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Social cost benefit analysis of solar power projects

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Abstract
The social cost benefit analysis provides a scientific base for the appraisal of projects with a view to determine whether the total social benefits of a project justify the total social costs. India is endowed with immense solar energy potential as it is located in the tropical zone of the earth. Government of India launched The Jawaharlal Nehru National Solar Mission with the intention of to be a global leader in solar energy. But, the main setback of the solar power is high generation cost. This study unveils social benefit is greater than the social cost in case of solar power. However, the high startup capital keeps the customers away from solar power. Thus, necessary measures to be taken to bring down the cost of solar power to ensure the viability. The wide range of technologies available today, to harness the sun energy, is classified into passive and active technologies. The active technologies, which formed the content of this paper, are broadly divided into photovoltaic and solar thermal, where solar thermal can be further classified into solar-thermal electric and non-electric applications. The market for many of the solar energy technologies has seen dramatic expansion over the past decade in particular the expansion of the market for grid-connected PV systems and solar hot water systems have been remarkable. Since solar power is in the nascent stage, it is mandatory to assess its impact on society. Solar power guarantees various benefits including carbon credit, renewable energy certificate, employment generation, rural electrification, curbing global warming and also ensures overall development.

Keywords: social benefit, social cost, solar power, economical effect, energy sources

Introduction

The Indian power sector is predominantly based on fossil fuels, with about three-fifths of the country‟s power generation capacity being dependent on vast indigenous reserves of coal. But in few last decades Indian government has taken several steps to reduce the use of fossil fuels-based energy while promoting renewable generation. Solar energy has emerged as a viable, cost- effective and commercial option for grid connected power generation. During the past few years, a significant trust has been given to the development and induction of solar energy technology for use in different sectors. India is the only country in the world with an exclusive Ministry to promote the renewable energy sources. Presently the installed capacity of solar energy projects in India is approximately 3000 MW. India plan to produce 20 GW of solar power by 2020. While the cost of energy from many solar energy technologies remains high compared to conventional energy technologies, the cost trend of solar energy technologies demonstrates rapid declines in the recent past and the potential for significant declines in the near future. Solar energy constitutes the most abundant renewable energy resource available and in most regions of the world even its technically available potential is far in excess of the current total primary energy supply. As such solar energy technologies are a key tool to lower worldwide carbon emissions. The wide range of technologies available today, to harness the sun energy, is classified into passive and active technologies. The active technologies, which formed the content of this paper, are broadly divided into photovoltaic and solar thermal, where solar thermal can be further classified into solar-thermal electric and non-electric applications. The market for many of the solar energy technologies has seen dramatic expansion over the past decade in particular the expansion of the market for grid-connected PV systems and solar hot water systems have been remarkable. At present India is fifth largest country in the world of electricity generation, having presently installed capacity of 243 GWs out of which 69.5 % is from thermal, 16.5 % from hydro, 2% from nuclear and rest about 12% from renewable energy sources. Although Indian power sector has experienced a seven times increased in its installed capacity a jump from 30,000 MW in 1981 to over 243028 MW by March, 2014 but still there is a huge gap in generation and demand in India hence need to be established more generation plants preferable to be come from renewable sources by governmental as well as various private participation. As per the load generation balance report for FY2013-14 issued by CEA, the anticipated peak shortage in the country during FY2013-14 works out to 6.2% based on the anticipated demand and availability of power. In addition to cost, it is found that a number of barriers that appear to limit the rapid growth of such technologies. These include technical barriers such as low-efficiencies, challenges with energy storage, reliability of balance of system components; and institutional barriers such as lack of information, outreach and regulatory structure. In response, a number of highly effective policy instruments have come together in some of the most successful markets for solar energy. These include fiscal and market based financial incentives (e.g. feed-in-tariff, rebates, tax credits), regulations (e.g. renewable portfolio standards, solar energy mandates) as well as a number of pilot demonstration projects. While the continued operation of such initiatives is imperative for the future growth of these markets it is also becoming apparent that innovative ways to reduce the fiscal burden of policy incentives are needed. As such, there is presently growing interest in market-based mechanisms to complement existing fiscal policy incentives.

Need for SCBA in Power Sector

At present, India is the seventh largest emitter of Green House Gases (GHGs) and fifth largest in case of emission from fossil fuel combustion in the World. It accounts for about 4 percent of the world's emissions. India plays a crucial role in the Copenhagen Accord, which emphasizes that climate change as one of the supreme challenges, it is mandatory to bring the carbon emissions down. The greenhouse gases are released during the combustion of fossil fuels, such as coal, oil, and natural gas, to produce electricity. India has made a commitment to reduce its emission per unit of GDP by 20 to 25 percent on 2005 levels by 2020 (Former Hon'ble PM, Manmohan Singh, NRDC).

