THEORETICAL ANALYSIS OF DESIGN OF LESS POLLUTING SOLAR POWER PLANT IN INDIA

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ABSTRACT

With abundant sunlight 300 days in a year, cost advantage in the production of solar cell and modules, India has a huge opportunity to become a super solar power in the world. Solar energy is treated as environment friendly compared to fossil fuels butmanufacturing of Solar cell is not a zero-emission technology. Solar cell production release hazardous gases and requires toxic materials. In India, we are less bother about this danger. But using proper manufacturing process and taking some advanced technology we can reduce the pollution of a solar power plant. Solar energy is perfectly suited for India as compared to many other sunlight starved countries. However at the cell level the pollution should be minimal. The switch to solar energy is must to save this planet and to leave a cleaner world for future generation. In response, solar firms have begunplanning and forming coalitions to recycle used panels before their materials can leachout, trumpeting their efforts to guarantee life-cycle sustainability. But the focus ondealing with used panels threatens to obscure a more pressing concern from waste in the manufacturing process. Until these issues are properly addressed, ashadow of doubt will hang over the true environmental impacts of solar energy.

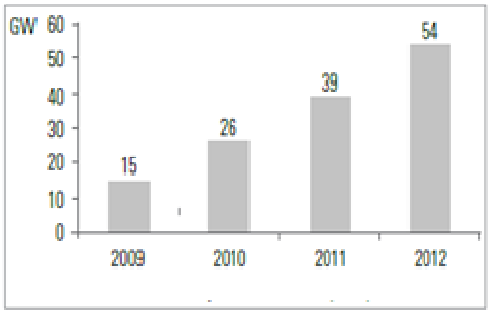
Keyword: Photovoltaic Cell Production, Toxic Materials And Gases, Production Process, Distributed Power Plant.

I INTRODUCTION

India occupies about 2% of world's land mass and currently generates about 2% of global electricity.Most of this generation is through coal. To achieve a high level of economic growth, the domestic generation capacity should be about 900GW.This huge amount of energy can't be produced only with coal, water, gas & other non conventional sources. Solar power holds a great potential in this scenario.

India being a topical country is geographically blessed with plenty of sunshine. India is both densely populated and has high solar insolation, providing an ideal combination for solar power in India. The average daily solar radiation varies between 4 to 7 kWh per square meter for different parts of the country. There is an average 301 clear sunny days a year. Hence India's theoretical solar power reception is about 600 TW. The daily solar energy incident over India varies from 4-7KWh/m^2 with about 2300-3200 sunshine hours per year, depending upon location. This is far more than current total energy consumption. For example, even assuming 10% conversion efficiency of for PV modules; it is still thousand times greater than the likely electricity demand in India by 2015.Compared with solar energy, the production of nuclearenergy is too costly. To generate 1MW, it is required Rs. 21000 crores(approximately). In compare with hydel power plant, Rs. 6000 crore is needed to generate 1 MW.

Cummulative Capacity of Solar PV until 2012

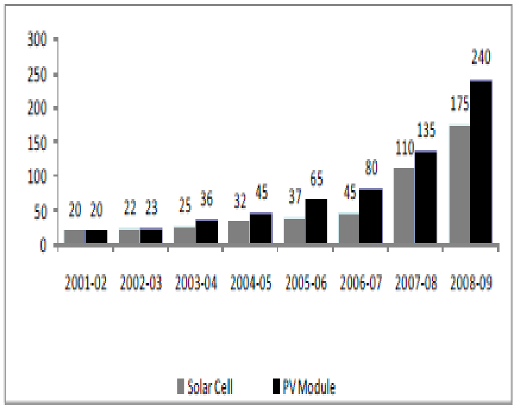


II OVERVIEW OF SOLAR PV INDUSTRY IN INDIA

Developing countries, in particular, face situations of limited energy resources, especially the provision of electricity in rural areas, and there is an urgent need to address this constraint to social and economic development. India faces a significant gap between electricity demand and supply. Demand is increasing at a very rapid rate compared to the supply. According to the World Bank, roughly 40 percent of residences in India are without electricity. In addition, blackouts are a common occurrence throughout the country's main cities. The World Bank also reports that one-third of Indian businesses believe that unreliable electricity is one of their primary impediments to do business. In addition, coal shortages are further straining power generation capabilities.

