NUCLEAR ENERGY VERSUS SOLAR ENERGY (NUKE VS. PV): THE COMPARISON OF THEIR ECONOMIC FEASIBILITIES AND ENVIRONMENTAL ASPECTS FOR TURKEY

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ABSTRACT

NUCLEAR ENERGY VERSUS SOLAR ENERGY (NUKE VS. PV): THE COMPARISON OF THEIR ECONOMIC FEASIBILITIES AND ENVIRONMENTAL ASPECTS FOR TURKEY

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Having global regime with increasing environmental threats, reaching limits to growth, ascending needs and aspirations, humanity is seeking for new options not only to meet the needs but also to reconcile economic feasibility considering environmental vulnerability. Energy is at the hub of above mentioned concerns as taking a part in both of creating problems and of producing solutions. This study examines and compares the economic feasibility and environmental effectiveness of nuclear energy and solar energy options for Turkey, a country which is at the threshold of new investments to meet its expanding electricity demand depending on sui-generis conditions. The comparison is made specifically for two case studies, the photovoltaic energy (PV) power plant in Karapinar Energy Specialised Industrial Zone and the nuclear energy (NUKE) power plant in Mersin Akkuyu. Former case study determines exposed solar irradiation amount, design parameters, total electricity production, life cycle assessment and inventory, CO_2 reduction potential, levelised cost of energy and payback of an aforementioned photovoltaic power plant. The latter similarly identifies the material use, environmental affect, CO_2 reduction potential, levelised cost of energy and payback of an above mentioned nuclear energy power plant. Then, the outputs are compared.

Abiding by allocation of same installed power, namely 4800 MW; both options have advantages and disadvantages. While PV is cheaper without land cost, NUKE produces more electricity. Although NUKE has much more cumulative CO_2 reduction, PV is more beneficial in terms of CO_2 reduction per unit of electricity. PV needs quite more area, however, it requires very much less days for commissioning and decommissioning when compared to NUKE. When PV installation needs less water, less concrete, less steel, NUKE requires less aluminum, less glass.

Key Words: Nuclear, PV, LCA, LCOE, CO_2

ÖZ

NÜKLEER ENERJİYE KARŞI GÜNEŞ ENERJİSİ (NUKE VS. PV): TÜRKİYE İÇİN EKONOMİK UYGULANABİLME VE ÇEVRESEL AÇIDAN KARŞILAŞTIRMASI

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Çevresel tehditlerin arttığı, büyümenin sınırlarına ulaşıldığı, ihtiyaç ve isteklerin arttığı küresel düzene sahip insanlık, hem talepleri karşılayacak hem de ekonomik uygulanabilirliğe sahip ve çevreye uyumlu yeni seçenekler aramaktadır. Enerji, yukarıda anlatılan endişelerin, hem problemlerinin hem de çözümünün bir parçası olarak tam merkezinde yer almaktadır. Bu çalışma, artan elektrik ihtiyacını karşılaması için yeni yatırımların eşiğinde olan Türkiye için, ülke koşullarında kendine özgü şartlarda, nükleer enerji ve güneş enerjisi seçeneklerinin ekonomik ve çevresel uygunluklarını incelemekte ve karşılaştırmaktadır. Mezkûr karşılaştırma Karapınar Enerji İhtisas Endüstri Bölgesine kurulacak olan Fotovoltaik enerji (PV) güç santrali ile Mersin Akkuyu'ya kurulacak olan nükleer enerji (NUKE) güç santralini içeren iki örnek çalışmanın karşılaştırılması şeklindedir. Birinci örnek çalışmada, söz konusu santralin kullanacağı güneş enerjisi miktarı, tasarım parametreleri, toplam elektrik üretimi, yaşam döngüsü analizi (YDA) ve envanteri, CO_2 azaltım potansiyeli, seviyelendirilmiş maliyet analizi (SMA) ve geri ödemesi tanımlanmaktadır. İkinci çalışmada ise, benzer olarak, ilgili santralin malzeme kullanımı, çevresel etki, CO_2 azaltım potansiyeli, seviyelendirilmiş maliyet analizi ve geri ödemesi belirlenmektedir. Ardından, iki örnek çalışmanın çıktıları aynı kurulu güçlere sahip olmaları koşulu ile karşılaştırılmaktadır.

4800 MW olmak üzere aynı kurulu güç miktarını tahsis ettiğimizde, iki seçeneğinde diğerine göre avantaj ve dezavantajları ortaya çıkmaktadır. Alan maliyeti hesaba katılmadığında PV daha ucuz iken, NUKE daha fazla elektrik üretir. NUKE çok daha fazla toplam CO_2 azaltım potansiyeli olmasına rağmen, birim elektrik başına CO_2 azaltımında PV daha faydalıdır. PV daha fazla alana ihtiyaç duyarken, çok daha kısa kurulum ve söküm süresi gerektirmektedir. PV kurulumu daha az su, beton, çelik gerektirirken, NUKE daha az alüminyum, daha az cam gerektirir.

Anahtar Kelimeler: Nükleer, Fotovoltaik, YDA, SMA, CO_2

to all who imagine

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LIST OF ABBREVIATIONS

AC	Alternating Current
AOX	Adsorbable Organic Halogen
APAC	Asia Pacific Countries
BOD	Biochemical Oxygen Demand
BM	Built Margin
BOO	Build-Own-Operate
BoS	Balance of System
CDM	Clean Development Mechanism
CFB	Circulating Fluidized Bed
CH_4	Methane
COD	Chemical Oxygen Demand
CO_2	Carbondioxide
c-Si	Crystalline silicon
CZ	Czochralski
DC	Direct Current
DG	Directorate General
DOC	Dissolved Organic Carbon
EDAM	Center for Economics and Foreign Policy Studies
EF	Emission Factor
EG	Electronic Grade
EIA	Environment Impact Assessment
EMRA	Energy Market Regulatory Authority
ESIZ	Energy Specialised Industrial Zone
ESRI	Environmental Services Research Institute
FBS	Fluidised Seperator
GHG	Green House Gases
GTOE	Giga Tones of Oil Equivalent
GW	Giga watt
HA	Hectare
HCI	Hydro chloric acid
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle

kWh	Kilo watt hours
LCA	Life Cycle Assessment
LCOE	Levelised Cost of Energy
LCI	Life Cycle Inventory
MDG	Millennium Development Goals
MG	Metallurgical Grade
MoENR	Ministry of Energy and Natural Resources
Mtoe	Million tones of oil equivalent
MW	Mega watt
N_2O	Nitrous oxide
NMVOC	Non Metal Volatile Organic Carbon
NOCT	Nominal Operating Cell Temperature
NPV	Net Present Value
NUKE	Nuclear Energy
OM	Operating Margin
O&M	Operation and Maintanance
PFBS	Pressurised Fluidised Bed Combustion
PM	Particulate Matter
PV	Photovoltaic
PP	Power Plant
SEPA	Solar Electrical Power Association
SoG	Solar Grade
TOC	Total Organic Carbon
TWh	Tera watt hours
TPVTP	Turkish PV Technology Platform
UNFCCC	United Nations Framework Convention on Climate Change
VVER	Water – Water Power Reactor
VAT	Value Added Tax

CHAPTER 1

INTRODUCTION

1.1. The Main Scenario of the Study

World is facing with environmental destruction threats leaded by an abrupt climate change phenomenon mainly as a result of the anthropogenic interventions to the environment [1]. Major reasons for an environmental destruction are over exploitation of natural resources and undesired emissions as an output of actions. The fundamental reasons why the anthropocene has above mentioned challenges against environment are energy consumption [2], population increase, endeavors and greed for economic growth and unsustainable production and consumption patterns.

The alarms given by the environment revealed that there are limits of growth and world is about to be a tipping point [1 - 2]. Even if being in charge of climate change, human is not keen on extermination himself. Consequently, human beings try to design a new life style rules consisting of economic, environmental and social aspects. What human being calls for the new life style ambitious to tackle with environmental threats while meeting needs and aspirations is called as sustainable development.

Energy sector plays a major role both for being reason of environmental destruction and having potential to serve as the top sector on tackling global environmental threats.

Turkey having sharply growing economic and population statistics needs energy investments to meet extra energy demands even energy efficiency is possible.

In this way, Turkey is in a threshold of having NUKE and PV investments because of some reasons such as the need to meet future energy demand, diversify her energy provider technologies, reduce energy dependency on import etc. Both NUKE and PV are not only unexplored areas for Turkey's investment climate but areas also Turkey desires to become mature.

This study compares both economic and environmental feasibilities of NUKE and PV options for Turkey. For the NUKE part, 4800 MW installed power NUKE

PP which is being constructed in Mersin Akkuyu is studied. As for the PV part, 1 MW PV PP is designed to be located in Karapınar ESIZ and then projected to 4800 MW. Former and the latter are compared by using LCA methods for a material use (environmental) comparison and LCOE method for an economic comparison.

Because NUKE and PV have different capacity factor and working hours, the comparisons of both LCA and LCOE are carried out per kWh. In other words, having same installed power, NUKE and PV generates different amounts of electricity. Then, the comparisons are carried out for a unit production of one kWh of energy.

For the first case studied under the main scenario, a PV PP having 1 MW installed power is considered in the Karapınar ESIZ. Firstly, LCA of a PV system installed in ESIZ is calculated and also its LCI is determined. Moreover, solar irradiation calculations are carried out for the pre-determined location where the PV PP would be installed. Owing to the features of the selected technology of PV arrays, PV system is designed by determining the appropriate PV technology, PV Panels, BoS components; required amounts of system components, area to establish the system; CO_2 reduction and electricity production potentials of a lifetime. For the computation of the electricity production of the system, the PV F Chart software is applied. Furthermore, owing to the method of LCOE, cost of the determined system is evaluated.

For the second case, NUKE PP having 4800 MW installed power planned to be established in Mersin Akkuyu by the Government is examined literally so as to have information concerning the LCOE, LCA, technological necessities and environmental effects of it.

So as to compare these two cases, the outputs of the first case is projected to same installed power / electricity production amount planned for the second case. Finally, the cases are compared in terms of both economic feasibility and environmental aspects.

1.2. Global Trends and Threats

(Relation Among Climate Change and Other Threats; Limits to Growth and Sustainable Development)

Maintaining its cycle without exceeding the assimilation capacity due to its nature, world entered the anthropocene as of the beginning of the industrial revolution. World has faced with 9 major environmental degredation threats[1] leaded by the global climate change as a result of the anthropogenic interventions. Among these environmental degredations, the followings seem the most important ones: biodiversity loss highly exceeded the limit, nitrogen cycle has exceeded the tolerance point and climate change has been sharply reaching the tipping point which has no return [3].

World history was faced with 5 ecological extinction period which are ordovocian, devonian, permian, triassic, cratecous. By resulting in environmental threats leaded by abrupt climate change, Antropocene is foreseen as sixth extinction period [4].

Major reasons for an environmental degradation are over exploitation of natural resources and undesired emissions of pollutants as an output of development. The fundamental reasons why anthropocene has above mentioned challenges against environment are population increase, endeavors and greed for economic growth and unsustainable production and consumption patterns.

Letting itself in for the environmental threats lead by climate change within so-called anthropocene, civilisation is in economic transformation with the intent of not only mitigating their effects but also adapting to them.

While global population was 1.2 billion in 1850, the time accepted as a starting point the negative effects of the industrial revolution started to be suffered, it exceeded 7 billion threshold as of 21st century. Meanwhile, the energy demand of 1.2 billion population was 0.5 GTOE/year; it reached 10 GTOE/year with 7 billion populations currently [5]. When the change is scrutinized, for the last 150 years energy demand increased 20 fold while a 7 fold increase in the population was recorded. According to Malthus, while population has increased geometrically, world

[1] Chemical pollution, climate change, ocean acidification, stratospheric ozone depletion, biochemical flow boundary (nitrogen cycle, phosporus cycle), global freshwater use, land system change, biodiversity loss, atmospheric aerosol loading

resources have increased arithmetically [6]. Additively, world population is estimated to reach 10 billion by the end of this century [7].

Scrutinizing specific to abrupt climate change threat, already: world average temperature increased 0.74 ˚C in the last 100 years; Arctic glaciers has shrinked 2.7 % for every decades as of 1978; at least 420 physical processes, biological species and community suffered a change; sea level raised 10-20 cm in the last century; excessive circumstances became more often; algae, plankton and fish seasons has been altered and precipitation regimes were remarkably changed [8].

The growth, magical word of the anthropocene, has expanded the volume of the economy by serving more people and resulting in more money handover. Being non-stable by having solely the growth, shrink and crisis faced in the current market economy's most important sources are energy and natural resources [2].

Looking from the energy aspect; actual energy production depended on hydrocarbon sources that have three major actors: oil, natural gas and coal. However, this situation has been compelled to change because of losing their feasibilities across other options, in particular renewable alternatives, with conjectural conditions.

Even oil is becoming out of fashion and renewable energy compensates it, shale oil/gas's becoming popular paves the way for the realization of "golden age of natural gas" as claimed by IEA [9].

In addition to energy resources, almost all other natural resources have similar situation. Main industrial sectors such as high technology electronic industry are depended on metal and nonmetals which are rare and some already about to be extinct. Metals have a vital role on indispensible sectors for the economy such as energy, manufacturing process equipments, transport vehicles manufacturing, agricultural truck manufacturing, road infrastructure manufacturing, pipelines establishment. Referencing to London Metal Stock Exchange except fluctuations in the crisis periods metals like zinc, copper, nickel, lead etc. have made considerable increase.

Another resource offered by the nature that has to be considered is water, which is a source launched to evoke its stress on various territories. MDG on water cannot also be achieved by having currently 2.5 billion having lack to access sanitation opportunities and 1.1 billion lack of accession to fresh water [10].

Increase in the production accelerated by an industrial revolution, the endeavors for the development by the countries like Germany, Japan, China etc.

especially after 2nd World War and consumption frenzy of the society brought about huge pressure on environment and natural resources. However, even these negative effects were experienced by human being and having some big phenomenon like London Episode, civilization ignored the destruction of environment and natural resources. When the threat reached the tipping point, civilization launched the intervention process.

Sustainable development term which is started to be mentioned in the Stockholm in 1992 [11]; was initially defined in 1980 [12] had widespread definition[2] in 1987 with Brundtland Report [13] was presented as a solution pathway in front of human being as of 1992 Rio [14]. This term was strengthened with 2002 Johannesburg [15] and 2012 Rio+20 meetings [16].

Sustainable development term should provide a conversion from brown economy definition method of today's economy into energy and resource efficient green economy, without exceeding the assimilation capacity of the world. The fundamental needs of the human kind should be accordingly defined, clearly and properly, which might lead to a better rephrasing of the definition of sustainability [17].

Energy is at the hub of both the reasons that resulted in the aforementioned troubles and ironically, the ways to get rid of the negative effects of this global dilemma. "The Future We Want" document the output of Rio+20 addresses energy issues many times such as establishing sustainable energy for all initiative, defining sustainable energy needs etc. Moreover, energy has the major responsiblility across GHGs production leaded by CO_2 which is the fundamental reason of climate change phenomenon by being responsible of two-thirds of the global GHGs [18 - 19].

1.3. Global Energy Outlook

Global energy issue subsuming many crucial variables like energy diplomacy, economy, engineering, technology etc. creates a huge stress on natural resources and effect on competitiveness of the countries, companies etc and contributes to environmental pollution.

[2] Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

While global cumulative GHG emission reached 31.60 billion tones of CO_2 with 1.2% increase in 2012, energy related CO_2 emission has increased its pie more, to about 400 million tones per year [19].

World had 12,789.25 Mtoe annual energy production [20] 508.87 quadtrillion Btu primary energy consumption [21] and 20,238.14 billion kWh electricity consumption [22] in 2010.

Oil had the biggest share in energy consumption pie with 4,069.38 Mtoe, coal is runner up with 3,596.04 Mtoe and natural gas, biofuels and waste, nuclear and hydro are following, respectively [20].

Taking into account the electricity consumption, 13,473.28 billion kWh of that is provided from fossils, remaining part is from renewable and nuclear with 4,167.20 and 2,620.28 shares respectively in 2010 [22].

In country basis, the USA was the biggest electricity consumer of the world by having 4,125.06 billion kWh followed by China having 3,904.12 global share [21].

In specific to NUKE and PV, the former is a mature energy technology and the latter is an emerging technology.

Pointing out devastating information at this point, PV PPs use the energy reaching the Earth from the sun which produce its energy based on nuclear reactions and interestingly, it is in principle, also used in NUKE PP’s.

1.3.1. PV Outlook

The global cumulative PV capacity exceeded 100 GW installed power capacity by reaching 102 GW as of the end of 2012. This amount being capable of producing at least 110 TWh of electricity every year is achieved with 31.1 GW additional capacities in 2012 [23].

Moreover, PV in 2012 became the most prioritized electricity source in the EU in terms of an added installed capacity. PV with 16.7 GW connected to the grid outsored gas and wind while nuclear capacity of Europe has decreased by an amount 1.25 GW [23].

Europe is leading with the predominant share of World PV market with 70 GW installed capacity. Next in the ranking are China with 8.3 GW, the USA with 7.8 GW and Japan with 6.9 GW. As a country basis in Europe, Germany leads the market with 32.41 GW installed power followed by Italy with 16.36 GW and Spain 5.17 GW [23].

In terms of types of PV Cells, the dominant PV technology having two main categories namely monocrystalline and polycrystalline, crystalline silicon (c-Si) modules represent 85-90% of the global annual market today [24]. It is also foreseen to maintain its dominant position in the near future [23]. In addition, monocrystalline cells have comparetively the highest efficiency but, greater energy payback period [24].

Adressing PV industry, the situation differs depending on value chain of PV manufacturing. Comparing 2012 data, China generally leads manufacturing steps of PV. 35% capacity and 27% production of polysilicon, 78% of capacity and 80% of production of wafers, 71% of capacity and 66% of production of c-Si cells, and 73% of capacity and 69% of production of c-Si modules are produced in China [23]. APAC, second major actor, has 20% capacity and 19% production of polysilicon, 13% capacity and 12% production of wafers, 22% capacity and 27% production of c-Si cells, 11% of capacity and 13% of production of c-Si modules. However, Europe, dominant end-use actor for solar electricity production, has only 17% capacity and 20% production of polysilicon, 8% capacity and 7% production of wafers, 5% capacity and 5% production of c-Si cells and 13% capacity and 14% production of c-Si modules [23].

On company basis, according to 2010 data, China dominates the industry of PV. Other PV manufacturing countries are Taiwan, Japan, USA, Norway and Germany. The fundamental solar companies from these countries are Suntech Power/China (sharing 7% pie from total), Ja Solar/China (6%), First Solar/USA (6%), Yingli Green Energy/China (5%), Trina Solar/China (5%), Q-Cells/Germany (4%), Kyocera/Japan (3%), Motech/Taiwan (3%), Sharp/Japan (3%), Gintech/Taiwan (3%), REC/Norway (2%), Sunpower/USA (2%), Canadian Solar/China (2%), Neo Solar/China (2%) and Hanwha-SolarOne/China (2%) [25].

1.3.2 NUKE Outlook

Nuclear energy presents about % 13 of global electricity [26 - 27] and 5.5% primary energy demand and little more than 2% of global energy consumption [26].

Nuclear energy generated 2,620.217 billion kWh globally in 2010, 2,507.22 in 2011 and 2,343.53 in 2012 [22]. This revels that the nuclear share in commercial primary energy consumption dropped to 4.5%, "the lowest since 1984" [28].

By July 2013, 427 nuclear reactors in 31 countries are under operation [29]. Besides, there are about 68 plants under construction around the world in 12 countries, principally China, India, Korea, and Russia [29]. The global installed capacity of nuclear power plants is 364 GW [29]. Owing to that amount, nuclear electricity corresponded 2.35 TWh[3] in 2012 [29].

The number of countries having more than 20% nuclear share in their electricity production is 15. In terms of the quantity of nuclear reactors the USA comes in first (with 104 reactor), however, in terms of the share of nuclear in the total electricity production France comes in first (78%) [28]. France has 79 reactors, Japan has 55 and Russia has 33 reactors compensating only its 18% electricity production.

Having non-homogenous deployment, NUKE is intensed in some countries. Such that, more than 90% of NUKE PPs are in 22 countries and approximately half of them are in the USA, France and Japan.

1.4. Turkey Energy Outlook

Turkey classified as upper middle income developing country by the WorldBank, has sharply increasing energy consumption amount in compliance with population and welfare increase and economic growth endeavors.

While having currently 105.13 Mtoe energy consumption and 180.21 TWh electricity consumption [20], Turkey is estimated to be consuming the amount between 259-500 TWh in 2020 [30 - 32].

The share of current electricity and energy consumption by source in Turkey accomplished as the following: 31.9% natural gas, 31.3% coal, 26.7% oil, 3.7% hydro, 2.7% non hydro renewables like wind, solar, geothermal for primary energy consumption [25] and 44.7% natural gas, 27.22% coal (lignite, imported coal, domestic coal), 1.99% liquid fuel, 24.19% hydro, 2.14% wind for electricity generation in 2012 [25]. On the basis of installed power as of end of 2012, natural

[3] Terawatt-hours = billion kWh

gas has 32.10%, hydro 34.38%, 21.73% coal, 7.04% oil, 3.96% wind, 0.28% geothermal and others [25].

However, future projections and policies reveal that the mentioned picture can be modified. Turkey has 36,000 MW hydro, 20,000 MW wind, 3,000 MW solar, 600 MW geothermal, 2,000 MW biomass targets for 2023 [33].

Specifically to NUKE and PV, Turkey is in a threshold of having NUKE and PV investments because of some reasons such as the need to meet future energy demand, diversify her energy provider technologies, reduce energy dependency on import etc. Both NUKE and PV are not only virgin areas for Turkey's field of investments but areas also Turkey needs to be grown up.

1.4.1. PV Turkey in Particular Karapinar ESIZ

Turkey, owing to her geographical position, has long sunshine duration and so receiving high solar irradiation as being in the solar belt. According to the DG for Renewable Energy of the Ministry of Energy and Natural Resources, Turkey's total annual sunshine duration is 2,640 hours and average total radiation is 1,311 kWh/m^2 [34]. The regions having longest sunshine duration and highest solar irradiation are Southeast and Mediterrenean parts of Turkey having 2,993 and 2,956 hours average sunshine durations and 1,460 kWh/m^2 and 1,390 kWh/m^2 average total irradiation, respectively.

What DG for Renewable Energy did is not a sole study for PV potantial of Turkey. For instance, TSMS model for Turkey's solar energy potential using sunshine duration and radiation data measured by 157 weather stations of TSMS as of 1971 till 2000 revealed that Turkey's average annual total sunshine duration is 2,573 h (7 h/day) and average annual total irradiation is 1,474 kWh/m^2-year (4 kWh/m^2- day) [35].

Moreover, SEPA, developed by using ESRI Solar Radiation Model combining solar irradiation, topography and seasonal data of the location revealed that Turkey has average annual total sunshine duration of 2,738 h (7.5 h/day) and average annual solar irradiation of 1,527 kWh/m^2- year (4.2 kWh/m^2-day) [36]. In other words, Turkey has a technical solar power generation capacity of 380 TWh/year [37 - 38].

Though having more solar irradiation than the European leading solar Energy investor countries like Germany, Spain, Czech Republic as seen in Figure 1, Turkey still falls behind these countries because of her regulations related to investment amount are newly done [39].

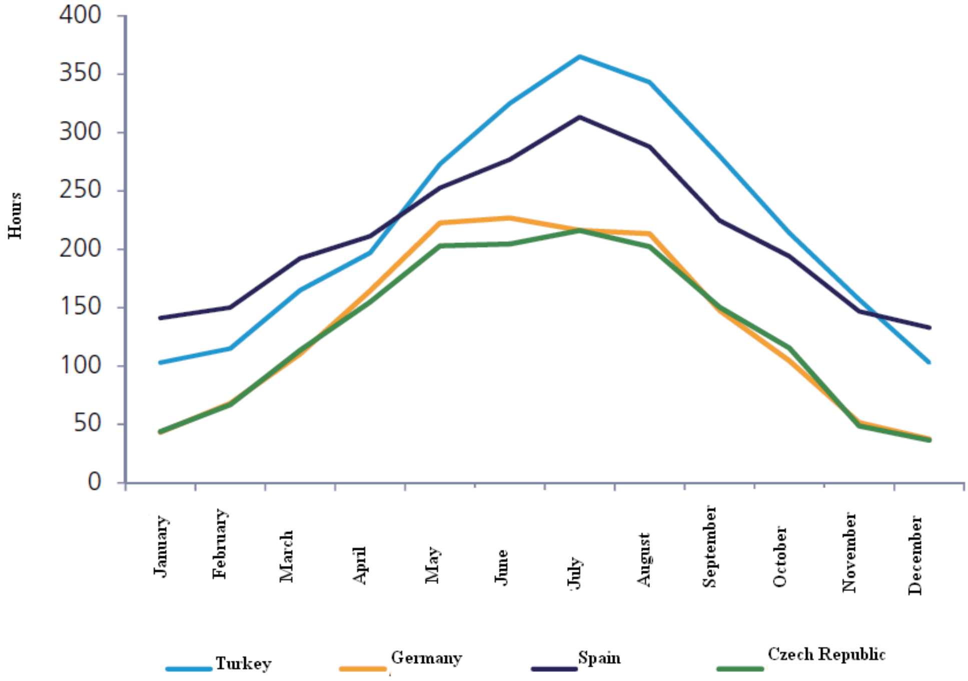


Figure 1 Comparison of sunshine duration [39]

While Turkey has still no considerable PV power plant being operated, EMRA decision taken in 24 May 2012 paved the way for the investments on PV. Pursuant to aforementioned decision, EMRA announced the license distribution for the installment of PV power plant having totally 600 MW installed capacity country wide [40]. The investors having realized their 6-month solar measurement precondition made their license application in 10-14 June 2013.

While the most 600 MW applications were licenced after June 2013, the PV volume in Turkey is foreseen to reach 3,000 MW in 2023 [41].

Furthermore, Turkey’s installed PV capacity is projected to reach 20 GWp by 2020 according to the EPIA [42]. In addition, TPVTP has a target of 6 GWp with a moderate scenario and 10 GWp with a policy driven scenario by 2020 [43].

The general arrangements of solar energy plants are regulated by Renewable Energy Law and secondary legislation determines the methods and procedures. The regulatory framework of PV in Turkey is listed in Table 1.

Table 1 Regulatory Framework of PV in Turkey

Law	Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy, No 5346 Electricity Market Law, No 4628
Secondary Legislation	Regulation on Electricity Power Plants based on Solar Energy (19/06/2011-27969) Regulation on Competition concerning Applications for the Establishment of Solar Power Plants (29/05/2012-28307) Paper on measurement standard concerning applications based on wind and solar energy (22/02/2012-28212) Paper on wind and solar measurement implentations to be done for applications pertaining to wind and solar energy (10/07/2012-28349) Regulation on the certification and promotion of renewable energy sources (21/07/2011-28001) Regulation on domestic production of assemblies used in renewable energy power plants (19/06/2012-27969) Unlicenced Production Regulation (21/07/2011-28001) Licencing Regulation (04/08/2002-24836)
EMRA Council Decisions and MoENR Announcements	Announcement on grid connection capacities Announcement on acceptance date of an application

Under the light shed by aforementioned regulatory framework concerning PV, Turkey investment climate for PV presents some advantages for investors.

Owing to the Law No. 5346, namely Renewable Energy Law, PV PPs have an opportunity to get benefit from 13.3 $ cents/kWh feed-in-tariff incentive for 10 years providing to be established before 31/12/2015. Moreover this amount can be extended for 5 years up to 20 $ cents/kWh by subsiding domestic productions.

Listing the subsidies for domestic productions: PV panel integration and manufacture of solar structual mechanics (0.8 $ cent/kWh), PV modules (1.3 $

cent/kWh), PV cells (3.5 $ cent/kWh), invertor (0.6 $ cent/kWh), PV solar concentrator (0.5 $ cent/kWh).

1.4.1.1. Karapınar Energy Specialised Industrial Zone

16/07/2012 dated and 2012/3574 numbered decision of the Ministerial Cabinet establishing Karapınar Energy Specialised Industrial Zone entered into force after having been published in 08/09/2012 dated and 28405 numbered Official Journal.

This zone is brought about two parts. The zone constitutes totally about 6,159 ha area. In other words, property having exactly 61,585,762 m^2 total area is determined [44]. Owing to the features of industrial zones, the infrastructure including cable connection till transformers will be provided by the government, namely the Ministry of Science, Industry and Technology, and loaned to the investers.

1.4.2. NUKE Turkey in Particular Mersin Akkuyu

Looking specific to Turkey, first reactor for research purpose was established in Istanbul in 1962, second one in 1979 and the third one in 1981. All of these reactors are small scale reactors and not in operation [26].

Turkey has no operating large scale NUKE PP; however, there are 3 PPs planned to be established. Some steps taken for the two of these planned PPs. The first one is programmed to be established in Mersin province located in the southern Anatolia at the coast of Mediterrenean. Second one is planned to be established in Sinop northern part of the Anatolia and near Blacksea.

The one to be established in Mersin is the closest one to the end. The intergovernmental agreement to establish NUKE PP having 4800 MW installed power was signed between Republic of Turkey as a host country and Russian Federation as a contractor in 2010. Currently, this project is in an EIA process. After having completed licensing and EIA approval periods, the construction step which takes about 7 years to start. Bearing in mind that nuclear power constitutes 4 reactors each having 1200 MW installed power, the electricity production through this PP will start in 2020 and the last reactor will be put into use in 2023. Moreover, the operating method of this PP is based on BOO [45].

CHAPTER 2

CASE STUDIES

2.1. Case Study 1 - 1 MW PV PP in Karapinar ESIZ

In this part of the study, 1-MW PV ground mounted and on grid PP in Karapinar ESIZ is planned. The approximate coordinates of the determined area for the establishment of PV PP are 37° 43' 45'' north and 33° 33' 01'' east.

The scenario determining PV PP having 1 MW installed power will be constituted from PV Panels and BoS components pursuant to the necessities to establish ground-mounted PV system.

PV panel type is selected as monocrystalline a sub technology of crystalline technology which dominates the PV market. It has the highest efficiency compared to equivalent technologies and has the highest possibility to be used by investers who will make an investment in the aforementioned zone. The model of the PV panels is preffered as YINGLI YL280C/30b Solar Panel having one of the highest efficiency among other panels in the market. Moreover, the brand producing mentioned panel, Yingli, is one of the biggest actors of PV industry [46].

The technologies of BoS components were also prefferred based on the same criteria.

The selections made in the course of the present study consisting of above mentioned preferences which is believed to seem reasonable and in addition, reflect the facts of the present market.

In the scenario of this case study; initially the solar radiation falling on the module having yearly optimal tilt angle of the determined area is designated, then the necessary parameters essential for the design of PV system having 1 MW installed power is considered. The parameters identified at this step are the number of PV panels required and BoS components like inverter, dimensions and necessary area, required mounting devices, ordering arrays and lines. The calculations are carried out, starting from fundamental principles, to determine some realistic quantities about the numbers to weight against. As the third step, to check and settle the outcomes properly, computations about the PV electricity production of the system, PV F Chart software program is utilized. The LCA of the designed system from mining to operation step is applied and LCI is computed out. From this step on, the designed system gets ready to be commissioned. The panels and inverters are ordered from the real suppliers. Then, the system is commissioned by seasonal workers, since commission of PV system does not demand highly specialized skilled work force if the modules are readily imported. Decommission is also realized by seasonal workers in a similar way.

In accordance with industrial zone features, the infrastructure of a field where the system is established is prepared by the Ministry of Science, Industry and Technology. The field is also loaned from the Government with an announced price by the Ministry of Finance.