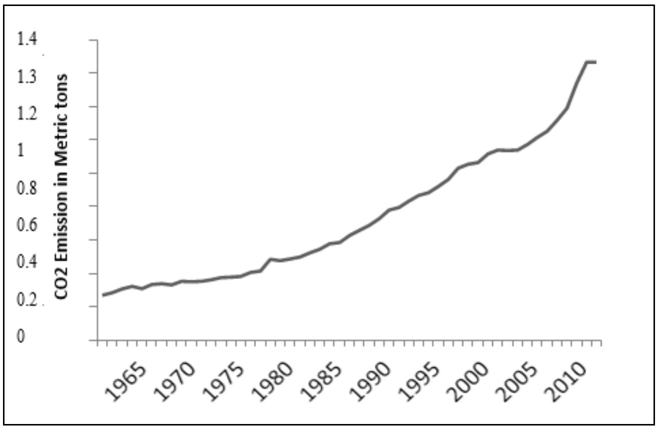
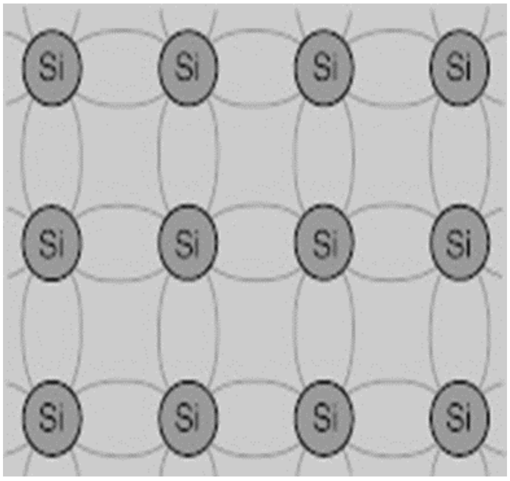


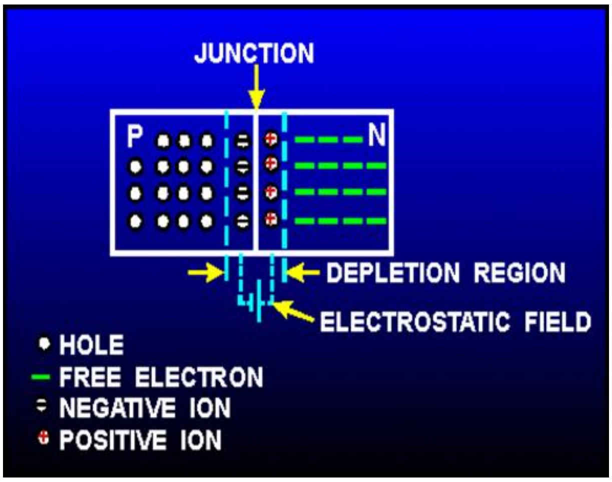
Fig 1: CO2 Emission Per Capita in India1.

Figure 1 shows CO_2 emission per capita in India from 1960 to 2010. It depicts CO_2 emission per capita is gradually increasing year on year. Industrialization and alarming population growth keep the CO_2 emission curve towards upward trend. Escalating the fraction of electricity derived from wind, solar, and small hydro from the present 8 percent to 20 percent by 2020, is the move taken by Indian government to hold back carbon emission. Thus, the government of India looks forward to make renewable as an alternative to curb carbon emission. Solar being a perennial source, both state and central government preferred it as the best alternative, thereby framing their own solar power policy. In this context, measuring the social cost benefit of solar is inevitable to make sure of feasibility.

Working principle: Sunlight is made out of tiny energy pockets called photons and that each individual solar cell is designed with a positive and negative layer thus being able to create an electric field (similar to the one in batteries). As photons are absorbed in the cell their energy causes electrons to get free, and they move to the bottom of the cell, and exit through the connecting wire which creates flow of electrons thus generate electricity. The bigger amount of the available sunlight the greater the flow of electrons and the more electricity gets produced in the process. It is a form of photoelectric cell (in that its electrical characteristics e.g. current, voltage,

or resistance vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source, but do require an external load for power consumption. Pure Si is a poor conductor of electricity. Doping – introducing impurities into an intrinsic (pure) semiconductor to change its electrical properties. Examples of n-type dopants – Phosphorus (Ph), Arsenic (As), Antimony (Sb). Examples of p-type dopants –Boron (B), Aluminium (Al). Doping provides with charge carriers (holes and electrons) that can carry electrical current. Electric field to force electrons to flow in a certain direction. This electric field is achieved by bringing together p-type and n-type semiconductors together to make a diode. Holes and electrons from p-region and n-region respectively recombine, creating a depletion region and an electric field. The movement of holes and electrons are represented below. Depletion region continues to grow till the electric field becomes large enough to prevent the flow of charge carriers from one side to the other. Now, if the diode is exposed to light, it frees the electrons in n-region and these electrons, repelled by the electric field, flow through the load to p-region. These electrons constitute current. The flow of electrons and hole can be represented as follows:





