FINANCIAL ANALYSIS OF ROOF TOP MOUNT SOLAR PHOTO VOLTIC POWER IN KERALA, INDIA

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INDIA

2014

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Acknowlegement

I would like to thank **Karunya University** for giving me access to their facilities and being kind to the guy so far away from home.

I would, firstly, like to express my profound gratitude and deep regards to my Professor **Dr. Joji Chandran** for his exemplary guidance, monitoring and constant encouragement throughout the course of this thesis.

I would like to thank **IAESTE IndiaKu** of course for giving me the opportunity to complete my project here and supporting me throughout my stay here.

I would especially like to thank my parents, **Sr. Luis Fernando Gonzalez G**. and **Mrs. Maritza Reyes M.** for the immense support, blessing, help and guidance given.

I am really thankful to them…

Abstract

GENERAL SUMMARY OF WORK OF GRADE

TITLE: FINANCIAL ANALYSIS OF ROOF TOP MOUNT SOLAR PHOTO VOLTIC POWER IN KERALA, INDIA

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ABSTRACT

The purpose of this project is to evaluate the feasibility of using solar panels in aluminum sheet roofs in Kerala that match the regions architectural style and energy supply problems. The renewable energy price are not as prone to market fluctuations such as oil or natural gas, and solar systems or wind energy are able to supply power to the developing regions or less accessible, which cannot have the economic resources or infrastructure to use fossil fuels. In addition to this, experts predict that increased investment in renewable energy systems will produce thousands of worldwide jobs to conduct a social economic impact. A first step, the information data for analysis is recollected. This information is used to apply the standard financial procedures like Net Present value, Internal Rate of Return, Sensitivity analysis. In addition, the study will also focus on interest rates, operational rates, maintenance cost and other factors in the process have included. The global objective is to study financial aspects of roof top mount solar photovoltaic power implementation in Kerala, India. Finally, all information obtained will be analyze and then a judgment value will be given concerning whether it is optimal or not this project, taking into account the financial barriers that involve the idea implementation.

KEYWORDS:

FINANCIAL ANALYSIS

V° B° DIRECTOR OF GRADUATE WORK

RESUMEN

RESUMEN GENERAL DE TRABAJO DE GRADO

TITULO: ANALYSIS FINANCIERO DE SOPORTES SOLARES FOTOVOLTAICOS EN KERALA, INDIA

AUTOR(ES): DIEGO FERNANDO GONZALEZ REYES

FACULTAD:

DIRECTOR(A): Orlando Federico González Casallas

RESUMEN

El propósito de este proyecto es evaluar la viabilidad de utilización de paneles solares en los techos de Kerala, India, que coinciden con el estilo arquitectónico de la región y los problemas de suministro de energía. El precio de las energías renovables no son tan propensas a las fluctuaciones del mercado, como lo son el petróleo y el gas natural. los sistemas solares o eólicos son capaces de suministrar energía a las regiones de difícil acceso, que no tienen los recursos económicos o la infraestructura a utilizar combustibles fósiles. Además, los expertos predicen que el aumento de la inversión en sistemas de energía renovable producirá miles de empleos en todo el mundo para llevar a cabo un impacto económico social. Como primera instancia, se recogieron los datos de información para el análisis. Esta información se utilizó con los indicadores financieros como valor actual neto, tasa interna de retorno, análisis de sensibilidad y se tocaron temas relacionados a tasas de interés, tipos de operación, el costo de mantenimiento y otros factores que se fueron incluyendo a medida de la elaboración del proyecto. Por último, toda la información obtenida se analizó y luego se dio un juicio de valor en cuanto a si es óptimo o no este proyecto, teniendo en cuenta las barreras financieras que involucraron la implementación de esta idea en Kerala, India.

PALABRAS CLAVES:

ANALYSIS FINANCIERO

V° B° DIRECTOR DE TRABAJO DE GRADO

Chapter I

Introduction

India is a rapidly growing economy which needs energy to meet its growth objectives in a sustainable manner. The Indian economy faces significant challenges in terms of meeting its energy needs in the coming decade. The increasing energy requirements coupled with a slower than expected increase in domestic fuel production has meant that the extent of imports in energy mix is growing rapidly. India is among the top five Green-house-gas (GHG) emitters globally. To reduce its dependency on the conventional sources, India has launched a solar mission in 2009. The Mission has set a target of 20,000 MW using solar. Solar Mission stipulates implementation and achievement of the target in 3 phases (first phase up to 2012-13, second phase from 2013 to 2017 and the third phase from 2017 to2022) including various components like grid connected solar power.

India has a population of over 1.21 billion (2011 census) with 70% of total population living in rural areas. Out of these 1210 million people, 396 million (44.7% of the total rural population compared to 7.3% of urban population) does not have access to electricity and 592 million (rural- 62.5%; urban- 20.1%) people still use firewood for cooking. Majority of these people reside in rural areas and are still dependent on non-commercial energy sources, such as fuel wood, crop residue, and animal waste for their energy needs. Furthermore, about 80% of the population - which includes 28% of urban inhabitants - still relies on biomass combustion fuels for cooking activities. The use of biomass for cooking also contributes to the indoor air pollution phenomenon, which caused 488.200 deaths in 2004.

Electricity Consumption in India was about 543 KWh/capita in 2009, among the lowest in the world. Although India has considerably improved its generating capacity, it still has difficulty in meeting demand and there are persistent power shortages which constrain India's economic growth. With the development of the industrial and commercial sectors as well as the wider electrical equipment use, electricity demand keeps increasing. Moreover, approximately 30 percent of India's generated power is lost in transmission. Distribution is the weakest link of India's power supply chain as it faces substantial technical losses (because of overloading of transformers and conductors, for instance) and commercial losses of electricity (because of low metering efficiency, poor billing and collection, large scale theft of power). Furthermore, transmission lack and power distribution to less densely populated areas which are located far away from the power generating stations is the major reason for not being able to achieve 100 percent electrification in the country.

Why Solar?

Solar Photo Voltaic (PV) technology has evolved over a period of time and has reached a stage where people have recognized it as a major power source for coming generation. In this chapter we will explore the key drivers of solar energy in India and how it is creating new market places and new employment as well as entrepreneurship opportunities.

Key drivers of solar Industry

1. Climate Change

Earth's average temperature has increased over 1.4 °F over the past century and as per projections it will increase by another 2 to 11.5°F over the next hundred years. The change in the rainfall pattern, the frequent droughts, cyclones, the new breed of viruses and related diseases, more severe winter as well as summer, the melting glaciers are attributed to climate change.

1.1 Role of Human in Climate Change

Greenhouse gases including CO2 have the ability to trap heat like a blanket. Human activities have caused an increase in the greenhouse gas emissions including CO2 resulting in an increase in the temperature globally. Even though there are conflicting views in popular media on human involvement in global warming, the scientific community has sufficient evidence to prove the human involvement in climate change. One of the compelling evidence states that the current level of CO_2 (around 400 ppm) is the highest in the history, and the same can hence be attributed to climate change.

1.2 Impact of climate change on life

One of the visible impacts of climate change, which is widely studied, is its impact on glaciers. Glaciers hold a significant part of earth's water as ice, and the melting glaciers due to global warming will lead to rise in the water level from a few inches to a few feet across the globe. It poses a significant threat to life since, half of the world population live along the costal line. The impact of the same is noticed in the two most climate change vulnerable countries; Maldives and Bangladesh.

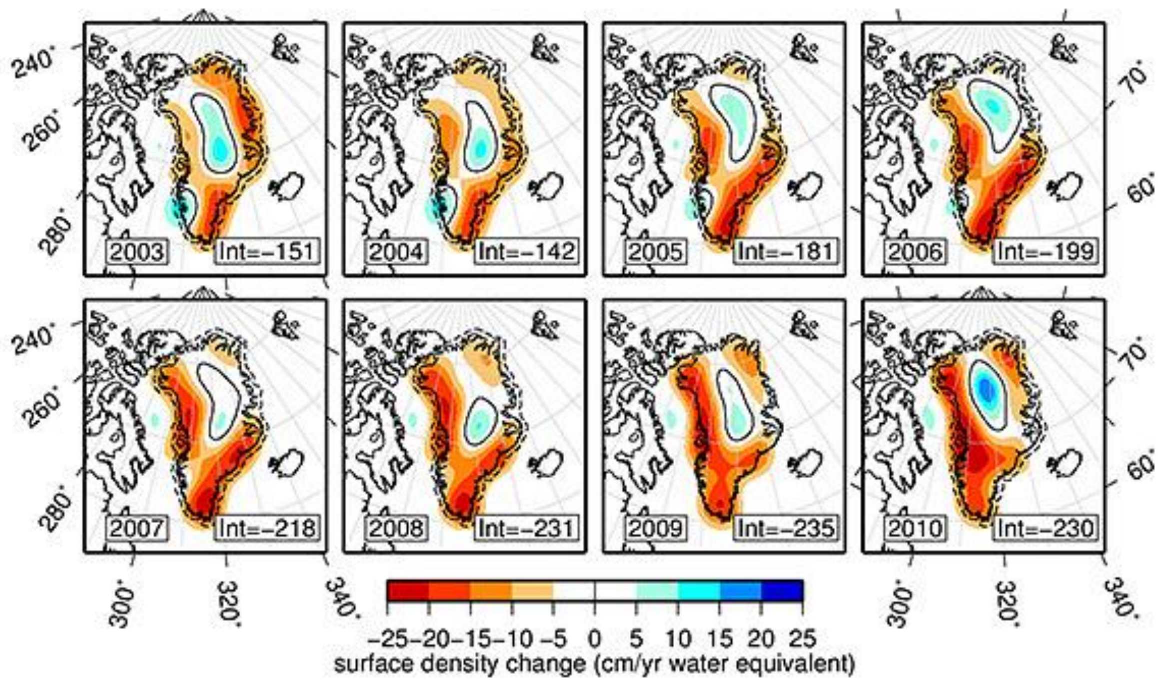

Figure 1. **Reduction in ice cap**

Moreover, the recent increase in the frequency of natural disasters, the emergence of news pests and infectious viruses are also attributed to climate change.