India is endowed with rich solar energy resource. The average intensity of solar radiation received on India is 200 MW/km square (megawatt per kilometer square). With a geographical area of 3.287 million km square, this amounts to 657.4 million MW. However, 87.5% of the land is used for agriculture, forests, fallow lands, and so forth, 6.7% for housing, industry, and so forth, and 5.8% is either barren, snow bound, or generally inhabitable. Thus, only 12.5% of the land area amounting to 0.413 million km square can, in theory, be used for solar energy installations. Even if 10% of this area can be used, the available solar energy would be 8 million MW, which is equivalent to 5 909 mtoe (million tons of oil equivalent) per year. In order to meet the situation, a number of options are considered. Power generation using freely available solar energy is one such option. Fortunately, India is both densely populated and has high solar insolation, providing an ideal combination for solar power in India. Jawaharlal Nehru National Solar Mission is one of the major global initiatives in promotion of solar energy technologies, announced by the Government of India under National Action Plan on Climate Change. Mission aims to achieve grid tariff parity by 2022 through the large-scale utilization and rapid diffusion and deployment of solar technologies across the country at a scale which leads to cost reduction and promotes the research and development activity to local manufacturing and infrastructural support.

Trends in production of solar PV cells and modules in India



The range of applications for solar PV in India is very different from the global mix. Globally, grid connectivity accounts for nearly75% of the installed capacity and off-grid lighting and consumer applications for the balance 25%. Currently, PV installations in India, almost entirely consist of offgrid connectivity and small capacity applications, used mostly for public lighting, such as street lighting, traffic lighting, and domestic power back up in urban areas and small electrification systems and solar lanterns in the rural areas. In recent years, it is also being used for powering water pumps for farming and small industrial areas. Government organizations like railways, telecom and other agencies are the major consumers of PV solar systems in India.

III REASONS FOR POLLUTION

3.1 Manufacturing

A large variety of materials may be used inmanufacturing of photovoltaic devices; some may be released as by-products of normal or abnormalplant operations. Table I lists some feedstock materials used in PV manufacturing which are toxic,carcinogenic.Although manufacturing facilities may produce liquid, solid, and gaseouseffluents, only gaseous effluents are likely to present acute hazards to public health.

Solar panel manufacturing generates a number of effluent gases contaminated with saline, trichlorosilane, dichlorosilane & hydrochloric acid. This manufacturing process also requires raw materials that have to be mined – quartz sand for silicon cells and metal ore from thin-film cell. During manufacturing of solar cells, some stages are followed in the company. During each process, toxic materials & greenhouse gases caused by heavy materials are exhausted which leads air pollution. But this emission is the lowest compare to coal emission (in case of Solar cell production it is 32 tonnes per GWh compared to coal 960tonnes per GWh).

TABLE – 1

MATERIAL	SOURCE	PERMISSIBLE LIMIT (ppm)
Arsine	GaAs CVD	0.05

Cadmium compounds	CdTe and CdS deposition	0.01 mg/m^3
Carbon tetrachloride	Etchant	5
Chloro-silanes	a-Si and x-Si	5
Diborane	a-Si deposition	0.1
Hydrogen fluoride	Etchant	3
Hydrogen sulfide	CIS sputtering	10

3.2 Disposal

Another cause of pollution is the waste of products. The hazardous materials (cadmium, mercury &fluoride product) may enhance the pollution. Now the amount of disposalmay not more but when large scale production will start, it can take a major role. According to an European survey team, the amount of waste will be 35000 tonnes in 2020.

TABLE – 2

POLLUTANTS AND THEIR EFFECT IN SOLAR PV WASTE

POLLUTANT	DANGER
Arsenic	Can damage skin
Chromium	Can damage liver and kidneys
Lead	A neurotoxin that affects the kidneys and the reproductive system
Polychlorinated biphenyls	Can harm reproductive and immune systems
Cadmium	It affects the kidneys and softens bones

IV HAZARDOUS MATERIALS USED IN SOLAR PV CELL PRODUCTION

Silicon-based solar PV production involves many of the same materials as the microelectronics industry and therefore presents many of the same hazards. At the same time, emerging thin-film and nanotech-based cells pose unknown health and environmental dangers.