Adding all the factors that were resulting in the investing of the capital are taken into account and the cost of the system is identified.

2.1.1. Solar Irradiation Computation for Karapinar Energy Specialised Industrial Energy Zone

Solar irradiation reaching the Earth will be the source of the input which will be converted into electricity, via PV panels for this study. Consequently, the primary need is to compute the solar irradiation available for PV system that is planned to be installed, in the region of interest to produce electricity.

The necessary data and conditional information for this computation starts with the short-wave radiation leaving sun and its value on the top of the atmosphere, firstly on a horizontal surface and secondly on the tilted PV module installed on the surface of the Earth. To carry out this computation, we first started with very fundamental measured value of the solar irradiation at the mean sun-earth distance. Secondly, we calculated the daily horizontal solar irradiation of the average day of the month for the location, at the zenith, directly outside of the atmosphere. Then monthly average of daily solar irradiation is transmitted by the atmosphere, that falls on the tilted PV panels at the location of interest was computed using a universal formula [47 - 48]. Solar irradiation reaching the PV modules is then converted into the electricity by photoelectric conversion process.

Mean Sun-Earth distance is 1.5×10^{11} meters and it varies by a small amount day by day, due to the elliptical orbit of the Earth around sun [49]. Solar constant is defined as the solar irradiation (W/m^2) reaching outside the atmosphere, on a unit area perpendicular to sun rays at the mean Sun Earth distance. Its value is determined using the regular and long-term measurements carried out by satellites. The recent decleared value is 1,367 Watts per m^2 [50 – 51].

Moreover, not the whole solar irradiation coming outside the atmosphere reaches to the Earth's surface, mainly because of natural and anthropogenic obstacles. Due to atmospheric reflection and absorption, reflection and absorption by the clouds, aerosols and other atmospheric constituents, scattering by particles, reflection from ground, about %50 of the solar irradiation coming outside of the atmosphere is transmitted and reaches to the Earth's surface, on the average [52].

Short wave irradiation of the sun reaches the Earth not only directly but also in an indirect way. That is, total (global) solar irradiation is classified under two components as the beam irradiation that reaches the surface without scattering, and diffuse irradiation which is the part of solar irradiation coming with scattering (by aerosols, dusts, molecules etc.). An advantage of PV technology is being able to work with both beam and diffuse irradiation.

2.1.1.1. How to Compute Solar Irradiation?

Computation steps are listed below derived from [47 - 48] and the set of formulas are debicted in Table 2.

1. Latitude of the place (ϕ) is determined. The latitude of this study is: $37^0$43'45". This is equal to 37.72^0.
2. Mean days of the months (n) are considered to calculate the monthly mean values of daily solar irradiation. These days for the 12 months starting from January are n values and given as 17, 47, 75, 105, 135, 162, 198, 228, 258, 288, 318, 344 respectively throughout a year [47].
3. Declination (δ) is computed from the related formula by using the above given'n' values.
4. Sunset hour angle (ω_s) is computed by using tangent of latitude and declination.
5. Monthly average daily value of the extraterrestrial irradiation incident on a horizontal surface (H_0) is calculated by reckoning the formula depending on G_{sc}, n, Φ, δ, ω_s.

6. Monthly average daily hours of bright sunshine, s are obtained from State Meteorological Office of Turkey and, monthly average of maximum possible daily hours of bright sunshine (daylength), S are computed [47].
7. Monthly average daily radiation on a horizontal surface (H) is then computed using s/S and the related formula revealed in the table [48].
8. Monthly average daily clearness index (K_t) is computed by determining the ratio between 'H' and 'H_0'.
9. Pursuant to 'ω_s' and 'K_t' values, both the ratio and the amount of the beam and diffuse components of the solar radiation are determined [47].
10. The ratio of beam radiation, R_b, and $\omega_s^{\prime}$ are calculated.
11. Monthly average daily solar irradiation on a tilted south-facing surface (H_t) is computed.
12. Finally, optimum tilt angle 'β' is specified with trials up to reach the maximum value for cumulative annual solar irradiation.

Table 2 Required parameters and their formulas/values/references so as to compute solar radiation

Parameter	Definition	Formula/ Value/Reference
n	Mean days of the month	[53]
ϕ	Latitude	37.72^0
δ	Declination	$\delta = 23.45 \times \sin[\frac{284+n}{365}]$
ω_s	Sunset hour angle	$\omega_s = \cos^{-1}(-\tan\phi\tan\delta)$
G_{sc}	Extraterrestrial solar irradiance falling on a 1 m^2 of a vertical surface at the mean-sun earth distance, Solar constant [47]	1367 W/ m^2
H_o	the monthly mean daily total extraterrestrial solar radiation on a horizontal surface in the absence of atmosphere, daily radiation (J/m^2–day or MJ/m^2–day)	$H_0 = \frac{24\times3600}{\pi} G_{sc}[1+0.033\cos\frac{360n}{365}](\cos\phi\cos\delta\sin\omega_s + \frac{\pi\omega_s}{180}\sin\phi\sin\delta)$
s	Monthly average daily hours of bright sunshine	[54]
S	Daylength	$S = \frac{2}{15}\cos^{-1}(-\tan\phi\tan\delta)$
H	the monthly mean of daily total terrestrial solar radiation falling on horizontal surface at a particular location, daily radiation (J/m^2–day= MJ/m^2–day) [48], [55]	$\frac{H}{H_0} = 0.145 + 0.845\times\frac{s}{S} - 0.28\times\left(\frac{s}{S}\right)^2$
K_t	Clearness index	$K_t = \frac{H}{H_0}$

Table 2 (continued)

Parameter	Definition	Formula/ Value/Reference
$\frac{H_d}{H}$	The ratio of beam and diffuse components of daily radiation [56]	$H = H_d + H_b$ $For\ \omega_s < 81.4$ $\frac{H_d}{H} = \begin{cases} 1.0 - 0.2727K_t + 2.4495K_t^2 - 11.9514K_t^3 + 9.3879K_t^4\ for\ K_t < 0.715 \\ 0.143\ for\ K_t \geq 0.715 \end{cases}$ $For\ \omega_s > 81.4$ $\frac{H_d}{H} = \begin{cases} 1.0 + 0.2832K_t + 2.5557K_t^2 + 0.8448K_t^3\ for\ K_t < 0.722 \\ 0.175\ for < K_t \geq 0.722 \end{cases}$
β	Optimum tilt angle	Optimum tilt angle is determined by examining the related values in order to find maximum solar radiation at a point. The most appropriate tilt angle for this aim is 27.8^0.
$\omega_s^{'}$	Sunset hour angle on a tilted surface for the mean day of the month	$\omega_s^{'} = \min \begin{Bmatrix} \cos^{-1}(-\tan\phi\tan\delta) \\ \cos^{-1}(-\tan(\phi-\beta)\tan\delta) \end{Bmatrix}$
$\bar{R}_b$	The ratio between the direct solar radiation received by a horizontal surface and the direct solar radiation over an inclined surface	$\bar{R}_b = \frac{\cos(\phi-\beta)\times\cos\delta\times\sin\omega_s^{'} + \frac{\pi}{180}\times\omega_s^{'}\times\sin(\phi-\beta)\times\sin\delta}{\cos\phi\times\cos\delta\times\sin\omega_s + \frac{\pi}{180}\times\omega_s\times\sin\phi\times\sin\delta}$
$\bar{H}_t$	Monthly average daily solar radiation on sloped surface [57] and extended by [53]	$\bar{H}_t = \bar{H}_b\bar{R}_b + \bar{H}_d\left(\frac{1+\cos\beta}{2}\right) + \rho g\left(\frac{1-\cos\beta}{2}\right)$

Abiding by the mentioned steps, monthly mean daily solar radiation on sloped surface which corresponds to tilted panel is acquired. By summing all the values, it is brought about that the determined area for this study has annual 1,688.25 kWh/m^2 solar radiation. The details of this calculation are seen in the following Table 3.

Table 3Excell sheet reckoning solar radiation amount reaching the surface of the determined field

Solar Irradiance for the determined place in Karapınar Energy Specialised Industrial Zone																		1 radian=pi/180*degrees	
n	Φ	δ	tan Φ	tan δ	Cosδ	Sinδ	CosΦ	SinΦ	cos ωs	ωs	sin ωs	360n/365	Cos 360n/365	(24*3600)/pi	Gsc	1+0,033..	piωs/180	Ho(J/m2)	Ho(MJ/m2)
17	37,72	-20,9	0,773446	-0,38186	0,93420447	-0,356738	0,79101	0,6118	0,29535014	72,8214655	0,95538908	16,76712	0,957485188	27501,97417	1367	1,031597	1,2709743	16622615	16,6226
47	37,72	-13	0,773446	-0,23087	0,97437006	-0,2249511	0,79101	0,6118	0,17856398	79,7138732	0,983928303	46,35616	0,690173388	27501,97417	1367	1,022776	1,3912695	21797165	21,7972
75	37,72	-2,4	0,773446	-0,04191	0,99912283	-0,0418757	0,79101	0,6118	0,03241697	88,1423188	0,999474432	73,9726	0,276096973	27501,97417	1367	1,009111	1,5383737	28471823	28,4718
105	37,72	9,4	0,773446	0,165549	0,98657216	0,16332596	0,79101	0,6118	-0,1280431	97,3565242	0,991768607	103,5616	-0,23449139	27501,97417	1367	0,992262	1,6991919	35206052	35,2061
135	37,72	18,8	0,773446	0,340428	0,94664926	0,3222657	0,79101	0,6118	-0,2633023	105,266102	0,964713364	133,1507	-0,683919422	27501,97417	1367	0,977431	1,8372401	39856286	39,8563
162	37,72	23,1	0,773446	0,426536	0,9198215	0,39233712	0,79101	0,6118	-0,3299025	109,262857	0,944015014	159,7808	-0,938377392	27501,97417	1367	0,969034	1,9069966	41698799	41,6988
198	37,72	21,2	0,773446	0,387874	0,9323238	0,36162457	0,79101	0,6118	-0,2999998	107,457589	0,953939276	195,2877	-0,964614176	27501,97417	1367	0,968168	1,8754887	40709768	40,7098
228	37,72	13,5	0,773446	0,240079	0,97236992	0,23344536	0,79101	0,6118	-0,1856879	100,701238	0,982608784	224,8767	-0,708626678	27501,97417	1367	0,976615	1,7575682	36965654	36,9657
258	37,72	2,2	0,773446	0,038416	0,99926292	0,03838781	0,79101	0,6118	-0,0297128	91,7026676	0,999558478	254,4658	-0,267814305	27501,97417	1367	0,991162	1,6005135	30841315	30,8413
288	37,72	-9,6	0,773446	-0,16914	0,98599604	-0,1667687	0,79101	0,6118	0,13081853	82,4831057	0,991406331	284,0548	0,242849722	27501,97417	1367	1,008014	1,4396018	23736397	23,7364
318	37,72	-18,9	0,773446	-0,34238	0,94608536	-0,3239174	0,79101	0,6118	0,2648096	74,6443602	0,964300717	313,6438	0,690173388	27501,97417	1367	1,022776	1,3027899	17821030	17,821
344	37,72	-23	0,773446	-0,42447	0,92050485	-0,3907311	0,79101	0,6118	0,32830816	70,83388	0,94457067	339,2877	0,935367949	27501,97417	1367	1,030867	1,2362844	15201302	15,2013

s	S	H(MJ/m2)	Kt	Hd/H	Hd(MJ/m2)	Hb(MJ/m2)	β	cos β	sin β	tan Φ tanδ	arccos(tan Φ tanδ)	Φ-β	tan (Φ-β) tanδ	arccos(tan (Φ-β) tanδ)	wsprime	sinwspr	cos(Φ-β)	sin(Φ-β)	Rb	Ht (MJ/m2)	Ht (kWh/m
3,2	9,70953	6,5339534	0,393076	0,769542	5,02814834	1,50580508	27,8	0,88458	0,46638664	-0,2953501	107,1785345	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,91394	7,61999568	2,116665
4,3	10,6285	9,6132769	0,441033	0,68611	6,59576853	3,01750834	27,8	0,88458	0,46638664	-0,178564	100,2861268	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,57169	10,9577081	3,043808
6,6	11,7523	15,12529	0,531237	0,502326	7,59782152	7,52746875	27,8	0,88458	0,46638664	-0,032417	91,85768124	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,27777	16,7777527	4,660487
7,1	12,9809	18,427349	0,523414	0,519168	9,56688361	8,86046548	27,8	0,88458	0,46638664	0,12804308	82,64347585	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,05546	18,3666623	5,101851
8,5	14,0355	22,082204	0,554046	0,452817	9,9992071	12,0829968	27,8	0,88458	0,46638664	0,26330235	74,73389763	9,92	0,174887659	79,92787936	74,7339	0,964713	0,9850493	0,172273	0,89617	20,2505795	5,625161
10,4	14,5684	25,249931	0,605531	0,341628	8,62609392	16,6238372	27,8	0,88458	0,46638664	0,32990249	70,73714286	9,92	0,174887659	79,92787936	70,73714	0,944015	0,9850493	0,172273	0,82019	21,7630194	6,045283
11,4	14,3277	26,057217	0,640073	0,270683	7,05325866	19,0039585	27,8	0,88458	0,46638664	0,29999976	72,54241111	9,92	0,174887659	79,92787936	72,54241	0,953939	0,9850493	0,172273	0,85383	22,8722866	6,353413
11,1	13,4268	24,10905	0,652201	0,247083	5,95693608	18,1521144	27,8	0,88458	0,46638664	0,18568785	79,29876175	9,92	0,174887659	79,92787936	79,29876	0,982609	0,9850493	0,172273	0,9901	23,5856405	6,551567
9,4	12,227	19,403396	0,629136	0,292618	5,67778783	13,725608	27,8	0,88458	0,46638664	0,02971278	88,29733243	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,18209	21,575052	5,99307
7,1	10,9977	13,620461	0,573822	0,409767	5,58122208	8,0392393	27,8	0,88458	0,46638664	-0,1308185	97,5168943	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,46278	17,0187494	4,72743
5,1	9,95258	8,9903466	0,50448	0,559441	5,02957221	3,96077436	27,8	0,88458	0,46638664	-0,2648096	105,3556398	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	1,81185	11,9156353	3,309899
3,1	9,44452	5,9618044	0,39219	0,770962	4,59632379	1,36548064	27,8	0,88458	0,46638664	-0,3283082	109,16612	9,92	0,174887659	79,92787936	79,92788	0,984588	0,9850493	0,172273	2,03671	7,11215814	1,975599
																				199,81524	**55,50423**
																				6077,71354	**1688,254**

2.1.2. 1 MW PV PP System Design in Karapinar ESIZ

Prepared with an aim to reach required panel numbers, total area, array position etc., necessary parameters to be used in various parts of this study is brought about and essential PV design parameters are identified.

The parameters needed to designate and the outputs obliged to bring about are the followings:

2.1.2.1. Features of selected PV Panel

The necessary information of the preffered panel are the followings as seen in Table 4 [58]:

Table 4 Features of the selected panel model [58]

Description	**Data**
PV Panel Model	Yingli YL280C/30b Monocrystalline Panel
Maximum Power	280 W_p
Solar Cell	Monocrystalline 156×156 mm
No. of Cells	60 (6×10)
Cell Area	1.46 m^2 (0.156 m×0.156 m×60)
Dimensions	1,650×990×40 mm
Area of a Panel	1.63 m^2 (1.65 m×0.99 m)

2.1.2.2. Required amount of PV Panels

Because of the system is designed to have 1 MW installed power; the system needs 3572 (1,000,000W_p/280W_p) PV Panels having 280 W_p value.

2.1.2.3. PV Design in the Process of PV Mounting

Because of not being any obstacle across the selection [59], the PV arrays are presumed as subsuming 15 PV modules 5 of which is placed in the same row and 3 of which is mounted to the same column.

PV Array width is found by multiplying PV module width with the number of PV Modules in the row of the array. This calculation gives 4,950 mm (990×5).

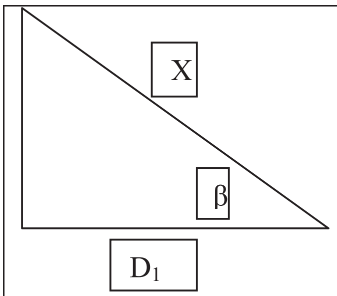
PV Array height is calculated via the multiplication of module height with the number of modules on the same column. This calculation presents 4,950 mm (1,650×3).

Mounting area quantity is procured through the multiplication of PV array height with width. Consequently, the mounting area per array is 24.50 m^2 (4.95m×4.95m)

Table 5 PV array design values

Panel Orientation	# Panel in a row	# Panel in a column	Total no. of panels	PV array width m	PV array height m	PV array area m^2
Portrait	5	3	15	4.95	4.95	24.50

1 MW PV PP systems contains 3,572 PV panels and eight 125 kW inverters pursuant to the design made in this study. That is why above mentioned reckoning has to be made 8 lines each having 447 panels (3,572/8) and 125 kW inverter at the end of each line.



Where;
X is PV array height,
β is optimum tilt angle and
D_1 is a projection of PV array width on the ground

Figure 2 Scheme of a PV array example

Therefore, D_1 corresponding a projection of PV array width on the ground is identified as 4.38 m (4.95 m×cos 27.8°).

In order to calculate essential ground area for PV Arrays of the PP, another required parameter is the width of the line including PV arrays, namely D_w as shown in the following figure. With an aim of attaining necessary parameter value, array width is multiplied with number of arrays in the line.

The number of arrays in the line is 30 (447 panels/15), ergo, width is specified as 148.5 m (30×4.95 m).

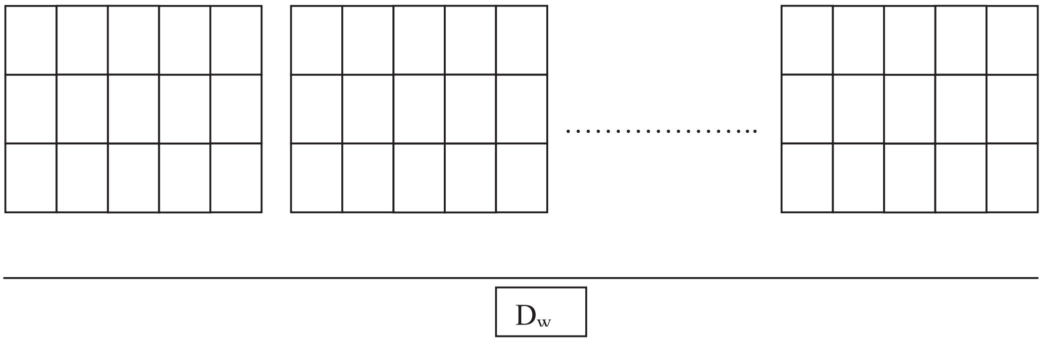


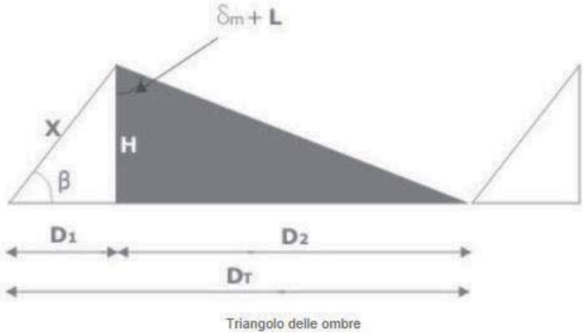
Figure 3 Layout of a PV line

Table 6 Essential dimensions for each line containing PV arrays

Line width m	**Array width** m	**Ground area** m^2
148.50	4.38	650.43

2.1.2.4. Array Row Spacing

Minimum distance between PV module lines is computed to avoid the shading which can result in strong reduction of the production of electricity. Hence, the minimum distance is determined when it marks the beginning of the so-called phenomenon of shading. The minimum distance for the placement of parallel lines with β ≠ 0 ° can be derived from the triangle shadows [59].



$$D_1 = X \times \cos \beta$$
$$H = X \times \sin \beta$$
$$D_2 = H \times \tan(\delta_m + L)$$
$$D_T = D_1 + D_2$$

Figure 4 Triangle shadow method for the computation of the array row spacing of the system [59]

Making calculations consistent with the mentioned method, the approached value determining the necessary distance between two module lines (D_T) is 8.57 m. The details of the calculations are found in Table 7.

Table 7 Array row spacing calculation

Description	Data	Description	Data	Description	Data
β	27.8°	D_1 (mm)	4,378.676	δ_m+L	61.17°
cosβ	0.89	δm	23.45°	tan(δ_m+L)	1.82
sinβ	0.47	L	37.72°	D_2 (mm)	4194.15
X (mm)	4,950	H (mm)	2,181.29	D_T (mm)	8,572.825
				D_T (m)	**8.57**

Table 8 Excell sheet of the study

Minimum Distance between PV Module Lines												
β	cosβ	sinβ	X (mm)	D_1 (mm)	δ_m	L	H (mm)	δm+L	tan(δm+L)	D_2	D_T (mm)	D_T (m)
27.8	0.884581	0.466387	4950	4378.676	23.45	37.72	2308.614	61.17	1.81673934	4194.15	8572.825	8.572825

2.1.2.5. The Frame of the Arrow Area

The system is designed as eight module lines connected to 125 kW inverters. Therefore, width of the system is attained by summing 7 D_1 and 8 D_2 up. As seen in Table 6, D_1 of the system is 4.38 m and D_2 of the system is 4.19 m. Then, the width of the system is 64.18 m (7×4.38+8×4.19).

On the other hand, the length of the system is constituted from the length of lines consisting of arrays (D_w) and the length of a place reserved for an inverter. So as to find out the length of each line, the width of a PV array is multiplied with the number of arrays. D_w is 148.50 m as taken from the previous calculation.

For the determination of a necessary area for each inverter having 1,724 mm width, 2,177 mm height and 594 mm depth [60] is 1.02 m^2 (1,724×0.594).

For the required area between assemblies and between modules 1.5 more meters is added to the calculation. Moreover, some distance (2 m) has been left from each side of the system. Consequently, the length of the system is 152.59 m (148.50 + 0.59 + 1.5 + 2) and the width of the system is 66.18 m (64.18 + 2).

By merging the information acquired system features are described as debicted in Table 9:

Table 9 System features

Description	Data
Installed Power	1 MW
Needed Panel Number	3572 [(10^6/280)W]
Total Panel Area	5822.36 m^2 [3572×1.63m^2]
Number of Panels in each array	15 (5 in a row and 3 in a column)
Number of Arrays	239 [3572/15]
Number of lines	8
Total Area needed for PV arrays	9,530.73 m^2 [64.18×148.50]
Total Area needed for the System	10,098.41 m^2 [66.18×152.59]

Owing to the determined dimensions, the layout of the system to be installed within this study is shown in the following figure basically.

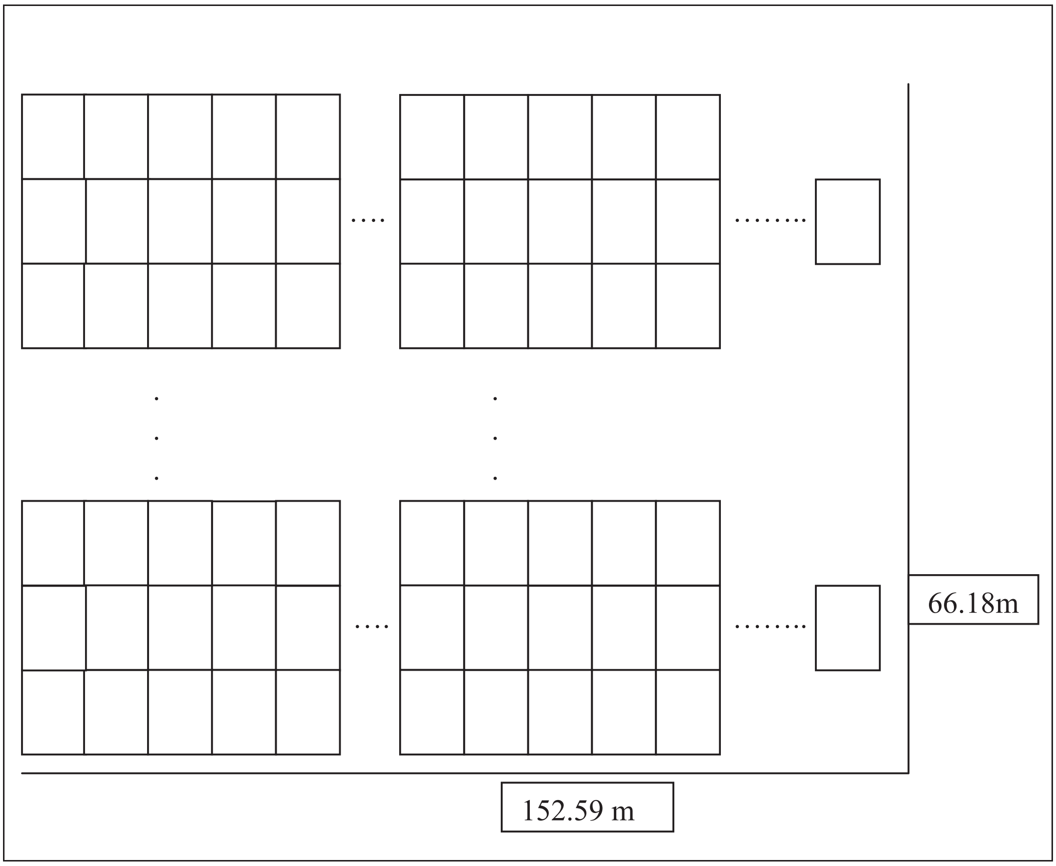


Figure 5 Layout of 1 MW PV PP to be established in Karapınar ESIZ

2.1.3. PV F-CHART Computations (Electricity Production Calculation)

Firstly, the electricity generation of the system is computed by using the relation of solar irradiance (1,688 kWh/m^2), total number of modules (3,572), module area for each (1.63 m^2), efficiency of the modules (0.171). Then, the found value is checked with PV F Chart programme.

Basically the first year electricity production of the system is 1,680,612.569 kWh (1,688×1.63×3,572×0.171) which corresponds to 1.680 GWh/year. However, exact value can be found by using PV F-Chart software programme which includes more inputs from many parameters.

Consequently, next necessarry step to reckon electricity production of the system is running PV F-Chart programme.

PV F-Chart, a computer program serving for the design and economic analysis of PV systems, is used for the designation of an electricity production of a system in this part of the study.

Looking at what is needed to run PV F-Chart programme so as to designate the electricity production of a system, followings are listed:

- General systems features
- Load amount
- Weather information including monthly solar radiation, temperature, humidity, reflectivity and latitude
- System parameters consisting of cell temperature at NOCT conditions, array reference efficiency, array reference temperature, array temperature coefficient, power tracking efficiency, power conditioning efficiency, array area, array slope and array azimuth [61].

2.1.3.1. Inputs for PV F-CHART

- ***General Systems Features***

Since system is composed of utility scale ground mounted array having fixed tilt, utility interface and flat-plate array options are selected.

- ***Load Amount***

Because this study does not deal with certain amount of demand, load quantity is not entered into the simulation.

Weather Information

➤ ***Monthly Solar Radiation***

Monthly solar radiation is given in Table 10 as calculated in the solar radiation part of the study. What has been found through the calculation in the solar radiation part is MJ/m^2 basis, while this software demands the data in kJ/m^2. Therefore, unit conversion is applied.

Table 10 Monthly solar radiation of a system

Time	**kJ/m^2**	**Time**	**kJ/m^2**
January	7,620	July	22,872
February	10,958	August	23,586
March	16,778	September	21,576
April	18,367	October	17,019
May	20,251	November	11,916
June	21,763	December	7,112

➤ ***Monthly Average Temperature***

Monthly average temperature is taken from the official statistics of Turkish Meteorological Institute archives covering 50 years between 1962-2012 [54]. The following values for Konya which constitutes Karapınar as a district are used and be negligibly closer to Karapınar, since exact values of Karapınar do not exist.

Table 11 Monthly average temperature of a location [54]

Time	**T**	**Time**	**T**
January	-0.2	July	23.6
February	1.2	August	23
March	5.7	September	18.6
April	11	October	12.5
May	15.7	November	6.1
June	20.2	December	1.8

- ***Humidity***

Figuring out from the unit of demanded humidity values, what is requested is specific humidity values. However, the official statistics of TURKSTAT provides relative humidity values for the determined city. Conseqently, there is a conversion need of data from relative one to specific one. Looking at a conversion formula:

$$SH = 0,622 \times RH \times \frac{\rho_{\omega s}}{\rho - \rho_{\omega s}} \times 100$$

Where SH is specific humidity (kg/kg), RH is relative humidity (%), ρ_{ws} corresponds density of water vapor (kg/m^3) and ρ corresponds density of the moist or humid air (kg/m^3) [62].

Using above mentioned equation and humidity conversion calculator [63] the following table reveals the humidity values both for former and latter unit types.

Table 12 Monthly humidity values [62 - 63]

Time	**Humidity (%)**	**Humidity (kg/kg)(×E-3)**	**Time**	**Humidity (%)**	**Humidity (kg/kg)(×E-3)**
January	85.9	3.17	July	31.8	5.70
February	83.4	3.42	August	36.4	6.30
March	63.2	3.56	September	34	6.64
April	46.9	3.79	October	59.7	4.48
May	59.3	6.51	November	78	4.52
June	39.6	5.77	December	82.7	3.54

- ***Reflectivity***

The field where the system is established is only composed of a soil. Hence the reflectivity of a typical soil which is accepted as 0.2 [64] is used in this study.

- ***Latitude***

The latitude of the determined field where the system is established is 37.72°.

- ***System Parameters***
  - ***<u>Cell Temperature at NOCT Conditions</u>***

Cell temperature at NOCT conditions is designated as 46°C, pursuant to the information given in the product brochure of the module [58].

- ***<u>Array Reference Efficiency</u>***

Array reference efficiency is described as the product of reference cell efficiency and cell packing factor or reference module efficiency [61]. The module reference efficiencies is directly given as 17.1% by the manufacturer respectively [58].. The array reference efficiency is taken as 0.171.

- ***<u>Array Reference Temperature</u>***

A temperature at which the array efficiency is known is generally accepted as 25^0, so, this system also [58].

- ***<u>Array Temperature Coefficient</u>***

The rate at which the array efficiency linearly decreases with temperature for maximum power-tracking operation. This coefficient is primarily a function of the cell material. Typical values are 0.0043 ($1/^0C$) for silicon cells. The value entered is a factor of 1000 greater than the actual coefficient.

- ***<u>Power Tracking Efficiency</u>***

Power tracking efficiency, the efficiency of the control logic and electronic equipment used to control the array to operate at its maximum power point. Power tracking efficiency is not taken into account in this study.

- ***<u>Power Conditioning Efficiency</u>***

The power conditioning efficiency parameter corresponds the efficiency of the inverter used to convert DC power into AC power so as to make it ready for the connection to the grid. Since the preferred inverter for this study has 96.5% efficiency, the mentioned value is entered instead of the aforementioned parameter.

- ***Array Area***

Array area for 1 MW PV system is taken as 5822.36 m^2 convenient to calculation made in PV System Design part of this study.

- ***Array Slope***

Array slope is specified as 27.8 ^0C as fitting with the previous computation.

