LOW-COST RESIDENTIAL SOLAR

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ABSTRACT

The purpose of this study is to understand the industry landscape of Residential Solar in the different segment in India. It also concentrates in finding the market analysis of solar power used in India. It also identifies the major players in terms of its market share and to improve solar efficiency with low cost manufacturing. It helps the manufacturers where to concentrate to yield more market share and also helps the customer to reveal the buying behavior.

KEY WORDS: Residential solar, solar spectrum, solar products, market landscape, opportunity, installed capacity, Industry value chain, solar components cost, effective ideas, Plasmonic solar cells, solar inverter, inverter efficiency, DC solar appliances, DC power house, printed solar cells, residential solar panel cost, residential solar energy

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INTRODUCTION

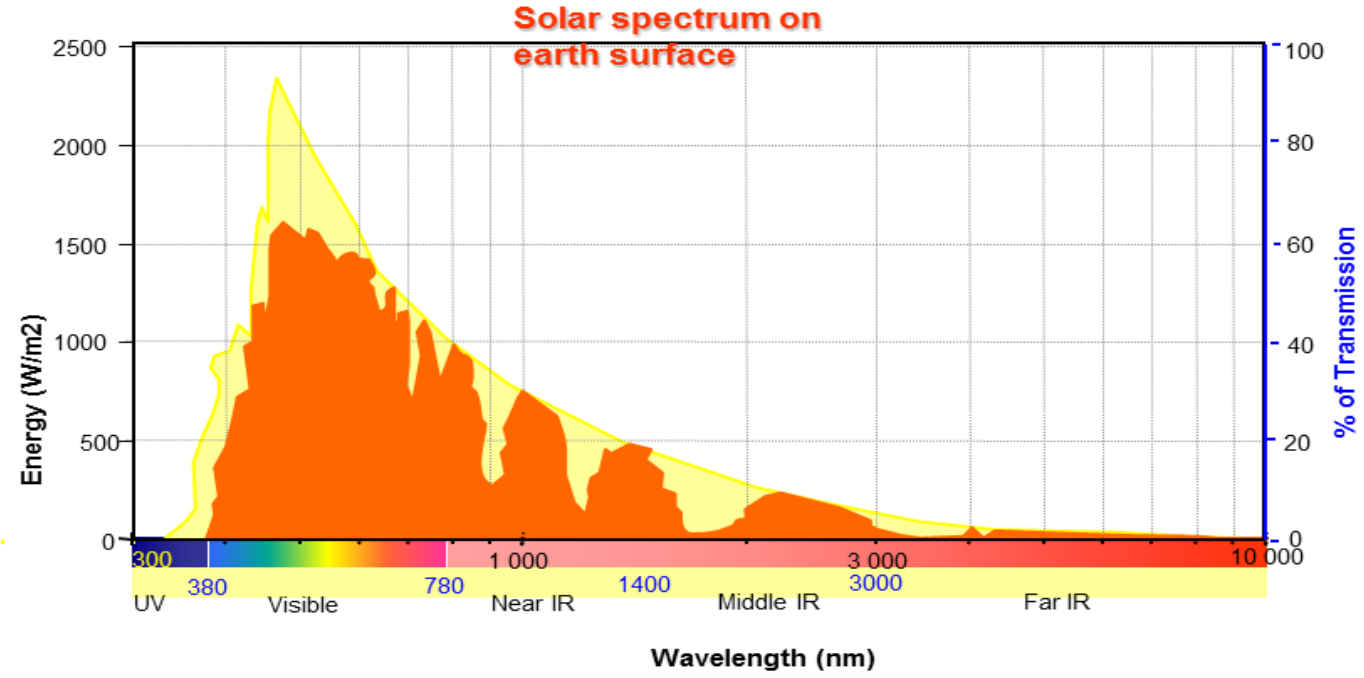
1.1 NATURE AND SCOPE OF THE PROJECT

This internship project is to explore the market landscape of Residential Solar Industry for Make in India. The product portfolio, market analysis on the industry also conducted in this project. Industry value chain been developed in order to cut the cost. Technical analysis been done on Residential Solar to improve its efficiency. In addition to that new process/product is to be developed for cost saving by using value chain. Business plan to be created for the Residential Solar.

1.2 HOW IS SOLAR ENERGY GENERATED

Electromagnetic radiation given by the sun in terms of infrared, visible and ultraviolet light. The band of radiation power be divided into regions by their wavelengths. Ultraviolet which spans a range from 100-400 nm, visible light which spans 380-780 nm, infrared which spans 700-1000000 nm.

FIGURE 1 SOLAR SPECTRUM ON EARTH SURFACE



The sun emits 3.86 x 10^{26} watts of energy. In that most of it goes off into space, but nearly 1.74 x 10^{17} watts strikes the earth. Solar power is produced from sunlight which converts into electricity by using Photovoltaics or by using Concentrated solar power.

By photovoltaic effect PV cells convert light into electric current. Array of photovoltaic cells are used to collect energy given by the sun and convert it to electricity. At present, solar cells panels convert, at best, about 15% of sunlight hitting them into electricity.