2. How Solar System Helps?

Solar power as compared to conventional source of power like coal, natural gas does not result in significant emission of CO_2 into the Earth's atmosphere. As Solar PV substitutes non-renewable source of power (coal/natural gas) the CO_2 emission due to power production decreases.

In India every unit of power consumed from the grid result in a carbon emission of 1Kg CO_2/unit (KWH). This is relatively high compared to other countries because of the significant contribution of coal in the overall power production mix (>50%), as well as the high transmission losses (>24%).

A 1KWp flare 1 series off-grid solar PV system can avoid emissions of 40 tons of C02 equivalent in India per year. The same is equivalent to CO_2 absorbed by planting 40 trees and nurturing them to their full lifetime.

Chapter II

1. Energy situation in India

The installed capacity of power plants in India as on 29.02.2012 is 1,90,593 MW (including 22,253 MW from Renewable Energy Sources). The gross electricity generation in the country during 2011-12 "up to February, 2012) including import from Bhutan was 798.9 Billion Units. The energy requirement, availability and shortage in the country during April, 2011 to February, 2012 are given below:

Year	**Energy Requirement (MU)**	**Energy Availability (MU)**	**Deficit (MU)**	**Deficit (%)**
2011-12 (till Feb 2012)	853324.00	782124.00	71200.00	8.30%

Table 1. Energy Situation in India

The fossil fuels like coal, oil and natural gas cannot remain the dominant sources of energy forever. Whatever the precise timetable for their depletion, oil and gas supplies will not keep up with growing energy demands. Coal is available in abundance, but its use exacerbates air and water pollution problems, and coal contributes even more substantially than the other fossil fuels to the buildup of carbon dioxide in the atmosphere.

For a long-term, sustainable energy source, solar power offers an attractive alternative energy in India. It is environmentally clean, and its energy is transmitted from the sun to the Earth free of charge and there is no out come any toxic gases.

2. Renewable Energy

India also has one of the highest potentials for harnessing the renewable energy as it is bestowed with such natural resources and geographical and climatic conditions that could support the promotion of renewable energy technologies like solar, wind, biomass and small hydro.

As on 31st January, 2012, the total installed capacity of grid connected Renewable Energy is 23.12 GW. Amongst this, the biggest chunk is from Wind power, which stands at around 16, 000 MW. The wind power sector growth in India is continuously increasing and around 2100 MW of wind power was added in the last year and it is expected to continue because of the continued government supported schemes in this sector.

Till last year, the share of grid connected Solar PV was negligible, only around 40 MW and most of the Government focus was on off grid Solar PV and Residential Solar Thermal. However, due to the new government initiative- Jawaharlal Nehru National

Solar Mission (announced in year 2010), the Grid connected Solar PV and the Concentrated Solar Power Market is on the boom. Around 440 MW of Solar PV was installed in the last year and is expected to increase many folds due to highly lucrative government schemes.

Small Hydro and Biomass technologies represent the remaining chunk of the Grid connected Renewable Energy mix, as shown in the graph below. Government also sees Geothermal Energy as an interesting Renewable Energy source for India and few sites in Andaman Nibobar Islands etc. have been identified for the pilot projects.

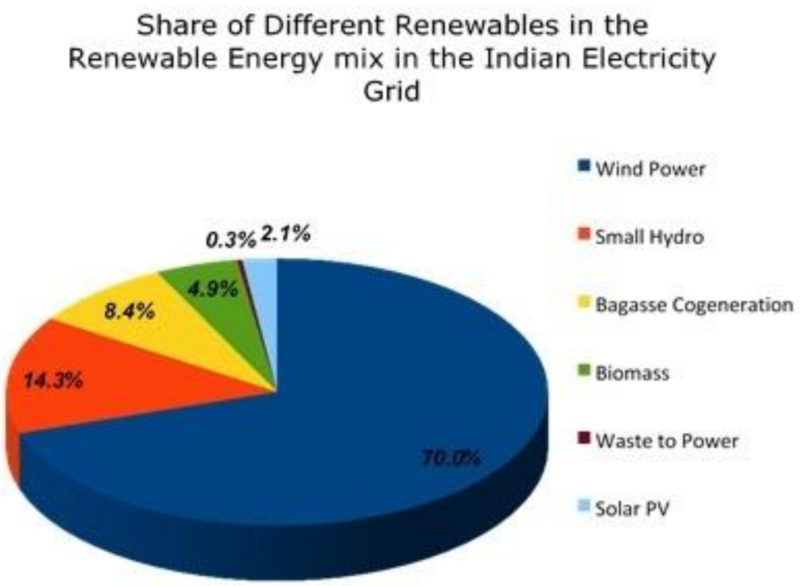

***Figure 2*. Renewable energy mix in the Indian electricity grid**

3. Solar Energy

India has high Solar Insolation levels with about 300 clear sunny days –most parts of the country receive 4-7 Kwh/m²/day with about 1500-2000 sunshine hours per-week (depending upon location) , which is far more than current total energy consumption . Ministry of New and Renewable energy (MNRE), Government of India estimates solar potential at over 10000 MW. States on West part of India such as Rajasthan and Gujrat have the highest potential. Parts of these states have the best solar irradiance in India with 4-7 Kwh/m²/day.

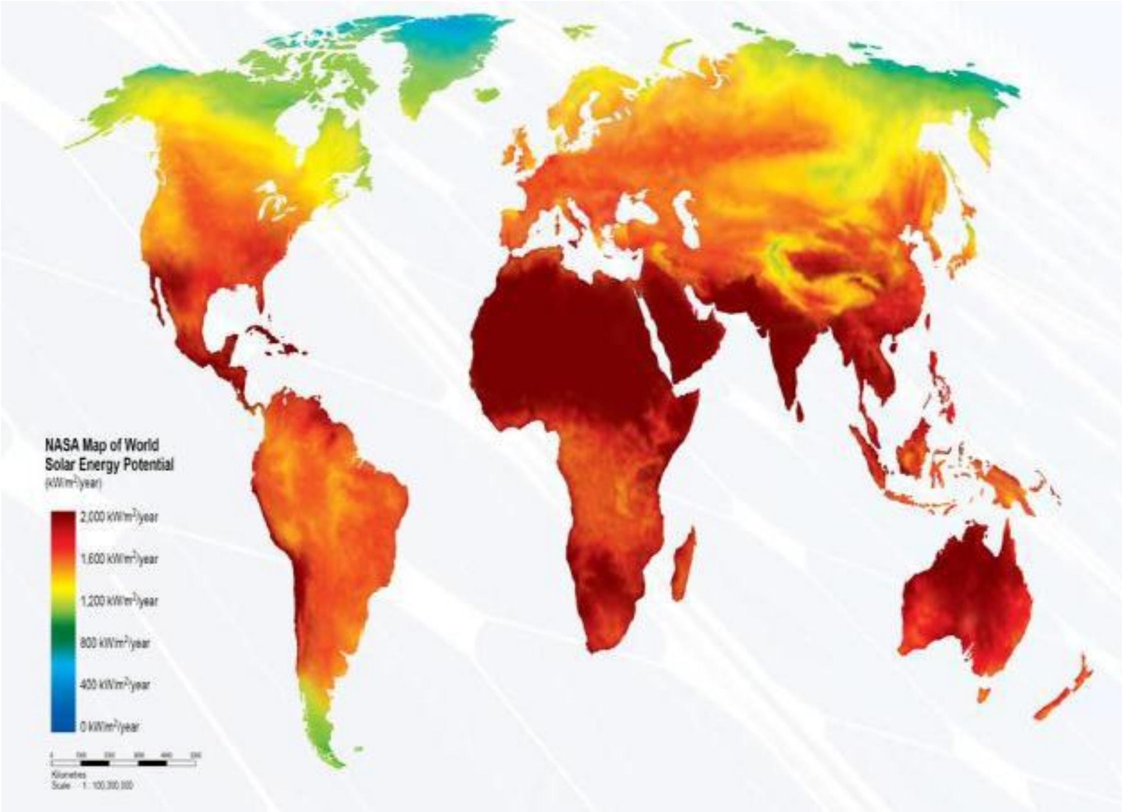

Figure 3. **Nasa map of world solar energy potential**

India is density populated and rich in solar energy. Solar energy is more important in India because most of the days (300-330 days per year) in India are Sunny. On only land area, the solar power reception is 5000 per watt-hours per year (PWh/yr). The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 1500–2000 sunshine hours per year (depending upon location), which is far more than current total energy consumption. India has a great potential to generate electricity from solar energy and the Country is on course to emerge as a solar energy hub. The techno-commercial potential of photovoltaics in India is enormous. Solar Energy is attractive because it is abundant and offers a solution to fossil fuel emissions and global climate change.

In India, electricity from solar is now cheaper than that from fuel based generators. The recent figures market analysis shows that the price of solar panels fell by almost 50 per cent in 2011. The panel prices are now just one-quarter of what they were in 2008. This makes them a cost-effective option for many people in developing countries. Solar electricity is eco-friendly but the fuel based electricity production leads to many health problems because some harmful gases. The one time investment for solar panels will get long lasting benefit to us.