- ***Array Azimuth***

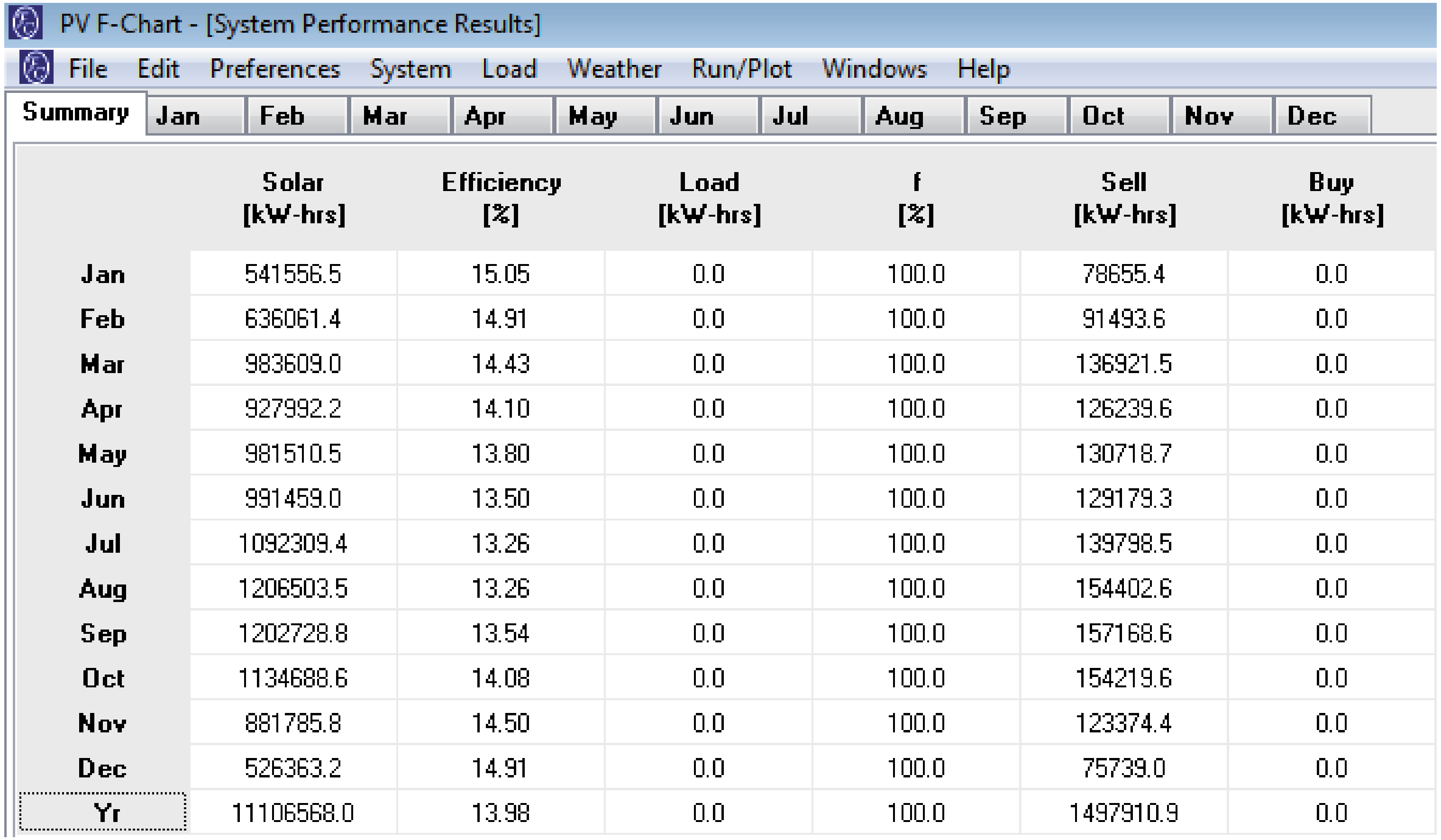
Array azimuth is zero. (south facing)

The above mentioned values are entered into the software and the software is runned in order to get design results.

2.1.3.2. Design Results

The PV FChart is used to simulate electricity production of 1 MW PV PP in Karapınar ESIZ in a year. Pursuant to the output of the simulation, first year electiricty production of the system, as seen in the Figure 6, is 1,497,910.9 kWhs which is equal to 1.498 GWh. So as to compute lifetime electricity production degredation factor should be taken into account.

Moreover, when compared, calculation made by taking into account solar irradiance, module area and efficiency has difference from the outputs of PV F-Chart simulation applied for the system.



PV F-Chart - [System Performance Results]

File Edit Preferences System Load Weather Run/Plot Windows Help

Summary Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

	Solar [kW-hrs]	Efficiency [%]	Load [kW-hrs]	f [%]	Sell [kW-hrs]	Buy [kW-hrs]
Jan	541556.5	15.05	0.0	100.0	78655.4	0.0
Feb	636061.4	14.91	0.0	100.0	91493.6	0.0
Mar	983609.0	14.43	0.0	100.0	136921.5	0.0
Apr	927992.2	14.10	0.0	100.0	126239.6	0.0
May	981510.5	13.80	0.0	100.0	130718.7	0.0
Jun	991459.0	13.50	0.0	100.0	129179.3	0.0
Jul	1092309.4	13.26	0.0	100.0	139798.5	0.0
Aug	1206503.5	13.26	0.0	100.0	154402.6	0.0
Sep	1202728.8	13.54	0.0	100.0	157168.6	0.0
Oct	1134688.6	14.08	0.0	100.0	154219.6	0.0
Nov	881785.8	14.50	0.0	100.0	123374.4	0.0
Dec	526363.2	14.91	0.0	100.0	75739.0	0.0
Yr	11106568.0	13.98	0.0	100.0	1497910.9	0.0

Figure 6 PV FChart table revealing monthly radiation, efficiency and electricity production

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2.1.4. Total Electricity Production of 1 MW PV PP in Karapinar ESIZ

So as to calculate the amount of electrical energy to be produced during lifetime of the PP, the output acquired via PV F-Chart revealing an electricity production for the first year of the project is projected to the whole life of the system by conceiving degradation of the PV system because of the degradation of PV panels through some reasons like ultraviolet affect. For PV systems an annual output drop of 0.6% [65 - 68] mainly as a result of module exposure to ultraviolet radiation, has been considered [69].

Table 13 Excell sheet projecting total electricity production of 1 MW PV PP

PV PP Electricity Production			
Degradation Factor (%) = 0,6			
Time (years)	**El. Production (kWh)**	**Time (years)**	**El. Production (kWh)**
1	1497910.9	16	1496563.346
2	1497821.025	17	1496473.552
3	1497731.156	18	1496383.764
4	1497641.292	19	1496293.981
5	1497551.434	20	1496204.203
6	1497461.581	21	1496114.431
7	1497371.733	22	1496024.664
8	1497281.891	23	1495934.903
9	1497192.054	24	1495845.147
10	1497102.222	25	1495755.396
11	1497012.396	26	1495665.651
12	1496922.575	27	1495575.911
13	1496832.76	28	1495486.176
14	1496742.95	29	1495396.447
15	1496653.145	30	1495306.723
Total (kWh)	44898253.41	**Total (GWh)**	44.89825341

As seen in the Figure 6, first electricity production exploited from the output of PV F-Chart simulation is determined as 1,497,910.9 kWh. Electricity production for remaining years till end of the lifetime of the system is formulated and computed with 0.6% degradation rate. Therefore, total electricity production of the system is summed as 44,898,253 kWh or 44.898 GWh.

2.1.5. LCA of 1 MW PV PP in Karapinar ESIZ

Because of having operation not generating any carbon dioxide, solar and nuclear electricity technologies often are considered as “carbon-free” [70]. However, this is not valid for the entire life cycle of energy production. During extraction, processing and disposal of related materials, in addition to the material use and source depletion gases mainly carbon dioxide are certainly emitted as well [71]. This LCA part of the study was prepared to take a life cycle inventory of PV technology.

2.1.5.1. How Electricity via PV Power Plant is produced?

As mentioned previously, solar irradiation has a possibility to reach the Earth surface both in a direct and diffused way which are classified as beam and diffuse irradiations. PV modules have a capability to use both type of irradiations for electricity production. Consequently, solar energy falling on a PV module being either direct or diffused is converted into DC electrical energy by PV modules constituting from PV cells. BoS components like inverters step in exactly at that point where produced electricity is converted into efficient and usable form, from DC power to AC power. Then, with direct connection to the grid, the electricity is ready to be used by the consumers [72].

With more detailed terms, a thin sheet of semiconductor material such as silicon is placed on the ground where has accessibility to solar irradiation. The sheet, known as a cell, is composed of two distinct layers formed by introducing impurities into the silicon resulting in a n-type layer and a p-type layer that form a junction at the interface. Striking the cell solar photons result in electron-hole pairs generation that are spatially driven by an intrinsic electric field at the junction. Owing to the creation of negative charges on one side of the interface and positive charges on the other side, voltage is brought about. Then, the connection of the two sides of the illuminated cell to the load provides for flowing of a current from one side of the device via the load to the other side of the cell generating electricity [73].

2.1.5.2. The Life Cycle of Solar Electiricity Generation

The life cycle of solar electricity generation mainly covers material extraction and production (e.g mining, smelting, refining, purification), solar cell- and PV module-production, BoS production (e.g. inverters, transformers, wiring, structural supports), system operation and maintanance, system decomissioning, and disposal or recycling [67]. The most important nuance to be taken attention is studying the lifecycles of PV modules and the BoS seperately based upon formers entailing more options and more evolution than the latter [70].

The basic life cycle of PV panels are shown in Figure 7 [70].

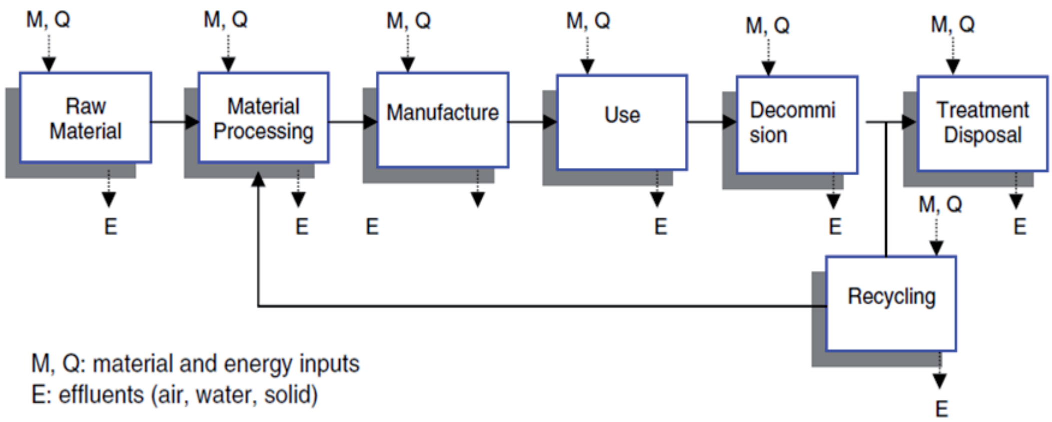

Figure 7 The lifecycle of a PV system [70]

2.1.5.3. PV Manufacturing Process and Value Chain

Exploiting from the solar energy by converting sunlight into electricity needs a multi-stage production process to be undergone. Within these stages, silicon is shaped into blocks, so-called ingots after extracted from sand and purified, melted down to produce crystalline Si material. Then, the ingots are cut into slices, namely wafers. In the next step, these are coated to produce solar cells which are then put together to form solar modules [74].

Summary and detailed PV Value Chain scheme derived from the references is given in the Figure 8 [74 - 77]:

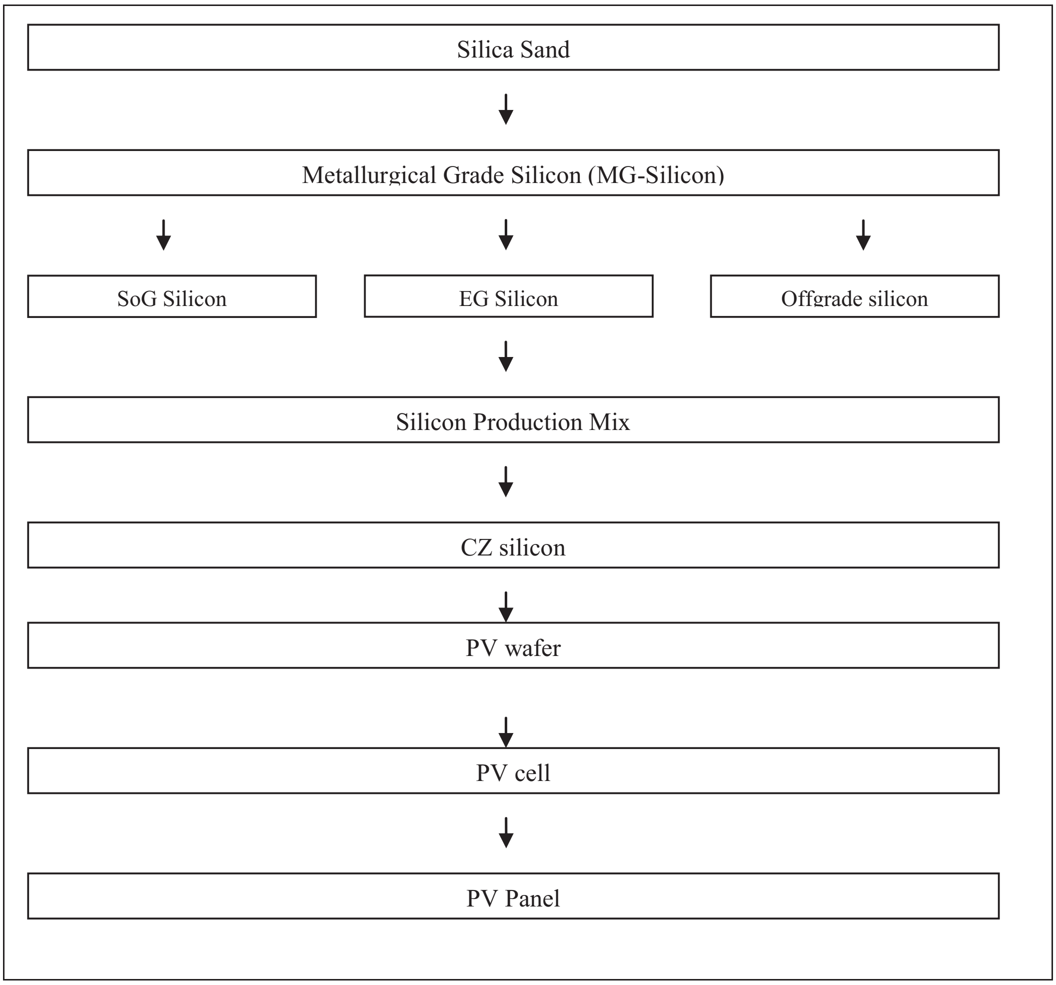

Figure 8 PV Value Chain used for this study [74 - 77]

2.1.5.4. Processes for the production of a PV Module with Monocrystalline Silicon Technology

Mainly, Silicon ($Si_{met.}$) is produced from silica (SiO_2), mined as quartz sand, that is reacted with carbon (wood, charcoal, and coal) in arc furnaces to yield metallurgical-grade Si, and then purified to solargrade Si and electronic grade silicon [70]. In order to bring about monocrystalline silicon, large ingots of silicon crystals are grown by the Czochralski method from a bath of molten metallurgical-grade Si. Mono-crystalline products must be cut into wafers, to produce the basis of the solar cells [77 - 78].

First Step - Extraction of a silica and Transformation of silica to silicon (Metallurgical Grade Silicon)

As being the second most frequent element in the Earth's crust, silicon can be esteemed to be unlimited (27.6%) [79]. Silicon dioxide (Silica) found mainly as huge deposists of quartzite or quartz sand is a form of silicon which is used in the PV industry.

Silicon belongs to the group IV of the periodic system of elements, is easily obtained and processed, is not toxic and does not build environmentally harmful effects [79].

Silicon mine and its purification is schematically shown in Figure 9 taken from [80].

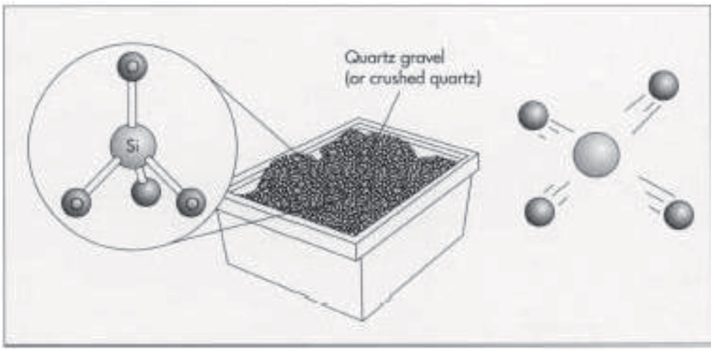

Figure 9 Silicon mine and its purification [80]

Silicon metal is produced in electric arc furnaces from quartz reacting at very high temperatures with reduction materials such as coal, coke, charcoal, wood chips and the furnace graphite electrodes [77], as seen in the Figure 10 [81].

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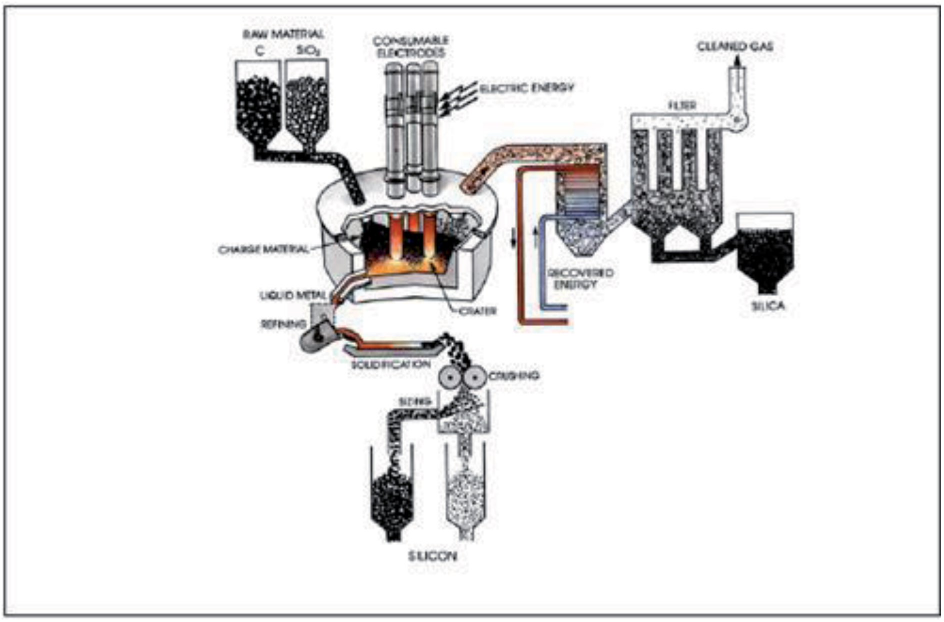

Figure 10 Typical layout production of a silicon metal [81]

The basic reaction to acquire silicon metal is the following:

$SiO_2 + 2C \rightarrow Si_{met.} + 2CO$.

Pure silicon which is not pure enough in its natural state is the basic component of a solar cell. The result of above mentioned process is metallurgical grade silicon (MG-Si), which is the precursor for polycrystalline or solar-grade silicon used in the photovoltaic industry and has a typical purity of about 98% which is not a sufficient purity level for monocrystal PV manufacturing. Typical impurities in metallurgical-grade silicon include carbon, alkali-earth and transition metals, as well as boron and phosphorus [82 - 83].

- ***Second Step - Purification of a silicon***

Since solar panels require at least 99.9999% (6 N) pure silicon, this mg-Si then goes through another purification step to produce useable solar silicon [81 - 84].

In this process MG-Si, not having required purity with a purity of about 98% is transformed into electronic grade and/or SoG-Si ($1\text{-}10^{-3 or -6}$ purity) [85].

- ***Third Step – Crystal Silicon Making***

Monocrystalline method is determined as a manufacturing process for single crystal ingots. The CZ method is used for the acquisition of ingots. Mono crystalline ingots produce wafers, basis of PV cells, with a regular, perfectly- arrayed crystal composition.

Within CZ process, a seed crystal of silicon is dipped into melted polycrystalline silicon. As the seed crystal is withdrawn and rotated, a cylindrical ingot or "boule" of silicon is formed. The ingot withdrawn is unusually pure, because impurities tend to remain in the liquid [80].

The scheme of CZ equipment (Czochralski Apparatus) which realizes aforementioned process is given in Figure 11 [80].

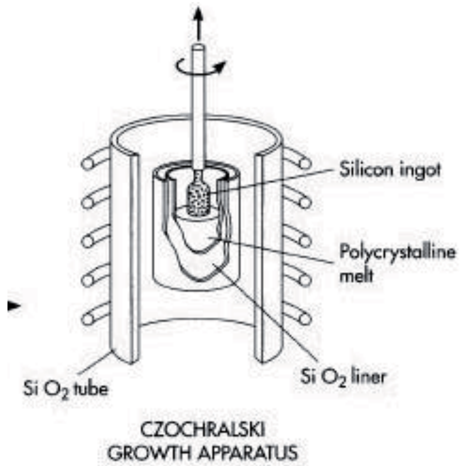

Figure 11 Czochralski equipment [80]

In CZ method, moreover, polycrystalline silicon purified till less than a few ppb of metal content is molten together with dopants in a quartz crucible. The dopants, such as boron and phosphorous, are used for the adjustment of resistivity. Then, a small single silicon rod (seed) is placed on the molten silicon in an inert gas atmosphere at about 1400 degrees Celcius. As the seed is slowly rotated and pulled up from the melt, a single crystalline ingot with the same orientation as the seed is produced [86]. The details of the steps of CZ methods and the apparatus are given in Figure 12 [86].

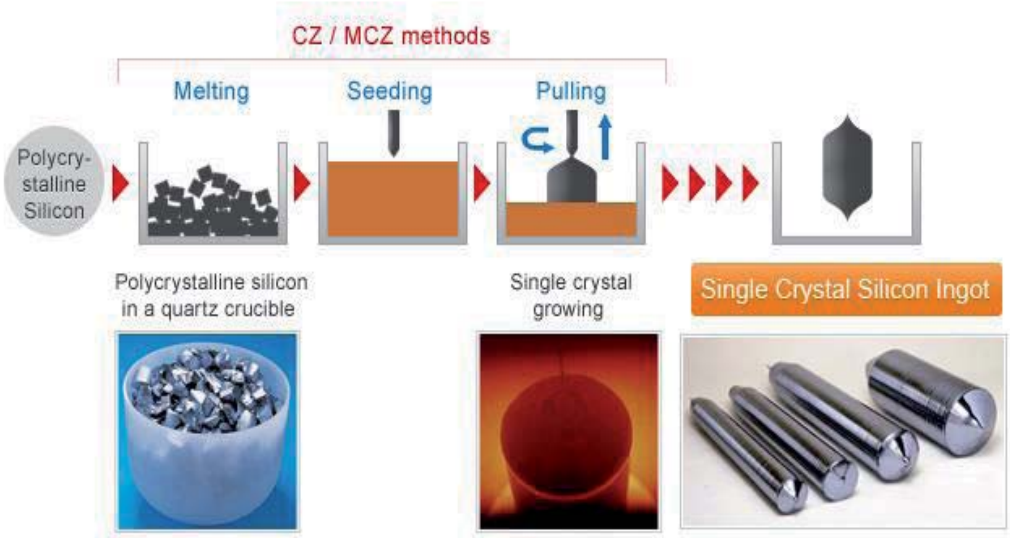

Figure 12 Details of the steps of CZ method [86]

The following reactions take place [77]:

$3\ Si + 4\ HNO_3 \rightarrow 3\ SiO_2 + 4\ NO + 2\ H_2O$,

and $SiO_2 + 6\ HF \rightarrow H_2SiF_6 + 2\ H_2O$.

Before being released, the waste gases of the process (e.g. NO_x, HF, acetic acid- and nitric acid) are treated in a gas cleaner. Moreover, deionised water is used for cleaning and acetone is used for final drying.

- ***Forth Step – Execution of silicon wafers***

Once the ingot produced via CZ process, it is sliced by using a circular saw to acquire silicon wafers. Preferably, the wafers are then polished to remove saw marks [80].

The slicing process of an ingot can be seen in Figure 13 [80].

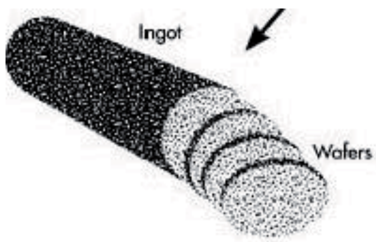

Figure 13 Scheme of wafer slicing from ingots [80]

The detailed stages of wafer shaping are the followings:

a. Slicing

After sliced into wafers about 1 mm in thickness by saw, a single crystalline ingot is cut pursuant to uniform diameter.

b. Lapping

In order to increase the parallelism and remove surface roughness made from saw cuts and process damages, the sliced wafers are mechanically lapped by use of alumina abrasive.

c. Etching

The mechanical damages induced during the previous processes are removed by chemical etching. Typically, 10 to 20 microns is etched from both sides of wafers cut by a wire saw. Alkaline etches are commonly used, with subsequent rinsing in deionised water.

d. Polishing

The mechano-chemical polishing process improves the parallelism and makes highly flat surface by use of colloidal silica.

e. Cleaning and inspection

The processed wafers are cleaned and inspected to be polished wafers [86].

- ***Fifth Step – Doping (creation of n-type and p-type wafers)***

The pure silicon is doped with phosporous and boron to produce an excess of electrons and a deficiency of electrons respectively for the acquisiton of a semiconductor being able to conduct electricity. Because of being shiny, the silicon disks need an anti reflective coating, usually titanium dioxide [80].

- ***Sixth Step – Placing Electrical Contacts***

The machining and coating of their surfaces turns the wafers into solar cells to load all the technical properties needed to convert sunlight into electric power. Contacts are coated to the front and rear of the wafer to extract the current produced by electron-hole pairs [75].

The scheme of electrically contacted PV module is presented in the following, Figure 14 [80].

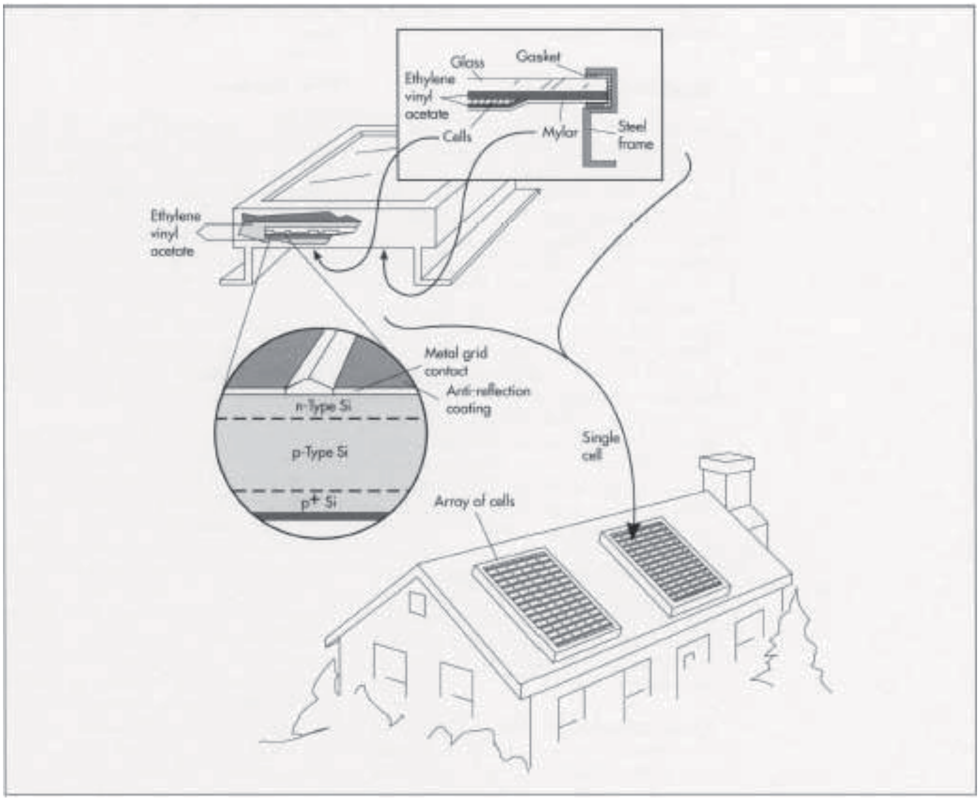

Figure 14 Scheme of electrically contacted PV module [80]

- ***Seventh Step - The anti-reflective coating***

Being shiny, pure silicon is able to reflect up to 35% of the sunlight. An anti-reflective coating is a solution way to reduce the sunlight lost caused by albedo effect [85].

- ***Eigthieth Step - Encapsulating the cell***

The finished solar cells are then encapsulated; that is, sealed into silicon rubber or ethylene vinyl acetate. The encapsulated solar cells are then placed into an aluminum frame that has a mylar or tedlar backsheet and a glass or plastic cover. Then, the panels are ready to be assembled [80].

- ***Ninth Step - Operations & Maintenance***

O & M may require semi-annual / annual system inspections, array cleaning, electrical checks / maintenance, and inverter maintenance.

Tenth Step – Recycling

Recycling of PV industry equipments include dismounting obsolete systems and recovering materials such as aluminium, glass and silicon to be reused in the maufacturing process as shown in Table 14 [87].

Table 14 Recyclable PV materials [87]

Silicon Cadmium	Silver
Selenium	Indium
Tetrachloride	Tin
Sulfur Hexafluoride	Nickel
Aluminum	Zinc
Plastics	Copper
Glass	CIGS filter cake
Silicon wafers	CdTe filter cake

The 1 MW PV PP system to be installed by this study subsumes 3572 panels of 280W_p having 60 monocrystalline cells in each. Total panel area of the system is reckoned as 5822 m^2.

2.1.6. The Life Cycle Inventory of PV Technology

Pursuant to Figure revealing the production hyerarchy of silicon based PV power plants, this inventory work specifies data from the process consisting of quartz reduction, silicon purification, wafer, panel and laminate production, manufacturing of inverter, mounting, cabling, infrastructure and 30 years of operation. For each production stages in the figure following informations have been thought: energy consumption, air- and waterborne process-specific pollutants at all production stages, materials, auxiliary chemicals, etc., transport of materials, of energy carriers, of semi-finished products and of the complete power plant, waste treatment processes for production wastes, dismantling of all components and infrastructure for all production facilities with its land use [77]. All the components of the life cycle inventories especially material use and energy use are dwelled upon this part of the study.

- ***First Step - Extraction of a silica and Transformation of silica to silicon (Metallurgical Grade Silicon)***

In the processes constituting extraction of a silica and transformation of it to silicon (MG-si), the necessary parameters such as material use, waste emissions etc. for the production of 1 kg MG-si are given in Table 15.

Table 15 Preffered data used in this study for the transformation of silica to silicon (metallurgical grade silicon) process

Description	**Quantity**	**Unit**	**Reference**
MG-Silicon (output)	1	kg	-
Silica Sand	2.70	kg	Average of references; [78], [84], [94 - 96]
Electricity	11	kWh	[78], [86] (47 MJ)
Wood Scraps	1500		Average of references;[78], [84], [94 - 97]
Charcoal	0.17		[78]
Coke[4]	0.387		[87]
CO_2	4		[97]
CO	0.002		
Arsenic	9.42 E-9	kg	
Aluminum	1.55 E-6		
Antimony	7.85 E-6		[78]
Boron	2.79 E-7		
Cadmium	3.14 E-10		
Calcium	7.75 E-7		
Chromium	7.85 E-9		
Chlorine	7.85 E-8	kg	[77]
Cyanide	6.87 E-6		

[4] 11.36 MJ/29.3 MJ/ kg because pursuant to European Nuclear Society, 1 kg coal equivalent is equal to 29.3MJ.