1.3 WHY SOLAR

Solar is an infinite power source, most significant investment one can make and also it reduces the dependence on fossil fuels. While the majority of the electricity supply is generated from fossil fuels i.e coal, oil and natural gas, these traditional energy sources face numerous of challenges including rise in price, concerns in security issues, dependence on imports from a countries which have significant supplies of fossil fuels, and environmental concerns over the change in climate risks associated with power generation using fossil fuels

Reduction in dependence on fossil fuels: Solar energy does not need fossil fuels for production and is therefore less dependent on this expensive natural resource. It's a emission less one and also reduces the electric bill.

1.4 RESIDENTIAL SOLAR

Residential Solar industry is about converting energy generated by the sun to a form of energy people would actually pay for. The most targeted form of energy is electricity. Most widely used technologies are Photovoltaic solar panels, Concentrated Solar Power, solar water heating. Solar energy potential in India is vast because of its geographic location. In this era power is more precious.

1.5 NEED FOR RESIDENTIAL SOLAR

Due to urbanization and economic development there is a rapid rise in energy demand that leads to a urban areas in our country to enhanced Green House Gas (GHG) emissions. To reduce that many cities are setting targets and come up with the policies for promoting renewable energy and reducing GHG emissions and many countries like Australia and USA are started developing the solar cities.

MARKET SCENARIO

2.1 EMERGING INDUSTRY

Residential solar industry is in an emerging stage due to lack of resources of fossil fuels, subsidies provided by the government, tax exemption, geographic region of India it has nearly 300 sunny days in a year and also concern on global warming

2.2 PRODUCTS

In India, demands for solar products are increasing over the years especially in rural areas. According to the survey conducted by the "Indian Solar Energy Market Outlook 2012", Indian solar industry has the opportunity where around 45% of its household, especially rural areas that do not have access to electricity can get use of residential solar because India has more than 300 sunny days. Solar products are solar heater, solar cooker, and water pump and so on. Solar water heating (SWH) is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. SWH systems comprises of various technologies that are used in worldwide.

2.3 PLAYERS

According to the latest report published by Bridge to India Su-Kam Power Systems Limited, India's leading power back up solutions provider as the leading player in residential solar market. Su-kam with 20.6% market share and pan India presence is the leading player in the residential solar market, says the report. Su-kam is also stands first in the domestic inverter supplier commanding 32% market share in the off-grid and hybrid inverters segments. Su-Kam has been focusing on rooftop Solar Projects primarily for off-grid and on-grid for residential, institutional and government segment.

2.3.1 TOP INVERTER PLAYERS

Indian UPS market is a growing market with both multinational and Indian players competing to attain a market share. According to a Frost and Sullivan report, Indian UPS market is expected to witness a CAGR of percent with projected market size of US$ 1316.5 million by 2014.This growth is driven by demands from major sectors like financial services ,insurance, telecom, retail, IT/ITES, manufacturing and others.