3.1 Grid Parity in India

The capital cost for solar power has come down by about 16% to 20% in the last two years. It is expected to continue the downward trend for the next three years as the manufacturing scale increases and the technology matures. At the same time, the cost for fossil fuels such as coal is expected to increase and subsidies in the power sector in India are expected to fall, thus driving up grid power prices. Given India's high irradiation levels, solar power will soon become a feasible choice for captive generation in the future. So it is expected that India will achieve Grid Parity in 2018.

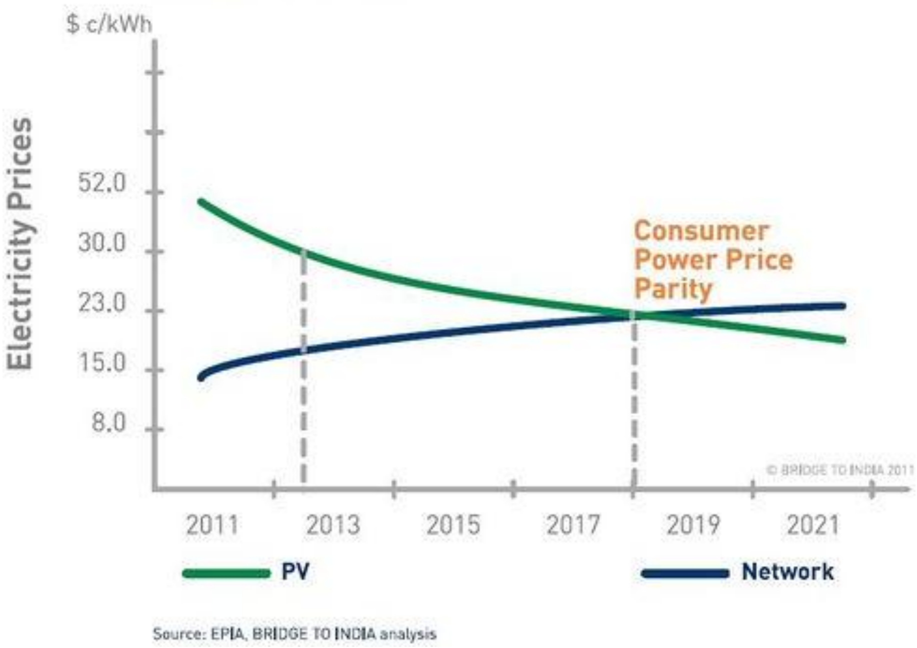

Figure 4. **Grid parity in India**

3.2 Electricity Situation

Electricity is the most important component of primary energy. Access to affordable and reliable electricity is critical to a country's growth and prosperity. The country has made significant progress towards the augmentation of its power infrastructure. In absolute terms, the installed power capacity has increased from only 1713 MW as on 31 December 1950 to 118 419 MW as on March 2005.Even the per capita electricity consumption rose from merely 15.6 kWh in 1950 to 592 KWh in 2003/04. However, it is a matter of concern that per capita consumption of electricity is among the lowest in the world.

In the recent years, India's energy consumption has been increasing at one of the fastest rates in the world due to population growth and economic development. Industrial consumers are the largest group of electricity consumers, followed by the domestic, agricultural and commercial consumers, in that order. Primary commercial energy demand grew at the rate of six per cent between 1981 and 2001Unknown Object. India ranks fifth in the world in terms of primary energy consumption, accounting for about 3.5% of the world commercial energy demand in the year 2003. Despite the overall increase in energy demand, per capita energy consumption in India is still very low (15.9 Million Btu) compared to other developing countries (Thailand: 57.9; China: 56.9)

For the past two decades, India has had to face increasing deficit in power supply, both for meeting its normal energy requirements as well as its peak load demand. The problem is acute during peak hours and summers, and necessitates planned load shedding by many utilities to maintain the grid in a healthy state. The average all-India shortages in 2009-10 were at 10 per cent in terms of normal energy requirement and about 13 per cent in terms of peak load.

Although India is increasing dependent on commercial fuels, a sizeable quantum of energy requirements (40% of total energy requirement), especially in the rural household sector, is met by non-commercial energy sources, which include fuel wood, crop residue, and animal waste, including human and draught animal power. However, other forms of commercial energy of a much higher quality and efficiency are steadily replacing the traditional energy resources being consumed in the rural sector.

3.3 Electricity Demand and Supply

Table summarizing the electricity demand and supply in India.

Table 2. *Electricity demand and supply*

Fiscal Year (FY)	**Energy (MU)**				**Peak Demand (MW)**			
	Demand	Availability	Shortage	%	Demand	Met	Shortage	%
2002-03	545,983	497,890	48,093	8.8	81,492	71,547	9,945	12.2
2003-04	559,264	519,398	39,866	7.1	84,574	75,066	9,508	11.2
2004-05	591,373	548,115	43,258	7.3	87,906	77,652	10,254	11.7
2005-06	631,024	578,511	52,513	8.3	93,214	81,792	11,422	12.3
2006-07	693,057	624,716	68,341	9.9	100,715	86,818	13,897	13.8
2007-08	737,052	664,660	72,392	9.8	108,866	90,793	18,073	16.6
2008-09	777,039	691,038	86,001	11.1	109,809	96,785	13,024	11.9
2009-10	830,594	746,644	83,950	10.1	118,472	102,725	15,747	13.3

However, the Indian Power Ministry has been trying to increase its generating capacity by adding to it every year.

4. Kerala State Information

Kerala is a state in the south-west region of India on the Malabar Coast, It was formed on 1 November 1956 as per the States Reorganization Act by combining various Malayalam-speaking regions. Spread over 38,863 km2 (15,005 sq. mi) it is bordered by Karnataka to the north and north east, Tamil Nadu to the east and south, and the Lakshadweep Sea to the west. With 33,387,677 inhabitants as per the 2011 census, Kerala is the twelfth largest state by population and is divided into 14 districts with the state capital being Thiruvananthapuram. Malayalam is the most widely spoken and official language of the state.

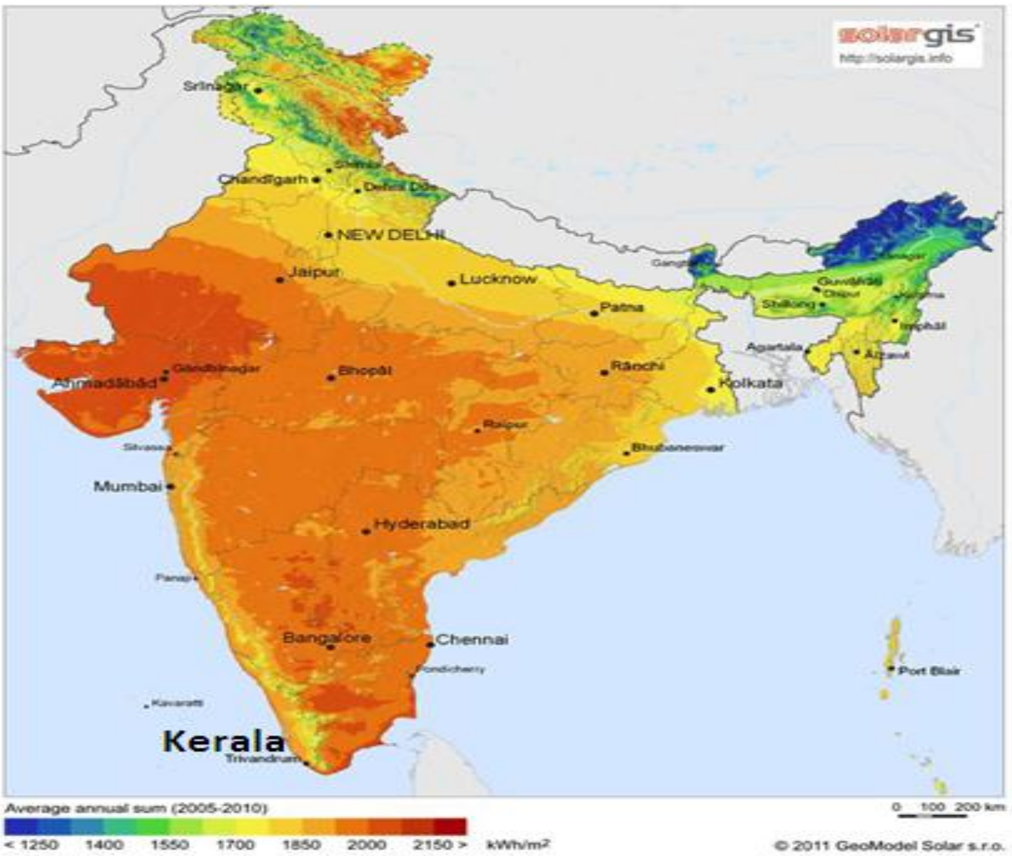

Figure 5. **Map of India – Average annual sun**

Kerala is a state which constitutes Sunny shoreline, caressed by perpetual bluish waves that adorn the endless beaches, with awe come green groves of coconuts that paint a shying borderline of natural harmony. The average temperature in Kerala is 27.0 °C (81 °F). The temperature in Kerala normally ranges from 28° to 32° C (82° to 90° F) on the plains but drops to about 20° C (68° F) in the highlands. Temperature during winter in Kerala is maximum of 28°C and minimum of 18°C. Avg. Summer starts in February and continues till May, the temperature during summer in Kerala is maximum of 36°C and minimum: 32°C. The Average temperature during summer and winter in Kerala is absolutely fits to use Solar Energy.

Table 3. *Average temperature per month in India*

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Average high °C (°F)	28	30	31	32	34	34	30	29	29	30	30	31
	-82.4	-86	-88	-90	-93	-93	-86	-84	-84	-86	-86	-88
Average low °C (°F)	22	23	24	25	25	24	23	23	23	23	23	22
	-72	-73	-75	-77	-77	-75	-73	-73	-73	-73	-73	-72

Chapter III

1. The Government

Introduction

The National Solar Mission is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change.