Table 15(continued)

Description	Quantity	Unit	Reference
Fluorine	3.88 E-8	kg	[77]
Hydrogen Sulfide	5.00 E-4		
Hydrogen Fluoride	5.00 E-4		
Iron	3.88 E-6		
Lead	3.44 E-7		
Mercury	7.85 E-9		
NMVOC	9.60 E-5		
Nitrogen Oxides	9.74 E-3		
Particulates, >10 μm	7.75 E-3		
Potassium	6.20 E-5		
Silicon	7.51 E-3		
Sodium	7.75 E-7		
Sulfur dioxide	1.22 E-2		
Tln	7.85 E-9		

The values are then multiplied with the total amount of MG-silicon to be used for 1 MW PV PP as seen in Table 16.

Table 16 Excell sheet revealing the outputs of the transformation of silica to silicon (metallurgical grade silicon) process

PV LCI for Karapınar ESIZ						
MG - Silicon						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amount***	***Total***
Panel No.	-	3572	Mg-Si	kg	1	
1 panel	m2	1.63	Silica sand	kg	2.7	15206.9
Panel Total	m2	5822.36	Electricity	kWh	11	61954
Solar Cell	m2	5426.4395	Wood scraps	kg	1500	8448270
Silicon wafers	m2	5752.0264	Charcoal	kg	0.17	957.471
Crystal Silicon	kg	5090.5466	Coke	kg	0.387	2179.65
Silicon Production Mix	kg	5446.8885	CO2	kg	4	22528.7
SoG Silicon	kg	4368.4058	CO	kg	0.002	11.2644
MG-Si	kg	5632.18	Arsenic	kg	9.42E-09	5.3E-05
Silica sand	kg	15206.886	Aluminium	kg	0.00000155	0.00873
			Antimony	kg	0.00000785	0.04421
			Boron	kg	0.000000279	0.00157
			Cadmium	kg	3.14E-10	1.8E-06
			Calcium	kg	0.000000775	0.00436
			Chromium	kg	7.85E-09	4.4E-05
			Chlorine	kg	7.85E-08	0.00044
			Cyanide	kg	0.00000687	0.03869
			Fluorine	kg	3.88E-08	0.00022
			Hydrogen Sulfide	kg	0.0005	2.81609
			Iron	kg	0.00000388	0.02185
			Lead	kg	0.000000344	0.00194

Second Step - Purification of a silicon

Purification of silicon comprises the conversion of metallurgical grade silicon into the harmonisation of electrical grade silicon and solar grade silicon.

The esmissions made, materials used during EG-silicon, off-grade silicon and silicon tetrachloride exploitation from MG-silicon are listed in Table 17.

Table 17 Preffered data used in this study for the purification of a silicon process by yielding EG-silicon, off-grade silicon and silicon tetrachloride

Description	**Unit**	**Value**	**Comment**
MG silicon (Input)	kg	1	
EG-silicon	kg	0.676	[77] 0.95, [91] 0.8, [92] 0.87
Off-grade silicon	kg	0.084	
Silicon tetrachloride	kg	1.20	
Water	m^3	43.50	[77]

Table 17 (continued)

Description	**Unit**	**Value**	**Comment**
Polyethylene	kg	6.37 E-4	[83]
HCl		2	[77]
Graphite		6.64 E-4	
AOX[5]		8.81 E-6	
BOD_5		1.43 E-4	
COD		1.41 E-3	
Chloride		2.51 E-2	
Copper, ion		7.15 E-8	
Nitrogen		1.45 E-4	
Phospate		1.96 E-8	
Sodium, ion		2.38 E-2	
Zinc, ion		1.37 E-8	
Iron, ion		3.92 E-8	
DOC[6]		6.35 E-4	
TOC[7]		6.35 E-4	

Then, the cumulative values for parameters to acquire necessary amount of inputs are calculated as follows, in Table 18.

[5] Adsorbable Organic halogen as Cl
[6] Dissolved Organic Carbon
[7] Total Organic Carbon

Table 18 Excell sheet revealing the outputs of the EG and off-grade silicon production

PV LCI for Karapınar ESIZ									
EG-Off Grade Silicon					EG-silicon=0,676 kg; off-grade silicon=0,0844 kg				
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amoun***	***Total***			
Panel No.	-	3572	Mg-Si	kg	1	1176.4			
1 panel	m2	1.63	Eg-silicon	kg	0.676	795.246			
Panel Total	m2	5822.36	off-grade	kg	0.0844	99.2881			
Solar Cell	m2	5426.44	silicon tetrachloride	kg	1.2	1411.68			
Silicon wafers	m2	5752.03	water	m3	43.5	51173.4			
Crystal Silicon	kg	5090.55	Polyethylene	kg	0.000637	0.74937			
Silicon Production Mix	kg	5446.89	HCl	kg	2	2352.8			
SoG Silicon	kg	4368.41	Graphite	kg	0.000664	0.78113			
			AOX	kg	0.00000881	0.01036			
			BOD5	kg	0.000143	0.16823			
			COD	kg	0.00141	1.65872			
			Chloride	kg	0.0251	29.5276			
			Copper, ion	kg	7.15E-08	8.4E-05			
			Nitrogen	kg	0.000145	0.17058			
			Phospate	kg	1.96E-08	2.3E-05			
			Sodium, ion	kg	0.0238	27.9983			
			Zinc, ion	kg	1.37E-08	1.6E-05			
			ıron, ion	kg	3.92E-08	4.6E-05			
			DOC	kg	0.000635	0.74701			
			TOC	kg	0.000635	0.74701			

The same calculations for the attainment of solar grade silicon are given in Table 19 as a unit basis and in Table 20 for cumulative amounts.

Table 19 Preffered data used in this study for the purification of a silicon process by yielding solar grade silicon

Description	**Quantity**	**Unit**	**Reference**
Sog Silicon (Output)	1	kg	-
Mg-Si	1.02		[85]
HCl	1.60		[93]
H_L	0.05		
NaOH	0.35		
AOX[8]	1.26 E-5		[77]

[8] Adsorbable Organic halogen as Cl

Table 19(continued)

Description	**Quantity**	**Unit**	**Reference**
BOD_5	2.05 E-4	kg	[77]
COD	2.02 E-3		
Chloride	3.60 E-2		
Copper, ion	1.02 E-7		
Nitrogen	2.08 E-4		
Phospate	2.80 E-6		
Sodium, ion	3.38 E-2		
Zinc, ion	1.96 E-6		
Iron, ion	5.61 E-6		
DOC[9]	9.10 E-4		
TOC[10]	9.10 E-4		

Table 20 Excell sheet revealing the outputs of the SoG silicon production

PV LCI for Karapınar ESIZ						
SoG Silicon						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amoun***	***Total***
Panel No.	-	3572	Mg-Si	kg	1.02	4455.78
1 panel	m2	1.63	HCl	kg	1.6	6989.46
Panel Total	m2	5822.36	Hl	kg	0.05	218.421
Solar Cell	m2	5426.44	NaOH	kg	0.348	1520.21
Silicon wafers	m2	5752.03	AOX	kg	0.0000126	0.05504
Crystal Silicon	kg	5090.55	BOD5	kg	0.000205	0.89552
Silicon Production Mix	kg	5446.89	COD	kg	0.00202	8.82419
SoG Silicon	kg	4368.41	Chloride	kg	0.036	157.263
			Copper	kg	1.02E-07	0.00045
			Nitrogen	kg	0.000208	0.90863
			Phospate	kg	0.0000028	0.01223
			Sodium	kg	0.0338	147.652
			Zinc	kg	0.00000196	0.00856
			Iron	kg	0.00000561	0.02451
			DOC	kg	0.00091	3.97525
			TOC	kg	0.00091	3.97525

[9] Dissolved Organic Carbon
[10] Total Organic Carbon

With ratios, the determination of required EG-silicon, off-grade silicon and SoG - silicon are another step to be applied.

Table 21 Preffered data used in this study for the acquisition of silicon production mix

Silicon production mix	kg	1	[94]
EG-silicon		14.6%	[77]
Off-grade silicon		5.2%	
SoG-silicon		80.2%	

Table 22 Excell sheet revealing the outputs of the acquisition of silicon production mix

PV LCI for Karapınar ESIZ						
Silicon Production Mix						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amount***	***Total***
Panel No.	-	3572	EG-silicon	%	14,6	795,246
1 panel	m2	1,63	Off-grade silicon	%	5,2	283,238
Panel Total	m2	5822,36	SoG-Silicon	%	80,2	4368,41
Solar Cell	m2	5426,44				
Silicon wafers	m2	5752,03				
Crystal Silicon	kg	5090,55				
Silicon Production Mix	kg	5446,89				

Third Step – Crystal Silicon Making

In this part of LCI; the inputs and outputs of CZ process is brought about as a unit basis in Table 23 and as total in Table 24.

Table 23 Preffered data used in this study for material use for CZ-sc-silicon production

Description	**Quantity**	**Unit**	**Reference**
CZ single crystalline silicon, PV	1	kg	-
Water, cooling	2.33	m^3	[95]
Water, river[11]	2.05	m^3	
Electricity	85.60	kWh	[93]

[11] Water supplied from river

Table 23 (continued)

Description	Quantity	Unit	Reference
Natural gas	68.20	MJ	[93]
Tap water	94.10	kg	[80]
Silicon Production Mix	1.07		[93]
Argon	5.79		[93]; protection gas for crystal growing
Hydrogen Flouride	0.05		[83], for etching
Nitric Acid	0.09		
Acetic Acid	0.10		
Acetone	0.05		
Socium Hydroxide	0.04		[83], waste gas neutralization
Ceramic Ties	0.34		[93], quartz crucible for melting the silicon
Lime	0.19		[83], waste water treatment
Fluoride	2.37E-3		[83], 50% reduction, basic uncertainity=3
Hydrocarbons	2.28E-2		
Hydroxide	7.42E-3		
Acetic Acid	5.4E-2		
BOD_5	0.13		[77]
COD	0.13		
DOC	0.04		
TOC	0.04		
Nitrogen	9.10E-3		[95], 50% of total emissions

Table 24 Excell sheet revealing the outputs of the process of crystal silicon making

PV LCI for Karapınar ESIZ						
Crystal Silicon Making						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amoun***	***Total***
Panel No.	-	3572	Water, cooling	m3	2.33	11861
1 panel	m2	1.63	water, river	m3	2.05	10435.6
Panel Total	m2	5822.36	Electricity	kWh	85.6	435751
Solar Cell	m2	5426.44	Natural gas	MJ	68.2	347176
Silicon wafers	m2	5752.03	Tap water	kg	94.1	479021
Crystal Silicon	kg	5090.55	Silicon Production Mix	kg	1.07	5446.89
			Argon	kg	5.79	29474.3
			Hydrogen Flouride	kg	0.05	254.528
			Nitric Acid	kg	0.094	478.512
			Acetic Acid	kg	0.1	509.055
			Acetone	kg	0.049	249.437
			Sodium Hydroxide	kg	0.041	208.713
			Ceramic Ties	kg	0.336	1710.42
			Lime	kg	0.191	972.295
			Flouride	kg	0.00237	12.0646
			Hydrocarbons	kg	0.0228	116.065
			Hydroxide	kg	0.00742	37.7719
			Acetic Acid	kg	0.054	274.89
			BOD5	kg	0.13	661.772
			COD	kg	0.13	661.772
			DOC	kg	0.0405	206.167
			TOC	kg	0.0405	206.167
			Nitrogen	kg	0.0091	46.324

Forth Step – Execution of silicon wafers

For 1 m^2 of wafer acquisiton how much material is used and related emissions are calculated and presented in Table 25.

Table 25 Preffered data used in this study for the execution of wafers

Description	**Unit**	**Quantity**	**General Comment**
Wafer	m^2	1	
Electricity	kWh	8	[77]
Natural gas	MJ	4	[93], for removing adhesives after sawing
Tap water	kg	6 E-3	[93]
Water	kg	6.5	[93], for wafer cleaning

Table 25(continued)

Description	Unit	Quantity	General Comment
CZ single cryst. silicon	kg	0.89	[77]; calculation with [102], data
Silicon carbide		2.14	[93], SiC use for sawing
NaOH		1.50 E-2	[93], for wafer cleaning
HCl		2.70 E-3	
Acetic acid		0.04	
Tryethylene glycol		2.6	[93], for sawing slurry
Dipropylene Glycol Monomethyl Ether		0.3	[93], for wafer cleaning
Alkylbenzene sulfonate		0.24	[93], for wafer cleaning
Acrylic binder		0.20 E-2	[93], for temporarily attachment of bricks to wire sawing equipment
Glass wool mat		0.01	
Paper		0.19	[83]
Ploystyrene		0.20	[77]
Packaging Film		0.10	
Brass		7.45 E-3	[93], wire saws, high resistance brass-coated steel with carbon content in the range 0,7%-0,9%, 5g/kg brass
Steel		1.48	
Wire drawing		1.49	[93], wire saws
Disposal		0.11	[93], estimate for unused parts of crystal
AOX		5.01 E-4	[95], formed by nitric acid use
Cadmium		6.05 E-6	[96]
Chromium		3.03 E-5	
COD		0.03	[95], formed by nitric acid use
Copper		6.05 E-5	[96]
Lead		3.03 E-5	
Mercury		6.05 E-6	
Nickel		6.05 E-5	
Nitrogen		9.94 E-3	[95], 50% of total emissions
Phospate		5 E-4	[95]
BOD_5		0.03	[77]
DOC		0.01	
TOC		0.01	

Total emissions made and materials used for the acquisition of necessary amount of wafer are calculated as follows in Table 26:

Table 26 Excell sheet revealing the outputs of the execution of silicon wafers

PV LCI for Karapınar ESIZ						
Execution of Silicon Wafers						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amoun***	***Total***
Panel No.	-	3572	Electricity	kWh	8	46016.2
1 panel	m2	1.63	natural gas	MJ	4	23008.1
Panel Total	m2	5822.36	Tap water	kg	0.006	34.5122
Solar Cell	m2	5426.44	Water	kg	6.5	37388.2
Silicon wafers	m2	5752.03	CZ single cryst. Silicon	kg	0.885	5090.55
			Silicon Carbide	kg	2.14	12309.3
			NaOH		0.015	86.2805
			HCl		0.0027	15.5305
			Acetic Acid		0.039	224.329
			Tryethylene glycol		2.6	14955.3
			dipropylene Glycol Monomethyl Ether		0.3	1725.61
			Alkylbenzene sulfonate		0.24	1380.49
			Acrylic binder		0.002	11.5041
			Glass wool mat		0.01	57.5203
			paper		0.19	1092.89
			polystyrene		0.2	1150.41
			packaging film		0.1	575.203
			Brass		0.00745	42.8526
			Steel		1.48	8513
			Wire drawing		1.49	8570.52
			Disposal		0.11	632.723
			AOX		0.000501	2.88177
			Cadmium		0.00000605	0.0348
			Chromium		0.0000303	0.17429
			COD		0.0296	170.26
			Copper		0.0000605	0.348
			Lead		0.0000303	0.17429
			Mercury		0.00000605	0.0348
			Nickel		0.0000605	0.348
			Nitrogen		0.00994	57.1752
			Phospate		0.0005	2.87602
			BOD5		0.0296	170.26
			DOC		0.011	63.2723
			TOC		0.011	63.2723

Fifth Step - PV Cell Production

The inputs and by products of PV Cell production process are computed then. The amounts in Table 27 are identified for 1 m^2 single Si PV Cell production.

Table 27 Solar cell production

Description	**Unit**	**Quantity**	**General Comments**
Single Si PV Cell (Output)	m^2	1	
Water	m^3	9.99E-1	[93]

Table 27 (continued)

Description	Unit	Quantity	General Comments
Electricity	kWh	0.30	[93]
Natural Gas	MJ	4.77	
Light Fuel Oil	MJ	1.16	
Single-si wafer	m^2	1.06	[93] 6% losses
Metallization paste, front size	kg	7.40 E-3	[93], for electric contacts
Metallization paste, back side		4.90 E-3	
Metallization paste, back side, aluminum		7.19 E-2	
Ammonia		6.74 E-3	[93], for re-oxidation
Phosphoric acid		7.67 E-3	[77], [93]
Phosphoryl Chloride		1.59 E-3	
Titanium dioxide		1.42 E-6	
Ethanol from ethylene		6.41 E-4	[93], for cleaning; [77]
Isopropanol		7.89 E-2	
Solvents		1.43 E-3	
Silicone product		1.21 E-3	[93], silane (SiH_4) for silicon nitride deposition; [77]
Sodium silicate		7.48 E-2	[77], [93]
Calcium chloride		2.16 E-2	[93]
Acetic acid		2.83 E-3	[93], for cleaning
Hydrochloric acid		4.56 E-2	[93], for surface etching
Hydrogen Flouride		3.77 E-2	[93], for etching phosporous glasses
Nitric Acid		2.57 E-2	[93]
Sodium Hydroxide		0.16	[93], for etching and cleaning

Table 27 (continued)

Description	**Unit**	**Quantity**	**General Comments**
Argon	kg	2.57 E-2	[93]
Oxygen		0.10	
Nitrogen		1.85	
Tetrafluoroethylene		3.16 E-3	
Polystyrene		4.07 E-4	
Water		137	
Disposal		0.28	
Aluminium		7.73 E-4	
Ethane		1.19 E-4	[93], calculated as 50% of CO_2-eq for FC-gases
Hydrogen Chloride		2.66 E-4	[93]
Hydrogen Flouride		4.85 E-6	
Lead		7.73 E-4	
NMVOC		0.19	
Nitrogen Oxides		5 E-5	[83],due to nitric acid use
Methane		2.84 E-4	[93], calculated as 50% of CO_2-eq for FC-gases
Particulates		2.66 E-3	[93]
Silicon		7.27 E-5	
Silver		7.73 E-4	
Sodium		4.85 E-5	
Tin		7.73 E-4	

The values in Table 27 are multiplied with total required area of solar cell and cumulative amounts are designated as shown in Table 28.

Table 28 Excell sheet revealing the outputs of the solar cell production process

PV LCI for Karapınar ESIZ						
Solar Cell Production						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amount***	***Total***
Panel No.	-	3572	Electricity	kWh	0.302	1638.78
1 panel	m2	1.63	natural gas	MJ	4.77	25884.1
Panel Total	m2	5822.36	Water	m3	0.999	5421.01
Solar Cell	m2	5426.44	Light Fuel Oil	MJ	1.16	6294.67
			Single-si Wafer	m2	1.06	5752.03
			Metallization paste, front side	kg	0.0074	40.1557
			Metallization paste, back side	kg	0.0049	26.5896
			metallization paste, back side aluminium	kg	0.0719	390.161
			Ammonia	kg	0.00674	36.5742
			Phosporic Acid	kg	0.00767	41.6208
			Phosphoryl Chloride	kg	0.00159	8.62804
			Titanium Dioxide	kg	0.00000142	0.00771
			Ethanol from ethylene	kg	0.000641	3.47835
			Isopropanol	kg	0.0789	428.146
			Solvents	kg	0.00143	7.75981
			Silicone product	kg	0.00121	6.56599
			Socium silicate	kg	0.0748	405.898
			Calcium chloride	kg	0.0216	117.211
			Acetic acid	kg	0.00283	15.3568
			Hydrochloric acid	kg	0.0456	247.446
			Hydrogen Flouride	kg	0.0377	204.577
			Nitric Acid	kg	0.0257	139.46
			Sodium Hydroxide	kg	0.157	851.951
			Argon	kg	0.0257	139.46
			Oxygen	kg	0.102	553.497

Sixth Step - Solar Panels and Laminate Formation

The requirements of each m^2 of single Si PV panel formation and emissions to produce them are calculated. The results are given in Table 29.

Table 29 Preffered data used in this study for solar panels and laminate formation

Description	**Unit**	**Quantity**	**General Comment**
Single Si PV panel (output)	m^2	1	
Electricity	kWh	4.71	[77]
Natural Gas	MJ	5.41	
Tap water	kg	21.30	[93]
Tempering		10.10	

Table 29 (continued)

Description	Unit	Quantity	General Comment
Wire drawing	kg	0.11	
Single- Si PV cell	m^2	0.93	
Aluminium alloy		2.63	
Nickel		1.63 E-4	
Brazing solder		8.76E-3	
Solar glass		10.10	
Copper		0.11	
Glass fibre reinforced plastic		0.19	
Ethylvinylacetate		1	
Polyvinylacetate		0.11	
Polyethylene terephthalate		0.37	
Silicone product		0.12	[93]
Acetone	kg	1.30E-2	
Methanol		2.16E-3	
Vinyl acetate		1.64E-3	
Lubricating oil		1.61E-3	
Corrugated board		1.10	
1-propanol		8.14E-3	
Disposal, municipal solid waste		0.03	
Disposal, polyvinylflouride		0.11	
Disposal, plastics		1.69	
Disposal, used mineral oil		1.61E-3	
Treatment wastewater class 2	m^3	2.13E-2	

Total panel area required for 1 MW is multiplied with the parameter values identified in Table 29 and given in Table 30.

Table 30 Excell sheet revealing the outputs of the production of solar panel and laminate formation process

PV LCI for Karapınar ESIZ						
Solar Panels and Laminate Formation						
Description	***Unit***	***Amount***	***Materials***	***Unit***	***Unit Amount***	***Total***
Panel No.	-	3572	Electricity	kWh	4.71	27423.3
1 panel	m2	1.63	natural gas	MJ	5.41	31499
Panel Total	m2	5822.36	tap water	kg	21.3	124016
			tempering	kg	10.1	58805.8
			wire drawing	kg	0.113	657.927
			Single Si PV Cell	m2	0.932	5426.44
			Aluminium Alloy	kg	2.63	15312.8
			Nickel	kg	0.000163	0.94904
			Brazing Solder	kg	0.00876	51.0039
			Solar Glass	kg	10.1	58805.8
			Copper	kg	0.113	657.927
			Glass Fibre reinforced Plastic	kg	0.188	1094.6
			ethylvinylacetate	kg	1	5822.36
			polyvinylacetate	kg	0.11	640.46
			polyethylene terephthalate	kg	0.373	2171.74
			Silicon Product	kg	0.122	710.328
			Acetone	kg	0.013	75.6907
			Methanol	kg	0.00216	12.5763
			Vinyl Acetate	kg	0.00164	9.54867
			Lubricating Oil	kg	0.00161	9.374
			Corrugated Board	kg	1.1	6404.6
			1-propanol	kg	0.00814	47.394
			Disposal, municipal waste	kg	0.03	174.671
			Disposal, polyvinylflouride	kg	0.11	640.46
			Disposal, plastics	kg	1.69	9839.79
			Disposal, used mineral oil	kg	0.00161	9.374
			Treatment ww class 2	m3	0.0213	124.016

2.1.6.1. Outputs of LCA

Necessary inputs for the manufacturing of 1 MW PV PP are determined and gathered in Table 31.

Table 31 Quantities acquired after computation of LCI

Description	**Unit**	**Quantity**
Panel Numbers	-	3,572
Panel Area	m^2	5,822
PV Cell Area		5,426
Wafer		5,752
CZ Single crystalline Silicon	kg	5,091
Silicon Production Mix		5,447
Mg-Silicon		5,632
SiO_2		15,207

All the values calculated in LCI for each step of LCA are emerged and total material use and emission made is found out. The result is presented in Table 32.

Table 32 Materials to be used, emissions to be made for 1 MW PV PP

Description	Unit	Quantity	Description	Unit	Quantity
Electricity	kWh	548,104	Polyvinylacetate		640
Natural Gas	MJ	427,567	Polyethylene Terephthalate		2172
Light Fuel Oil	MJ	6,295	Silicon Product		710
Water		719,350	Acetone		325
Tempering		58,806	Methanol		13
Wire Drawing		658	Vinyl Acetate		10
Aluminium Alloy		15,313	Lubricating Oil	kg	9
Nickel		1	Corrugated Board		6,405
Brazing Solder	kg	51	1-propanol		47
Solar Glass		58,806	Disposal, municipal waste		175
Copper		658	Disposal, polyvinylflouride		640
Glass Fibre reinforced Plastic		1095	Disposal, plastics		9,840
Ethylvinylacetate		5,822	Disposal, used mineral oil		9
Charcoal		957	Calcium chloride		117

Table 32 (continued)

Description	Unit	Quantity	Description	Unit	Quantity
Coke	kg	2,180	Iron	kg	5E-02
Metallization paste, front side and back side		67	Acetic acid		1023
Metallization paste, back side aluminium		390	Hydrochloric acid		247
Ammonia		37	Hydrogen Flouride		459
Phosporic Acid		42	Nitric Acid		617
Phosphoryl Chloride		9	Sodium Hydroxide		1060
Titanium Dioxide		8E-3	Argon		29,613
Ethanol from ethylene		3	Oxygen		554
Isopropanol		428	Silicon Carbide		12,309
Solvents		8	NaOH		1,606
Silicone product		7	HCl		9,358
Socium silicate		406	Polyethylene		8E-01
Tryethylene glycol		14,955	AOX		3
dipropylene Glycol Monomethyl Ether		1,726	Fluorine		2E-4

Table 32 (continued)

Description	**Unit**	**Quantity**	**Description**	**Unit**	**Quantity**
Alkylbenzene sulfonate	kg	1,380	Hydrogen Sulfide	kg	3
Acrylic binder		12	COD		843
Glass wool mat		58	Cyanide		4E-02
Paper		1,093	Lead		2E-01
Polystyrene		1,150	Mercury		3E-02
Packaging film		575	Nickel		3E-01
Brass		43	Nitrogen		58
Steel		8,513	Phospate		3
Wire drawing		8,571	BOD_5		803
Disposal		633	DOC		273
Graphite		8E-01	TOC		273
Wood scraps		8E+06	CO_2		22,529
Ceramic Ties		1,710	CO		11

Table 32 (continued)

Description	Unit	Quantity	Description	Unit	Quantity
Lime	kg	972	Arsenic	kg	5E-5
Flouride		12	Aluminium		8E-03
Hydrocarbons		116	Antimony		4E-02
Hydroxide		38	Boron		2E-3
Nitrogen		46	Cadmium		2E-6
Hl		218	Calcium		4E-3
Chloride		187	Chromium		4E-5
Sodium		28	Chlorine		4E-4
Zinc		9E-2			

2.1.6.2. LCI of BoS

LCI of BoS consists of energy use during the erection of PV modules, material use for mounting and material use and energy consumption for the manufacturing of inverters.

Table 33 reveals an energy use for the erection of a 1 MWe ground mount PV plant [77].

Table 33 (Energy use for mounting) Diesel use for the erection of a 1 MWe plant mounted on open ground

	Diesel, l
PV with piled foundation: Total	**375**
Thereof for piling profiles	275
Thereof for Wheel loader	100
PV with concrete foundation: Total	**1472**

Material inputs and waste emissions for mounting in terms of 1 m^2 is listed in Table 34 and for 1 MW PV PP are given in listed in Table 35.

Table 34 Unit process raw data of different mounting systems and correction factor used in this study

Description	**Unit**	**Quantity**	**General Comment**
Open ground construction, on ground	m^2	1	
Aluminium	kg	3.98	[77], [93]
Corrugated board, mixed fibre, single wall	kg	8.64E-2	[97]
Polyethylene	kg	9.09 E-4	[77], recycled PE
Polystrene	kg	4.55 E-3	[97]
Chromium steel	kg	0.25	[77]
Reinforcing steel	kg	7.21	[77]
Concrete	m^3	5.74 E-4	[77], fence foundation
Section bar rolling, steel	kg	6.15	[77], [98]

Table 34 (continued)

Description	Unit	Quantity	General Comment
Wire drawing, steel	kg	1.06	[77]
Zinc coating, pieces		0.25	[77], [98]
Disposal, packaging cardboard		8.64E-2	[77]
Disposal, building		9.09 E-4	[77], disposal of plastics parts at end of life
Total weight, materials		11.50	
Total weight structure		11.40	
Panel area	m^2	1	

Table 35 Excell sheet revealing the material uses of mounting systems

PV BoS LCI					
Mounting Systems					
		Materials	*Unit*	*Unit Amoun*	*Total*
Area (m2)	5822,36	Aluminium	kg	3,98	23173
		Corrugated Board	kg	0,0864	503,052
		Polyethylene	kg	0,000909	5,29253
		Polystrene	kg	0,00455	26,4917
		Chromium Steel	kg	0,247	1438,12
		Reinforcing Steel	kg	7,21	41979,2
		Concrete	m3	0,000574	3,34203
		Section bar rolling, steel		6,15	35807,5
		Wire drawing, steel		1,06	6171,7
		Zinc coating	kg	0,25	1455,59
		Disposal, packaging cardboard		0,0864	503,052
		Disposal, building		0,000904	5,26341

Inverters

The material use, energy consumption and waste emision during the manufacturing of inverters which are another major equipment besides PV modules are calculated as listed in Table 36 for each inverter and total use, consumption and emission are listed in Table 37.

Table 36 Preffered data for a unit process raw data of "Inverter, 500kW, at plant"

Description	Unit	Quantity	General Comments
Electricity	kWh	4580	[97]
Aluminium	kg	131	[98], recycled after use, [77]
Copper		335	
Steel		1440	
Polyethylene		22	[77], [98]
Alkyd paint		22	
Lubricating oil		881	
Glass fibre reinforced plastic		115	
Printed wiring board	m^2	2.25 E-1	
Connector	kg	47.40	
Inductor		0.35	
Integrated circuit		2.8 E-2	
Transistor		3.8 E-2	
Diode		4.7 E-2	
Capacitor		0.6	
Resistor		0.5 E-2	
Sheet rolling, steel		144	
Injection moulding		71	
Wire drawing, copper		335	
Section bar extrusion, alum.		131	[77]
Corrugated board		13.6	
Polystyrene foam slab		1.60	[97]
Fleece		0.3	

Table 36 (continued)

Description	**Unit**	**Quantity**	**General Comments**
Disposal	kg	3.9	Sum of polystrene, polyethylene, electronics, mineral oil, treatment of printed wiring boards, [77]

Table 37 Excell sheet revealing the material uses of inverter production

PV BoS LCI					
Inverter					
		Materials	**Unit**	**Unit Amount**	**Total**
Inverter 125 kW	8	Electircity	kWh	4850	9700
	16	Aluminium	kg	131	262
		Copper	kg	335	670
		Steel	kg	1440	2880
		Ploethylene	kg	22	44
		Alkyd paint	kg	22	44
		Lubricating Oil	kg	881	1762
		Glass fibre reinforced p	kg	115	230
		Printed wiring board	m^2	0,225	0,45
		Connector	kg	47,4	94,8
		Inductor	kg	0,351	0,702
		Integrated circuit	kg	0,028	0,056
		Transistor	kg	0,038	0,076
		Diode	kg	0,047	0,094
		Capacitor	kg	0,6	1,2
		Resistor	kg	0,005	0,01
		Sheet rolling, steel	kg	144	288
		Injection moulding	kg	71	142
		Wire drawing, copper	kg	335	670
		Section bar extrusion, a	kg	131	262
		Corrugated Board	kg	13,6	27,2
		Polystryrene foam slab	kg	1,6	3,2
		Fleece	kg	0,3	0,6
		Disposal	kg	3,9	7,8

2.1.7. PV LCOE

The Basic Definition of LCOE

The economic feasibility of an electricity generation project can be evaluated by various methods, but LCOE is the most frequently used when comparing electricity generation technologies or considering grid parities for emerging technologies [99 - 101].

LCOE is basically the constant unit cost (per kWh or MWh) of a payment stream that has the same present value as the total cost of building and operating a generating plant over its life [99].

LCOE Formula For PV Cost

The basic LCOE formula reckoning the energy cost of a system is the following:

$$LCOE = \frac{C + L + \sum_{n=1}^{N} \frac{(OPEX + I)\times C}{(1+r)^n}}{\sum_{n=1}^{N} \frac{Total\ Electricity \times (1-d)^n}{(1+r)^n}}$$

Where:

C is a cost of the system; *L* is a land cost; *OPEX* is operation and maintenance cost; *I* is insurance cost; *r* is discount rate; *n* is determined year; *N* is lifetime of the system; *d* is annual degredation rate [103].