TOP INVERTER PLAYERS

1.Luminous power technologies

2.Genus power Infrastructure

3.Su-Kam power system

4.Numeric power system

5.Delta power solutions

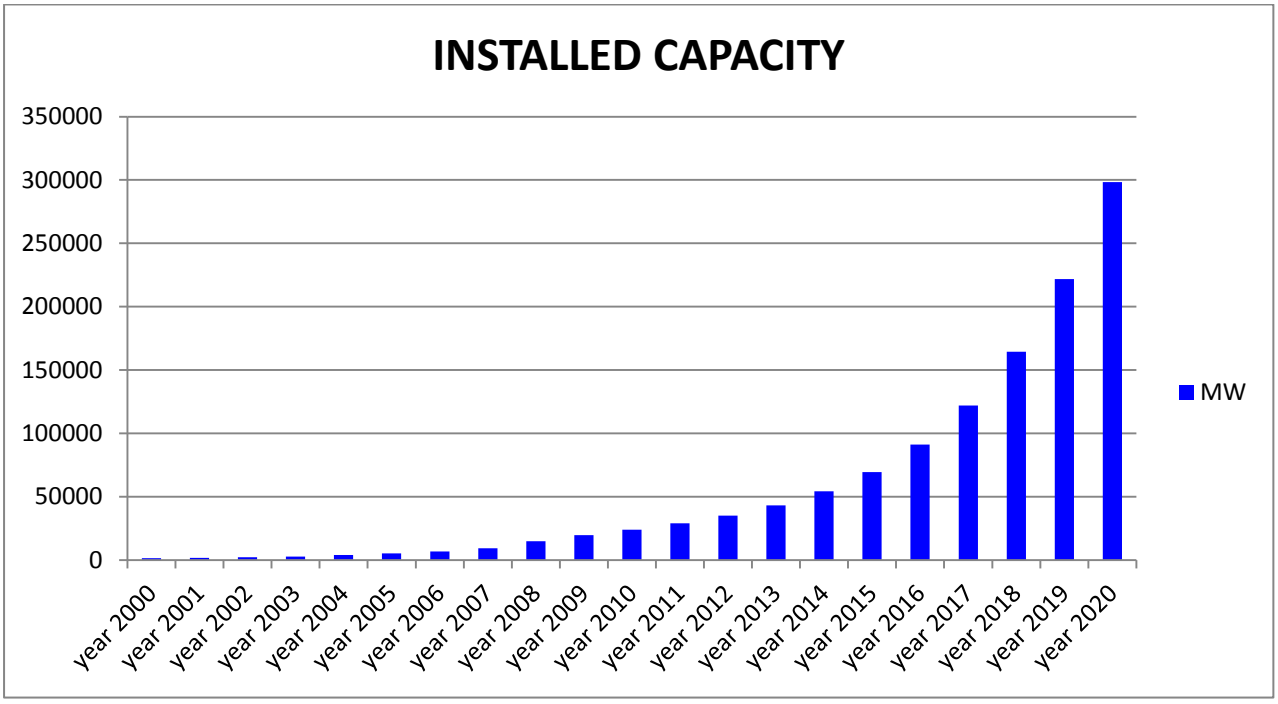
2.4 GAP/OPPORTUNITY

Solar energy remains popular because it is both renewable and clean source of energy. Long lasting energy source, can be used to create huge in quantity. It has only few numbers of competitors. Along with daily fluctuations and shortage of power residential solar has much opportunity for the people to opt for there they can get potential power throughout the day.

2.5 MARKET ANALYSIS

Global PV installations increases year by year and its forecasted capacity on 2020 be 2,98,415 MW.

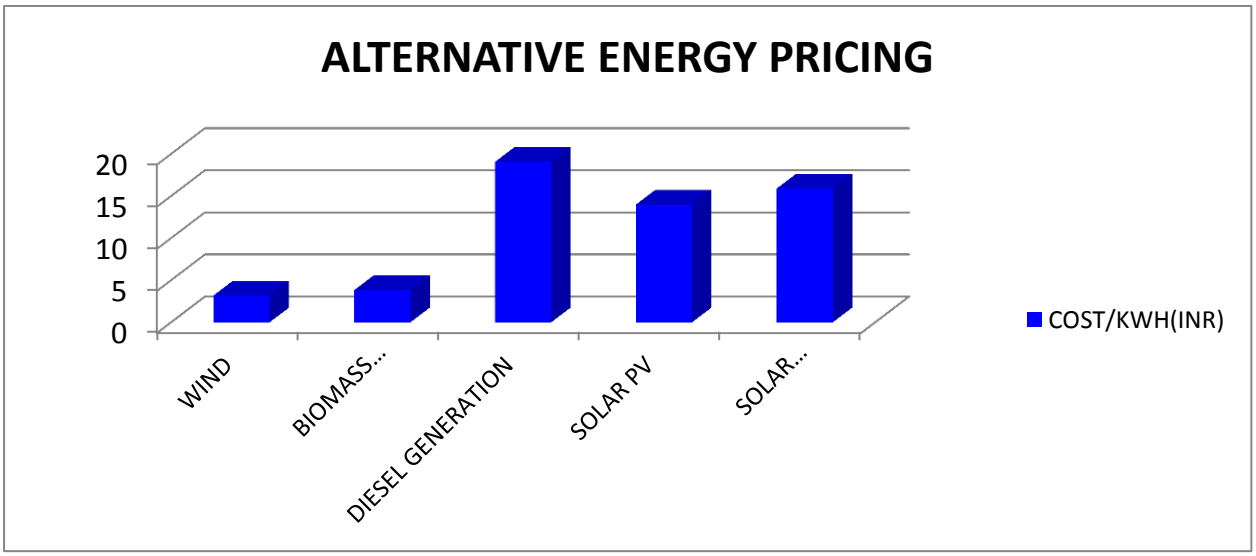
Figure 2: CUMULATIVE INSTALLED SOLAR PV POWER CAPACITY



Source:http://www.greenchipstocks.com/report/alternative-energy-a-2009-report-card/449