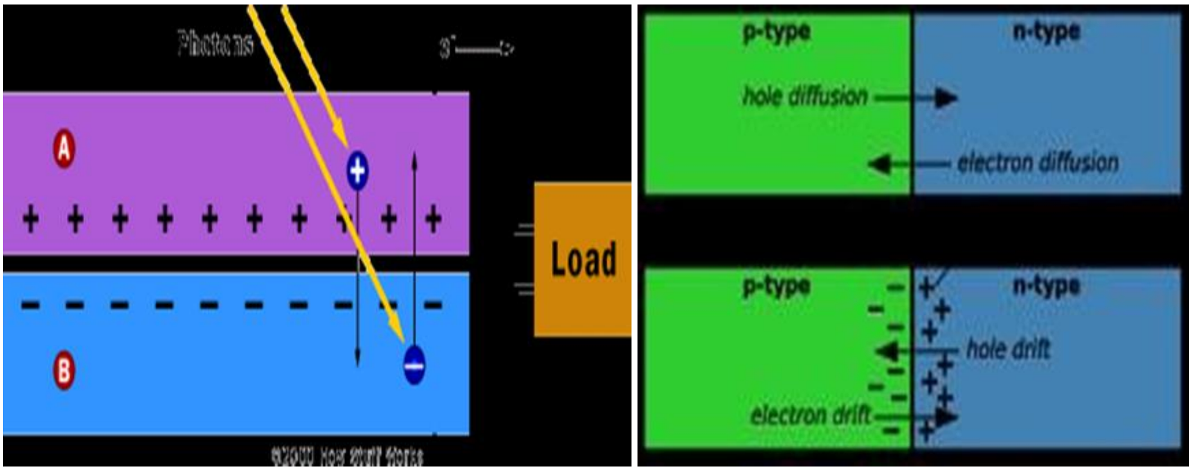


Fig 2

The movement of hole and electrons resulting flow of electricity across the cell represented as given below:
Several solar cells are connected together, encapsulated in a glass covered frame to form a module. A solar cell made from a mono-crystalline silicon wafer with its contact grid made from bus bars (the larger strips) and fingers (the smaller ones) As light hits the solar panels, the solar radiation is converted into direct current electricity (DC). The direct current flows from the panels and is converted into alternating current (AC) used by local electric utilities. Finally, the electricity travels through transformers, and the voltage is boosted for delivery onto the transmission lines so local electric utilities can distribute the electricity to homes and businesses.

Social Benefits of Solar Power Project

Solar power ensures carbon emission reduction and paves the way for availing carbon credit. Carbon credits are "Entitlement Certificates" disbursed by the United Nations Framework Convention on Climate Change (UNFCCC) to the implementers of the permitted Clean Development Mechanism (CDM) projects (National Renewable Energy Laboratory, 2010). One carbon credit is equivalent to one tonne of carbon dioxide or its equivalent greenhouse gas. Under the UNFCCC, charter any corporation from the developed country can join hands with a corporation in the developing country that is a signatory to the Kyoto Protocol (Prabhakant & Tiwari, 2008) [7]. And the company in developing country should implement latest tech-know-how to reduce carbon emission. There are two ways for an obligatory to offset carbon footprints. They can either use newest tech-know-how to bring down the carbon emission or buy carbon credit in exchanges (Saravanan, 2011) [5].
MCX has become the first exchange in Asia to trade carbon credits. Reliance power is the world's leading carbon offset originator with a CDM registered project portfolio of over 0.012 Million MW, with potential to offset 60 million certified carbon credits. Carbon credit projects based on Solar Photovoltaic (PV) technologies support the project developers to cover the project cost related to the technology and equipment's.