2.1.7.1. Factors to compute LCOE of 1 MW PV in Karapinar ESIZ

1. *Initial Investment*

Initial investment constitutes the cost of the system, *C*, and the cost of the required land, *L*.

a. *Cost of a PV System, C*

Cost of a PV system constitutes from the module costs and BoS costs.

i. Module Cost

For the computation of total module cost, module price proposal is taken from and checked with the companies which are currently operating in Turkey on PV investments. Pursuant to the proposal taken module price is calculated from 0.59 €/Wp unit price. Having 3572 modules each have 280 Wp, total amount of module price is found as 796,627 $ (0.59 €/Wp ×3572×280×1.35$/€) [102].

Under favour of investment incentive certificate, solar energy projects are exempt from customs duty and value added tax [104].

With the intention of avoidance from duplication, the costs reasoned by mounting systems, erection of PV modules and installation of PV modules are considered in commission part separately.

ii. Balance of System (BoS) Costs

BoS components include all non-module costs of a solar PV installation, including mainly wiring, inverter and land [103].

Inverter cost proposal is also taken from Turkish Companies, as mentioned in module price part. Accordingly, the unit cost of 125 kW inverter is 33,750 $ (25,000€×1.35$/€) [102]. The system will need eight 125 kW – inverters to be changed every 10 years [103]. Hereupon, on the brink of 8 in the launching, 8 in 10th year and 8 in 20th year afterwards, there will totally be 24 inverters needed. As technology matures, the inverter price is not supposed to increase, rather supposed to be decreased. This study assumes the decrease in the inverter price will compensate the inflate rate. Therefore, the inverter price is assumed to stay as it is. By this way, the NPV value computed for the inverters is 537,517$.

Some part of remaining part of BoS cost excluding inverters and land is negligible because wiring is made by the Ministry of Science, Industry and Technology as an advantage of ESIZ. Therefore, the cost of the wiring and the environmental effects in producing its primary products were assumed to be irrevelant and negligible, respectively.

b. Land Cost, L

According to the advantages Karapınar ESIZ serves for, the infrastructure of the field is prepared by the Ministry of Science, Industry and Technology of the Republic of Turkey. The investor is only responsible for the payment of current value of the loan of the land determined by the Ministry of Finance of the Republic of Turkey [105].

The appropriate adequate pay amount for the determined site is 15 TL/m^2 yearly according to the verbal information gathered from the officers of the Ministry of Finance of the Republic of Turkey which is solely responsible authority to adjust adequate pay amount. Although this value is quite outsized, this study takes this declared value, hence, the adequate pay amount is taken as 15 TL/m^2 annually. The Exchange Rate designated by the Central Bank of the Republic of Turkey 1 $ corresponds 2 TL in 04/10/2013.

Taking into account 1 TL corresponds 0.5 $, the lifetime of the system is 30 years, discount rate is 5% and total necessary area is 10,098 m^2, the NPV of the total landcost is 1,239,968 $.

2. *Annual Costs*

a. *Operation and Maintanance Costs, OPEX*

Operation and maintanance costs of PV PP are comperatively low owing to its not consuming fuel which is a major item for OPEX. Moreover, because of not having tracking part by the system taken into account for this study, OPEX only consists of regular cleaning, monitoring of performance and inverter replacement approximately every 10 years [106 – 108].

This study, based on the average of reported values, considers annual operation and maintenance cost as 1.5% of the total cost of the system, C [42], [109-113]. Consequently, the OPEX of the system is reckoned as 20,012 $.

b. *Insurance Costs*

Owing to the relatively high technological risks associated with PV system, in contrast with conventional ones, an insurance policy should be adopted. The annual insurance rate for PV systems is foreseen as 0.25% [107] of the capital cost of the system, C. So the insurance cost of the system is 3,336 $.

3. Electricity Production

Electricity production values of the system is referenced to the part where electricity production is calculated for this study. The values gathered from electricity production part are exposed to the division of discount rate in order to identify net present value of the electricity production which is compelled by LCOE method. The values computed is 23,011 MWh.

4. Financial Factors

a. Discount Rate

Taking into account the time value of money as well as the risk of the investment, discount rate is one of the most important assumptions on the input parameters to the LCOE.

According to the information taken from the Central Bank of the Republic, the interest rate of Turkey is about 5% [114]. Similar studies also use the same discount rate [115].

b. Lifetime of the System

PV modules, the key component of PV systems, are warranted for a duration in the range 25–30 years by most producers [101], [111], [116-118]. The practical lifetime of the silicon-made PV modules is expected to be at least 30 years [119 - 120]. In parallel with the mentioned information, the lifetime assumption for this study is 30 years.

5. Additional Expenditures and Benefits

a. Carbon Trading

PV systems are included in the carbon trading mechanism. Hence, each tones of CO_2 emission reduction is awarded with certificates which is saleable in appropriate markets. The carbon emission price is taken as 2.4 €/tones of CO_2 that is equal to the actual average price (1.8-3€) in Turkish voluntary carbon market [121].

The CO_2 emission reduction potential, 0.6031 tCO_2/MWh, of the studied PV system is computed in CO_2 reduction comparison part of this study. The electricity production amount of the studied PV system is also reckoned in the electricity production part of the study. So, the amount the system will gain from the carbon trading is calculated as 87,733$(0.6031 tCO_2/MWh×44,898.25 MWh×1.35$/€×2.4€).

b. Commissioning

As seen details in the next subtitle, labour cost of commission of 1 MW PV PP is 4,500$ (2 workers×150 days×15 $/day).

c. Decommissioning

Since decommissioning will be applied at 31st year of the project, the NPV of the value is taken. This amount is 992$.

d. Ground Mounting

Another spending item for commissioning is PV module erection materials. According to the calculations made in PV mounting part of this study, the cost of aluminium and steel to be used for mounting are 41,755$ and 8,383$, respectively.

2.1.7.2. Total Cost and LCOE

Designated total cost and LCOE are compiled in Table 38.

Table 38 Monetary values of the system design

Description	**Unit**	**Quantity**
Module Price	$	796,627
NPV of Inverter Price		537,517
L		1,239,968
C		1,334,144
OPEX		20,012
I		3,336
Carbon Trade Gain		87,733
Commissioning+Decommissioning		5,492
Ground Mounting		50,139
NPV of the Total Cost		2,565,357
NPV of the Total Cost (excluding land)		1,325,389
NPV of the Total Electricity Production	MWh	23,011
LCOE (including Land cost)	$/MWh	111.49
LCOE (excluding Land cost)		57.60

Table 39 Excell sheet revealing monetary calculations of 1 MW PV PP in Karapinar ESIZ

	LCOE OF PV (1 MW)														
Total ($)		796.627	537.517	1334144,2	1239968	20012,16	3335,36		87733,15602				2.565.357	23.011	111,4851006
	Time (years)	**Module Cost ($)**	**Inverter ($)**	**C ($)**	**L ($)**	**OPEX ($)**	**I ($)**	**r**	**Carbon Trading ($)**	**Commissioning ($)**	**Decommissioning ($)**	**Ground Mounting ($)**	**Total Cost ($)**	**El. Prod. (NPV)**	**LCOE ($/MWh)**
	0	796.627	270.000	1.334.144	75735	20012,16	3335,36	0,05	87733,15602	4500	991,6176371	50138,91			111,4851006
	1				72128,57			0,05						1426581,81	
	2				68693,88			0,05						1358567,823	
	3				65422,74			0,05						1293796,485	
	4				62307,37			0,05						1232113,197	
	5				59340,35			0,05						1173370,734	
	6				56514,62			0,05						1117428,888	
	7				53823,45			0,05						1064154,135	
	8				51260,43			0,05						1013419,32	
	9				48819,46			0,05						965103,3473	
	10		165756,58		46494,72			0,05						919090,896	
	11				44280,69			0,05						875272,1434	
	12				42172,08			0,05						833542,5019	
	13				40163,89			0,05						793802,371	
	14				38251,32			0,05						755956,8979	
	15				36429,83			0,05						719915,7527	
	16				34695,08			0,05						685592,9122	
	17				33042,93			0,05						652906,4538	
	18				31469,46			0,05						620531,7996	
	19				29970,91			0,05						592134,338	
	20		101760,16		28543,72			0,05						563903,6283	
	21				27184,5			0,05						537018,8516	
	22				25890			0,05						511415,8385	
	23				24657,14			0,05						487033,4798	
	24				23482,99			0,05						463813,5788	
	25				22364,76			0,05						442290,7292	
	26				21299,77			0,05						420642,1069	
	27				20285,49			0,05						400587,4937	
	28				19319,52			0,05						381489,0079	
	29				18399,54			0,05						363301,0654	
	30				17523,37			0,05						345980,2545	
											991,6176371				

2.1.8. PV Commissioning and Decommissioning

PV system for 4800 MW installed power has commissioning and decommissioning periods which must be taken into account.

In this part of the study the time and cost for commissioning and decommissioning of PV system having cumulative 4800 MW installed power by addressing the calculation to be made for 1 MW one.

According to the calculations made previously, 1 MW PV PP needs 3572 PV modules having 280 Wp. Owing to direct correlation, total amount of modules needed for 4800 MW PV PP is designated as 17,145,600 (3572×4,800).

One more point to be taken into consideration is 4800 MW installed power PV PP's being constituted by 4800 1 MW PV PP's.

Here are the assumptions made for the computation:

- Each enterprise having 1 MW PV PP employs 2 workers.
- Each worker is capable of commission / decommission 12 panels in a day.
- These workers will be seasonal workers.
- Gender of these workers will be male.

Thus, each enterprise having 2 workers has an ability to commission / decommission 40 panels in a day.

Each enterprises has to pay 15 $ / day salary for each worker. This value is stemming from the seasonal worker prices announced by TURKSTAT [122].

For 4800 enterprises 9600 workers to be appointed in commissioning / decommissioning processes are needed.

Moreover, the commissioning process will be applied in the beginning of the project. On the other hand, the decommissioning process is applied when the lifetime of the system ends.

Gathering all the information and assumptions, the commissioning and decommissioning requires 150 days (3572/24) for each. The salary to be paid for the commissioning will be 21.60 million $ (9600×150×15$). The NPV of the cost to be paid for the decommissioning is 4.76 million $ ($[9600\times150\times15\$]/(1+0.05)^{31}$).

As a result, the first half of the first year of the investment is reserved for the commission. In addition, there will approximately be half year need at the end of the project to be allocated for decommissioning.

2.1.8.1. PV Ground Mounting

Required parameters needed to be known on the purpose of computing required ground mount materials are module length, width and thickness.

Inserting modules to attain arrays, module mid clamps are installed between modules in a row and require 1.27 cm of space between modules [123]. Considering 2-line, 1 MW PV system subsuming 101 PV arrays having 15 modules (3 in a column×5 in a row) each in a line. Hence, each array will need 5 cm (4×1.27) and system will totally need extra 1.5 meters ((30-1)×5) to be allocated for module mid clamps. The extra 5 meters reserved for the required area between assemblies and modules compensates this mentioned amount.

The space between rows of modules is not critical, but it is common for rows of modules to be installed so that the modules are flush with each other [123]. Moreover, a scheme revealing typical ground mounting method is seen in Figure 15.

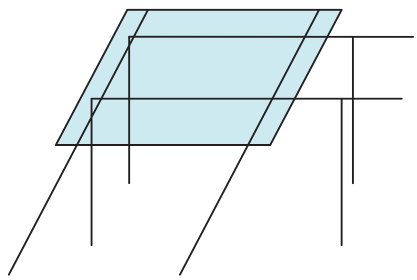

Figure 15 Scheme revealing typical ground mounting method

According to the literature data [77], for mounting systems 6.15 kg/m^2 steel (zinc coated), 0.25 kg/m^2 stainless steel, 3.98 kg/m^2 aluminium is assumed to be used. From this point forth, as calculated in the PV LCI BoS Component part of the study, 1 MW PV PP needs 23,171.6 kg aluminium (3.98×5,822), 37,260.8 kg steel ((6.15+0.25)×5,822) are needed. Benefiting from London Metal Exchange, the actual prices of aluminium and steel are 1,802 $/tonne and 225 $/tonne respectively. Hence, the cost of aluminium and steel to be used for mounting are 41,755.23 $ and 8,383.68 $, respectively.

2.1.9. PV Scale Projection from 1 MW to 4800 MW

In order to project PV data from 1MW to 4800 MW both of which is classed as utility-scale size, the economies of scale is an issue to be paid an attention. Dealing with crystalline, fixed-tilt utility scale system which are appropriate properties of the system this study handles, the capacity-weighted average price of systems >10MW was \$3.1/W when price for systems ≤ 10 MW was \$3.5/W according to 2012 data [124].

Abiding by a different reference, the price for the size >10 MW ranges from \$2,80-3,50/W and the one for the size ≤ 10 MW is priced between \$3.50-5.00/W [125].

Another reference concieves the price difference between 1 MW and 100 MW sizes as having 4,610 and 3,210 capital costs respectively [126].

Following figure, Figure 16, also reveals how the price changes with a system size increase [127].

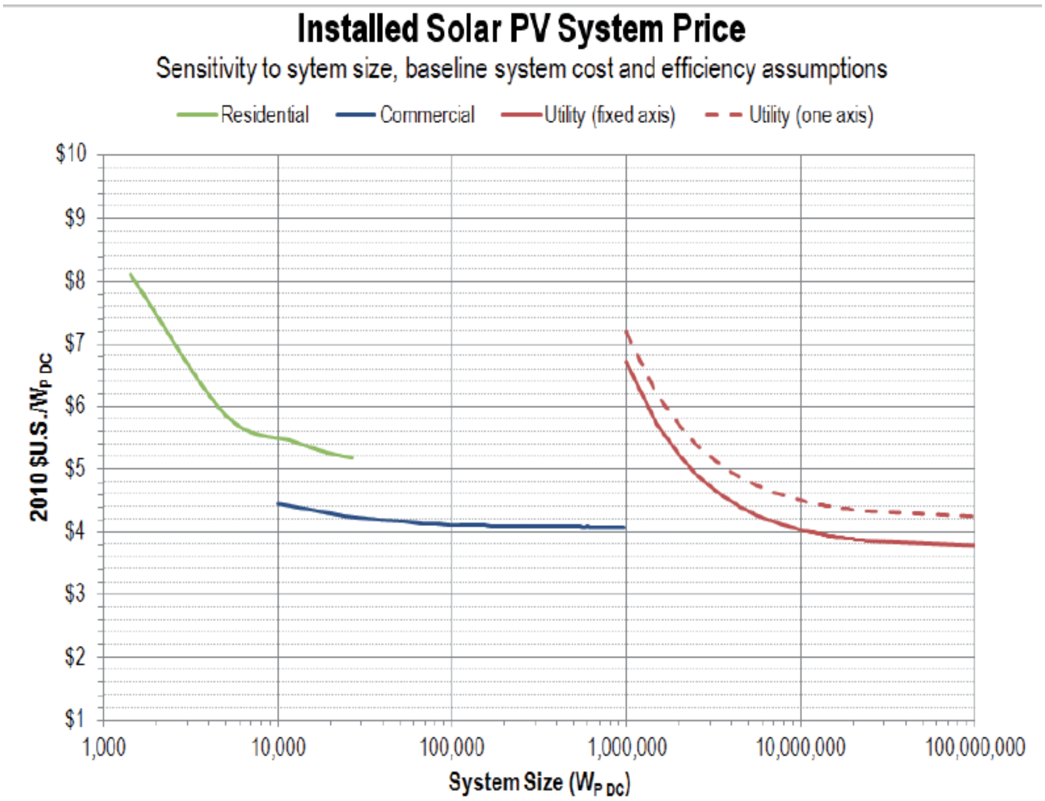

Figure 16 Economy-of-scale benefits: residential and commercial rooftop, ground-mount utility scale PV [127]

While projecting 1 MW PV to 4800 MW PV, the assumption derived from the aforementioned information can be constituted as multiplication of system price of 1MW with 3.1/3.5 ratio as the most conservative conjecture.

Based upon 1 MW PV PP cost designed in this study which is 2,565,357 $ for total cost including landing and 1,366,454 $ excluding land cost. Projecting these values to 4800 MW with an aforementioned ratio, the results are attained as 10.91 Billion $ (2,565,357×4800×3.1/3.5) for the total cost including land cost and 5.63 Billion $ (1,325,389×4800×3.1/3.5) for the total cost excluding land cost.

Furthermore, electricity projection is directly projected by multiplying electricity production of 1 MW PV PP with 4800. Then, the electricity amount to be produced by PV PPs having 4800 MW cumulative is 215,510 GWh (44.898 GWh×4800) which equals to 215.51 TWh.

As done previously, so as to take electricity production into account its net present value should be taken. Consequently, it is better to multiply annual electricity productions year by year and sum them up. That is the way how the required electricity production value by LCOE is acquired. This reveals that NPV of cumulative electricity production of 4800 MW PV PP's are also 110.45 TWh (4800×23.011) which differs from the total electricity production amount.

LCOE of 4800 MW is determined as 98.74 $/MWh (10,906,432,046 / 110,452,800) for the total cost. In addition, the LCOE for the cost excluding land cost is 51.02 $/MWh. (5,634,796,663 / 110,452,800).

The results for PV PPs having cumulative 4800 MW installed power is given in Table 40.

Table 40 Features of 4800 MW PV PPs

Description	**Quantity**
Installed Power	4800 MW
Project Duration	31 years
Lifetime	30 years
Total area needed	48.47 km^2
Electricity Production	215.51 TWh
NPV of Electricity Production	110.45 TWh
Total cost (w land cost)	10.91 Billion $
Total cost (w/o land cost)	5.63 Billion $
LCOE (w land cost)	98.74 $/MWh
LCOE (w/o land cost)	51.02 $/MWh

Moreover, LCI of 4800 MW PV PPs revealing the Material and energy use during LCA of system manufacturing is given in Table 70 in order to avoid from duplication.

2.2. Case Study 2 – 4800 MW NUKE PP to be established in Mersin – Akkuyu

Together with having no currently established and operating NUKE PP, Turkey is about the investment of 2 NUKE PPs, one in the South of Turkey on which studied through this thesis and the other is in the North part of Turkey, namely Sinop Province. Akkuyu NUKE PP is the initial one entering an investment period owing to an Intergovernmental Aggreement signed in 12 May 2010 between Russian and Turkish governments.

This part of the study analyses NUKE PP to be established in Mersin Akkuyu. During monitoring and assessment process of NUKE PP, literature information gathered are used and results are derived from this knowledge. The weld pool for this part of the study is accumulated from sources like EIA of PP; declerations and statements by project contractor company, namely Rosatom (Росатом); statement made by government authorities such as the Minister, Undersecretary etc.; studies of internationally accepted instutitions and academic studies. The assumption at this point is a trust to mentioned information weld pool.

The followings are the devastating information gathered from information weld pool concerning NUKE PP in Akkuyu related to this study:

- Project has 4 years preperation and 30 years decomissioning stage [128].
- The installed power of the PP is 4800 MW;
- The reactors have VVER 1200 (AER 2006) technology;
- The system have 4 reactors each having 1200 MW installed power;
- Total worth of the construction part of the Project is foreseen between 20-25 billion USD excluding VAT by the related Authorities recent declarations [29], 128 - 130].
- Yearly operating time is 7800 hours [131].
- Capacity factor is 90% [131 - 132].
- After all the reactors are taken into operation yearly electricity production will be 33.70 TWh (4800×0.90×7800) [131].

- Construction periods of the units of PP covers the time between 2016-2024.
- First unit will start its operation 7 years after having all necessary permits and approvals for launching the construction. Consequently, the electiricity production will most probably start at the end of 2020. Remaining units will start operation every other year in a row [133].
- The designed lifetime for the units are 60 years [45].
- The management method of the Project is Built-Own-Operate [45].
- The Project site is located in the maritime province of Mersin. Detailed adress is Gulnar District, Buyukeceli Municipality.
- Nuclear fuel is uraniumdioxide which has been enriched via U-235 isotope with 5% enrichment.
- The weight of uranium for each fuel assemblies is 534 kg while the nuclear reactor has 163 fuel assemblies, 312 fuel rods and consequently 50,856 emerged fuel sticks [134].
- Total uranium dioxide included by them are 87,042 kg. (534kg×163 fuel assembly)
- Taking 60 years life time an account total 10,080 used fuel assemblies or approximately 5,382 tonnes of used uranium dioxide are brought about.
- The flowrate of cooling water for each unit will be totally 220,000 m^3/hours. The cooling water will be provided from the Mediterrenean. Taking into account four units, the total 880,000 m^3/hours [131].
- The neccessary flowrate for the requirements of drinking and using waters are 450 m^3/days [135].
- Approximate mean flowrate of industrial water supply system is 342 m^3/days [131].
- Every power unit is constituted from a reactor and turbine building.
- 1,023 ha (10,230,000m^2) public domain is allocated for the Project site. Moreover 35 ha extra area is reserved for the living space and 125 ha for sea embankment. Hence, total 1,183 ha area is necessary for the Project [131].
- The total volume of excavation waste is foreseen as 12.6 million m^3, 4.8 million m^3 of this waste will be used as filling material; 3.3 million m^3 of which is for sea embankment and 1.5 million m^3 of which is for earth embankment. The remaning 7.8 million m^3 will be stored on the fields allocated by the Ministry of Forestry and Water Works of the Republic of Turkey [131].

- In the statistics brought about by TURKSTAT, Mersin Province has 212 L/day per capita wastewater production [133]. Pursuant to this assumption, the part of employess working in the contruction field but not staying there will have totally 461 m^3 of domestic wastewater production. (5,800 people×0.212 m^3/capita days×9/24 hours) (9 hours amount comes from 63th Article of 4857 numbered Labor Law.)
- For 6,700 remaining employees who will not only be working but also staying in Wellness Center, total wastewater production is 1,420 m^3/days. (6700 people×0.212 m^3/capita day). Consequently, total wastewater consumption of the mentioned NUKE PP is 1,881 m^3/days [131].
- The fresh water requirement of operation term of the abovementioned PP will be 507 m^3/hours. This amount will be provided from desalination method by using the Mediterranean [131].
- The tap water requirement which is 92 m^3/ hours will be provided from Babadil wells [131].
- The daily domestic solid waste production per capita is 1.21 kg according to TURKSTAT statistics [137]. 5800 people will then have 2,631.25 kg daily domestic solid waste (5,800 people×1.21 kg/capita daily×9/24 hours). Remaining 6,700 people will produce 8,107 kg/days (6,700 people×1.21 kg/capita days). Then the total amount of domestic solid waste is 10,738.25 kg/day.
- For the construction 516 trees will be uprooted [131].
- In the construction period, more than 2 million m^3 cement and 500 thousand tonnes of steel will be used [131].

2.2.1. NUKE Material Use

The material use and output emissions constituting LCI for 4800 MW NUKE PP are compiled in this part of the study. The major method used to form this LCI is supplied with literature informations and their transpositions.

Initially, benefitting from per kWh electiricity literature data [138] given in the Table 27, total approximate life cycle CO_2 (fossil); CH_4 (fossil); NO_x; NMVOC; SO_2; PM 2.5-10; PM 2.5; Carbon-14; Iodine-129; Radon-222 values are identified.

Table 41 Unit values of parameters for LCI key emissions of NUKE PP

Parameter	Unit	Quantity
CO_2 (fossil)	kg/kWh	5.91E-3
CH_4 (fossil)		1.02E-5
NO_x		3.05E-5
NMVOC		7.35E-6
SO_2		2.74E-5
PM 2.5-10		2.39E-6
PM 2.5		4.68E-6
Carbon-14	kBq/kWh	5.09E-2
Iodine-129		5.29E-5
Radon-222		776

Then, taking into consideration 33,696,000,000 kWh annual electricity production potential, the values transposed to the study is as given in Table 42.

Table 42 LCI emissions of 4800 MW NUKE PP

Parameter	Unit	Quantity
CO_2 (fossil)	kg/year	199,143,360
CH_4 (fossil)		343,699
NO_x		1,027,728
NMVOC		247,666
SO_2		923,270
PM 2,5-10		80,533
PM 2,5		157,697
Carbon-14	kBq/year	1.72E+09
Iodine-129		1,782,518
Radon-222		2.62E+13

Moreover, material use, water consumption, waste generation amounts derived from calculations and references stemming from literature are compiled in the following Table 43.

Table 43 Material use, water consumption, waste generation of LCI of 4800 MW NUKE PP established in Mersin Akkuyu (just for the construction period)

Description	**Unit**	**Quantity**
Uranium fuel sticks	amount	50,586
Uranium dioxide	kg	5,382,000
Cooling water use	m^3/hours	880,000
Drinking and using water use		450
Industrial water use		342
Excavation waste	m^3	12,600,000
Wastewater consumption	m^3/days	1,881
Freshwater requirement	m^3/hours	507
Tap water requirement	m^3/days	92
Domestic solid waste	kg/day	10,738.25
Uprooted trees	unit	516
Cement	m^3	2,000,000
Steel	kg	500,000,000

2.2.2. LCOE of 4800 MW NUKE PP in Mersin Akkuyu

The formula identified for the NUKE so as to compute LCOE is [139];

$$LCOE = \sum_{t}^{T}\left[\frac{Investment + O\,\&\,M + Decommissioning}{(1+r)^{t}}\right] \Bigg/ \sum_{t}^{T}\frac{Electricity}{(1+r)^{t}}$$

The components of the LCOE formula and the data used for this study are the followings:

1. Discount Rate

The discount rate is assumed as 5% as the same with PV.

2. Investment Cost

As the mean quantity of what is declared by the authorities as a cost, the investment cost of the Mersin Akkuyu NUKE PP is assumed as 22.5 billion $ excluding VAT. According to current VAT rates designated by Revenue Administration, assuming VAT is taken as 1% of the exact investment cost is 22.5 billion $ [140]. At a 5% discount rate, the ratio of the investment cost is assumed as 60% of the total cost [139].

The investment cost including VAT is then 22.725 billion $.

3. Operation and Maintanance (O&M)

O&M cost is assumed as 24% of the total cost [139]. Consequently, the O&M is calculated as 5.478 billion $.

4. Decommissioning

The decomission made after the operation life time of the systems end has a cost being 15% of the investment cost [139]. So the cost to be spent for decommissioning is 3.409 billion $. The NPV of the mentioned cost is 101,616,824 $

5. Fuel Cycle Cost

The fuel cycle cost is assumed as 16% of the total cost [139]. Consequently, the designated fuel cycle cost is 3.652 billion $.

6. Land Cost

As previously described the required land for the establishment of the project is 1,183 ha which is equal to 11.83 km^2.

The appropriate adequate pay amount for the determined site is 0.83 TL/m^2 yearly according to the verbal information gathered from the officers of the Ministry of Finance of the Republic of Turkey which is solely responsible authority to adjust adequate pay amount. This study takes thus declared value, hence, the adequate pay amount for this study is assumed as 0.83 TL/m^2 annually. The Exchange Rate designated by the Central Bank of the Republic of Turkey 1 $ corresponds 2 TL in 04/10/2013.

Taking into account 1TL corresponds 0,5 $, the duration of the project is 101 years, discount rate is 5% and total necessary area is 1183 ha (11,83 km^2), the NPV of the total landcost is 104,779,847 $.

7. Electricity Production

Taking into account 4 years preperation time and 7 years construction time the first unit launches its electricity production process in 12^{th} year of the project, then the other units will be taken into operation every other year in a row. Electricity production process will have been maintained during 60 years.

The NPV of the electiricty production is calculated by bearing in mind abovementioned information. The result is 347,363,212 MWh.

Total Cost and LCOE

Designated total cost and LCOE are compiled in Table 44.

Table 44 Designated total cost and LCOE of NUKE

Description	Unit	Quantity
Investment	$	22.725 billion
Decomissioning (cost)		3.409 billion
Decommissioning (NPV)		101.617 million
O&M		5.478 billion
Fuel Cycle		3.652 billion
L		104.780 million
NPV of the Total Cost		32.062 billion
NPV of the Total Electricity Production	MWh	347,360,213
LCOE	$/MWh	92.30

P.S. These calculations do not include opportunity costs and externality costs, i.e. damage costs for nuclear plants cost from radioactive wastes and associated risks.

2.3. Mutual Subjects

2.3.1. PV vs NUKE: CO_2 Emission Reduction Potentials

As being major actor for the formation of a green house effect which is the fundamental reason of climate change threat, CO_2 means more than a gas emitted by the technology and/or because of manufacturing of a technology. This situation paves the way for CO_2 emission comparison between technology options being necessity. Moreover, since solar energy is in the scope of carbon trading, the recknoning made in this part of the study provide an input for carbon trading cost calculations.

So as to examine and compare the effectiveness of a nuclear power plant and PV power plant in reducing green house gas emissions in Turkey, the national emission factor[12] should be calculated in conformity with the international methodology. Since the level of greenhouse gas emissions other than CO_2, such as CH_4 and N_2O, is negligibly small, computations are focused on CO_2 emission reduction.

1. Methodology to Calculate an Emission Factor for Turkey

UNFCCC's latest methodological tool namely "Tool to Calculate the Emission Factor for an Electricity System" is a reference document to compute Turkey's emission factor for electricity generation [141]. With reference to the above mentioned tool, Operating Margin (OM)[13] and Build Margin (BM)[14] have to be determined and integrated so as to designate an emission factor. Consequently, the computation method includes the determination of OM and BM and their integration by relevant formula to be determined later on this study [141]. Incidentally, during the calculation process, the support was taken from EDAM's study [142] which has done the relevant work previously.

On the occasion of the Turkish transmission system's being interconnected, the estimation of OM and BM emission factors are based on the definition of the

[12] The amount emission per unit electricity generation
[13] OM is the emission factor that refers to the group of existing power plants whose current electricity generation would be affected by the project activity.
[14] BM is the emission factor that refers to the group of prospective power plants whose construction and future operation would be affected by the proposed CDM project activity.

Turkish electricity network as one single interconnected system and grid power plants serving the system.

a. *Operating Margin Emission Factor*

There are four alternative methods available to calculate the OM emission factor: "Simple OM"; "Simple adjusted OM"; "Dispatch data analysis OM"; and "Average OM".

Because of not being able to have plant-specific data which belong to power plants connected to the grid, "Simple adjusted OM", "Dispatch data analysis OM" and "Average OM" calculation methods are eliminated. Hence, "Simple OM" method leaves in wake of that selection. This method, based on the total net electricity generation of all power plants serving the system, is applicable when low cost and/or must run resources constitute, as an average of the five most recent years, less than 50 percent of the total generation for the grid. The only major low operating cost and must run resource in Turkey is hydropower because the share of all other renewable resources is negligibly small. As seen in a Table 45, the share of low-cost / must run sources do not exceed 50% for the most recent 5 years [142].

Table 45 Share of hydroelectric production in Turkey, 2006 – 2010 [142]

	2006	**2007**	**2008**	**2009**	**2010**
Turkey's Gross Electricity Production (GWh)	176,300	191,558	198,418	194,813	211,208
Electricity Production from Hydro (GWh)	44,244	35,851	33,270	35,958	51,796
Total Share of Hydro (%)	25	19	17	18	25

The way to calculate emission factor via simple OM method is based on the calculation of the generation weighted average CO_2 emissions per unit net electricity generation (tCO_2 /MWh) of all generating power plants serving the system, not including low-cost/must run power plants/units.