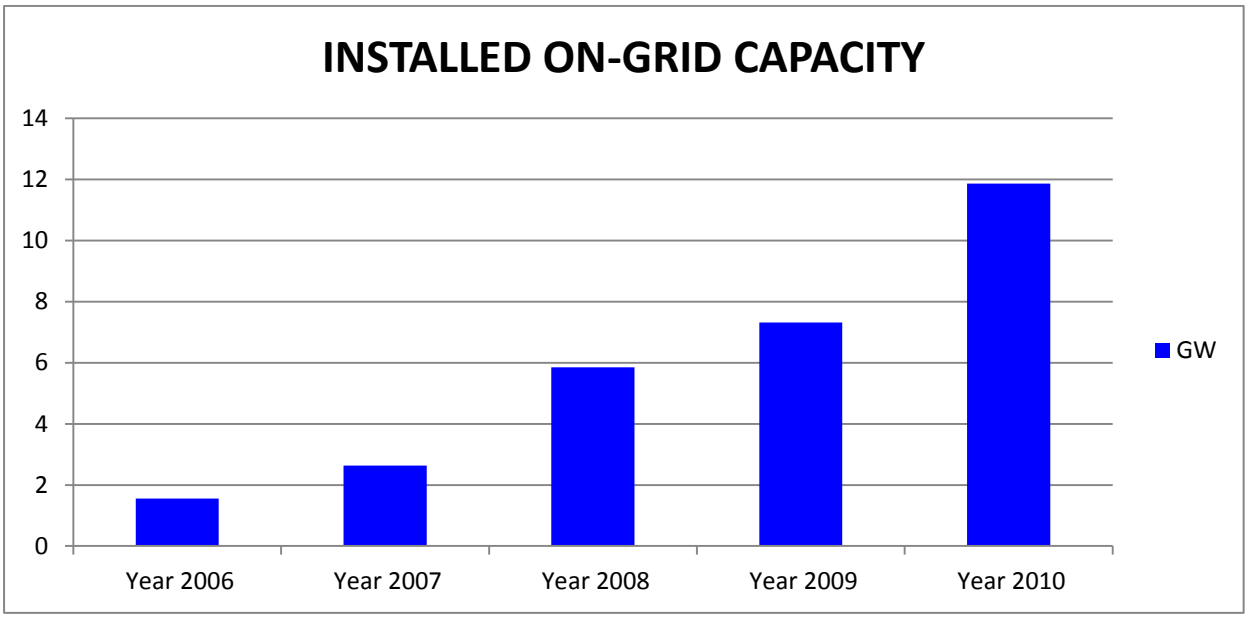
This shows about the alternative energy pricing compared with other possible energy resources. Solar energy be close parity with electric grid rates when the fall in silicon prices and improve efficiency in the thin film production. Residential market share when compared to commercial and appliance market share. Residential market share is emerging year by year rapidly.

FIGURE 3: ENERGY PRICE PER KWH



Source: http://greenecon.net

FIGURE 4: INSTALLED PV MARKET SIZE (ON-GRID)



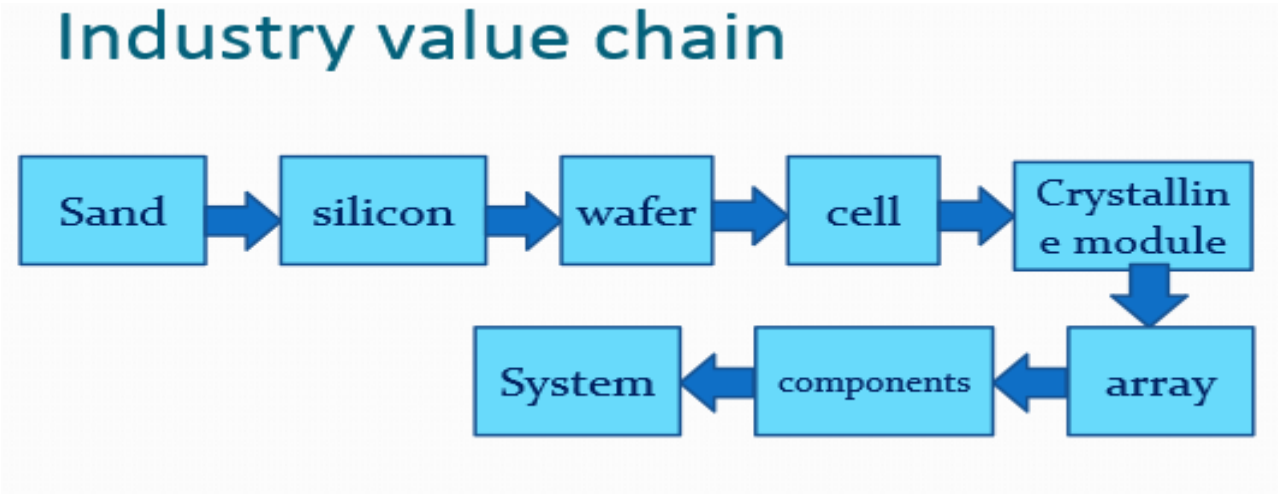
Source:http://www.solarbuzz.com/facts-and-figures/markets-growth/market-growth

VALUE CHAIN

3.1 INDUSTRY VALUE CHAIN

Industry value chain consists of the silicon production starts with sand raw silicon with 98%purity by coke reduction, then by purification high purity silicon, after the process of purification wafer cutting to get wafer. Then by doping cleaning cell be manufactured. Crystalline module be created by using connecting cells, laminate, frame and connect. After that array be formed and system with the components like inverter, battery, charge controller etc.., Then the circuit be connected to the system.

FIGURE 5: INDUSTRY VALUE CHAIN



Example: Cost associated with 40W capacity of solar power be nearly around 20000-25000 including battery, inverter, installation cost. In this low capacity panel cost be nearly 4000, remaining cost be the inverter and the battery.