The National Action Plan on Climate Change also points out: "India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level". Based on this vision a National Solar Mission is being launched under the brand name "Solar India".

2. Objectives and Targets

The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.

The Mission was adopt a 3-phase approach, spanning the remaining period of the 11th Plan and first year of the 12th Plan (up to 2012-13) as Phase 1, the remaining 4 years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3. At the end of each plan, and mid-term during the 12th and 13th Plans, there will be an evaluation of progress, review of capacity and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global. The aim would be to protect Government from subsidy exposure in case expected cost reduction does not materialize or is more rapid than expected.

3. Policy and regulatory framework

The objective of the Mission is to create a policy and regulatory environment which provides a predictable incentive structure that enables rapid and large-scale capital investment in solar energy applications and encourages technical innovation and lowering of costs.

Although in the long run, the Mission would seek to establish a sector-specific legal and regulatory framework for the development of solar power, in the shorter time frame, it would be necessary to embed the activities of the Mission within the existing framework of the Electricity. The Electricity Act already provides a role for renewables but given the magnitude and importance of the activities under the Mission, it would be necessary to make specific amendments. The National Tariff Policy 2006 mandates the State Electricity Regulatory.

Commissions (SERC) to fix a minimum percentage of energy purchase from renewable sources of energy taking into account availability of such resources in the region and its impact on retail tariff.

National Tariff Policy, 2006 would be modified to mandate that the State electricity regulators fix a percentage for purchase of solar power. The solar power purchase obligation for States may start with 0.25% in the phase I and to go up to 3% by 2022. This could be complemented with a solar specific Renewable Energy Certificate (REC) mechanism to allow utilities and solar power generation companies to buy and sell certificates to meet their solar power purchase obligations.

The Central Electricity Regulatory Commission has recently issued guidelines for fixing feed-in-tariff for purchase of solar power taking into account current cost and technology trends. These will be revised on an annual basis. The CERC has also stipulated that Power Purchase Agreement that utilities will conclude with solar power promoters, should be for a period of 25 years.

In order to enable the early launch of "Solar India" and encourage rapid scale up, a scheme is being introduced in cooperation with the Ministry of Power, the NTPC and the Central Electricity Authority, which would simplify the off-take of solar power and minimize the financial burden on Government.

Many investors are willing to set up solar based power plants. However, sale of power may be an issue due to the high cost of power and realization of tariff for the same from the distribution companies.

In order to incentivize setting up of a large number of Solar Power Projects, while minimizing the impact on tariff various alternatives were explored. One of the options is to bundle solar power along with power out of the cheaper unallocated quota of Central stations and selling this bundled power to state distribution utilities at the CERC regulated price. This will bring down the gap between average cost of power and sale price of power. For the purpose of bundling, power has to be purchased by an entity and re-sold to the state power distribution utilities. Such function can be done only by a trading company/Discoms, as per the existing statutory provisions.

4. Institutional Arrangements for Implementing the Mission

This Mission will be implemented by an autonomous Solar Energy Authority and or an autonomous and enabled Solar Mission, embedded within the existing structure of the Ministry of New and Renewable Energy. The Authority/Mission secretariat will be responsible for monitoring technology developments, review and adjust incentives, manage funding requirements and execute pilot projects. The Mission will report to the Prime Minister's Council on Climate Change on the status of its program.

5. International Collaboration

There is considerable work going on in several countries to develop Solar Energy as a clean and alternative source of energy. Strategic international collaborations and partnerships aimed at meeting the priorities set out under the Mission would be developed, along with effective technology transfer mechanisms and strong IPR protection.

Cooperation will be encouraged at the level of research organizations along with industry partners and at individual level also to generate new ideas. Wherever feasible, cooperation through bilateral and multilateral arrangements would be facilitated. DST has been supporting joint research with several countries under bilateral programs. More recently a research programme is to be taken up by DST, in consultation with MNRE, with the European Union. MNRE is also implementing some bilateral projects under the Asia Pacific Partnership Programme with Japan and Australia. A project on solar radiation data collection is under implementation with USA.

6. Financing the Mission Activities

The fund requirements for the Mission would be met from the following sources or combinations:

- Budgetary support for the activities under the National Solar Mission established under the MNRE;
- International Funds under the UNFCCC framework, which would enable upscaling of Mission targets.

The Mission strategy has kept in mind the two-fold objectives, to scale-up deployment of solar energy and to do this keeping in mind the financial constraints and affordability challenge in a country where large numbers of people still have no access to basic power and are poor and unable to pay for high cost solutions.

The funding requirements and arrangements for Phase II will be determined after a review of progress achieved at the end of the 11th Plan and an analysis of the efficacy of the model adopted for capacity building of utility scale solar power.

Chapter IV

1. Introduction to Solar PV system

1.1 Importance of solar energy

- **About Sun**

The solar system has the sun and its center with all the planets revolving around it. The sun is the sole source of energy for all forms of life on earth. The sun is made up of hydrogen and helium by 74% and 25% of mass respectively. The rest is made up of trace quantities of heavier elements. The sun generates energy by the process of nuclear fusion of hydrogen nuclei into helium. The sun fuses 620 million metric tons of hydrogen every second. The surface temperature of the sun is approximately 5500K

- **Sun the source of all Energy**

Solar energy is the main source of energy that can be harnessed by various natural and synthetic process. The most important process is photosynthesis by which plants capture solar radiation and convert it into glucose using carbon dioxide and water, releasing oxygen as a by-product. Photosynthesis is the most important biochemical pathway and nearly all life on earth depends of it. Basically all forms of energy on earth are of solar in origin. Oil, natural gas, coal and wood are originally produced by photosynthesis followed by complex chemical reactions, subjecting the decaying vegetable matter to high temperatures and pressures over long periods of time. Wind and tidal energy are also due to solar energy since they are caused by the differences in temperatures in various regions of the earth.

- **Understanding Solar Energy**

Solar energy is clean and has no environment impact. It is ever lasting and renewable. The Earth receives a total of 174 petawatts (PW) of solar radiation at the upper atmosphere. Out of this, 30% is reflected to space while clouds, oceans and landmasses absorb the rest. The atmosphere causes a reduction of the extra-terrestrial radiation by 30% on a very clear day and up to 90% on a cloudy day.

As solar radiation passes through the earth atmosphere, it is:

- ✓ Absorbed (the reason for some atmospheric heating)
- ✓ Reflected (the reason astronauts can see the earth from outer space)
- ✓ Scattered (the reason you can read a book in the shade under a tree)
- ✓ Transmitted directly (the reason there are shadows)

The sun radiates energy at the rate of 3.9 x 10^26 watts. An average power of 1367W/ m^2 passes through a plane perpendicular to the direction of the sun.

2. Advantages

Solar energy means the generation of heat or electricity by harnessing sunlight and there are plenty of excellent reasons that equate to advantages in using solar energy. Here are some advantages in using solar energy.

✓ **The abundance of solar energy:** Even in the middle of winter each square meter of land still receives a fair amount of solar radiation. Sunlight is everywhere and the resource is practically inexhaustible. Even during cloudy days we still receive some sunlight and it is this that can be used as a renewable resource.

- ✓ **Sunlight is free:** Sunlight is totally free. There is of course the initial investment for the equipment. After the initial capital outlay you won't be receiving a bill every month for the rest of your life from the electric utility.

- ✓ **Solar energy is getting more cost effective:** The technology for solar energy is evolving at an increasing rate. At present photovoltaic technology is still relatively expensive but the technology is improving and production is increasing. The result of this is to drive costs down. Payback times for the equipment are getting shorter and in some areas where the cost of electricity is high payback may be as short as five years.

- ✓ **Solar energy is non-polluting:** Solar energy is an excellent alternative for fossil fuels like coal and petroleum because solar energy is practically emission free while generating electricity. With solar energy the danger of further damage to the environment is minimized. The generation of electricity through solar power produces no noise. So noise pollution is also reduced.

- ✓ **Accessibility of solar power in remote locations:** Solar power can generate electricity no matter how remote the area as long as the sun shines there. Even in areas that are inaccessible to power cables solar power can produce electricity.

- ✓ **Solar energy systems are virtually maintenance free:** Once a photovoltaic array is setup it can last for decades. Once they are installed and setup there are practically zero recurring costs. If needs increase solar panels can be added with ease and with no major revamp.

3. Solar Photovoltaic System (PV)

3.1 Definition

Photovoltaic system are solar energy system that produce electricity directly from sunlight. Photovoltaic modules are solid-state devices that convert sunlight directly into electricity without an intervening heat engine or rotating equipment. PV equipment has no moving parts and hence requires minimal maintenance and has a long life.

Photovoltaic systems can be virtually built in any size ranging from mille watts to megawatts and the systems are modular i.e. more panels can be easily added to increase power output.

3.2 Components

Typically photovoltaic system will constitute integration of one or more of the following components:

FUNTIONAL DESCRIPTION

- **Photovoltaic cell:** Solar panel electricity systems, also known as solar photovoltaics (PV), capture the sun's energy using photovoltaic cells. These cells don't need direct sunlight to work – they can still generate some electricity on a cloudy day. The cells convert the sunlight into electricity, which can be used to run household appliances and lighting.

- **Mounting Structure:** Support the Solar PV panels.

- **Inverter:** Is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).

- **Battery:** Batteries for solar power store the excess energy from your solar panels for use after the sun goes down or at times when your electrical loads are drawing out more than the panels are putting in.

- **Combiner Box:** The DC Combiner box provides a means of combining multiple source circuits from a PV array into a single DC Source. Each source circuit is fused separately according to the requirements of the National Electric Code (NEC). The combiner box allows for fail-safe operation of the system in the unlikely event that a problem with a source circuit leads to abnormally high current. In addition, the combiner box provides a convenient means of diagnosing the DC portion of a PV system for routine maintenance and troubleshooting.