The formula given below is applied for computing $EF_{grid, OMsimple, y}$[15] with respect to the aforementioned tool:

[15] Simple operating margin carbondioxide emission factor in year y (tCO_2/MWh)

$$EF_{grid,OMsimple,y} = \frac{\sum_i FC_{i,y} \times NCV_{i,y} \times EF_{CO_2,i,y}}{EG_y}$$

where

$EF_{grid,OMsimple,y}$	–	Simple operating margin CO_2 emission factor in year y (t CO_2/MWh)
$FC_{i,y}$	–	Amount of fossil fuel type i consumed in the project electricity system in year y (mass or volume unit)
$NCV_{i,y}$	–	Net calorific value (energy content) of fossil fuel type i in year y (GJ / mass or volume unit)
$EF_{CO2,i,y}$	–	CO_2 emission factor of fossil fuel type i in year y (tCO_2/GJ)
EGy	–	Net electricity generated and delivered to the grid by all power sources serving the system, not including low-cost / must-run power plants / units, in year y (MWh)
i	–	All fossil fuel types combusted in power sources in the project electricity system in year y
y	–	Either the three most recent years for which data is available at the time of submission of the CDM-PDD to the DOE for validation (ex ante option) or the applicable year during monitoring (ex post option), following the guidance on data vintage in step 2

Correspondance with EDAM study, emission factors specified by IPCC were used for the calculation of fuel-specific emissions[16] [143].

Table 46 IPCC emission factors [143]

	kg CO_2 /GJ			**Default Carbon Oxidation Factor**
	min	mid	max	
Hard Coal	92.8	96.1	100	
Lignite	90.9	101	115	
Fuel Oil	75.5	77.4	78.8	
Diesel Oil	72.6	74.1	74.8	1
Natural Gas	54.3	56.1	58.3	
LPG	61.6	63.1	65.6	
Naptha	69.3	73.3	76.3	

Then, the annual CO_2 emissions from electricity production are given in Table 47 gathered from [142].

[16] To be on the conservative side, the minimum values are used in the OM calculations. Based on these values, CO_2 emissions from electricity generation in Turkey are computed as shown in Table 32.

Table 47 Annual CO_2 emissions from electricity production [142]

	2008	2009	2010
Annual CO_2 Emissions from Electricity Production (tCO_2)	104,062,368	98,532,497	99,128,859

Net Electricity Production from Thermal Sources[17] are also referred to [142] and given in Table 48.

Table 48 Net electricity production from thermal sources [142]

	2008	2009	2010
Gross Electricity Production [GWh] (a)	198,418	194,813	211,208
Net Electricity Production [GWh] (b)	189,762	186,619	203,046
Net/Gross (c-a/b)	0.956	0.958	0.961
Gross Electricty Production from Thermal Sources [GWh] (d)	163,919	156,583	155,370
Net Electricity Production from Thermal Sources [GWh] (c*d)	156,768	149,998	149,366

Using the same relation for both overall electricity production and thermal production is an approximation based on a rough assumption. Yet, obviously, such an assumption results in a conservative estimation because the efficiency of thermal plants is typically much lower than other plants. The OM emission factors are calculated by dividing total emissions by net electricity production from thermal sources as shown in Table 49 [142].

Table 49 OM emission factor for 2008 – 2010 [142]

	2008	2009	2010
$EF_{grid,\ OMsimple,\ y}$ [tCO_2/MWh]	0.6638	0.6569	0.6637

[17] As the efficiency factor from gross to net electricity for thermal resources is not known, the overall relation between overall gross and net electricity production is assumed to be the same for thermal production [142].

As the generation-weighted average of the figures between 2008 and 2010, Turkey's OM emission factor is computed as **0.6603 tCO_2 / MWh** [142].

b. Build Margin Emission Factor

Another essential parameter is build margin (BM) which is based on the sample of the plants. There are two ways to compute BM as; the set of five power units that have been built most recently, or the set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.

Among these two options, the sample group that comprises the larger annual generation should be used. The data for recently built power plants is available in TEİAŞ's capacity projection reports documenting capacity, type of utility, fuel type and date of commissioning. According to the data:

- The total annual generation of the five plants that have been built most recently is 5,271 GWh. This represents approximately 2.7% of the overall electricity generation capacity in Turkey. Obviously, it is far below the 20 percent threshold proposed by the methodology.
- The most recent capacity additions that comprise the 20% of the total system generation corresponds to 42.1 TWh [142].

According to the methodology, BM Emission Factor EF_{BM} is calculated as the generation-weighted average emission factor of a simple of power plants for a specific year, as follows:

$$EF_{grid,BM,y} = \frac{\sum_{i,m} EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

where:

$EF_{grid,BM,y}$	Build margin CO_2 emission factor in year y (tCO_2 / MWh);
$EG_{m,y}$	Net quantity of electricity generated and delivered to the grid by power unit m in year y (MWh)
$EF_{EL,m,y}$	CO_2 emission factor of power unit m in year y (tCO_2 / MWh) m
m	Power units included in the build margin
y	Most recent historical year for which power generation data is available

As electricity production figures of some small facilities were not available, annual electricity productions of these plants have been calculated as

$EG_{m,y}$ = Full Load Working Hours × Installed Capacity

In the calculation of $EF_{grid,,BM,y}$ first $FEEL_{,m,y}$ values are computed by using the formula

$$EF_{EL,m,y} = \frac{EF_{CO_2,m,i,y} \text{ x } 3.6}{\eta_{m,y}}$$

where

$EF_{EL,m,y}$	CO_2 emission factor of power unit *m* in year y (tCO_2 / MWh);
$EF_{CO_2,m,i,y}$	Average net energy conversion efficiency of power unit m in year y (tCO_2 / GJ)
$\eta_{m,y}$	Average net energy conversion efficiency of power unit m in year y (ratio)
m	All power units serving the grid in year y except low-cost/must-run power units
y	The relevant year as per the data vintage chosen

For this computation, the default efficiency values shown in Table 50 were used [141].

Table 50 Default efficiency factors for power plants [141]

Grid Power Plants		
Generation technology	**Old units (before and in 2000)**	**New units (after 2000)**
Coal		
Subcritical	37%	39%
Supercritical	-	45%
Ultra-supercritical	-	50%
IGCC	-	50%
FBS	35.5%	-
CFBS	36.5%	40%
PFBS	-	41.5%
Oil		
Steam Turbine	37.5%	39%
Open Cycle	30%	39.5%
Combined Cycle	46%	46%

Table 50 (continued)

Grid Power Plants		
Generation technology	**Old units (before and in 2000)**	**New units (after 2000)**
Natural Gas		
Steam Turbine	37.5%	37.5%
Open Cycle	30%	39.5%
Combined Cycle	46%	60%

Accordingly, the BM emission factor is calculated as 0.4315 tCO_2/MWh.

c. *The Combined Margin Emission Factor*

The combined margin emissions factor is calculated as follows:

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM}$$

where

$EF_{grid,BM,y}$ – Build margin CO_2 emission factor in year y (tCO_2/MWh)
$EF_{grid,OM,y}$ – Operating margin CO_2 emission factor in year y (tCO_2/MWh)
w_{OM} – Weighting of operating margin emissions factor (%)
w_{BM} – Weighting of build margin emissions factor (%)

i. For NUKE

The methodological tool namely "Tool to calculate the emission factos for an electricity system" favors equal weighting for electricity generation projects other than wind and solar power. Hence, the emission factor for nuclear is reckoned as:

$EF_{grid, OM,y} = 0.6603 \times 0.5 + 0.4315 \times 0.5 =$ **0.5459** $\mathbf{tCO_2/MWh}$

ii. For PV

The tool suggests the related values for PV projects as EF_{OM}=0.75 EF_{BM}=0.25. Consequently, the emission factor for PV is reckoned as:

$EF_{grid, OM,y} = 0.6603 \times 0.75 + 0.4315 \times 0.25 =$ **0.6031** $\mathbf{tCO_2/MWh}$

d. Total CO_2 Emission Reduction by NUKE and PV

i. By NUKE

The assumption for a capacity factor of the Akkuyu Nuclear Power Plant is taken as 85% [139]. Owing to that assumption, the total electricity power to be generated by Akkuyu Nuclear Power Plant can be reckoned as 33,696,000 MWh/year (= 4,800 MW × 7,800 hours/year × 0.85).

Table 51 Akkuyu Nuclear Power Plant electricity generation amounts

Year	**Generation Amount**
2019	1200 MW×7800 hours×0.90 = 8,424,000 MWh
2020	2400MW× 7800hours×0.90 = 16,848,000 MWh
2021	3600 MW×7800 hours×0.90=25,272,000 MWh
2022	4800 MW×7800 hours×0.90=33,696,000 MWh
2023 - 2086	33,696,000 MWh/year
2087	25,272,000 MWh
2088	16,848,000 MWh
2089	8,424,000 MWh

The total CO_2 emission reduction to be achieved by the Akkuyu Nuclear Power Plant is calculated and depicted in Table 52:

Table 52 The amount of CO2 emission reduction enables by the Akkuyu Nuclear Power Plant

Year	**CO_2 Emission Reduction Amount**
2019	8,424,000 MWh×0.5459 tCO_2 / MWh = 4,592,662 tCO_2
2020	16,848,000 MWh × 0.5459 tCO_2 / MWh = 9,197,323 tCO_2
2021	25,272,000 MWh × 0.5459 tCO_2 / MWh = 13,795,985 tCO_2
2022	33,696,000 MWh × 0.5459 tCO_2 / MWh = 18,394,646 tCO_2
2023-2086	18,394,646 tCO_2 / year
2087	25,272,000 MWh × 0.5459 tCO_2 / MWh = 13,795,985 tCO_2
2088	16,848,000 MWh × 0.5459 tCO_2 / MWh = 9,197,323 tCO_2
2089	8,424,000 MWh × 0.5459 tCO_2 / MWh = 4,592,662 tCO_2
Total	1,048,482,824 tCO_2

ii. By PV

Cumulative electricity production of the PV system for the lifetime of the study is 44,898.253 MWh. Hence, total CO_2 emission reduction of 1 MW PV PP is 27,078.14 tCO_2 (44,898.253 MWh × 0.6031 tCO_2/MWh). The cumulative CO_2 reduction potential of 4800 MW PV PPs is then 129,975,055 tCO_2.

2.3.2. PV vs. NUKE Energy Payback and Profit Comparison

This part of the study compares payback time and profits of PV and NUKE investments to examine the monetary feasbilities of the options. In order to make this comparison, when the cost is worked out and how much investments reap a profit are matched. While making these matches previously calculated data in this study are utilized.

Before passing to the comparison part, the last but not the least, following calculations stem from the assumption that PV and NUKE are in the same boat in the eye of governmental policies.

1. ***When 4800 MW PV investment work out the cost and how much does it reap a profit?***

With respect to the outputs gathered during this study, PV PPs having cumulative 4800 MW installed power having 30 years life time and 215.51 TWh electricity production cost for 11.08 billion $.

In accordance with the legal arrangement covering PV investments, namely Renewable Energy Law, during first 10 years government presents guarantee of purchase to the electricity produced by PV PPs. This procurement price is 13.3 $ cents per kWh. Moreover, if the system have domestic equipments, this price increases for 5 years in compliance with mentioned quantities in the aforementioned regulation.

Taking notice of annual electricity production of 1 MW PV PP during its life time, seen in the Table 13 as transferred from electricity production part of this study, whole electricity produced during first 10 years are foreseen as purchased by the goverment in paralel with government decision.

Table 53 PV electricity production for the first 10 years

Year	**Electricity Production (kWh)**	**Year**	**Electricity Production (kWh)**
1	1,497,910.900	6	1,497,461.581
2	1,497,821.025	7	1,497,371.733
3	1,497,731.156	8	1,497,281.891
4	1,497,641.292	9	1,497,192.054
5	1,497,551.434	10	1,497,102.222

With only domestic PV mounting production, feed-in-tariff proposal for this system is 14.1 dollar cents per kWh (13.3 + 0.8) for the first 5 years. Next 5 years have 13.3 dollar cents subsidy. Hence, if the electricity produced by the system is sold to the government, the money earned is given in Table 54.

Table 54 Money earned through feed-in-tariff system for the first ten years

Year	**Money Earned with 5% discount rate ($ cents)**	**Year**	**Money Earned with 5% discount rate ($ cents)**
1	20,114,803.51	6	14,861,804.20
2	19,155,806.31	7	14,153,249.99
3	18,242,530.44	8	13,478,476.95
4	17,372,796.08	9	12,835,874.52
5	16,544,527.35	10	12,223,908.92
		Total	158,983,778.3 $ cents

The mentioned table reveals that if whole electricity is benefited from the feed-in-tariff system of the government, total money earned becomes 1,589,837.78 $ with 5% discount rate.

After 10 years, electricity to be produced can be sold in an open market unless government decides not to maintain its feed-in-tariff system. Important point to emphasize is the possiblity of sustaining feed-in-tariff system applied to solar energy with governmental decision in accordance with the Regulation.

At this point of the study, therefore, both options, maintanance of the feed-in-tariff system and selling electricity to open market is assessed.

As the first option, namely maintanance of the feed-in-tariff system, the benefit gained for the time period between 10th year and end of the Project lifetime are summarised in Table 55.

Table 55 Money earned through feed-in-tariff system after 10 years

Time	**Electricity Produced (kWh)**	**with 5% disc. Rate ($ cents)**
10		158,983,778.3
11	149,701,239.6	11,641,119.51
12	149,692,257.5	11,086,115.28
13	149,683,276.0	10,557,571.53
14	149,674,295.0	10,054,226.74
15	149,665,314.5	9,574,879.51
16	149,656,334.6	9,118,385.73
17	149,647,355.2	8,683,655.84
18	149,638,376.4	8,269,652.21
19	149,629,398.1	7,875,386.70
20	149,620,420.3	7,499,918.26
21	149,611,443.1	7,142,350.78
22	149,602,466.4	6,801,830.65
23	149,593,490.3	6,477,545.28
24	149,584,514.7	6,168,720.60
25	149,575,539.6	5,874,619.50
26	149,566,565.1	5,594,540.02
27	149,557,591.1	5,327,813,67
28	149,548,617.6	5,073,803.81
29	149,539,644.7	4,831,904.17
30	149,530,672.3	4,601,537.39
	Total Revenue	311,239,355.40 $ cents

Together with an assumption claiming all the electricity to be produced sold at the moment the amount to be earned from the system is 3,112,394 $ if 5% discount rate is conceived.

Multiplying the results with 4800 so as to acquire money earned via 4800 MW PV PPs, the related quantity becomes 14.94 billion $.

For the second option, this electricity produced is sold to Day Ahead Electricity Market which is a system determined by the Ministry of Energy and Natural Resources in order to purchase electricity produced. Together with no future projections existed current average price in Day Ahead Electricity Market is about 15 krş[18]/kWh corresponding 7.5 $ cents per kWh.

Depending on many variables such as supply-demand relation, international connections, the change in the share of energy options, fluctuations in dollar – Turkish lira parity etc., the estimation of future electricity cost is a hard work and does not give exact values. Consequently, future electricity prices are accepted in three ways in this study as an electricity price with constant 7.5 $ cents per kWh, one increasing with 1% inflation rate and one increasing with 1.5% inflation rate.

Taking into account three electricity price options, the quantity gained from Day Ahead Electricity Market is summarised in the following Table 56.

Table 56 Total money earned with day ahead electricity market option

Time (yrs)	**Electricity Produced (kWh)**	**Revenue ($ cents) with 5% discount rate**		
		with no inflation rate	**with 1% inflation rate**	**with 1.5% inflation rate**
10		158,983,778.3		
11	149,701,239.6	6,564,541.08	7,323,850.69	7,732,694.19
12	149,692,257.5	6,251,568.77	7,044,424.16	7,474,489.22
13	149,683,276.0	5,953,517.78	6,775,658.58	7,224,906.06
14	149,674,295.0	5,669,676.73	6,517,147.20	6,983,656.81
15	149,665,314.5	5,399,368.15	6,268,498.80	6,750,463.20
16	149,656,334.6	5,141,946.84	6,029,337.06	6,525,056.23

[18] 1 krş = 0,01 Turkish Lira

Table 56 (continued)

Time (yrs)	Electricity Produced (kWh)	Revenue ($ cents) with 5% discount rate		
		with no inflation rate	**with 1% inflation rate**	**with 1.5% inflation rate**
17	149,647,355.2	4,896,798.41	5,799,300.05	6,307,175.90
18	149,638,376.4	4,663,337.71	5,578,039.63	6,096,570.89
19	149,629,398.1	4,441,007.54	5,365,220.95	5,892,998.26
20	149,620,420.3	4,229,277.21	5,160,521.93	5,696,223.19
21	149,611,443.1	4,027,641.39	4,963,632.79	5,506,018.70
22	149,602,466.4	3,835,618.79	4,774,255.54	5,322,165.40
23	149,593,490.3	3,652,751.10	4,592,103.60	5,144,451.20
24	149,584,514.7	3,478,601.84	4,416,901.29	4,972,671.11
25	149,575,539.6	3,312,755.36	4,248,383.46	4,806,626.99
26	149,566,565.1	3,154,815.80	4,086,295.09	4,646,127.31
27	149,557,591.1	3,004,406.20	3,930,390.87	4,490,986.92
28	149,548,617.6	2,861,167.56	3,780,434.85	4,341,026.88
29	149,539,644.7	2,724,757.99	3,636,200.10	4,196,074.21
30	149,530,672.3	2,594,851.91	3,497,468.33	4,055,961.70
	Total	244,842,186.4	262,771,843.2	273,150,122.6

Coming to day ahead electricty market option, the total revenue of the project is 2,448,422 $, 2,627,718 $ and 2,731,501 $ respectively for three electricity price versions with 5% discount rate.

The findings are summarised in the following two tables in a row which are Table 57 and 58.

Table 57 Revenue from 1 MW PV PP based on the options

Options	Revenue with 5% discount rate ($)		
	No inflation	With 1% inflation	With 1.5% inflation
Feed-in tariff	3,112,394		
Feed-in Tariff + Day Ahead Market	2,448,422	2,627,718	2,731,501

Table 58 Revenue projection to 4800 MW

Options	Revenue with 5% discount rate ($)		
	No inflation	With 1% inflation	With 1.5% inflation
Feed-in tariff	14,939,491,200		
Feed-in Tariff + Day Ahead Market	11,752,425,600	12,613,046,400	13,111,204,800

Comparing with total cost of the system both including and excluding land costs which are 2,606,422 $ and 1,366,454 $ respectively that are projected to 4800 MW as 11.08 Billion $ and 5.81 Billion $, the payback times changing with options are calculated.

In order to determine payback time for PV PP initial invesment and yearly gains remaining after expenditure are determined and the time when the Project start to earn money after compensating its expenditure including initial investment gives the payback time.

The following two tables are designed for the determination of a payback time of 1MW PV PP for both options for the total cost both exluding and including land costs.

Table 59 Payback table of 1 MW PV PP without land cost

PV Payback and Revenue Check (1 MW) w/o Land Cost																		
Time (years)	Investment ($)	El. Production (kWh)	Electricity Price ($ cents)				Revenue r=5% ($)				Profit ($)				Cumulative Profit ($)			
			Opt 1	Opt 2 no inf	Opt 2 1% inf	Opt 2 1.5% inf	Opt 1	Opt 2 no inf	Opt 2 1% inf	Opt 2 1.5% inf	Opt 1	Opt 2 no inf	Opt 2 1%in	Opt 2 1.5%in	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt2 1.5%inf
0	1033533						0	0	0	0	-1033533	-1033533	-1033533	-1033533	-1033533	-1033533	-1033533	-1033533
1	778,2666667	1497910,9	14,1	14,1	14,1	14,1	201148,0351	201148,0351	201148,0351	201148,0351	200369,8	200369,77	200369,77	200369,7685	-833163,23	-833163,23	-833163,23	-833163,232
2	778,2666667	1497821,025	14,1	14,1	14,1	14,1	191558,0631	191558,0631	191558,0631	191558,0631	190779,8	190779,8	190779,8	190779,7964	-642383,44	-642383,44	-642383,44	-642383,435
3	778,2666667	1497731,156	14,1	14,1	14,1	14,1	182425,3044	182425,3044	182425,3044	182425,3044	181647	181647,04	181647,04	181647,0377	-460736,4	-460736,4	-460736,4	-460736,397
4	778,2666667	1497641,292	14,1	14,1	14,1	14,1	173727,9608	173727,9608	173727,9608	173727,9608	172949,7	172949,69	172949,69	172949,6942	-287786,7	-287786,7	-287786,7	-287786,703
5	778,2666667	1497551,434	14,1	14,1	14,1	14,1	165445,2735	165445,2735	165445,2735	165445,2735	164667	164667,01	164667,01	164667,0068	-123119,7	-123119,7	-123119,7	-123119,696
6	778,2666667	1497461,581	13,3	13,3	13,3	13,3	148618,042	148618,042	148618,042	148618,042	147839,8	147839,78	147839,78	147839,7754	24720,079	24720,079	24720,079	24720,079
7	778,2666667	1497371,733	13,3	13,3	13,3	13,3	141532,4999	141532,4999	141532,4999	141532,4999	140754,2	140754,23	140754,23	140754,2333	165474,31	165474,312	165474,312	165474,3123
8	778,2666667	1497281,891	13,3	13,3	13,3	13,3	134784,7695	134784,7695	134784,7695	134784,7695	134006,5	134006,5	134006,5	134006,5028	299480,82	299480,815	299480,815	299480,8151
9	778,2666667	1497192,054	13,3	13,3	13,3	13,3	128358,7452	128358,7452	128358,7452	128358,7452	127580,5	127580,48	127580,48	127580,4785	427061,29	427061,294	427061,294	427061,2936
10	166535,2667	1497102,222	13,3	13,3	13,3	13,3	122239,0892	122239,0892	122239,0892	122239,0892	-44296,2	-44296,18	-44296,18	-44296,1775	382765,12	382765,116	382765,116	382765,1161
11	778,2666667	1497012,396	13,3	7,5	8,3675126	8,834617031	116411,1951	65645,41076	73238,50689	77326,94185	115632,9	64867,144	72460,24	76548,67519	498398,04	447632,26	455225,356	459313,7913
12	778,2666667	1496922,575	13,3	7,5	8,451187726	8,967136286	110861,1528	62515,68765	70444,24163	74744,89216	110082,9	61737,421	69665,975	73966,62549	608480,93	509369,681	524891,331	533280,4168
13	778,2666667	1496832,76	13,3	7,5	8,535699603	9,10164333	105575,7153	59535,17782	67756,58583	72249,06055	104797,4	58756,911	66978,319	71470,79389	713278,38	568126,592	591869,65	604751,2107
14	778,2666667	1496742,95	13,3	7,5	8,621056599	9,23816798	100542,2674	56696,76734	65171,47204	69836,56809	99764	55918,501	64393,205	69058,30142	813042,38	624045,093	656262,856	673809,5121
15	778,2666667	1496653,145	13,3	7,5	8,707267165	9,3767405	95748,79513	53993,68147	62684,98797	67504,63196	94970,53	53215,415	61906,721	66726,3653	908012,91	677260,508	718169,577	740535,8774
16	778,2666667	1496563,346	13,3	7,5	8,794339837	9,517391607	91183,85734	51419,46842	60293,37061	65250,5623	90405,59	50641,202	59515,104	64472,29563	998418,5	727901,71	777684,681	805008,1731
17	778,2666667	1496473,552	13,3	7,5	8,882283235	9,660152482	86836,55839	48967,98405	57993,00051	63071,75902	86058,29	48189,717	57214,734	62293,49235	1084476,8	776091,427	834899,415	867301,6654
18	778,2666667	1496383,764	13,3	7,5	8,971106068	9,805054769	82696,52209	46633,37712	55780,39632	60965,70889	81918,26	45855,11	55002,13	60187,44223	1166395	821946,537	889901,545	927489,1076
19	778,2666667	1496293,981	13,3	7,5	9,060817128	9,95213059	78753,86695	44410,07535	53652,20952	58929,98258	77975,6	43631,809	52873,943	58151,71592	1244370,6	865578,346	942775,487	985640,8235
20	102538,2667	1496204,203	13,3	7,5	9,1514253	10,10141255	74999,18259	42292,77214	51605,21932	56962,23189	-27539,1	-60245,49	-50933,05	-45576,0348	1216831,6	805332,852	891842,44	940064,7888
21	778,2666667	1496114,431	13,3	7,5	9,242939553	10,25293374	71423,50727	40276,41388	49636,32785	55060,18702	70645,24	39498,147	48858,061	54281,92035	1287476,8	844830,999	940700,501	994346,7091
22	778,2666667	1496024,664	13,3	7,5	9,335368948	10,40672774	68018,30654	38356,1879	47742,55539	53221,65396	67240,04	37577,921	46964,289	52443,3873	1354716,8	882408,92	987664,79	1046790,096
23	778,2666667	1495934,903	13,3	7,5	9,428722638	10,56282866	64775,4528	36527,51098	45921,03595	51444,51197	63997,19	35749,244	45142,769	50666,24531	1418714	918158,164	1032807,56	1097456,342
24	778,2666667	1495845,147	13,3	7,5	9,523009864	10,72127109	61687,20597	34786,01841	44169,01285	49726,71113	60908,94	34007,752	43390,746	48948,44446	1479623	952165,916	1076198,31	1146404,786
25	778,2666667	1495755,396	13,3	7,5	9,618239963	10,88209016	58746,19499	33127,55357	42483,83461	48066,26994	57967,93	32349,287	41705,568	47288,00327	1537590,9	984515,203	1117903,87	1193692,789
26	778,2666667	1495665,651	13,3	7,5	9,714422362	11,04532151	55945,40021	31548,15801	40862,95089	46461,2731	55167,13	30769,891	40084,684	45683,00643	1592758	1015285,09	1157988,56	1239375,796
27	778,2666667	1495575,911	13,3	7,5	9,811566586	11,21100133	53278,13665	30044,06202	39303,90867	44909,86924	52499,87	29265,795	38525,642	44131,60257	1645257,9	1044550,89	1196514,2	1283507,398
28	778,2666667	1495486,176	13,3	7,5	9,909682252	11,37916635	50738,03806	28611,6756	37804,34852	43410,26883	49959,77	27833,409	37026,082	42632,00216	1695217,7	1072384,3	1233540,28	1326139,401
29	778,2666667	1495396,447	13,3	7,5	10,00877907	11,54985385	48319,04169	27247,5799	36362,00101	41960,74207	47540,78	26469,313	35583,734	41182,4754	1742758,4	1098853,61	1269124,02	1367321,876
30	778,2666667	1495306,723	13,3	7,5	10,10886686	11,72310165	46015,37386	25948,51909	34974,68331	40559,61695	45237,11	25170,252	34196,417	39781,35028	1787995,6	1124023,86	1303320,43	1407103,226
31	992						0	0			-992	-992	-991,617	-991,617	1787003,6	1123031,86	1302328,82	1406111,609

Table 60 Payback table for 1 MW PV PP with land cost

PV Payback and Revenue Check (1 MW) w Land Cost															
Time (years)	Investment ($)	Land Cost ($)	Inv. w L ($)	Revenue r=5% ($)				Profit ($)				Cumulative Profit ($)			
				Opt 1	Opt 2 no inf	Opt 2 1% inf	Opt 2 1.5% inf	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt 2 1.5%inf	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt2 1.5%inf
0	1033533	75735	1109268	0	0	0	0	-1109268	-1109268	-1109268	-1109268	-1109268	-1109268	-1109268	-1109268
1	778,2666667	72128,57143	72906,838	201148,0351	201148,0351	201148,0351	201148,0351	128241,2	128241,2	128241,2	128241,197	-981026,803	-981026,8	-981026,8	-981026,803
2	778,2666667	68693,87755	69472,144	191558,0631	191558,0631	191558,0631	191558,0631	122085,9	122085,92	122085,92	122085,9189	-858940,884	-858940,88	-858940,88	-858940,884
3	778,2666667	65422,74052	66201,007	182425,3044	182425,3044	182425,3044	182425,3044	116224,3	116224,3	116224,3	116224,2972	-742716,587	-742716,59	-742716,59	-742716,587
4	778,2666667	62307,37193	63085,639	173727,9608	173727,9608	173727,9608	173727,9608	110642,3	110642,32	110642,32	110642,3222	-632074,265	-632074,26	-632074,26	-632074,265
5	778,2666667	59340,35422	60118,621	165445,2735	165445,2735	165445,2735	165445,2735	105326,7	105326,65	105326,65	105326,6526	-526747,612	-526747,61	-526747,61	-526747,612
6	778,2666667	56514,62306	57292,89	148618,042	148618,042	148618,042	148618,042	91325,15	91325,152	91325,152	91325,15229	-435422,46	-435422,46	-435422,46	-435422,46
7	778,2666667	53823,45054	54601,717	141532,4999	141532,4999	141532,4999	141532,4999	86930,78	86930,783	86930,783	86930,78273	-348491,677	-348491,68	-348491,68	-348491,677
8	778,2666667	51260,42908	52038,696	134784,7695	134784,7695	134784,7695	134784,7695	82746,07	82746,074	82746,074	82746,07376	-265745,603	-265745,6	-265745,6	-265745,603
9	778,2666667	48819,45627	49597,723	128358,7452	128358,7452	128358,7452	128358,7452	78761,02	78761,022	78761,022	78761,02223	-186984,581	-186984,58	-186984,58	-186984,581
10	166535,2667	46494,72026	213029,99	122239,0892	122239,0892	122239,0892	122239,0892	-90790,9	-90790,9	-90790,898	-90790,8977	-277775,479	-277775,48	-277775,48	-277775,479
11	778,2666667	44280,68596	45058,953	116411,1951	65645,41076	73238,50689	77326,94185	71352,24	20586,458	28179,554	32267,98923	-206423,236	-257189,02	-249595,92	-245507,489
12	778,2666667	42172,08187	42950,349	110861,1528	62515,68765	70444,24163	74744,89216	67910,8	19565,339	27493,893	31794,54363	-138512,432	-237623,68	-222102,03	-213712,946
13	778,2666667	40163,88749	40942,154	105575,7153	59535,17782	67756,58583	72249,06055	64633,56	18593,024	26814,432	31306,90639	-73878,8708	-219030,66	-195287,6	-182406,039
14	778,2666667	38251,32142	39029,588	100542,2674	56696,76734	65171,47204	69836,56809	61512,68	17667,179	26141,884	30806,98	-12366,1915	-201363,48	-169145,72	-151599,059
15	778,2666667	36429,82992	37208,097	95748,79513	53993,68147	62684,98797	67504,63196	58540,7	16785,585	25476,891	30296,53537	46174,507	-184577,89	-143668,82	-121302,524
16	778,2666667	34695,07612	35473,343	91183,85734	51419,46842	60293,37061	65250,5623	55710,51	15946,126	24820,028	29777,21951	101885,022	-168631,77	-118848,8	-91525,3046
17	778,2666667	33042,92964	33821,196	86836,55839	48967,98405	57993,00051	63071,75902	53015,36	15146,788	24171,804	29250,56272	154900,384	-153484,98	-94676,992	-62274,7419
18	778,2666667	31469,4568	32247,723	82696,52209	46633,37712	55780,39632	60965,70889	50448,8	14385,654	23532,673	28717,98543	205349,182	-139099,33	-71144,319	-33556,7564
19	778,2666667	29970,91123	30749,178	78753,86695	44410,07535	53652,20952	58929,98258	48004,69	13660,897	22903,032	28180,80468	253353,871	-125438,43	-48241,288	-5375,95176
20	102538,2667	28543,72499	131081,99	74999,18259	42292,77214	51605,21932	56962,23189	-56082,8	-88789,22	-79476,772	-74119,7598	197271,062	-214227,65	-127718,06	-79495,7115
21	778,2666667	27184,49999	27962,767	71423,50727	40276,41388	49636,32785	55060,18702	43460,74	12313,647	21673,561	27097,42037	240731,803	-201914	-106044,5	-52398,2911
22	778,2666667	25889,99999	26668,267	68018,30654	38356,1879	47742,55539	53221,65396	41350,04	11687,921	21074,289	26553,38731	282081,843	-190226,08	-84970,21	-25844,9038
23	778,2666667	24657,14284	25435,41	64775,4528	36527,51098	45921,03595	51444,51197	39340,04	11092,101	20485,626	26009,10246	321421,886	-179133,98	-64484,584	164,198621
24	778,2666667	23482,99319	24261,26	61687,20597	34786,01841	44169,01285	49726,71113	37425,95	10524,759	19907,753	25465,45127	358847,832	-168609,22	-44576,831	25629,6499
25	778,2666667	22364,75541	23143,022	58746,19499	33127,55357	42483,83461	48066,26994	35603,17	9984,5315	19340,813	24923,24786	394451,005	-158624,69	-25236,018	50552,8978
26	778,2666667	21299,76706	22078,034	55945,40021	31548,15801	40862,95089	46461,2731	33867,37	9470,1243	18784,917	24383,23937	428318,372	-149154,56	-6451,1011	74936,1371
27	778,2666667	20285,49244	21063,759	53278,13665	30044,06202	39303,90867	44909,86924	32214,38	8980,3029	18240,15	23846,11013	460532,749	-140174,26	11789,048	98782,2473
28	778,2666667	19319,51661	20097,783	50738,03806	28611,6756	37804,34852	43410,26883	30640,25	8513,8923	17706,565	23312,48555	491173,004	-131660,37	29495,614	122094,733
29	778,2666667	18399,53963	19177,806	48319,04169	27247,5799	36362,00101	41960,74207	29141,24	8069,7736	17184,195	22782,93578	520314,239	-123590,6	46679,808	144877,669
30	778,2666667	17523,37107	18301,638	46015,37386	25948,51909	34974,68331	40559,61695	27713,74	7646,8814	16673,046	22257,9792	548027,975	-115943,71	63352,854	167135,648
31	992		992	0	0			-992	-992	-992	-992	547035,975	-116935,71	62360,854	166143,648

According to the computations made at above mentioned two tables, payback times of 1MW PV PP with options are given in Table 61.