3.2 Tools for cost calculation of solar components

Tool which consists of Solar components cost and cost savings when the usage of electricity by Solar installation. Find the link for excel tool EXCEL TOOL

- $P_{peak, usage}$ = Power usage in kilowatts
- E_{used} = Daily energy usage in kilowatt-hours
- T_{sun} = Average sunshine hours
- $Cost_{inverter} = P_{peak, usage}$ x $1000/kilowatt
- $Cost_{panels} = (E_{used} / T_{sun})$ x $8000/kilo-watt
- $Cost_{batteries} = 2 \times E_{used}$ x $100/kilowatt-hour
- $Cost_{batteries, life-cycle} = 4 \times Cost_{batteries} = 8 \times E_{used}$ x $100/kwh
- $Cost_{upfront} = Cost_{inverter} + Cost_{panels} + Cost_{batteries}$
- $Cost_{life-cycle} = Cost_{inverter} + Cost_{panels} + Cost_{batteries, life-cycle}$
- $Cost_{kwh} = Cost_{life-cycle} / (9125 \times E_{used})$

For example

- Usage of electricity for a year be 15 kWh
- Usage of electricity per day be 0.0410 kWh
- Usage of watts per day be approximately 40 watts
- Finding out the average hours of sunlight

Then the size and specifications of 40 W solar panel:

- Max Output Power 40W
- Max Output Voltage 17.8V
- Max Output Current 2.25A
- Open Circuit Voltage 21.6V
- Working Temperature -40 to +80 degree centigrade
- Dimension 550*610*23mm
- Weight 4.3kg

4 IDEAS

4.1 NEW IDEA EVALUATION

According to CAGR nearly 30% of the rural areas are off the grid. Their basic requirement be light and fan, to install that capacity it costs nearly around 25000 with high cost of solar panel, battery and inverter. If the inverter, panel cost be reduced with low cost manufacturing, the rural area market can be easily developed and their off grid percentage becomes minimum.

EFFECTIVE IDEAS FOR LOW COST RESIDENTIAL SOLAR

4.1.1 PLASMONIC SOLAR CELLS

- **Plasmonic solar cells** are photovoltaic devices that convert light into electricity with the usage of plasmons
- Plasmonic solar cells are thin film solar cell with the thickness of 1-2µm
- Plasmonic solar cells are cheaper than silicon

4.1.2 WHAT ARE PLASMONS?

- When light hits a metal under specific circumstances waves of electrons are created
- These waves are
  - Generated at optical frequencies
  - Small and Rapid
- Plasmons are generally nanostructure metals

- Around 40% of the cost of a solar module made from crystalline silicon is the cost of the silicon wafers. So plasmonic solar cells be replaced by crystalline silicon in order to cut the cost.
- Plasmonic cells improve absorption by scattering light using metal nanoparticles excited at their surface plasmon resonance.

4.1.3 BASIC PRINCIPLES

When a photon hits a semi-conductor, one of three things can happen: The photon (lower than Si band gap energy) can pass through the material or The photon can reflect off the surface or The photon (higher than Si band gap energy) can be absorbed by the silicon.

Three plasmonic approaches to enhance the absorption of light in the active layer of a solar cell

- Metal nanoparticles at the top surface of the solar cell
- Metal nanoparticles inside the absorber
- At the back surface of the cell

Purpose of plasmonic solar cells

- Plasmonic Solar Cells (PSCs) have great potential to cut down the cost of solar power
- To make SC a viable energy source, trapping of light is crucial for thin film SCs
- Plasmonic nanoparticles be used to increase the efficiency of thin film SCs
- The scattered light from plasmonic nanoparticles excited at LSPR make them efficient

- The design of a PSC varies depending on the method being used to trap light through the material
- It can also used as the back contact of the cell where charge carried be efficiently collected due to a very short distance they travel to reach the contact.

Efficiency benefits from plasmonic solar cells

- Increase in optical absorption
- Increase in open circuit voltage
- Increase in sheet conductivity

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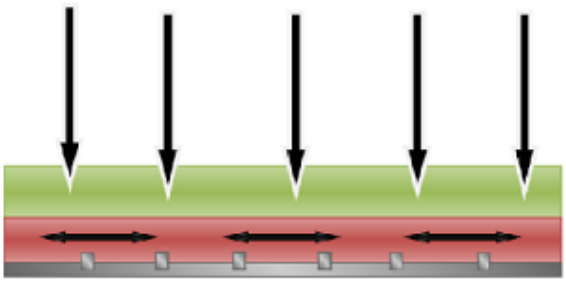

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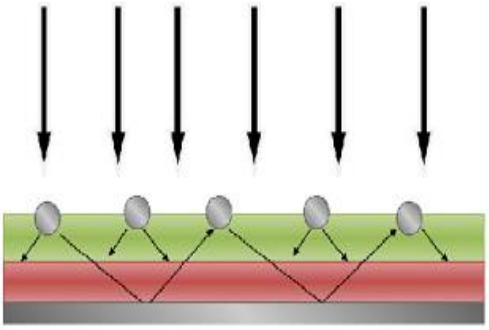

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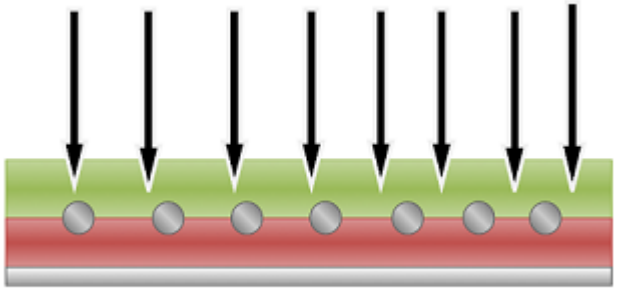