- **Main Junction Box:** Electrical junction boxes are devices that contain the wiring junctions or intersections that allow the wiring in the home or public building to interface with the main power supply provided by a local utility. The presence of the box is generally regarded as both practical and more esthetically pleasing than a bunch of exposed electrical wires.

- **Fuses & Disconnects:** Is a combination of a fuse and a switch, used in primary overhead feeder lines and taps to protect distribution transformers from current surges and overloads. An overcurrent caused by a fault in the transformer or customer circuit will cause the fuse to melt, disconnecting the transformer from the line. It can also be opened manually by utility linemen standing on the ground and using a long insulating stick called a hot stick.

- **Energy Monitoring Meter:** Provide prompt, convenient feedback on electrical or other energy use.

4. Solar PV module

Photovoltaic principle – How it produces power?

The photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light. When photons in the sunlight strike the electrons in the material it excites electrons to create an electric voltage, which causes current to flow in the electrical circuit.

Photovoltaic cell is the basic unit of the photovoltaic system. PV cells convert sunlight to electricity by the photovoltaic effect. The PV effects was discovered in 1954, when scientists at bell telephone discovered that silicon (an element found in sand) created an electric charge when exposed to sunlight. Soon solar cells were being used to power space satellites and smaller items like calculators and watches. Today, thousands of people power their homes and business with individual solar PV system. Utility companies are also using PV technology for large power stations.

4.1 Types of Modules

Variation in the cell components can vary performance, manufacturing process and cost. The various forms of silicon used are briefed below.

Commercial solar cells technology, materials and efficiency.

Table 4. *Types of solar modules*

Solar Photovoltaic Technologies	Solar cell type	Materials used	Efficiency (%)
Crystalline Silicon (c-Si) solar cell	Mono-crystalline silicon	Mono-crystalline silicon	14 – 16%
	Poly or Multicrystalline Si (mc-Si)	Multi-crystalline silicon	14 – 16 %
Thin Film solar cell	Amorphous Si (a-Si)	Amorphous silicon	6 – 9 %
	Cadmium telluride (CdTe)	Cadmium and tellurium	8 –11 %
	Copper-Indium-Gallium-Selenide (CIGS)	Copper, Indium, Gallium, Selenium	8 – 11 %
Multi-junction solar cell	GaInP /GaAs/Ge Gallium indium phosphide/ Gallium arsenide/Germanium	Gallium (Ga), Arsenic (Ar), Indium (In), Phosphorus (P), Germanium (Ge)	30 – 35 %

Typical solar cell parameters (η,A, J_{SC},V_{OC} and FF) of commercial solar cells with available cell areas.

Table 5. *Specifications of the solar panels*

Solar cell type	Efficiency, η (%)	Cell area, A (cm^2)	Output Voltage, V_{OC} (V)	Output Current, J_{SC}(mA/cm^2)	Fill Factor, FF (%)
Mono-crystalline silicon	14 – 17	5 - 156	0.55 – 0.68	30 - 38	70 - 78
Poly or Multi-crystalline Si (mc-Si)	14 – 16	5- 156	0.55 – 0.65	30 - 35	70 - 76
Amorphous Si (a-Si)	6 – 9	5 - 200	0.70 – 1.1	8 -15	60 - 70
Cadmium telluride (CdTe)	8 –11	5 – 200	0.80 – 1.0	15 - 25	60 - 70
Copper-Indium-Gallium-Selenide (CIGS)	8 – 11	5 – 200	0.50 – 0.7	20 - 30	60 -70
Gallium indium phosphide/ Gallium arsenide/ Germanium (GaInP /GaAs/Ge)	30 – 35	1- 4	1.0 – 2.5	15 to 35	70 - 85

4.1.1 Mono-crystalline Panels. The solar cells in mono-crystalline panels are slices cut from pure drawn crystalline silicon bars. The entire cell is aligned in one direction, which means that when the sun is shining brightly on them at the correct angle, they are extremely efficient. So, these panels work best in bright sunshine with the sun shining directly on them. They have a uniform black color since they absorb most of the light.

Pure cells are octagonal, so there is unused space in the corners when cells are assembled into a solar module. Because of its high efficiency, the mono-crystalline modules occupy less space as compared to a poly crystalline module of the same rating. Since, the cost of producing pure silicon wafers is a little more than polycrystalline, and as mono crystalline modules occupy less space as compared to polycrystalline modules, they command a premium price in the market.

Figure 6. **Mono-crystalline Panels**

4.1.2 Poly-crystalline Panels (Multicrystalline). Polycrystalline panels are made up from the silicon offcuts, molded to form blocks and, hence results in a cell made up of several bits of pure crystal. Since the individual crystals are not necessarily aligned perfectly together, there are losses at the joints between them. Their efficiency is low as compared to a mono crystalline module. However, this misalignment can help in some circumstances, as it leads to better performance in diffused light.

Since the wafers are cut into rectangular blocks, there is no wastage of space in the poly crystalline modules. The appearance of a poly crystalline module reflects the same.

Figure 7. **Poly-crystalline Panels (Multicrystalline)**

4.1.3 Thin Film. Thin films are made by depositing extremely thin layers of photosensitive materials in the micrometer range on a low-cost backing, such as glass, stainless steel or plastic. The first generation of thin film solar cell produced was a-Si. To reach higher efficiencies, thin amorphous and microcrystalline silicon cells have been combined with thin hybrid silicon cells. With 2-4 semiconductor compounds, other thin film technologies have been developed, including cadmium telluride (CdTe) and copper-indium-gallium-diselenide (CIGS).

The main advantages of thin films are their relatively low cost due to low consumption of raw materials; high automation and production efficiency; ease of building integration and improved appearance; good performance at high ambient temperature; and reduced sensitivity to overheating. The current drawbacks are lower efficiency and the industry's limited experience with lifetime performances. For utility production, thin film technologies will require more land than crystalline silicon technologies in order to reach the same capacity due to their lower efficiency.

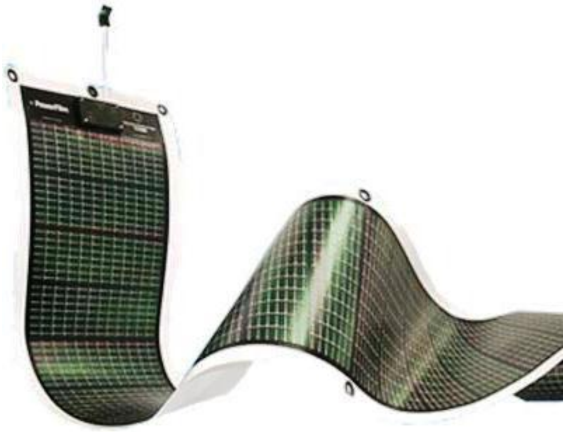

Figure 8. **Thin Film**

4.1.4 Multi-Junction Panel. The highest-efficiency solar cells use multiple materials with bandgaps that span the solar spectrum. Multi-junction solar cells consist of some single-junction solar cells stacked upon each other, so that each layer going from the top to the bottom has a smaller bandgap than the previous, and so it absorbs and converts the photons that have energies greater than the bandgap of that layer and less than the band gap of the higher layer.

Multi-junction solar cells experience a fundamental limitation relating to the availability of materials with optimal bandgaps that simultaneously allow high efficiency through low defect densities. Alloys of groups III and V of the periodic

table are good candidates for fabricating such multijunction cells: their bandgaps span a wide spectral range, and most of the bandgaps have direct electronic structure, implying a high absorption coefficient, and their complex structures can be grown with extremely high crystalline and optoelectronic quality by high-volume growth techniques.

Figure 9. **Multi-Junction Panel**

5. Module Performance

The power (watts) produced by a photovoltaic module is equal to the product of voltage (V) and operating current (A). Unlike batteries, PV modules produce current at a wide range of voltages depending on the solar insolation.

I-V Curve

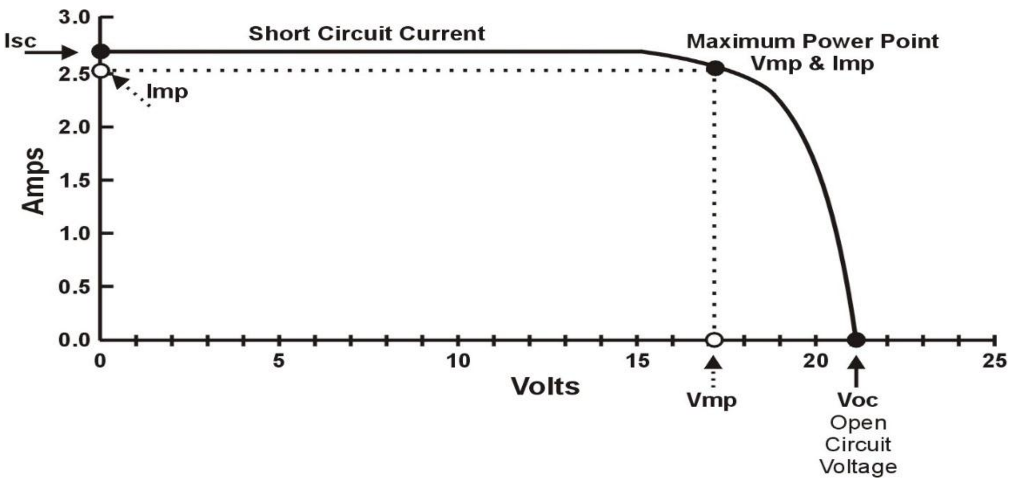

Figure 10. **Module Performance I-V CURVE**

The figure above shows an I-V curve under standard test conditions (STC) for a solar module. STC implies 1000 watts per square meter irradiation on module (often called as a peak sun) at 25 ºC cell temperature. Following are the key points in the I-v curve.