Table 61 Payback situation of options for 1 MW PV PP

	Opt 1 (years)	Opt 2 (years)		
		w/o inf.	w 1% inf.	w 1.5% inf.
Pay Back Time with 5% discount rate with land cost	14.20	No payback	26.36	23
Pay Back Time with 5% discount rate w/o land cost	5.86 (for all options)			

With scaling to 4800 MW, the following two tables are designed for the determination of a payback time of 4800 MW PV PP for both options for the total cost both exluding and including land costs. Although one of the options, without accounting the inflation rate and with the land cost, 1 MW PV PP does not pay back, but the scale projected 4800 MW PV PP does give pay back of 24.77 years (see below).

Table 62 Payback table of 4800 MW PV PP without land cost

PV Payback and Revenue Check (4800 MW) w/o Land Cost													
Time (years)	Investment ($)	Revenue r=5% ($)				Profit ($)				Cumulative Profit ($)			
		Opt 1	Opt 2 no inf	Opt 2 1% inf	Opt 2 1.5% inf	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt 2 1.5%inf	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt2 1.5%inf
0	4345862777	0	0	0	0	-4345862777	-4345862777	-4345862777	-4345862777	-4345862777	-4345862777	-4345862777	-4345862777
1	3308745,143	965510569	965510569	965510569	965510569	962201823,9	962201823,9	962201824	962201823,9	-3383660953	-3383660953	-3383660953	-3383660953
2	3308745,143	919478703	919478703	919478703	919478703	916169957,9	916169957,9	916169958	916169957,9	-2467490995	-2467490995	-2467490995	-2467490995
3	3308745,143	875641461	875641461	875641461	875641461	872332715,9	872332715,9	872332716	872332715,9	-1595158280	-1595158280	-1595158280	-1595158280
4	3308745,143	833894212	833894212	833894212	833894212	830585466,9	830585466,9	830585467	830585466,9	-764572813	-764572813	-764572813	-764572813
5	3308745,143	794137313	794137313	794137313	794137313	790828567,9	790828567,9	790828568	790828567,9	26255755,14	26255755,14	26255755,1	26255755,14
6	3308745,143	713366602	713366602	713366602	713366602	710057856,9	710057856,9	710057857	710057856,9	736313612	736313612	736313612	736313612
7	3308745,143	679356000	679356000	679356000	679356000	676047254,9	676047254,9	676047255	676047254,9	1412360867	1412360867	1412360867	1412360867
8	3308745,143	646966894	646966894	646966894	646966894	643658148,9	643658148,9	643658149	643658148,9	2056019016	2056019016	2056019016	2056019016
9	3308745,143	616121977	616121977	616121977	616121977	612813231,9	612813231,9	612813232	612813231,9	2668832248	2668832248	2668832248	2668832248
10	708010996,8	586747628	586747628	586747628	586747628	-121263368,8	-121263368,8	-121263369	-121263369	2547568879	2547568879	2547568879	2547568879
11	3308745,143	558773736	315097972	351544833	371169321	555464990,9	311789226,9	348236088	367860575,9	3103033870	2859358106	2895804967	2915429455
12	3308745,143	532133533	300075301	338132360	358775482	528824787,9	296766555,9	334823615	355466736,9	3631858658	3156124662	3230628582	3270896192
13	3308745,143	506763434	285768854	325231612	346795491	503454688,9	282460108,9	321922867	343486745,9	4135313346	3438584770	3552551448	3614382937
14	3308745,143	482602884	272144483	312823066	335215527	479294138,9	268835737,9	309514321	331906781,9	4614607485	3707420508	3862065769	3946289719
15	3308745,143	459594217	259169671	300887942	324022233	456285471,9	255860925,9	297579197	320713487,9	5070892957	3963281434	4159644966	4267003207
16	3308745,143	437682515	246813448	289408179	313202699	434373769,9	243504702,9	286099434	309893953,9	5505266727	4206786137	4445744400	4576897161
17	3308745,143	416815480	235046323	278366402	302744443	413506734,9	231737577,9	275057657	299435697,9	5918773462	4438523715	4720802057	4876332859
18	3308745,143	396943306	223840210	267745902	292635403	393634560,9	220531464,9	264437157	289326657,9	6312408023	4659055180	4985239214	5165659517
19	3308745,143	378018561	213168362	257530606	282863916	374709815,9	209859616,9	254221861	279555170,9	6687117839	4868914797	5239461075	5445214688
20	435934796,8	359996076	203005306	247705053	273418713	-75938720,8	-232929490,8	-188229744	-162516084	6611179118	4635985306	5051231331	5282698604
21	3308745,143	342832835	193326787	238254374	264288898	339524089,9	190018041,9	234945629	260980152,9	6950703208	4826003348	5286176960	5543678757
22	3308745,143	326487871	184109702	229164266	255463939	323179125,9	180800956,9	225855521	252155193,9	7273882333	5006804304	5512032480	5795833950
23	3308745,143	310922173	175332053	220420973	246933657	307613427,9	172023307,9	217112228	243624911,9	7581495761	5178827612	5729144708	6039458862
24	3308745,143	296098589	166972888	212011262	238688213	292789843,9	163664142,9	208702517	235379467,9	7874285605	5342491755	5937847225	6274838330
25	3308745,143	281981736	159012257	203922406	230718096	278672990,9	155703511,9	200613661	227409350,9	8152958596	5498195267	6138460886	6502247681
26	3308745,143	268537921	151431158	196142164	223014111	265229175,9	148122412,9	192833419	219705365,9	8418187772	5646317680	6331294305	6721953047
27	3308745,143	255735056	144211498	188658762	215567372	252426310,9	140902752,9	185350017	212258626,9	8670614083	5787220433	6516644322	6934211674
28	3308745,143	243542583	137336043	181460873	208369290	240233837,9	134027297,9	178152128	205060544,9	8910847921	5921247731	6694796450	7139272219
29	3308745,143	231931400	130788384	174537605	201411562	228622654,9	127479638,9	171228860	198102816,9	9139470575	6048727369	6866025309	7337375035
30	3308745,143	220873795	124552892	167878480	194686161	217565049,9	121244146,9	164569735	191377415,9	9357035625	6169971516	7030595044	7528752451
31	4761600	0	0	0	0	-4761600	-4761600	-4761600	-4761600	9352274025	6165209916	7025833444	7523990851

Table 63 Payback table for 4800 MW PV PP with land cost

PV Payback and Revenue Check (4800 MW) with Land Cost															
Time (years	Investment ($)	Land Cost ($)	Inv. w L ($)	Revenue r=5% ($)				Profit ($)				Cumulative Profit ($)			
				Opt 1	Opt 2 no inf	Opt 2 1% inf	Opt 2 1.5% inf	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt 2 1.5%in	Opt 1	Opt 2 no inf	Opt 2 1%inf	Opt2 1.5%inf
0	4345862777	363528000	4709390777	0	0	0	0	-4709390777	-4709390777	-4709390777	-4709390777	-4709390777	-4709390777	-4709390777	-4709390777
1	3308745,143	346217143	349525888,1	965510569	965510569	965510569	965510569	615984680,9	615984680,9	615984680,9	615984680,9	-4093406096	-4093406096	-4093406096	-4093406096
2	3308745,143	329730612	333039357,1	919478703	919478703	919478703	919478703	586439345,9	586439345,9	586439345,9	586439345,9	-3506966750	-3506966750	-3506966750	-3506966750
3	3308745,143	314029154	317337899,1	875641461	875641461	875641461	875641461	558303561,9	558303561,9	558303561,9	558303561,9	-2948663189	-2948663189	-2948663189	-2948663189
4	3308745,143	299075385	302384130,1	833894212	833894212	833894212	833894212	531510081,9	531510081,9	531510081,9	531510081,9	-2417153107	-2417153107	-2417153107	-2417153107
5	3308745,143	284833700	288142445,1	794137313	794137313	794137313	794137313	505994867,9	505994867,9	505994867,9	505994867,9	-1911158239	-1911158239	-1911158239	-1911158239
6	3308745,143	271270191	274578936,1	713366602	713366602	713366602	713366602	438787665,9	438787665,9	438787665,9	438787665,9	-1472370573	-1472370573	-1472370573	-1472370573
7	3308745,143	258352563	261661308,1	679356000	679356000	679356000	679356000	417694691,9	417694691,9	417694691,9	417694691,9	-1054675881	-1054675881	-1054675881	-1054675881
8	3308745,143	246050060	249358805,1	646966894	646966894	646966894	646966894	397608088,9	397608088,9	397608088,9	397608088,9	-657067792	-657067792	-657067792	-657067792,3
9	3308745,143	234333390	237642135,1	616121977	616121977	616121977	616121977	378479841,9	378479841,9	378479841,9	378479841,9	-278587950	-278587950	-278587950	-278587950,4
10	708010996,8	223174657	931185653,8	586747628	586747628	586747628	586747628	-344438025,8	-344438025,8	-344438026	-344438026	-623025976	-623025976	-623025976	-623025976,2
11	3308745,143	212547293	215856038,1	558773736	315097972	351544833	371169321	342917697,9	99241933,86	135688794,9	155313282,9	-280108278	-523784042	-487337181	-467712693,3
12	3308745,143	202425993	205734738,1	532133533	300075301	338132360	358775482	326398794,9	94340562,86	132397621,9	153040743,9	46290516,5	-429443479	-354939559	-314671949,5
13	3308745,143	192786660	196095405,1	506763434	285768854	325231612	346795491	310668028,9	89673448,86	129136206,9	150700085,9	356958545	-339770031	-225803353	-163971863,6
14	3308745,143	183606343	186915088,1	482602884	272144483	312823066	335215527	295687795,9	85229394,86	125907977,9	148300438,9	652646341	-254540636	-99895374,8	-15671424,75
15	3308745,143	174863184	178171929,1	459594217	259169671	300887942	324022233	281422287,9	80997741,86	122716012,9	145850303,9	934068629	-173542894	22820638,1	130178879,1
16	3308745,143	166536365	169845110,1	437682515	246813448	289408179	313202699	267837404,9	76968337,86	119563068,9	143357588,9	1201906034	-96574556	142383707	273536468
17	3308745,143	158606062	161914807,1	416815480	235046323	278366402	302744443	254900672,9	73131515,86	116451594,9	140829635,9	1456806707	-23443040,2	258835301,8	414366103,8
18	3308745,143	151053393	154362138,1	396943306	223840210	267745902	292635403	242581167,9	69478071,86	113383763,9	138273264,9	1699387875	46035031,67	372219065,7	552639368,7
19	3308745,143	143860374	147169119,1	378018561	213168362	257530606	282863916	230849441,9	65999242,86	110361486,9	135694796,9	1930237317	112034274,5	482580552,5	688334165,5
20	435934796,8	137009880	572944676,8	359996076	203005306	247705053	273418713	-212948600,8	-369939370,8	-325239624	-299525964	1717288716	-257905096	157340928,7	388808201,7
21	3308745,143	130485600	133794345,1	342832835	193326787	238254374	264288898	209038489,9	59532441,86	104460028,9	130494552,9	1926327206	-198372654	261800957,6	519302754,6
22	3308745,143	124272000	127580745,1	326487871	184109702	229164266	255463939	198907125,9	56528956,86	101583520,9	127883193,9	2125234331	-141843698	363384478,4	647185948,4
23	3308745,143	118354286	121663031,1	310922173	175332053	220420973	246933657	189259141,9	53669021,86	98757941,86	125270625,9	2314493473	-88174675,7	462142420,3	772456574,3
24	3308745,143	112718367	116027112,1	296098589	166972888	212011262	238688213	180071476,9	50945775,86	95984149,86	122661100,9	2494564950	-37228899,8	558126570,2	895117675,2
25	3308745,143	107350826	110659571,1	281981736	159012257	203922406	230718096	171322164,9	48352685,86	93262834,86	120058524,9	2665887115	11123786,02	651389405	1015176200
26	3308745,143	102238882	105547627,1	268537921	151431158	196142164	223014111	162990293,9	45883530,86	90594536,86	117466483,9	2828877409	57007316,87	741983941,9	1132642684
27	3308745,143	97370364	100679109,1	255735056	144211498	188658762	215567372	155055946,9	43532388,86	87979652,86	114888262,9	2983933356	100539705,7	829963594,7	1247530947
28	3308745,143	92733680	96042425,14	243542583	137336043	181460873	208369290	147500157,9	41293617,86	85418447,86	112326864,9	3131433514	141833323,6	915382042,6	1359857812
29	3308745,143	88317790	91626535,14	231931400	130788384	174537605	201411562	140304864,9	39161848,86	82911069,86	109785026,9	3271738378	180995172,4	998293112,4	1469642838
30	3308745,143	84112181	87420926,14	220873795	124552892	167878480	194686161	133452868,9	37131965,86	80457553,86	107265234,9	3405191247	218127138,3	1078750666	1576908073
31	4761600		4761600	0	0	0	0	-4761600	-4761600	-4761600	-4761600	3400429647	213365538,3	1073989066	1572146473

Then, the payback times for 4800 MW PV PP for different options are given in Table 64.

Table 64 Payback times of 4800 MW PV PP for different options

	Opt 1 (years)	Opt 2 (years)		
		w/o inf.	w 1% inf.	w 1.5% inf.
Pay Back Time with 5% discount rate with land cost	11.86	24.77	14.81	14.10
Pay Back Time with 5% discount rate w/o land cost	4.97 (for all options)			

Moreover, cumulative revenue of the system is found as 14.94, 11.75, 12.61 and 13.11 billion $ respectively for option 1 and different verisons of option 2.

- ***When 4800 MW NUKE investment work out the cost and how much does it reap a profit?***

The intergovernmental aggrement between the Republic of Turkey as a host of the Project and Russian Federation as an contractor of the Project adresses that the 70% of the output of the first two units and 30% of that from units 3 & 4 of the NUKE PP in Mersin is guaranteed to be purchased with 12.35 $ cents per kWh during 15 years by TETAS which is Turkish Electricity Trading and Contracting Corporation. The remaining amount of the electiricity can be sold in open electricity market.

Therefore the formula is derived as 70% of the electricity from the first two reactors is sold with 12.35 $ cents, 30% of it is with 7.5 $ cents for contant price option; 30% of the electricity from the third and fourth reactors are sold with 12.35 $ cents and remaining is with 7.5 $ cents for the first 15 years. As of sixteenth year the electricity is sold to day ahead electricity market with three options such as contant 7.5 $ per kWh price, increasing price with 1% inflation rate and increasing price with 1.5% inflation rate.

Multiplying electricity production of NUKE PP with related prices, Table 65 is brought about.

Table 65 Money income via electricity production by NUKE

Time (years)	Electricity Production (kWh)	Revenue with 5% discount ($ cents)			Time (years)	Electricity Production (kWh)	Revenue with 5% discount ($ cents)		
		With no inflation rate	With 1% inflation	With 1.5% inflation			With no inflation rate	With 1% inflation	With 1.5% inflation
12	8.424 E+9	5.111E+10	5.244E+10	5.317E+10	24	3.370E+10	1.037E+11	1.202E+11	1.239E+11
13	1.685E+10	9.735E+10	1.001E+11	1.016E+11	25	3.370E+10	9.876E+10	1.147E+11	1.185E+11
14	2.5272E+10	1.308E+11	1.434E+11	1.457E+11	26	3.370E+10	9.406E+10	1.095E+11	1.133E+11
15	3.370E+10	1.609E+11	1.825E+11	1.857E+11	27	3.370E+10	6.769E+10	1.046E+11	1.084E+11
16	3.370E+10	1.532E+11	1.742E+11	1.775E+11	28	3.370E+10	6.447E+10	8.518E+10	9.781E+10
17	3.370E+10	1.459E+11	1.663E+11	1.697E+11	29	3.370E+10	6.140 E+10	8.194E+10	9.455E+10
18	3.370E+10	1.390E+11	1.587E+11	1.622E+11	30	3.370E+10	5.847 E+10	7.881E+10	9.140E+10
19	3.370E+10	1.323E+11	1.515E+11	1.551E+11	31	3.370E+10	5.569E+10	7.581E+10	8.835E+10
20	3.370E+10	1.260E+11	1.447E+11	1.483E+11	32	3.370E+10	5.304E+10	7.292E+10	8.541E+10
21	3.370E+10	1.200E+11	1.381E+11	1.418E+11	33	3.370E+10	5.051E+10	7.015E+10	8.256E+10
22	3.370E+10	1.143E+11	1.318E+11	1.355E+11	34	3.370E+10	4.811E+10	6.747E+10	7.981E+10
23	3.370E+10	1.089E+11	1.259E+11	1.296E+11	35	3.370E+10	4.582E+10	6.490E+10	7.715E+10

Table 65(continued)

Time (years)	Electricity Production (kWh)	Revenue with 5% discount ($ cents)			Time (years)	Electricity Production (kWh)	Revenue with 5% discount ($ cents)		
		With no inflation rate	With 1% inflation	With 1.5% inflation			With no inflation rate	With 1% inflation	With 1.5% inflation
36	3.370E+10	4.363E+10	6.243E+10	7.458E+10	48	3.370E+10	2.430E+10	3.917E+10	4.965E+10
37	3.370E+10	4.156E+10	6.005E+10	7.209E+10	49	3.370E+10	2.314E+10	3.768E+10	4.780E+10
38	3.370E+10	3.958E+10	5.776E+10	6.969E+10	50	3.370E+10	2.204E+10	3.624E+10	4.640E+10
39	3.370E+10	3.769E+10	5.556E+10	6.736E+10	51	3.370E+10	2.099E+10	3.486E+10	4.485E+10
40	3.370E+10	3.590E+10	5.345E+10	6.512E+10	52	3.370E+10	1.999E+10	3.354E+10	4.335E+10
41	3.370E+10	3.419E+10	5.141E+10	6.295E+10	53	3.370E+10	1.904E+10	3.226E+10	4.191E+10
42	3.370E+10	3.256E+10	4.945E+10	6.085E+10	54	3.370E+10	1.813E+10	3.103E+10	4.051E+10
43	3.370E+10	3.101E+10	4.757E+10	5.882E+10	55	3.370E+10	1.727E+10	2.985E+10	3.916E+10
44	3.370E+10	2.953E+10	4.576E+10	5.686E+10	56	3.370E+10	1.645E+10	2.871E+10	3.786E+10
45	3.370E+10	2.813E+10	4.401E+10	5.497E+10	57	3.370E+10	1.566E+10	2.762E+10	3.660E+10
46	3.370E+10	2.679E+10	4.234E+10	5.313E+10	58	3.370E+10	1.492E+10	2.656E+10	3.537E+10
47	3.370E+10	2.551E+10	4.072E+10	5.136E+10	59	3.370E+10	1.421E+10	2.555E+10	3.420E+10

Table 65(continued)

Time (years)	Electricity Production (kWh)	Revenue with 5% discount ($ cents)			Time (years)	Electricity Production (kWh)	Revenue with 5% discount ($ cents)		
		With no inflation rate	With 1% inflation	With 1.5% inflation			With no inflation rate	With 1% inflation	With 1.5% inflation
60	3.370E+10	1.353E+10	2.458E+10	3.306E+10	68	3.370E+10	9.157E+9	1.801E+10	2.520E+10
61	3.370E+10	1.289E+10	2.364E+10	3.195E+10	69	2.527E+10	8.721E+9	1.733E+10	2.436E+10
62	3.370E+10	1.227E+10	2.274E+10	3.089E+10	70	1.685E+10	8.306E+9	1.667E+10	2.355E+10
63	3.370E+10	1.169E+10	2.188E+10	2.986E+10	71	8.424E+9	7.910E+9	1.603E+10	2.277E+10
64	3.370E+10	1.113E+10	2.104E+10	2.886E+10	72		5.650E+9	1.157E+10	1.651E+10
65	3.370E+10	1.060E+10	2.024E+10	2.790E+10	73		3.587E+9	7.417E+9	1.064E+10
66	3.370E+10	1.010E+10	1.947E+10	2.697E+10	74		1.708E+9	3.567E+9	5.141E+9
67	3.370E+10	9.615E+9	1.873E+10	2.607E+10					
Total ($cents)	**3.0506E+12**	**3.9723E+12**	**4.4765E+12**			**Total (billion $)**	**30.506**	**39.723**	**44.765**

Owing to have income and expenditure costs of 4800 MW NUKE PP, payback time is calculated as follows:

Table 66 Payback table of 4800 MW NUKE PP without land cost

NUKE Payback and Revenue Check (4800 MW)

Time (yrs)	Investment ($)	Revenue w no interest rate ($)	Revenue w 1% int rate	Revenue w 1.5% int rate	Profit w no int rate ($)	Profit w 1% int rate ($)	Profit w 1.5% int rate ($)	Cumulative Profit ($)		
0	22725000000	0	0	0	-22725000000	-2.2725E+10	-2.2725E+10	-22725000000	-22725000000	-2.2725E+10
1		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
2		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
3		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
4		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
5		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
6		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
7		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
8		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
9		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
10		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
11		0	0	0	0	0	0	-22725000000	-22725000000	-2.2725E+10
12	36653225.81	511062486.8	524447976	531708608.5	474409261	487794751	495055382.7	-22250590739	-22237205249	-2.223E+10
13	73306451.61	973452355.9	1001213830	1016383704	900145904.3	927907379	943077252.8	-21350444835	-21309297870	-2.1287E+10
14	109959677.4	1308105189	1433573982	1457204554	1198145512	1323614305	1347244877	-20152299323	-19985683566	-1.994E+10
15	146612903.2	1608678950	1824603399	1857156578	1462066046	1677990496	1710543675	-18690233276	-18307693070	-1.8229E+10

Table 66 (continued)

Time (yrs)	Investment ($)	Revenue w no interest rate ($)	Revenue w 1% int rate	Revenue w 1.5% int rate	Profit w no int rate ($)	Profit w 1% int rate ($)	Profit w 1.5% int rate ($)	Cumulative Profit ($)		
16	146612903.2	1532075190	1741749822	1775234044	1385462287	1595136919	1628621141	-17304770989	-16712556151	-1.66E+10
17	146612903.2	1459119229	1662688041	1696995466	1312506325	1516075138	1550382563	-15992264664	-15196481013	-1.505E+10
18	146612903.2	1389637361	1587243348	1622272656	1243024457	1440630445	1475659753	-14749240206	-13755850568	-1.3574E+10
19	146612903.2	1323464153	1515249129	1550905192	1176851250	1368636225	1404292288	-13572388957	-12387214343	-1.217E+10
20	146612903.2	1260442050	1446546489	1482740057	1113829147	1299933586	1336127154	-12458559809	-11087280756	-1.0834E+10
21	146612903.2	1200421000	1380983896	1417631299	1053808097	1234370993	1271018396	-11404751712	-9852909763	-9562977518
22	146612903.2	1143258096	1318416834	1355439694	996645192.4	1171803931	1208826790	-10408106520	-8681105833	-8354150728
23	146612903.2	1088817234	1258707476	1296032439	942204330.7	1112094573	1149419535	-9465902189	-7569011260	-7204731192
24	146612903.2	1036968794	1201724377	1239282851	890355891	1055111474	1092669947	-8575546298	-6513899786	-6112061245
25	146612903.2	987589327.9	1147342174	1185070083	840976424.6	1000729271	1038457179	-7734569873	-5513170515	-5073604065
26	146612903.2	940561264.6	1095441305	1133278852	793948361.4	948828401	986665948.4	-6940621512	-4564342113	-4086938117
27	146612903.2	676906271.8	1045907734	1083799180	530293368.6	899294831	937186277.3	-6410328143	-3665047282	-3149751840
28	146612903.2	644672639.8	851800136	978111628	498059736.6	705187232	831498724.8	-5912268407	-2959860050	-2318253115
29	146612903.2	613973942.7	819350607	945507907.1	467361039.4	672737703	798895003.8	-5444907367	-2287122347	-1519358111
30	146612903.2	584737088.2	788137250	913990976.8	438124185	641524347	767378073.6	-5006783182	-1645598000	-751980037
31	146612903.2	556892465	758112974	883524610.9	410279561.8	611500071	736911707.7	-4596503621	-1034097929	-15068329.8
32	146612903.2	530373776.2	729232480	854073790.6	383760873	582619576	707460887.3	-4212742748	-451478352.6	692392557.5
33	146612903.2	505117882.1	701452195	825604664.2	358504978.9	554839292	678991761	-3854237769	103360938.9	1371384319
34	146612903.2	481064649.6	674730206	798084508.7	334451746.4	528117303	651471605.5	-3519786022	631478242.1	2022855924
35	146612903.2	458156809.1	649026199	771481691.8	311543905.9	502413295	624868788.6	-3208242116	1133891537	2647724713
36	146612903.2	436339818.2	624301391	745765635.4	289726915	477688488	599152732.2	-2918515201	1611580025	3246877445
37	146612903.2	415561731.6	600518481	720906780.9	268948828.4	453905578	574293877.6	-2649566373	2065485603	3821171322

Table 66 (continued)

Time (yrs)	Investment ($)	Revenue w no interest rate ($)	Revenue w 1% int rate	Revenue w 1.5% int rate	Profit w no int rate ($)	Profit w 1% int rate ($)	Profit w 1.5% int rate ($)	Cumulative Profit ($)		
38	146612903.2	395773077.8	577641586	696876554.8	249160174.5	431028683	550263651.6	-2400406199	2496514286	4371434974
39	146612903.2	376926740.7	555636193	673647336.3	230313837.5	409023289	527034433.1	-2170092361	2905537575	4898469407
40	146612903.2	358977848.3	534469100	651192425.1	212364945.1	387856196	504579521.9	-1957727416	3293393771	5403048929
41	146612903.2	341883665.1	514108372	629486011	195270761.8	367495469	482873107.7	-1762456654	3660889240	5885922037
42	146612903.2	325603490.5	494523291	608503143.9	178990587.3	347910388	461890240.7	-1583466067	4008799628	6347812277
43	146612903.2	310098562.4	475684309	588219705.8	163485659.2	329071405	441606802.6	-1419980408	4337871033	6789419080
44	146612903.2	295331964.2	457563002	568612382.3	148719061	310950098	421999479.1	-1271261347	4648821132	7211418559
45	146612903.2	281268537.3	440132030	549658636.2	134655634.1	293519127	403045733	-1136605713	4942340258	7614464292
46	146612903.2	267874797.5	423365096	531336681.7	121261894.2	276752192	384723778.4	-1015343818	5219092451	7999188071
47	146612903.2	255118854.7	407236901	513625458.9	108505951.5	260623998	367012555.7	-906837866.8	5479716449	8366200626
48	146612903.2	242970337.8	391723115	496504610.3	96357434.61	245110212	349891707.1	-810480432.2	5724826661	8716092333
49	146612903.2	231400321.7	376800329	479954456.6	84787418.52	230187426	333341553.4	-725693013.7	5955014087	9049433887
50	146612903.2	220381258.8	362446031	463955974.7	73768355.58	215833128	317343071.5	-651924658.1	6170847215	9366776958
51	146612903.2	209886913.1	348638563	448490775.6	63274009.92	202025660	301877872.4	-588650648.2	6372872875	9668654831
52	146612903.2	199892298.2	335357094	433541083.1	53279395.01	188744191	286928179.8	-535371253.2	6561617066	9955583010
53	146612903.2	190373617.4	322581586	419089713.6	43760714.14	175968683	272476810.4	-491610539	6737585749	10228059821
54	146612903.2	181308207	310292764	405120056.5	34695303.79	163679860	258507153.3	-456915235.2	6901265609	10486566974
55	146612903.2	172674482.9	298472087	391616054.6	26061579.65	151859184	245003151.4	-430853655.6	7053124793	10731570126
56	146612903.2	164451888.5	287101722	378562186.1	17838985.22	140488818	231949282.9	-413014670.4	7193613611	10963519408
57	146612903.2	156620846.1	276164513	365943446.6	10007942.92	129551610	219330543.4	-403006727.5	7323165221	11182849952
58	146612903.2	149162710.6	265643960	353745331.7	2549807.387	119031057	207132428.5	-400456920.1	7442196278	11389982380
59	146612903.2	142059724.4	255524190	341953820.7	-4553178.833	108911287	195340917.4	-405010098.9	7551107565	11585323298
60	146612903.2	135294975.6	245789936	330555360	-11317927.61	99177032.3	183942456.7	-416328026.5	7650284597	11769265754
61	146612903.2	128852357.7	236426509	319536848	-17760545.5	89813606.2	172923944.7	-434088572	7740098204	11942189699

Table 66 (continued)

Time (yrs)	Investment ($)	Revenue w no interest rate ($)	Revenue w 1% int rate	Revenue w 1.5% int rate	Profit w no int rate ($)	Profit w 1% int rate ($)	Profit w 1.5% int rate ($)	Cumulative Profit ($)		
62	146612903.2	122716531.2	227419785	308885619.7	-23896372.06	80806882	162272716.5	-457984944.1	7820905086	12104462416
63	146612903.2	116872886.8	218756174	298589432.4	-29740016.4	72143271.2	151976529.2	-487724960.5	7893048357	12256438945
64	146612903.2	111307511.3	210422606	288636451.3	-35305391.96	63809702.6	142023548.1	-523030352.4	7956858059	12398462493
65	146612903.2	106007153.6	202406507	279015236.3	-40605749.64	55793603.3	132402333	-563636102.1	8012651663	12530864826
66	146612903.2	100959193.9	194695783	269714728.4	-45653709.34	48082879.3	123101825.2	-609289811.4	8060734542	12653966651
67	146612903.2	96151613.23	187278800	260724237.4	-50461290	40665897.1	114111334.2	-659751101.4	8101400439	12768077985
68	146612903.2	91572964.98	180144370	252033429.5	-55039938.25	33531466.6	105420526.3	-714791039.7	8134931906	12873498512
69	146612903.2	87212347.6	173281727	243632315.2	-59400555.63	26668823.9	97019411.98	-774191595.3	8161600730	12970517924
70	146612903.2	83059378.67	166680519	235511238	-63553524.56	20067615.3	88898334.8	-837745119.8	8181668345	13059416258
71	146612903.2	79104170.16	160330784	227660863.4	-67508733.07	13717881.2	81047960.2	-905253852.9	8195386226	13140464219
72	109959677.4	56502978.68	115667209	165054126	-53456698.74	5707531.38	55094448.57	-958710551.6	8201093758	13195558667
73	73306451.61	35874907.1	74173892.6	106368214.5	-37431544.51	867441.012	33061762.91	-996142096.2	8201961199	13228620430
74	36653225.81	17083289.1	35674110.3	51411303.69	-19569936.71	-979115.544	14758077.88	-1015712033	8200982083	13243378508
75	87780433				-87780433	-87780433	-87780433	-1103492466	8113201650	13155598075