Source: http://www.nature.com/nmat/journal/v9/n3/abs/nmat2629.html

FIGURE 6: 1. Light trapping done by the excitation of Surface Plasmon Polaritons on the metal or semiconductor interface.2.At the surface of the solar cell light trapping by metal nanoparticles. 3. By the excitation of surface plasmons Metal nanoparticles embedded in the semiconductor

4.1.4 Emerging techniques in Plasmonic Solar Cells

Hyperbolic metamaterials

To enable more efficiency light harvesting, metamaterials gets the advantage of plasmonic effect. These Metamaterials are materials that have designed nanoscale features layered into surfaces. Nanoscale“superlattice” crystalline structure made by the metal titanium nitride and a semiconductor called as aluminum scandium nitride. Titanium nitride which also has the property of being stable at high temperature and durable, and also has the property that growing of about 5-20 nanometers in nanoscale crystalline films layer. It deals with the cloud of electrons freed by the presence of sunlight. When light passes through in one direction the material acts as a metal, when the light passes in a perpendicular direction it act as a dielectric. This leads to “hyperbolic dispersion” of light and from devices it has the potential to extract more photons, which results in high performance.

New Plasmonic solar cell design

Plasmonic tandem cell geometries be made, semiconductors with different bandgaps are stacked on top of each other, separated by a metal contact layer with a plasmonic nanostructure that couples different spectral bands in the solar spectrum into the corresponding semiconductor layer. Coupling sunlight into SPPs could also In order to solve the problem of light absorption in quantum-dot solar cells coupling sunlight into Surface Plasmonic Polariton. It has more benefits because of its flexibility in the semiconductor bandgap by its particle size, and the effective light absorption requires thick quantum-dot layers, through which carrier can able to transport . As in a recent research, a 20-nm-thick layer of CdSe semiconductor quantum dots deposited on a Ag film can absorb light confined into SPPs within a decay length of 1.2 µm at an incident photon energy above the CdSe quantum-dot bandgap at 2.3 eV. To generate plasmons, the reverse geometry in which quantum dots are electrically excited. The plasmon light-trapping concepts rely on scattering using localized modes, and are thus relatively insensitive to angle of incidence. This is an advantage for solar cell designs made for areas where incident sunlight is mostly diffuse rather than direct.

4.1.5 Applications of Plasmonic Solar Cells

- Rural electrification
- Power station
- Space Exploration Vehicles
- Low power electronics

4.2 TO IMPROVE SOLAR INVERTER EFFICIENCY

An inverter uses a Direct Current power supply and generates an Alternating Current supply, at a voltage similar to that of your normal mains supply.

4.2.1 WHY SOLAR INVERTER

- The main function of solar inverter is converting DC voltage to a stable value
- As the solar inverter market is ,these inverters require high efficiency and reliability in its function
- By an electrical switching process the usage of solar inverters is to convert direct current into alternating current
- It has the potential to be used as alternative sources of energy.

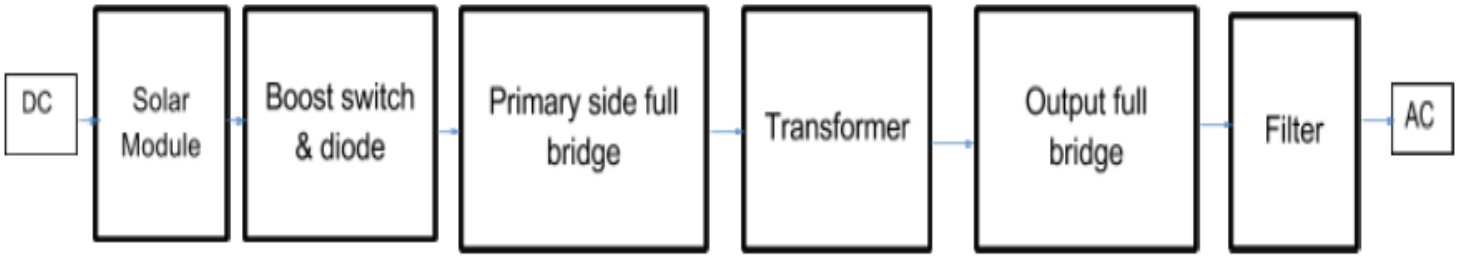
4.2.2 INVERTER EFFICIENCY

Is achieved by using

- Boost converter
- Boost switch
- Isolated full bridge converter
- Boost diode
- Maximum power point tracking

Solar inverters use MPPT to attain maximum power from the solar panel. Inverters can have a technique that could be named as **"Sleep Mode"** to increase efficiency. This be done with the help of a sensor within the inverter sensing if AC power is required or by effectively switch the inverter off, continuing to sense if power is required.

