	772	846	783	829	853	13.337
Jan-15	967	1.001	942	991	1.001	14.440
Feb-15	909	986	933	983	963	14.269
Mar-15	1.632	1.727	1.606	1.711	1.715	28.498
Apr-15	2.930	3.007	2.844	3.004	2.969	48.091
May-15	3.412	3.506	3.263	3.494	3.445	56.451
Jun-15	3.058	2.490	2.959	3.126	3.088	48.366
Jul-15	3.733	3.834	3.673	3.832	3.766	63.764
Aug-15	2.845	2.923	2.764	2.904	2.883	46.767
Sep-15	918	1.903	1.785	1.890	1.873	33.370
Oct-15	-	1.402	1.322	1.397	1.389	20.946
Nov-15	-	1.274	1.206	1.283	1.296	20.380
Dec-15	689	829	764	832	850	12.491
Jan-16	42	643	634	667	666	10.034
Feb-16	-	1.393	1.345	1.421	1.416	21.304
Mar-16	-	1.002	970	1.024	1.017	21.808
Apr-16	2.261	3.149	3.036	3.208	3.171	50.007
May-16	2.680	2.735	2.642	2.780	2.734	38.169
Jun-16	2.173	3.381	3.267	3.404	3.358	49.909
Jul-16	-	3.742	3.570	3.716	3.677	51.142
Aug-16	-	2.969	2.786	2.939	2.897	44.493
Sep-16	-	1.403	1.332	1.402	1.393	34.404
Oct-16	796	1.236	1.324	1.406	1.407	25.117
Nov-16	1.026	883	1.076	1.173	1.177	17.982
Dec-16	625	667	638	688	679	11.986
Jan-17	376	418	402	427	429	8.682
Feb-17	1.197	1.374	1.321	1.396	1.388	22.582
Mar-17	1.674	2.075	1.998	2.107	2.087	35.220
Apr-17	2.246	2.872	2.787	2.923	2.875	49.520
May-17	2.494	3.173	3.081	3.233	3.170	54.191
Jun-17	1.372	1.717	1.656	1.748	1.720	41.284
Jul-17	1.940	2.486	2.400	2.520	2.469	48.085
Aug-17	2.375	2.933	2.808	2.941	2.877	50.243
Sep-17	2.229	2.689	2.593	2.706	2.651	46.179
Oct-17	1.784	2.053	1.985	2.095	2.061	34.932
Nov-17	1.204	1.284	1.219	1.310	1.293	21.699
Dec-17	911	954	874	959	965	16.576
TOTAL	**76.996,50**	**98.471,70**	**93.578,90**	**96.856,20**	**100.039,80**	**1.672.323,70**

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