5.1 Maximum Power Point (Vmp and Imp)

MPPT in the point on the I-V curve where the module achieves maximum power output. Current and voltage at MMPT is indicate by Vmp (maximum power point voltage) and Imp (maximum power point current) respectively in the curve. These conditions are measured under standard conditions of 25 ºC cell temperature and insolation of 1000W/m^2. The voltage at maximum power point can be read by drawing a vertical line from the maximum power point to the horizontal voltage axis. In the graph above, the voltage at maximum power is 17 volts.

The current at maximum power can be read by drawing a horizontal line from the maximum power point to the vertical current axis. In the above graph, Imp is equal to 2.5 amps.

The power at maximum power point is equal to the product of voltage at maximum power point and current at maximum power point. In the above graph it is egual to 17 volts x 2.5 amps = 42.5W. This is represent by the rectangle under the I-V curve.

5.2 Open Circuit Voltage (Voc)

The maximum potential voltage that prevails when zero current is drawn from the module is termed as open-circuit voltage, Voc. The power output at Voc is zero watts. In the above graph, Voc is equal to 21 volts. It is recommended that the open circuit voltage be tested before installing a PV module. The Voc can be measured with a multimeter across the positive and negative terminal of the module. The module operates close to Voc at early morning and late evenings.

5.3 Short Circuit Current (Isc)

The maximum current that can be reached by a module when there is no resistance or under short circuit condition is termed as the short circuit current, Isc. In the above graph Isc is equal to 2.56 amps. The power output is zero watts at Isc. It is recommended that the short circuit current is tested while buying a PV module to see if it meets the specifications.

The Isc can be measured by making a direct short across the positive and negative terminal. This test has to be done only on a single module at a time and no other components should be connected to the module with a multimeter across the positive and negative terminal of the module. It should be ensured that the DC amperage of the multimeter does not exceed the Isc mentioned in the specifications, to protect the equipment.

6. External Factors That Affect Module Performance

6.1 Load Resistance

The voltage at which the module operates is affected by the battery or load directly connected to the module. If the PV module charges a battery bank of 12V, the module must operate at a voltage slightly higher than the battery bank voltage (mostly 12.5 to 15V) to charge it.

The PV system should be designed to operate at voltages close to the maximum power point. If the load resistance is not closely matched to the module I-V curve, there would be decrease in efficiency and power output, even if the module operates at maximum power point. When powering inductive loads like pumps or motors, the PV array has to be matched with load to operate at maximum power point to attain maximum efficiency.

For effectively managing the efficiency of the module power conversion, a control device (maximum power point tracker-MPPT), is used to continuously track the maximum power point. An MPPT circuitry can increase the power production by up to 30%.

6.2 Intensity of Sunlight

The current output of a PV module is directly proportional to the intensity of sunlight. Greater the insolation greater is the output. From the graph below it can be seen that with change in insolation levels, the shape of the I-V curve remains the same but the area covered under each curve decreases, indicating a decrease in current and power output. The voltage does not change much with intensity of sunlight.

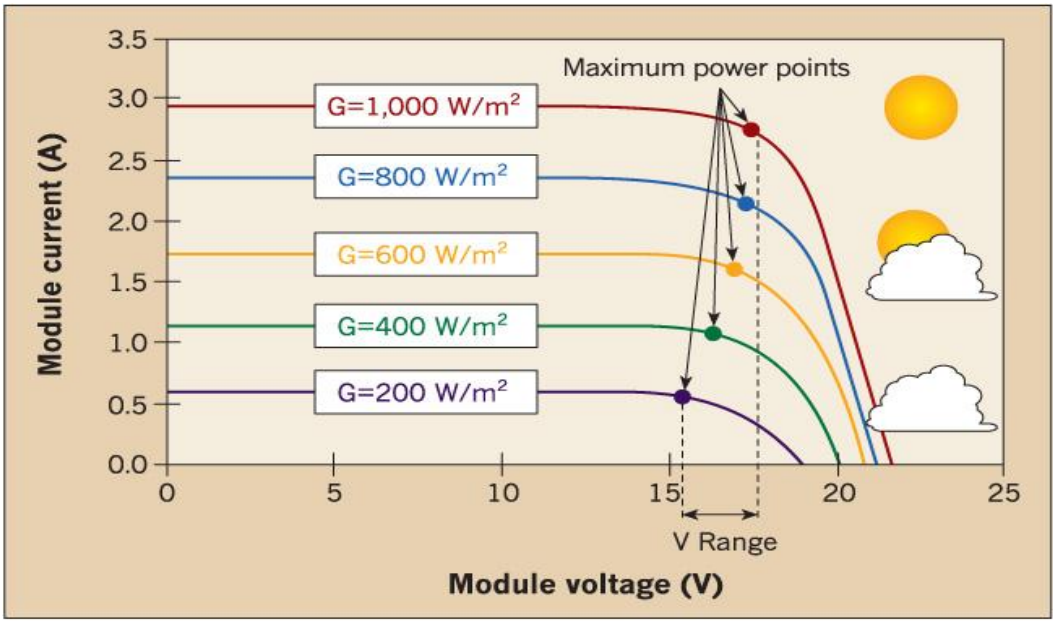

Figure 11. **Intensity of Sunlight**

6.3 Cell Temperature

The module efficiency and operating voltage decrease with increase in cell temperature beyond the standard operating temperature of 25 ºC. as the cell temperature increases, the shape of the I-V curve remains the same but it shifts leftward indicating a decrease in the voltage. This leads to a reduction in power output. Heat has the same effect on the cell as the effect resistance has on the flow electrons.

The modules should be mounted to promote airflow on all sides, to reduce the heating of the cell. Mounting options like standoff roof mount, ground mount, or pole mount, can help maintain lower cell temperatures. Some modules are designed to offset high temperature by having a better temperature coefficient. Some modules have better temperature coefficients and can perform better in high temperatures. In other modules many more cells are connected in series to offset the decrease in voltage due to high temperature.

6.4 Shading

Shading has a very big impact on the power output of the PV module. Shading on cell of a single crystalline module has a bigger impact than on a module with bypass diodes. Many modules now employ bypass diodes to reduce the effect of shading on output. A bypass diode is a semiconductor device that allows electric current to only flow in one direction, and prevents current from flowing into shaded areas.

Shade analysis is an important aspect of site analysis. Various objects that can cause shade are analyzed during the site analysis and the most appropriate site whit minimal shade is chosen. If the shading analysis is not done accurately even partial shadings can diminish the entire system's performance.

Table 6. *Effects of shading on module power*

Effects of shading on module power	
Percent of one cell shaded	Percent of module power loss
0%	0%
5%	25%
50%	50%
75%	66%
100%	75%
3 cells shaded	93%

Mounting modules at a different tilt and orientation angle on a roof can cause shading. If modules are mounted on east and west roofs, some parts of the array will have shade throughout the day.

MPPT is expected to take care of variation in external conditions and adjust the voltage so as to optimize power production. Typically, in a system, an array of modules will have a single MPPT (system with micro inverters and optimizers are exceptions). If the irradiance varies among modules in an array, a single MPPT circuitry will find it difficult to manage difference in irradiation, which will decrease the efficiency of the system. Hence, it is important to ensure that, the modules connected in an array have the same orientation.

7. Key Performance Indicators of Modules

7.1 Performance Warranty

The power production of a solar module degrades over a period of time. In order to cover the risk of customer against faster degradation or failure before lifetime of 25 to 30 years, solar manufacturers provide performance warranty. The duration of performance warranty varies from 15 years to 30 years depending on the module manufacturers.

7.2 Temperature Coefficient

The temperature coefficient was explained in detail in cell temperature section above. As explained earlier, a lower temperature coefficient will result in better temperature performance of modules. Specifically, In India conditions, it is better to choose modules with lower temperature coefficient.

7.3 Product Warranty

Solar module manufactures provide products warranty from 5 years to 25 years. Product warranty is a measure of reliability of the solar module. Hence, it is better to choose manufacturers who provide longer product warranty.

7.4 Efficiency

The efficiency of a solar module decides the area occupied by the solar PV module. A high efficiency solar module will occupy less area as compared to a low efficiency one. For e.g. a 245 Wp module of 19% efficiency will occupy less space as compared to a 245 Wp module of 13.5% efficiency.

Chapter V

1. Design of Solar PV System

The various components, parameters and operations have been covered in the previous chapter. This will explains the various steps to design a 2kw solar PV off-grid system. Recollecting the various factors covered previously, the system will be sized.