FIGURE 7: FUNCTION OF INVERTER



4.2.3 REACTIVE POWER CONTROL TO IMPROVE EFFICIENCY

- To avoid the resonances grid tie inverter can have anti- islanding protection built in to inject pulses that are out of phase with the AC
- To absorb or supply reactive power, capacitor is installed
- Integrated thyristor-switched capacitors functioning as a Flexible AC Transmission System, will increase the provision of reactive power, it increases efficiency by the reduction of line losses

Solar inverter

- A solar inverter, generally is grid tied and will transfer the energy from the grid
- A solar inverter can basically feed into the electrical grid and it has functions to attach to photovoltaic arrays
- To prevent automatic re-connection, solar inverters also have islanding protection

Regular inverter

- When the supply is available a regular inverter or a UPS will basically have a battery to store energy from the grid
- When the grid is cut off, it will basically switch to power from the energy which is already stored in the battery

4.2.5 Advantages of Solar inverter

- Solar inverter has the potential to yield about 20% more power in unshaded conditions and 27% more in shaded conditions
- Solar inverters are automatically programmed to switch off during power losses for safety concern, it adds the value of the product
- It brings the excess energy to the utility grid

4.3 ALL DC SOLAR APPLIANCES FOR LOW COST RESIDENTIAL USAGE

Solar electric system which convert sunlight to Direct Current electricity or DC. Solar cells, generally consisting of 2 layers of silicon (semiconductor material) and a separation layer, are wired together and assembled into panels or modules. When a solar panel is manufactured, the PV cells are wired together in “series”. The output voltage of the panel depends on the number of cells in the series. Common output voltages are 12, 18, and 24 volts DC.

4.3.1 WHY SOLAR CELLS PRODUCE DC

- In solar cell, light stimulates electrons to move from one semiconductor layer to another layer
- The direction of this occurs depends on the physical and chemical properties of the two layers, which is fixed (one is more positive and one more negative)
- So they will always flow in the same direction, hence is called DC
- To get AC current need to pass to the inverter

4.3.2 LOW COST DC APPLIANCES

- DC ceiling fans
- LED lights
- Solar cook stove
- Water and well pump
- Electric gate opener
- Refrigerator
- Battery charger
- Radio

4.3.3 PURPOSE OF USING DC LOW COST APPLIANCES

Appliances such as DC ceiling fans, LED lights, DC motor pump are low cost appliances.

Solar power needed to run these appliances-300 W

Solar installation cost- Rs.20,000 (Approx)

Total annual savings by using solar-Rs.7840

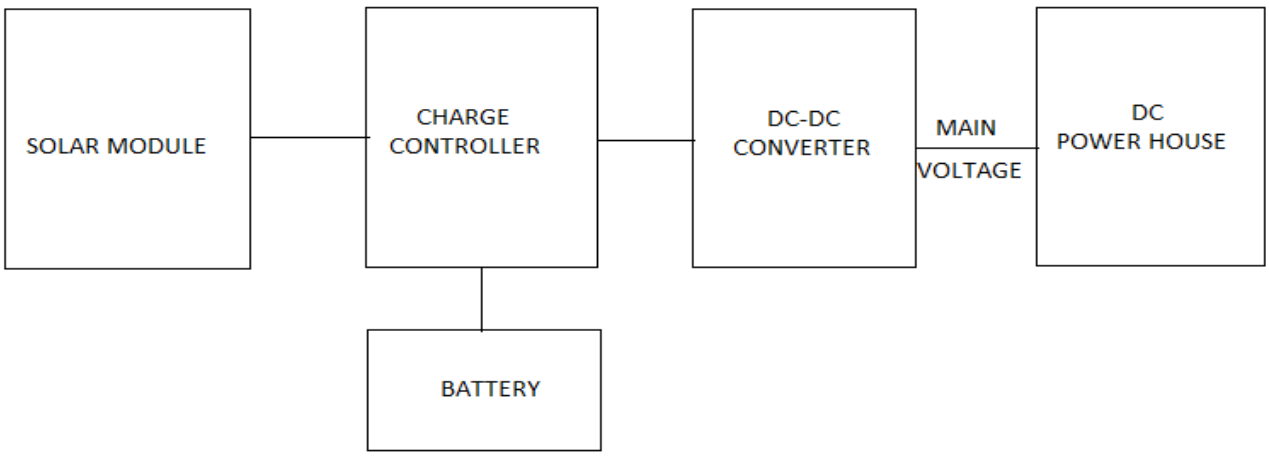
According to CAGR nearly 30% of rural India is off the grid. Solar plays a vital role to rural electrification even though it's initial investment is high. Inverter cost is excluded because of all DC appliances.