Renewable Energy Certificate

Renewable Energy Certificates (RECs) are a type of environmental commodity intended to provide an economic incentive for electricity generation from renewable energy sources (Shrimali & Tirumalachetty, 2013) [3]. One REC is equivalent to 1 MWh of clean energy and also there is a provision to separate RECs from the solar and non-solar by considering the high cost of solar power generation. The floor and forbearance price determined for solar REC from 2012-17 are Rs. 0.0093 million/MWh and Rs. 0.0134 million/MWh respectively. The State Electricity Regulatory Commissions (SERC) under the Electricity Act, set target for distribution companies of the respective states to procure a certain percentage of the total power requirement from renewable energy sources. This target is referred to as Renewable Purchase Obligation (RPO). RPO is the key driver for REC market. Renewable purchase obligated entities comprising not only distribution companies, but also open access consumers and high-tension consumers. REC helps the obligated entities to comply with regulatory requirements. A Power Exchange is a platform on which REC is traded. Only the exchange members, who have been admitted by exchange, are eligible to enter into contracts, and undertake transactions relating to such contracts. (IEX, 2012). The Clients can take part in trade through a registered exchange member. REC assists the solar power generator to trade the generated solar power as a commodity.

Employment Generation

Renewable energy technologies are more labor intensive than mechanized fossil fuel technologies, meaning there is a greater prospect to create domestic jobs through the market augmentation (NRDC & CEEW, 2015). The aggressive players of solar market include manufacturers, developer, integrator, engineering and procurement contractor and consultants, etc. On-grid solar PV systems are power systems energized by photovoltaic panels which are connected to the utility grid. Off-grid solar PV uses batteries to save and transmit electricity, which is an alternative for grid tied system.

Table 1: Future projections of Employment in Solar PV On-grid

Year	Estimated Employment (in Millions)		
	Manufacturing	O&M	Total
2016	0.023	0.011	0.040
2021	0.091	0.060	0.150

Table 1 depicts the future employment projection in solar PV on-grid based on JNNSM targets. It is estimated that the solar PV on-grid sector would employ 0.040 million employees by 2016 and 0.150 million by 2021. It also reveals that solar on-grid is expected to employ 0.093 million for manufacturing activities and 0.060 million for Operation &Maintenance work by 2021.

Table 2: Future Projections of Employment in Solar PV Off-grid

Year	Estimated Employment (in Millions)		
	Direct	Indirect	Total
2016	0.048	0.090	0.12
2021	0.070	0.10	0.220

It is clear from the table 2 that solar PV off-grid sector would make use of 0.14 million employees by 2016 and 0.220 million employees by 2021. The total proposed employment by 2021 would be 0.220 million of which 0.12 million indirect and 0.070 million direct employment. It is obvious that solar off-grid has greater potential for employment generation than on-grid.

Curbing Global Warming

India is profoundly reliant on fossil fuels for its energy needs. Most of the power generation is carried out by fossil fuel plants which contribute greatly to greenhouse gas emission (Murthy, 2012) [11]. Global warming threatens the existence of human society and also countless species. Fortunately, decades of research have led to efficient solar panel systems that generate electricity without discharging greenhouse gases. Therefore, solar is conferred as one of the most important solutions to the global warming crisis.

Rural Electrification

According to the census of 2011, in rural India, more than 44 percent of the households lack basic access to electricity. Even those villages that have been provided with grid power receive less than 6 hour supply in most cases (Ratho, n.d). India is paying huge developmental costs due to its energy poverty, such as education, health, and economic development are at a standstill in rural India. Addressing this challenge remains a huge task for the Government of India. In the last few years, mini-grids have largely been developed by independent developers, non-governmental organizations and social business entities using external funds. To meet the unmet community demand for electricity, standalone rural solar PV power plants with battery storage in a micro grid mode, would be provided Rs. 0.00015 million/Wp of capital subsidy and soft loan at 5% by the Ministry of New and Renewable Energy (MNRE, 2010) [16]. Hence, mini-grid using solar power has gained momentum to help the government to achieve cent percent rural electrification.

Reduction in Fossil Fuel Subsidy

Energy subsidy is a direct cash imbursement by the government to an energy producer or consumer to stimulate the production or use of a particular fuel or form of energy. According to the Organization for Economic Co-operation and Development (OECD), subsidies supporting fossil fuels, particularly coal and oil, represent greater threats to the environment. Subsidies to nuclear power contribute to unique environmental and safety issues, related mostly to the risk of high-level environmental damage. Subsidies to renewable energy are generally considered more environmentally beneficial, although the full range of environmental effects should to be taken into account.