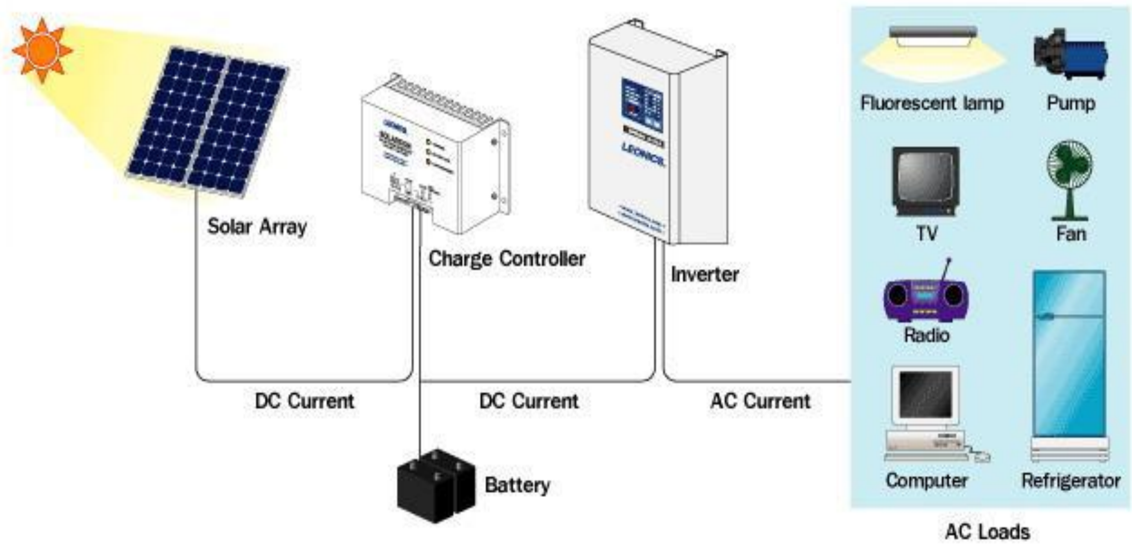

Figure 12. **Solar PV system**

Features:

- UPV Solar generator is a standalone PV system
- Sun light is converted to DC electric power by UPV solar crystalline solar modules.
- System is designed for very low loss of load probability.

2. Principle Design

A solar PV system has to be design, taken into consideration various parameters. A logical order has to be followed to get the right numbers; otherwise certain parameters may be under or over estimated.

- **Begin with Load:** Determine the connected load and daily energy consumption (watts, Wh).
- **Type of load:** Resistive inductive or conductive load energy consumption pattern.
- **Inverter/converter (Dc off grid system):** Design the inverter power rating, current and control logic.
- **System Voltage:** Choose the best-suited DC, autonomy, C-rating and type (numbers, capacity, voltage)
- **Charge Controller:** Design the charge controller (protection requirements like reverse power protection; reverse polarity protection)
- **PV Modules:** Design the PV modules (numbers, power, voltage and current ratings).
- **Wiring:** Design wire size.

The purpose of the solar PV system should be well understood. The types of load the system should power and the load characteristics have to be analyzed and estimated in load analysis. Since we are focusing on solar off-grid systems, the most common utility of these systems are in the residential front. Hence, we will deal with commonly used domestic load.

The appliance to be powered by the solar plant has to be listed and the wattage of each of them needs to be known. Two main parameters need to be calculated.

3. Peak Load (KW / KVA)

The total wattage of the all appliances connected to the system is equal to the peak load. This is the wattage requirement if all the appliances are operated simultaneously. Resistive loads add up to the Kw rating while capacitive or inductive loads add up to the KVA rating. Types of loads is been explained later.

3.1 Total Energy Consumption (KWh)

The sum of the electrical units consumed by all the appliances connected to the system is the total energy consumption. This is depend on the wattage of the appliance and the time span for which the appliance is operated. This factor may also be termed as the total power consumption, total units consumptions etc.

3.2 Diversity Factor of Loads

Diversity factors is a part of load analysis to include the reduction in energy consumption assuming that the entire connected load may not be used simultaneously. Diversity factor is an important consideration for lighting load and fans. It is fairly accurate to assume that all the lights and fans will not be operated at a time in a residential building. To factor out this simultaneity in load, the diversity factor is used.

Depending on the specific load conditions, location and requirements, the system has to be design with the right diversity factors.

4. System Description

2kWp Solar Generator System

Model: SG200W/300Ah/48V/3KVA/M

4.1 Bill of Materials

Table 7. *Bill of materials*

SG2000W/300Ah/48V/3KVA/MS			
	Description	Specification	Quantity
1	Solar Array-UPV Solar Make	**2.000Kwp** 250W-8No	1 set
2	Solar Array Mounting structure	Painted MS steel structure & SS304 Fasteners.	1 structure fixed over roof to hold 4+4 modules of 250Wp.
3	Battery-Exide Tubular	Conditions like 25Deg C temperature, DOD & Max Discharge current of 20% of C10 Rating.**48v-300Ah**	48V-300Ah C10 rated tubular batteries.
4	Battery interconnection wires	**16 Sqmm wire-1Pair**	6M
5	Inverter- Microtek	**3KVA** sine wave o/p inverter 230V, 1 Phase, 50Hz	1
6	Charge controller Cum optimizer	**40A/48V** 1. LCD Display 2. PWM Charge controller. 3. Lightning protection.	1No
7	Array interconnect cable	4 Sqmm Wire.	30M.
8	Array Junction Box	IP 65 rated, outdoor box with wago connectors for parallel circuit connection.	2
9	Solar array to battery bank cable	6Sqmm 4 core copper cable	20M

4.2 SPV System Design Sheet:

Table 8. *SPV System design sheet*

*** Solar Irradiation of 5.5KWHrs / Sq M / Day @ 25 Deg C, AM 1.5 Sun Spectrum**

Energy generated Solar Array per day at STC condition*	**8.00 (In KWHrs)**
Open to sky, space required for mounting SPV module array	**16-24Sq meter**

NOTE:** The design and the prices in this project were taken in coordination and supervision of the company ***UDHAYA ENERGY PHOTOVOLTAICS PVT LTD.

Chapter VI

1. Financial Analysis

Introduction

This unit reviews basic financial analysis techniques. The issue involved is fundamentally this:

- Net present value.
- Internal rate of return.
- Modified internal rate of return.
- Accounting rate of return.
- Profitability Index or Benefit Cost Ratio.
- Payback period analysis.

This is what investment analysis is all about. We cannot simply sum up the future net-returns and compare this sum with the project's initial costs, because people have a bias in favor of benefits received in the present period. Hence, future benefits or costs must be weighted, or discounted, to convert them into current-period equivalents. Once future returns are converted into "present value equivalents", everything can be summed up, allowing a comparison of the "present value" of the project's net-benefits against its costs.

2. Net Present Value

The net present value method compares flow of cash across various time periods. Taking a capital budgeting project that involves a given outlay, we can intuitively try to assess the value of all flows in terms of today's money and then compare this with the outlay. If the value today of all the inflows is greater than the outlay, then the investment is viable.

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + ... + \frac{C_T}{(1+r)^T}$$

$$-C_0 = Initial\ Investment$$
$$C = Cash\ Flow$$
$$r = Discount\ Rate$$
$$T = Time$$

Equation 1. Net present value - Inflows

Net Present Value (NPV) is a formula used to determine the present value of an investment by the discounted sum of all cash flows received from the project. The formula for the discounted sum of all cash flows can be rewritten as:

$$NPV = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

Equation 2. Net present value - Investment

When a company or investor takes on a project or investment, it is important to calculate an estimate of how profitable the project or investment will be. In the formula, the **-C_0** is the initial investment, which is a negative cash flow showing that money is going out as opposed to coming in. Considering that the money going out is subtracted from the discounted sum of cash flows coming in, the net present value would need to be positive in order to be considered a valuable investment.

Table 9. *Net present value*

Periods	0	1	2	3	4	5	6	7	8	9	10	11	12
Fixed Investment	-3,20,250.00												
Deferred Investment Valué	-												
Total Investment	-3,20,250.00	-	-	-	-	-20,000.00	-	-	-	-	-25,000.00	-	-
Annual growth	-	-	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Cash Flow	-	21,600.00	23,760.00	26,136.00	28,749.60	31,624.56	34,787.02	38,265.72	42,092.29	46,301.52	50,931.67	56,024.84	61,627.32
Net Balance To Assess	-3,20,250.00	21,600.00	23,760.00	26,136.00	28,749.60	11,624.56	34,787.02	38,265.72	42,092.29	46,301.52	25,931.67	56,024.84	61,627.32
Rate	9.75%												
Net Present Value	($3,20,250.00)	$19,681.09	$19,725.93	$19,770.86	$19,815.89	$7,300.52	$19,906.28	$19,951.62	$19,997.07	$20,042.62	$10,227.87	$20,134.03	$20,179.90
Σ Net Present Value	$1,50,167.92	ACCEPT											

Periods	13	14	15	16	17	18	19	20	21	22	23	24	25
Fixed Investment													
Deferred Investment Valué													
Total Investment	-	-	-30,000.00	-	-	-	-	-35,000.00	-	-	-	-	-
Annual growth	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Cash Flow	67,790.05	74,569.06	82,025.96	90,228.56	99,251.42	1,09,176.56	1,20,094.21	1,32,103.64	1,45,314.00	1,59,845.40	1,75,829.94	1,93,412.93	2,12,754.23
Net Balance To Assess	67,790.05	74,569.06	52,025.96	90,228.56	99,251.42	1,09,176.56	1,20,094.21	97,103.64	1,45,314.00	1,59,845.40	1,75,829.94	1,93,412.93	2,12,754.23
Rate													
Net Present Value	$20,225.86	$20,271.94	$12,887.01	$20,364.40	$20,410.79	$20,457.28	$20,503.88	$15,105.84	$20,597.40	$20,644.32	$20,691.34	$20,738.47	$20,785.72
Σ Net Present Value													