4.3.4 Advantages of using DC instead of AC

- Infinite power source
- Solar energy can be used in remote areas where it is too expensive to extend the electricity power grid especially in rural areas
- Solar does not cause pollution
- All DC solar appliances is cheaper because inverter is not required for using these appliances

- High efficiencies off of battery power
- DC power transmission have high power densities
- It reduces the energy losses
- Shrinking power supplies

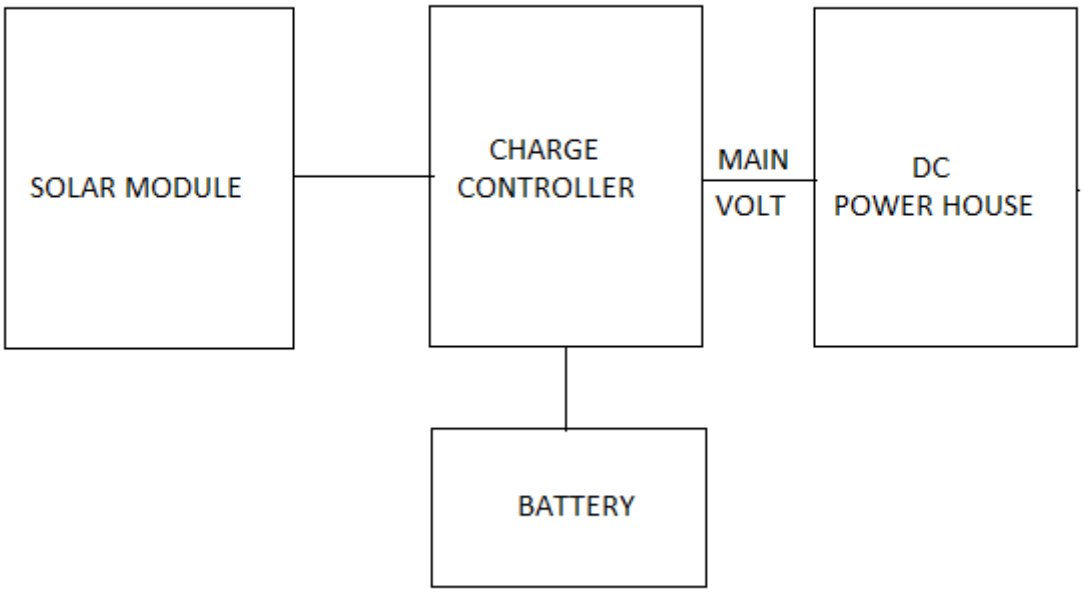
FIGURE 8: LAYOUT OF A DC POWER HOUSE



DC electrical system must be safe to the user as per NEC guidelines.

Layout of a DC should be based on radial grid because these grid be easy to build and maintain.

FIGURE 9: LAYOUT OF A DC POWER HOUSE WITHOUT DC-DC CONVERTER



DC power house without DC-DC converter will reduce the cost.Hence its more cost efficient for using DC fans and lights.

4.3.4 Emerging technology in Solar cells to cut cost mainly for rural electrification

PRINTED SOLAR CELLS

- In remote locations the malleable nature of the paper-thin solar cells makes it ideal especially for rural communities
- The solar cells produced are paper-thin, flexible and inexpensive for transportation. Interest in printed solar cells has boosted in recent years
- Existing solar energy technology consists of silicon-based panels which are produced in wafers and require a large amount of sunlight to be efficient

- Printed solar cells employ a more organic approach that uses perovskites, a mineral which is made out of a precise mixture of lead, Iodine and a simple organic component

PLASMONIC SOLAR CELLS

- Plasmonic solar cells are photovoltaic devices that convert light into electricity by using plasmons.
- Plasmonic solar cells are thin film solar cell with the thickness of 1-2µm
- Plasmonic solar cells are cheaper than silicon

5.1 CONCLUSION

As the energy is infinite it can be utilized to its fullest. Residential Solar market is emerging due to the subsidies and tax exemption from the government. But the market penetration is low due to lack of awareness among the people and due to high investment cost. India has a plenty of resources for solar power due to more no of sunny days but the utilization is very low.With the low cost manufacturing of components, more no of market share of residential solar be achieved.

5.1.1 LIST OF REFERENCES

- Dapeng Liu, Gang Li et al;"Solar potential in urban residential building"; ScienceDirect(Volume:111, January 2015)Pg:225-235
- http://www.renewableenergyworld.com/rea/home
- http://www.nrel.gov/docs/fy13osti/51644.pdf
- http://www.sunipod.com/solar-module-panels-70W-100W.php
- http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1128&context=eesp
- http://cleantechnica.com/2014/05/15/hyperbolic-metamaterials-drive-solar-costs-down

5.1.2 APPENDIX

1. Organization profile

ATOA Scientific Technologies (ATOAST) is an Engineering simulations services and solution provider founded in 2005. ATOA provide advanced Computer Aided Engineering simulation for engineered material, product, process and system design. ATOA leverage cutting edge research in computational mechanics, multi physics modeling, material, system and application technology for providing innovative simulation solution to clients

2. **Mission**

The business mission is to Provide high quality, cost effective, customer centric engineering services for virtual Innovative material, product, process and system development using state of the art tools and Technology. The technology mission is to devote 20% of our resources for Research and Innovation to develop breakthrough technology development for the benefit of clients. The social mission is to redirect or invest 10% of the profit or resources for the benefit of society or sustainable social causes.

3. **Vision**

The Business vision of ATOAST is to become a global leader for multiphysics engineering Simulation solution provider for every successful product, process, material and system design for our clients.

The technical vision of ATOAST is to proliferate multiphysics engineering simulations and material unity for innovative material, product, process and system design, by bridging Atom to Application.

The social vision of ATOAST is to support economic empowerment of the society with a focus on sustainable technology solution development.