In fiscal year 2012-2013, the Indian Government spent Rs. 962 billion (1.75 percent of GDP) for compensating Oil Marketing Companies for retail under-recoveries accrued in this period. The Ministry of Petroleum and Natural Gas estimates that total under-recoveries could reach Rs. 1.81 trillion in 2013-2014, a year-on-year increase of 12 percent from 2012- 2013 (Clarke, Sharma & Vis-Dunbar, 2014). Solar subsidy controls the oil and gas subsidy, especially Kerosene subsidy. Unlike other fossil fuel subsidy, solar subsidy is a one-time subsidy. As the government is spending huge amount of oil subsidy, solar power brings down the subsidy burden of the government too.

Overall Development

In India, about 20,000 villages are located in isolated and inaccessible areas so the government found it difficult to electrify through conventional grid. The Ministry of New and Renewable Energy has implemented the 'Remote Village Electrification Programme' (RVEP) to electrify such remote villages by using solar photovoltaic home lighting systems across India. An evaluation study was done by the National Council of Applied Economic Research (NCAER) in six states, *viz.* Assam, Meghalaya, Jharkhand, Odisha, Madhya Pradesh, and Chhattisgarh, indicates that the usage of kerosene has come down. Nearly 53 to 69 percent reported that there is considerable progress in their children's education, and 37 to 78 percent stated that there is improvement in the standard of living after setting up of solar lighting. Beneficiaries now spend extra time on income generating activities. The crime rate has also reduced due to the presence of solar street lights in the villages (Buragohain, 2012) [19].

Social Cost of Solar Power Projects

Solar power offers plenty of benefits than a setback. The major shortcomings of solar power are given below:

High Generation Cost

The generation cost of solar power is very high when compared to other sources of power generation. Despite decades of research to lower its price, each kilowatt-hour costs roughly two to three times as much as the same amount of electricity produced from fossil fuels.

Table 3: CERC Determined Solar PV Plant Benchmark Cost for 2012-13

Particulars	Capital Cost (Rs. In Million/MW)	Percentage of Total Cost
PV modules	31.582	38.9%
Additional module cost as against degradation	0.970	1.1%
Land cost	1.67	2.0%
Civil and general works	8.45	10.9%
Mounting structures	9.5	12.2%
Power conditioning unit	5.0	6.5%

Evacuation cost up to interconnection point	10.5	13.2%
Preliminary and pre-operative expenses	8.0	10%
Total capital cost	75.701	100%

Table 3 presents the breakup of benchmark capital cost norm for solar PV projects for the year 2012-13. In view of the above, the capital cost of solar photovoltaic power projects after rounding off arrived at Rs. 80 million/MW considered as the benchmark cost of solar PV projects for determining tariff.

According to the report by Photon Consulting, a German research group, reveals the scarcity of silicon result in soaring price of solar panel. The project developers have little faith on local manufacturers. Despite the government favoring local procurement, 70% of solar power projects set up under the National Solar Mission have used imported modules or cells. Compared to the locally manufactured modules, the imported thin film modules are cheaper. To bring down the cost of solar power, the governments should carry out various researches concerning solar power and also encourage domestic panel manufacturers with different perks. Solar power could be made financially viable with government tax incentives and rebates.

Health Hazard

The potential menaces and consequences of increasing solar photovoltaic cell production are being neglected by most of the producers. Solar energy is an indispensable part of the global move towards clean energy, and it is critical that the growing solar photovoltaic industry is itself truly secure and sustainable.

Table 4: Health Hazards in Solar PV Waste

Pollutant	Outcome
Arsenic	Increased lung cancer risk
Cadmium	Toxic to the respiratory system
Chromium	Provoke asthma and lung cancer
Lead	Affects the kidneys and the reproductive system
Polychlorinated biphenyls	Harm reproductive and immune systems

Table 4 shows despite solar is a clean energy it has some mild contaminant which can harm social being. The toxicity of the PV cell differs on account of its components. The major pollutants in solar PV are arsenic, cadmium, chromium, lead and polychlorinated biphenyls which can harm the human well-being. Silicon based solar PV production involves many of the same materials as the microelectronics industry and, therefore, creates various health hazards. Solar being an electronic waste, disposal of the panel and other subsystem becomes a major challenge. Thus, proper recycling measures are required to handle these electronic wastes.

Conclusion

Social Cost Benefit Analysis estimates the social cost and the benefits obtained from a specific project. Since solar power is in the burgeoning stage, it is mandatory to assess its impact on society. Solar power guarantees various benefits including carbon credit, renewable energy certificate, employment generation, rural electrification, curbing global warming and also ensures overall development. But, the main setback of solar power is high generation cost. This study unveils that the social benefit is greater than the social cost in case of solar power. However, high startup capital keeps the customers away from solar power. Thus, necessary measures should be taken to bring down the cost of solar power to ensure the viability.

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Conflict of Interest

Author does not show any Conflict of Interest.

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