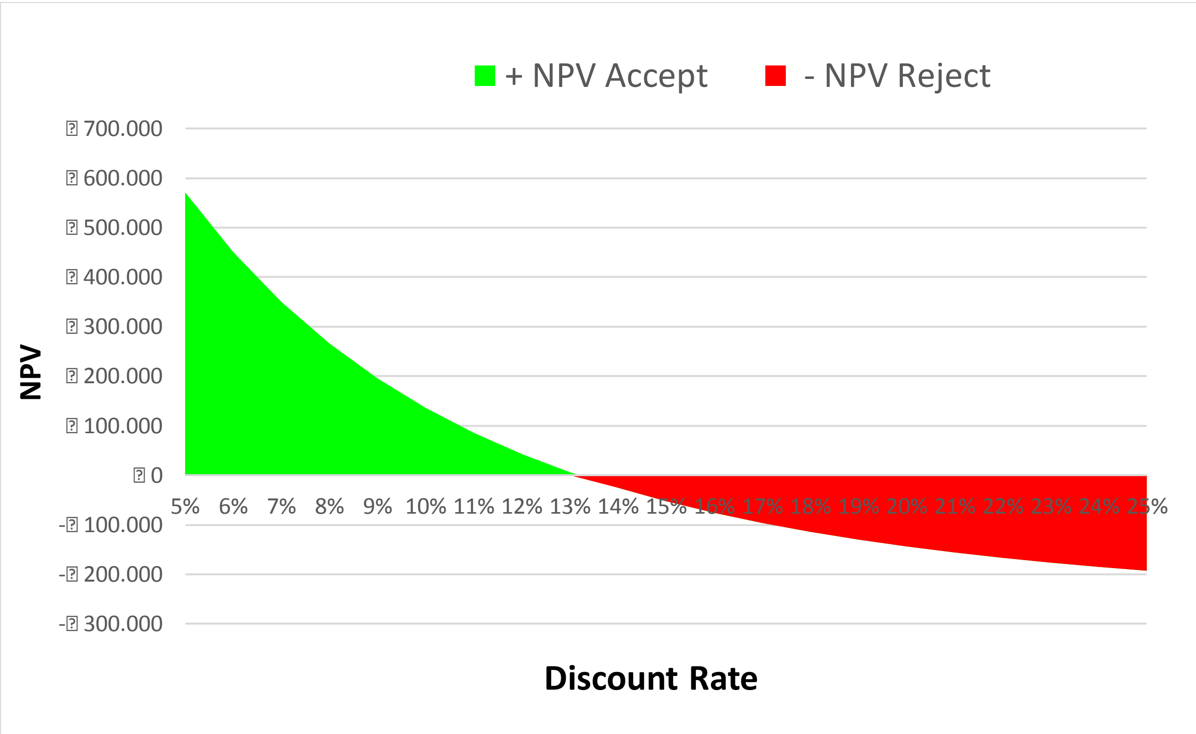

Figure 13. **NPV Accept, NPV Reject**

NPV = Rs. 1,50167.92

3. Internal Rate of Return

The internal rate of return (IRR) is a rate of return used in capital budgeting to measure and compare the profitability of investments. It is also called the discounted cash flow rate of return (DCFROR) or simply the rate of return (ROR). In the context of savings and loans the IRR is also called the effective interest rate.

The internal rate of return on an investment or project is the "annualized effective compounded return rate" or discount rate that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero.

In more specific terms, the IRR of an investment is the interest rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment.

Internal rates of return are commonly used to evaluate the desirability of investments or projects. The higher a project's internal rate of return, the more desirable it is to undertake the project. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first.

Because the internal rate of return is a rate quantity, it is an indicator of the efficiency, quality, or yield of an investment. This is in contrast with the net present value, which is an indicator of the value or magnitude of an investment.

An investment is considered acceptable if its internal rate of return is greater than an established minimum acceptable rate of return or cost of capital. In a scenario where an investment is considered by a firm that has equity holders, this minimum rate is the cost of capital of the investment (which may be determined by the risk-adjusted cost of capital of alternative investments). This ensures that the investment is supported by equity holders since, in general, an investment whose IRR exceeds its cost of capital adds value for the company (i.e., it is economically profitable).

The IRR in this project is calculated as 13.19% which is more than cost of capital which is estimated as 9.75%. Hence this project can be **accepted** as per IRR analysis.

4. Modified Internal Rate of Return

Modified internal rate of return (MIRR) is an improved version of the internal rate of return (IRR) approach to capital budgeting decisions. It does not require the assumption that the project cash flows are reinvested at the IRR; rather, it factors in a discrete reinvestment rate into the model.

Decision rule: projects with MIRR greater the project's hurdle rate should be accepted; while in case of mutually exclusive projects, the project with higher MIRR should be preferred.

MIRR = MIRR (values, finance rate, reinvest rate)

Values represent the array of the project's cash flows, finance rate is the relevant cost of capital, and reinvest rate is the rate of return at which the project's cash flows are expected to be reinvested.

The manual approach to calculation of MIRR involves finding the sum of terminal values of all the net cash flows (other than initial investment) and then using the following equation to solve for MIRR:

$$MIRR = \sqrt[n]{\frac{FV(PositiveCashFlows, costofcapital)}{PV\ (InitialOutlays, FinancingCost)}} - 1$$

Equation 3. Modified internal rate of return

Where n is the number of periods.

In this project the MIRR is calculated as 11%

The IRR is a very popular method in determining capital budgeting that is used by many businesses; however, it also has many flaws that skew a company's projected numbers. The biggest problem is that it does not take into account the risk factors or other costs that could come from a company's return. This is where the MIRR comes in. What MIRR does is fill in the limitations that come from the IRR. As seen in the picture above, the calculation for the MIRR combines both future value and that of the present value, allowing for finance rates and money flowing out of the business. The IRR is more of an optimistic view of returns, while the MIRR is a realistic view.

5. Accounting rate of return

The simplest method of measuring the return on an investment is the accounting rate of return (ARR). The formula is

Accounting Rate of Return = (Annual cash inflows – Depreciation) / Initial investment.

Depreciation is calculated using the straight line method:

Depreciation = (Cost – Salvage value) / Useful Life

(325400 -0) / 25 = 13016

ARR = (84971 -13016) / 325400 = 0.22 = 22%

The accounting rate of return is 22% its mean that the project is earning 22paisa for one Rupee.

As bigger is the percentages more we will earn.

6. Profitability Ratio or Benefit Cost Ratio

Profitability Index is a ratio of discounted cash inflow to the discounted cash outflow. Discounted cash inflow is our benefit in the project and the initial investment is our cost, which is why we also call it benefit to cost ratio.

The formula indicates the benefits in the numerator and costs in the denominator. Formula for calculating Profitability Index is as follows:

$$Profitability\ Index\ (PI)\ or\ Benefit\ to\ Cost\ Ratio = \frac{\sum_{t=0}^{n} \frac{Benefit_t}{(1 + Discount\ Rate)^t}}{\sum_{t=0}^{n} \frac{Cost_t}{(1 + Discount\ Rate)^t}}$$

Equation 4. Profitability Ratio or Benefit Cost Ratio

A profitability index of anything equal to or greater than 1 is considered good. It means that the project is worth executing. PI greater than 1 indicates that the project is paying something more than the required rate of return of the investor. In this project the PI is greater than 1 i.e. 1.08.

7. Payback Period Analysis

The payback period analysis is the way of looking the project idea that tells about the duration that the money invested on the project can be earned back. The formula used is:

Cost of project

________________ = Payback Period.

Annual Cash inflow

The project cost is Rs. 325400 and the expected annual cash flow is Rs. 21600 and it will increase 10% every year.

Payback period = Year 10, Month 7, Day 6

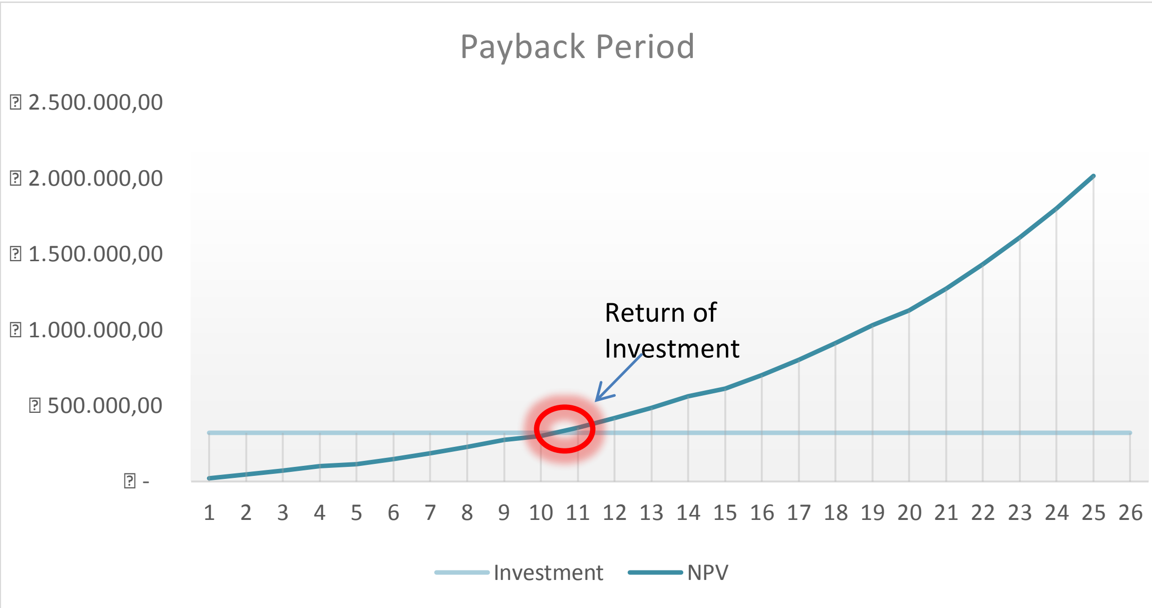

Figure 14. **Payback Period**

Findings

I accept the project and give green card to implement it, in all the aspects that we have studied were positive.

The net present value analysis study show that the cash inflow is bigger than the cash outflow and the summation is positive, also the net present value is zero when the internal rate of return is 13.19%, greater than the bank rate which is 9.75%.

The payback period will be in 10 years but during this time we won't touch the system, since is evaluated for the next 25 years.

Finally, the study gives a clear picture of the project financial feasibility in Kerala. The project will be more attractive if the government (state or central) gives any additional support in the form of subsidy.

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