Table 67 Payback table of 4800 MW NUKE PP with land cost

NUKE Payback and Revenue Check (4800 MW) w Land Cost

Time (years)	Investment ($)	Landcost ($)	Inv. w L ($)	Revenue no inf	Revenue1% inf	Revenue 1.5% inf	Profit (no inf)	Profit (1%inf)	Profit (1.5% inf)	Cumulative Profit ($)		
0	2.3E+10	0	2.27E+10	0	0	0	-2.3E+10	-2.27E+10	-2.3E+10	-2.27E+10	-2.27E+10	-2.27E+10
1	0	5E+06	5027750	0	0	0	-5027750	-5027750	-5027750	-2.27E+10	-2.27E+10	-2.27E+10
2	0	5E+06	4788333	0	0	0	-4788333	-4788333	-4788333	-2.27E+10	-2.27E+10	-2.27E+10
3	0	5E+06	4560317	0	0	0	-4560317	-4560317	-4560317	-2.27E+10	-2.27E+10	-2.27E+10
4	0	4E+06	4343159	0	0	0	-4343159	-4343159	-4343159	-2.27E+10	-2.27E+10	-2.27E+10
5	0	4E+06	4136342	0	0	0	-4136342	-4136342	-4136342	-2.27E+10	-2.27E+10	-2.27E+10
6	0	4E+06	3939374	0	0	0	-3939374	-3939374	-3939374	-2.28E+10	-2.28E+10	-2.28E+10
7	0	4E+06	3751784	0	0	0	-3751784	-3751784	-3751784	-2.28E+10	-2.28E+10	-2.28E+10
8	0	4E+06	3573128	0	0	0	-3573128	-3573128	-3573128	-2.28E+10	-2.28E+10	-2.28E+10
9	0	3E+06	3402979	0	0	0	-3402979	-3402979	-3402979	-2.28E+10	-2.28E+10	-2.28E+10
10	0	3E+06	3240932	0	0	0	-3240932	-3240932	-3240932	-2.28E+10	-2.28E+10	-2.28E+10
11	0	3E+06	3086602	0	0	0	-3086602	-3086602	-3086602	-2.28E+10	-2.28E+10	-2.28E+10
12	3.7E+07	3E+06	39754137	5.11E+08	5.2E+08	531708609	4.71E+08	4.85E+08	4.92E+08	-2.23E+10	-2.23E+10	-2.23E+10
13	7.4E+07	3E+06	76428672	9.73E+08	1E+09	1.016E+09	8.97E+08	9.25E+08	9.4E+08	-2.14E+10	-2.14E+10	-2.13E+10
14	1.1E+08	3E+06	1.13E+08	1.31E+09	1.4E+09	1.457E+09	1.19E+09	1.32E+09	1.34E+09	-2.02E+10	-2E+10	-2E+10
15	1.5E+08	3E+06	1.5E+08	1.61E+09	1.8E+09	1.857E+09	1.46E+09	1.67E+09	1.71E+09	-1.87E+10	-1.84E+10	-1.83E+10
16	1.5E+08	2E+06	1.5E+08	1.53E+09	1.7E+09	1.775E+09	1.38E+09	1.59E+09	1.63E+09	-1.74E+10	-1.68E+10	-1.67E+10
17	1.5E+08	2E+06	1.5E+08	1.46E+09	1.7E+09	1.697E+09	1.31E+09	1.51E+09	1.55E+09	-1.61E+10	-1.53E+10	-1.51E+10
18	1.5E+08	2E+06	1.49E+08	1.39E+09	1.6E+09	1.622E+09	1.24E+09	1.44E+09	1.47E+09	-1.48E+10	-1.38E+10	-1.36E+10
19	1.5E+08	2E+06	1.49E+08	1.32E+09	1.5E+09	1.551E+09	1.17E+09	1.37E+09	1.4E+09	-1.36E+10	-1.25E+10	-1.22E+10
20	1.5E+08	2E+06	1.49E+08	1.26E+09	1.4E+09	1.483E+09	1.11E+09	1.3E+09	1.33E+09	-1.25E+10	-1.12E+10	-1.09E+10
21	1.5E+08	2E+06	1.49E+08	1.2E+09	1.4E+09	1.418E+09	1.05E+09	1.23E+09	1.27E+09	-1.15E+10	-9.93E+09	-9.64E+09

Table 67 (continued)

Time (years)	Investment ($)	Landcost ($)	Inv. w L ($)	Revenue no inf	Revenue1% inf	Revenue 1.5% inf	Profit (no inf)	Profit (1%inf)	Profit (1.5% inf)	Cumulative Profit ($)		
22	1.5E+08	2E+06	1.49E+08	1.14E+09	1.3E+09	1.355E+09	9.94E+08	1.17E+09	1.21E+09	-1.05E+10	-8.76E+09	-8.43E+09
23	1.5E+08	2E+06	1.49E+08	1.09E+09	1.3E+09	1.296E+09	9.4E+08	1.11E+09	1.15E+09	-9.54E+09	-7.65E+09	-7.28E+09
24	1.5E+08	2E+06	1.49E+08	1.04E+09	1.2E+09	1.239E+09	8.88E+08	1.05E+09	1.09E+09	-8.66E+09	-6.59E+09	-6.19E+09
25	1.5E+08	2E+06	1.49E+08	9.88E+08	1.1E+09	1.185E+09	8.39E+08	9.99E+08	1.04E+09	-7.82E+09	-5.6E+09	-5.16E+09
26	1.5E+08	1E+06	1.49E+08	9.41E+08	1.1E+09	1.133E+09	7.92E+08	9.47E+08	9.85E+08	-7.03E+09	-4.65E+09	-4.17E+09
27	1.5E+08	1E+06	1.49E+08	6.77E+08	1E+09	1.084E+09	5.28E+08	8.97E+08	9.35E+08	-6.5E+09	-3.75E+09	-3.24E+09
28	1.5E+08	1E+06	1.49E+08	6.45E+08	8.5E+08	978111628	4.96E+08	7.03E+08	8.3E+08	-6E+09	-3.05E+09	-2.41E+09
29	1.5E+08	1E+06	1.49E+08	6.14E+08	8.2E+08	945507907	4.65E+08	6.71E+08	7.97E+08	-5.54E+09	-2.38E+09	-1.61E+09
30	1.5E+08	1E+06	1.48E+08	5.85E+08	7.9E+08	913990977	4.36E+08	6.4E+08	7.66E+08	-5.1E+09	-1.74E+09	-8.44E+08
31	1.5E+08	1E+06	1.48E+08	5.57E+08	7.6E+08	883524611	4.08E+08	6.1E+08	7.35E+08	-4.69E+09	-1.13E+09	-1.09E+08
32	1.5E+08	1E+06	1.48E+08	5.3E+08	7.3E+08	854073791	3.82E+08	5.81E+08	7.06E+08	-4.31E+09	-5.47E+08	596387409
33	1.5E+08	1E+06	1.48E+08	5.05E+08	7E+08	825604664	3.57E+08	5.53E+08	6.77E+08	-3.95E+09	5655474.8	1.274E+09
34	1.5E+08	1E+06	1.48E+08	4.81E+08	6.7E+08	798084509	3.33E+08	5.26E+08	6.5E+08	-3.62E+09	532122708	1.924E+09
35	1.5E+08	1E+06	1.48E+08	4.58E+08	6.5E+08	771481692	3.1E+08	5.01E+08	6.23E+08	-3.31E+09	1.033E+09	2.547E+09
36	1.5E+08	9E+05	1.48E+08	4.36E+08	6.2E+08	745765635	2.88E+08	4.76E+08	5.98E+08	-3.02E+09	1.509E+09	3.144E+09
37	1.5E+08	9E+05	1.48E+08	4.16E+08	6E+08	720906781	2.67E+08	4.52E+08	5.73E+08	-2.75E+09	1.961E+09	3.717E+09
38	1.5E+08	8E+05	1.48E+08	3.96E+08	5.8E+08	696876555	2.48E+08	4.3E+08	5.49E+08	-2.51E+09	2.391E+09	4.266E+09
39	1.5E+08	8E+05	1.48E+08	3.77E+08	5.6E+08	673647336	2.29E+08	4.08E+08	5.26E+08	-2.28E+09	2.799E+09	4.792E+09
40	1.5E+08	7E+05	1.48E+08	3.59E+08	5.3E+08	651192425	2.11E+08	3.86E+08	5.03E+08	-2.07E+09	3.185E+09	5.295E+09
41	1.5E+08	7E+05	1.48E+08	3.42E+08	5.1E+08	629486011	1.94E+08	3.66E+08	4.82E+08	-1.87E+09	3.551E+09	5.776E+09
42	1.5E+08	7E+05	1.48E+08	3.26E+08	4.9E+08	608503144	1.78E+08	3.47E+08	4.61E+08	-1.69E+09	3.898E+09	6.237E+09
43	1.5E+08	6E+05	1.48E+08	3.1E+08	4.8E+08	588219706	1.62E+08	3.28E+08	4.4E+08	-1.53E+09	4.226E+09	6.677E+09
44	1.5E+08	6E+05	1.48E+08	2.95E+08	4.6E+08	568612382	1.47E+08	3.1E+08	4.21E+08	-1.38E+09	4.535E+09	7.098E+09
45	1.5E+08	6E+05	1.48E+08	2.81E+08	4.4E+08	549658636	1.33E+08	2.92E+08	4.02E+08	-1.25E+09	4.828E+09	7.5E+09
46	1.5E+08	6E+05	1.48E+08	2.68E+08	4.2E+08	531336682	1.2E+08	2.76E+08	3.84E+08	-1.13E+09	5.103E+09	7.883E+09

Table 67 (continued)

Time (years)	Investment ($)	Landcost ($)	Inv. w L ($)	Revenue no inf	Revenue1% inf	Revenue 1.5% inf	Profit (no inf)	Profit (1%inf)	Profit (1.5% inf)	Cumulative Profit ($)		
47	1.5E+08	5E+05	1.48E+08	2.55E+08	4.1E+08	513625459	1.07E+08	2.59E+08	3.66E+08	-1.02E+09	5.363E+09	8.249E+09
48	1.5E+08	5E+05	1.48E+08	2.43E+08	3.9E+08	496504610	95204726	2.44E+08	3.49E+08	-9.29E+08	5.606E+09	8.598E+09
49	1.5E+08	5E+05	1.48E+08	2.31E+08	3.8E+08	479954457	83658879	2.29E+08	3.32E+08	-8.45E+08	5.836E+09	8.93E+09
50	1.5E+08	5E+05	1.48E+08	2.2E+08	3.6E+08	463955975	72662834	2.15E+08	3.16E+08	-7.72E+08	6.05E+09	9.246E+09
51	1.5E+08	4E+05	1.48E+08	2.1E+08	3.5E+08	448490776	62190410	2.01E+08	3.01E+08	-7.1E+08	6.251E+09	9.547E+09
52	1.5E+08	4E+05	1.48E+08	2E+08	3.4E+08	433541083	52216673	1.88E+08	2.86E+08	-6.58E+08	6.439E+09	9.833E+09
53	1.5E+08	4E+05	1.48E+08	1.9E+08	3.2E+08	419089714	42717876	1.75E+08	2.71E+08	-6.15E+08	6.614E+09	1.01E+10
54	1.5E+08	4E+05	1.48E+08	1.81E+08	3.1E+08	405120057	33671403	1.63E+08	2.57E+08	-5.82E+08	6.776E+09	1.036E+10
55	1.5E+08	4E+05	1.48E+08	1.73E+08	3E+08	391616055	25055714	1.51E+08	2.44E+08	-5.57E+08	6.927E+09	1.061E+10
56	1.5E+08	3E+05	1.48E+08	1.64E+08	2.9E+08	378562186	16850296	1.4E+08	2.31E+08	-5.4E+08	7.067E+09	1.084E+10
57	1.5E+08	3E+05	1.48E+08	1.57E+08	2.8E+08	365943447	9035612	1.29E+08	2.18E+08	-5.31E+08	7.195E+09	1.106E+10
58	1.5E+08	3E+05	1.48E+08	1.49E+08	2.7E+08	353745332	1593056	1.18E+08	2.06E+08	-5.29E+08	7.313E+09	1.126E+10
59	1.5E+08	3E+05	1.48E+08	1.42E+08	2.6E+08	341953821	-5495093	1.08E+08	1.94E+08	-5.35E+08	7.421E+09	1.146E+10
60	1.5E+08	3E+05	1.48E+08	1.35E+08	2.5E+08	330555360	-1.2E+07	98249250	1.83E+08	-5.47E+08	7.52E+09	1.164E+10
61	1.5E+08	3E+05	1.48E+08	1.29E+08	2.4E+08	319536848	-1.9E+07	88899282	1.72E+08	-5.66E+08	7.609E+09	1.181E+10
62	1.5E+08	3E+05	1.48E+08	1.23E+08	2.3E+08	308885620	-2.5E+07	79905375	1.61E+08	-5.9E+08	7.689E+09	1.197E+10
63	1.5E+08	2E+05	1.48E+08	1.17E+08	2.2E+08	298589432	-3.1E+07	71253971	1.51E+08	-6.21E+08	7.76E+09	1.212E+10
64	1.5E+08	2E+05	1.47E+08	1.11E+08	2.1E+08	288636451	-3.6E+07	62932028	1.41E+08	-6.57E+08	7.823E+09	1.226E+10
65	1.5E+08	2E+05	1.47E+08	1.06E+08	2E+08	279015236	-4.1E+07	54927001	1.32E+08	-6.99E+08	7.878E+09	1.24E+10
66	1.5E+08	2E+05	1.47E+08	1.01E+08	1.9E+08	269714728	-4.7E+07	47226822	1.22E+08	-7.45E+08	7.925E+09	1.252E+10
67	1.5E+08	2E+05	1.47E+08	96151613	1.9E+08	260724237	-5.1E+07	39819882	1.13E+08	-7.96E+08	7.965E+09	1.263E+10
68	1.5E+08	2E+05	1.47E+08	91572965	1.8E+08	252033430	-5.6E+07	32695016	1.05E+08	-8.52E+08	7.997E+09	1.274E+10
69	1.5E+08	2E+05	1.47E+08	87212348	1.7E+08	243632315	-6E+07	25841482	96192070	-9.13E+08	8.023E+09	1.283E+10
70	1.5E+08	2E+05	1.47E+08	83059379	1.7E+08	235511238	-6.4E+07	19248949	88079668	-9.77E+08	8.042E+09	1.292E+10
71	1.5E+08	2E+05	1.47E+08	79104170	1.6E+08	227660863	-6.8E+07	12907477	80237556	-1.05E+09	8.055E+09	1.3E+10

Table 67 (continued)

Time (years)	Investment ($)	Landcost ($)	Inv. w L ($)	Revenue no inf	Revenue1% inf	Revenue 1.5% inf	Profit (no inf)	Profit (1%inf)	Profit (1.5% inf)	Cumulative Profit ($)		
72	1.1E+08	2E+05	1.11E+08	56502979	1.2E+08	165054126	-5.4E+07	5066286	54453203	-1.1E+09	8.06E+09	1.305E+10
73	7.4E+07	1E+05	73778912	35874907	7.4E+07	106368215	-3.8E+07	394980.2	32589302	-1.14E+09	8.061E+09	1.309E+10
74	3.7E+07	1E+05	36957259	17083289	3.6E+07	51411304	-2E+07	-1283149	14454045	-1.16E+09	8.06E+09	1.31E+10
75	8.8E+07	1E+05	87916379	0			-8.8E+07	-87916379	-8.8E+07	-1.25E+09	7.972E+09	1.301E+10

Then, the payback times of 4800 MW NUKE PP for different options are shown in Table 68.

Table 68 Payback times for NUKE

	Cost with land cost	**Cost w/o land cost**
Payback time with 5% discount rate w/o inflation rate	No payback	No payback
Payback time with 1% inflation rate	32.50 years	32.45 years
Payback time with 1.5 inflation rate	31.20 years	31.15 years

CHAPTER 3

OUTCOMES AND RESULTS

The eligibility comparison of PV and NUKE for Turkey within the context of determined circumstances is given in Table 69.

Table 69 Final comparison table

Technology	**PV**	**NUKE**	**Comments, Explanations, Units**
Installed Power	4800 MW	4800 MW	PV has 4800 PPs each having 1 MW installed power
			NUKE has 1 PP with 4 units
Project Duration	31 years	101 years	PV, construction and decommissioning will be completed in a year
			NUKE, 4 years preparation + 7 years construction + 60 years operation + 30 years decommissioning
Lifetime	30	60	years
Total Cost with land cost	10.91	32.06	Billion $
Total Cost without land cost	5.63	31.91	Billion $
Electricity Production	215.51	1920.67	TWh
NPV of Electricity Production	110.45	347.36	TWh

Table 69 (continued)

<table>
<tr><th>Technology</th><th colspan="3">PV</th><th colspan="3">NUKE</th><th>Comments, Explanations, Units</th></tr>
<tr><td>LCOE with land cost</td><td colspan="3">98.74</td><td colspan="3">92.30</td><td>$/MWh</td></tr>
<tr><td>LCOE w/o land cost</td><td colspan="3">51.02</td><td colspan="3">92</td><td>$/MWh</td></tr>
<tr><td>Total Area Needed</td><td colspan="3">48.47</td><td colspan="3">11.83</td><td>km^2</td></tr>
<tr><td>CO_2 reduction potential</td><td colspan="3">0.6031</td><td colspan="3">0.5459</td><td>t CO_2/MWh</td></tr>
<tr><td>Cumulative CO_2 reduction</td><td colspan="3">129,975,055</td><td colspan="3">1,048,482,824</td><td>t CO_2</td></tr>
<tr><td rowspan="2">Revenue</td><td colspan="3">14.94</td><td rowspan="2">30.50</td><td rowspan="2">39.72</td><td rowspan="2">44.77</td><td rowspan="2">PV: with 2 options and 3 electricity price versions;
Both: Billion $, price with 5% discount rate</td></tr>
<tr><td>11.75</td><td>12.61</td><td>13.11</td></tr>
<tr><td rowspan="2">Payback (with land cost)</td><td colspan="3">11.86</td><td rowspan="2">No payback</td><td rowspan="2">32.50</td><td rowspan="2">31.20</td><td rowspan="2">PV: with 2 options and 3 electricity price versions;
Both: Years, with 5% discount rate</td></tr>
<tr><td>24.77</td><td>14.81</td><td>14.10</td></tr>
<tr><td>Payback (without land cost)</td><td colspan="3">4.97</td><td>No payback</td><td>32.45</td><td>31.15</td><td>PV: with 2 options and 3 electricity price versions;
Both: Years, with 5% discount rate</td></tr>
</table>

Table 70 Material use comparison of the options, namely PV and NUKE

NUKE					
Used Material	**Unit**	**Amount**	**Used Material**	**Unit**	**Amount**
Uranium fuel sticks	unit	50,586	Wastewater consumption	m^3/days	1,881
Uranium dioxide	kg	5,382,000	Freshwater requirement	m^3/hours	507
Cooling water use	m^3/hours	880,000	Tap water requirement	m^3/days	92
Drinking and using water use		450	Domestic solid waste	kg/day	10,738
Industrial water use		342	CO_2 (fossil)	kg/year	199,143,360
Uprooted trees	unit	516	CH_4 (fossil)		343,699
Cement	m^3	2,000,000	NO_x		1,027,728
Steel	kg	500,000,000	NMVOC		247,666
Excavation waste	m^3	12,600,000	SO_2		923,270
Carbon-14	kBq/year	1.72E+09	PM 2,5-10		80,533
Iodine-129		1,782,518	PM 2,5		157,697
Radon-222		2.62E+13			
PV					
Material	**Unit**	**Amount**	**Material**	**Unit**	**Amount**
Electricity	kWh	2,630,889,200	Tempering	kg	282,268,800
Natural gas	MJ	2,052,321,600	Wire drawing		3,158,400

Table 70 (continued)

Material	Unit	Amount	Material	Unit	Amount
Light Fuel Oil	MJ	30,216,000	Aluminum alloy	kg	73,502,400
Water	kg	3,452,880,000	Nickel		4,800
Brazing Solder		244,800	Polyvinylacetate		3,072,000
Solar Glass		282,268,800	Polyethylene Terephthalate		10,425,600
Copper	kg	3,158,400	Silicon Product		3,408,000
Glass Fibre reinforced plastic		5,256,000	Acetone		1,560,000
Ethylvinylacetate		27,945,600	Methanol		62,400
Vinyl Acetate		48,000	Fluorine		1
Lubricating Oil		43,200	Metallization paste		321,600
Corrugated Board		30,744,000	Metallization paste back side aluminum		1,872,000
1-propanol		225,600	Ammonia		177,600
Disposal, municipal waste		840,000	Phosphoric Acid		201,600
Disposal, polyvinylflouride		3,072,000	Phosphoryl Chloride		43,200
Disposal, plastics		47,232,000	Titanium Dioxide		38
Disposal, used mineral oil		43,200	Ethanol from ethylene		14,400
Isopropanol		2,054,400	HCl		44900

Table 70 (continued)

Material	Unit	Amount	Material	Unit	Amount
Solvents	kg	38,400	Polyethylene	kg	3,840
Silicone product	kg	33,600	Tryethylene glycol	kg	71,784,000
Socium silicate	kg	1,948,800	dipropylene Glycol Monomethyl Ether	kg	8,284,800
Calcium chloride	kg	561,600	Alkylbenzene sulfonate	kg	6,624,000
Acetic acid	kg	4,910,000	Acrylic binder	kg	57,600
Hydrochloric acid	kg	1,190,000	Glass wool mat	kg	278,400
Hydrogen Flouride	kg	2,200,000	Paper	kg	5,246,400
Nitric Acid	kg	2,960,000	Polystyrene	kg	5,520,000
Sodium Hydroxide	kg	5,090,000	Packaging film	kg	2,760,000
Argon	kg	142,000	Brass	kg	206,400
Oxygen	kg	2,660,000	Steel	kg	40,862,400
Silicon Carbide	kg	59,100,000	Wire drawing	kg	41,140,800
NaOH	kg	7,710	DOC	kg	1,310,400
Disposal	kg	3,038,400	TOC	kg	1,310,400
Graphite	kg	3,840	Aluminum	kg	38
AOX	kg	14,400	Ceramic Ties	kg	8,208,000

Table 70 (continued)

Material	Unit	Amount	Material	Unit	Amount
Cadmium		1E-2	Lime		4,665,600
Chromium		2E-1	Flouride		57,600
COD		4,046,400	Hydrocarbons		556,800
Copper		3,158,400	Hydroxide		182,400
Lead		960	Nitrogen		220,800
Mercury		144	Hl		1,046,400
Nickel		1,440	Chloride		897,600
Nitrogen		278,400	Sodium		134,400
Phosphate	kg	14,400	Zinc	kg	432
BOD_5		3,854,400	Iron		240
Wood Scraps		38,400,000,000	Boron		10
Charcoal		4,593,600	Hydrogen Sulfide		14,400
Coke		10,464,000	Calcium		19
CO_2		108,000,000	Antimony		192
CO		52,800	Chlorine		2
Arsenic		2E-01	Cyanide		192

CHAPTER 4

CONCLUSION AND DISCUSSIONS

The physical mechanisms behind the solar and nuclear energy are somewhat similar mechanisms, as both are the nuclear reactions. Solar energy which is the input of PV PP and originated and sourced by the sun has working principle based on nuclear reactions (fusion). A different type of nuclear reaction (fission) is used in NUKE PP's.

This study deals with the selection of better option to be invested in order to contribute to meet the electricity needs of Turkey. The options, PV and NUKE, are compared through their costs, electricity production amounts, CO_2 reduction potentials, material uses, environmental affectabilities, required land amounts, payback times, revenues and profits, life time and project durations. The scenario of the study stems from the comparison of above mentioned parameters by sticking to fixed 4800 MW installed for both options.

Long story short, following outputs are determined owing to this study:

- While PV has 31 years project duration with 30 years operation and about 1 year commission and decommission, NUKE has 101 years, 4 years of which is allocated to preparation period, 11 years for construction period and 30 years for decommissioning. NUKE has 60 years operation lifetime.
- 4800 MW PV PP's have cumulative 10.91 billion $ cost if the land cost is taken into account. If not, this amount decreases to 5.63 billion $. The moral of a story, the location of ESIZ where PV PP is established does not seem to be an optimum place because of having huge loan quantity.The total cost of PV without land cost is calculated with the presumption whether the government accords the same right which NUKE has to PV. This right is land cost exemptions as determined in the intergovernmental agreement.
- NUKE has 32.06 billion $ total cost only 105 million $ of which is land cost. It is obviously seen that PV is cheaper investment compared to NUKE.

- Total electricity production of PV is 215.51 TWh during its whole lifetime. However, this amount is 1920.67 TWh for NUKE. Matching electricity production amounts, it is obviously seen that NUKE has quite more electricity production capacity than PV with same installed power.
- On the other hand, dealing with NPVs of electricity productions of two option, the value is 110.45 and 347.36 respectively for PV and NUKE.
- PV is better pursuant to LCOE amounts. In other words, PV generates cheaper electricity than NUKE (Note however that, if the high land cost of PV-PP is accounted, they produce unit electricity almost with the same price.)
- For 1 MW PV PP, taking *C* as generally accepted turnkey price in market which is 1.26 Million € instead of the value calculated by this study, the LCOE with land cost becomes 127.51 $/MWh. And the LCOE without land cost becomes 73.63 $/MWh which is still cheaper than NUKE.
- PV needs about 4 fold area of NUKE PP. The total area necessary for PV is 48.47 km^2; however, it is 11.83 km^2 for NUKE.
- Designing system having 2 lines instead of 8 lines, total area needed decreases about 4.5 km^2.
- PV reduces more CO_2 per MWh; however, owing to considerably high electricity production amount, NUKE reduces more CO_2 totally.
- Payback time and expenditure-income balances of NUKE do not seem feasible. Paranthetically, PV has insufficient feasibility unless government subsidy the cost of land allocation. If it is, then, having reasonable payback time, PV PP investment becomes feasible.
- Therefore, even if the options of PV investment both with and without land cost can be taken into account as profitable, PV investment seems quite much profitable with land cost exemption.
- The quantity of feed-in-tariff purchacement amount and time is insufficient for having profitable investment with land cost.
- Even both options are environmental friendly during operation unless force majeur occurs for NUKE, the life cycle has intense material use and environmental effect in the construction stage. PV has intense electricity, natural gas consumption and considerable metal consumptions like aluminum, steel etc in its life cycle. NUKE has highly considerable amount uranium waste, water consumption, excavation waste, cement and steel use.

- Both options create the junk of industry. Consequently, in order not to face on the hardness at the end of project life, recycling possibilities should be worked well.
- In reality, both options are supported by the government from different aspects. For instance, government establishes the infrastructure of PV PP to be established in ESIZ. On the other hand, the government allocates the land to NUKE PP for free.
- For the calculation of solar irradiance shifting the assumption from isotropic sky to anisotropic one, 5-10 % more energy input is attained according to Perez model.
- The location of Karapinar ESIZ does not seem to be the best place being exposed the highest solar irradiation. The cities like Antalya, Gaziantep which are located south of Karapinar are capable of having more solar irradiation amount when compared to Karapinar. Turkish solar maps constituting solar irradiance amounts, locations available to feed-in-tariff systems and location of Karapinar ESIZ are given in Appendix A [36], [144-145].
- Since NUKE PP to be established in Mersin does not have operating example, some pictures taken from animations of aforementioned PP are given in Appendix B [146-147].
- Together with feed-in-tariff subsidy and unlicensed PV PP establishment opportunity for investments lower than 1 MW installed-power have boosted Turkish solar investments. In the upcoming days, Turkey will be able to have many PV PP investments. One of them which has 500 kW installed power has newly established in Bandırma by Mumcu Teneke Company. Some pictures from mentioned PP which has similarity with the system this study dealth with are given in Appendix C [148].

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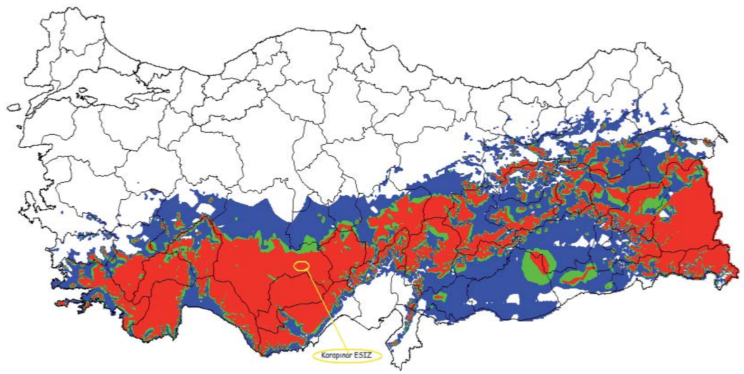
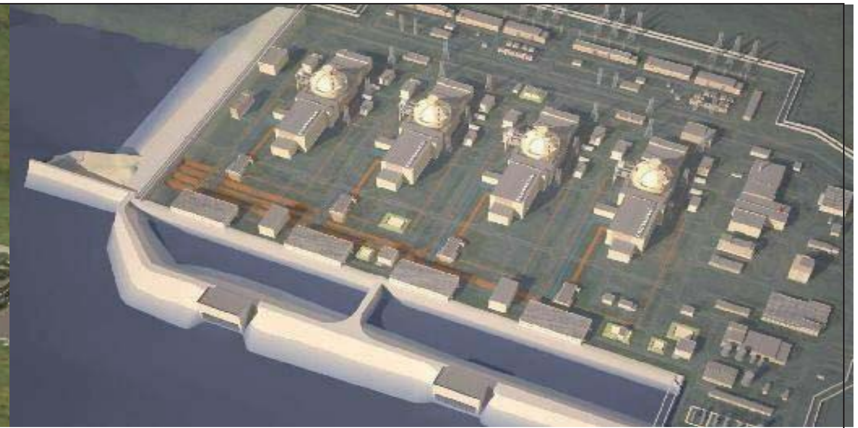
APPENDICES

A - Turkey Solar Energy Atlas and Location of Karapınar ESIZ



Left top	Map revealing locations that can be benefited from 600 MW feed-in-tariff subsidies together with the mention of the location of Karapinar ESIZ [144]
Right Top	Turkey’s solar atlas potential in parallel with previous map together with the mention of the location of Karapinar ESIZ. P.S. Red reveals areas having more than 1650 kWh/m^2year solar irradiation. Green shows places with 1620-1650 kWh/m^2year solar irradiation. Blue shows places having solar irradiation lower than 1620 kWh/m^2year [145]
Left down	Turkey’s solar atlas potential in parallel with previous map together with the mention of the location of Karapinar ESIZ. P.S. Total Solar Irradiation: (kWh/m^2year) [36] 

B – Some Pictures from NUKE PP in Mersin Akkuyu

C – Some Pictures from 500 kW PV PP in Balıkesir