As with the production of silicon chips, production of c-Si wafers begins with the mining of silica (SiO2), found in the environment as sand or quartz.Silica is refined at high temperatures to remove the O2 and produce metallurgical grade silicon, which is approximately 99.6 percent pure. However, silicon for semiconductor use must be much purer. Higher purities are achieved through a chemical process that exposes metallurgical grade silicon to hydrochloric acid and copper to produce a gas called trichlorosilane (HSiCl3). The trichlorosilane is then distilled to remove remaining impurities, which typically include chlorinated metals of aluminum, iron, and carbon. It is finally heated or with hydrogen to produce silane (SiH4) gas. The silane gas is heated again to make molten silicon, used to grow monocrystalline silicon crystals, or used as an input for amorphous silicon (see next section). The next step is to produce crystals of either monocrystalline or multicrystalline silicon. Monocrystalline silicon rods are pulled from molten silicon, cooled, and suspended in a reactor at high temperature and high pressure. Silane gas is then introduced into the reactor to deposit additional silicon onto the rods until they “grow” to a specified diameter. To produce multicrystalline silicon, molten silicon is poured into crucibles and cooled into blocks or ingots. Both processes produce silicon crystals that are extremely pure (from 99.99999 to 99.9999999 percent), which is ideal for microchips, but far more than required by the PV industry. The high temperatures required for c-Si production make it an extremely energy intensive and expensive process, and also produces large amounts of waste. As much as 80 percent of the initial metallurgical grade silicon is lost in the process.21 Sawing c-Si wafers creates a significant amount of waste silicon dust called kerf, and up to 50 percent of the material is lost in air and water used to rinse wafers.22 This process may generate silicon particulate matter that will pose inhalation problems for production workers and those who clean and maintain equipment.

Other chemicals used in the production of crystalline silicon that require special handling and disposal procedures include the following:

• Large quantities of sodium hydroxide (NaOH)are used to remove the sawing damage on the silicon wafer surfaces.

• Corrosive chemicals like hydrochloric acid, sulfuric acid, nitric acid, and hydrogen fluoride are used to remove impurities from and clean semiconductor materials.

• Toxic phosphine (PH3) or arsine (AsH3) gas is used in the doping of the semiconductor material. Though these are used in small quantities, inadequate containment or accidental release poses occupational risks.

V SOLUTIONS TOREDUCE POLLUTION

5.1 Using The Abatement System

PV manufacturing processes produce hazardous by-products. These processes produce toxic, reactive and corrosive gases. In order to reduce pollution, hazardous gases need to be treated before released into the atmosphere. There are a number of solar cell technologies in use, some of which employ hazardous materials as basic constitutes. The unutilized, non-consumed or unreacted gases can be passed through an abatement system that works with the dry or wet method. This would help in neutralizing the harmful effect of toxic gases. Some of them are :

- Develop chlorine-free methods for making polysilicon feedstock that eliminate the use of trichlorosilane(which results in waste silicon tetrachloride, an extremely toxic substance). This is the most toxic and energy intensive phase of silicon production, and several methods are being developed to potentially replace it.
- Phase out use of sulfur hexafluoride (SF6). One ton of sulfur hexafluoride has the greenhouse effect equivalent of 25,000 tons of CO2.102 It is imperative that a replacement for sulfur hexafluoride be found, because accidental or fugitive emissions will greatly undermine the greenhouse gas reductions gained by the use of solar power.
- Phase out use of hydrogen selenide. This highly toxic material is used in the production of CIS/CIGS PV. New processes to make CIS/CIGS have been developed that avoid using hydrogen selenide.

- Phase out use of arsenic. Arsenic, used in production of gallium arsenide PV, is highly toxic and carcinogenic.
- Phase out phosphine and arsine. Phosphine and arsine are highly toxic gases used in the production of GaAs crystals (although they are not found in the final PV cells).
- Reduce fugitive air emissions from facilities. Reduce fugitive air emissions by PV manufacturing facilities, which include such chemicals as trichloroethane, acetone, ammonia, and isopropyl alcohol and greenhouse gases such as sulfur hexafluoride and nitrogen trifluoride.

The basic processing stages of **chlorine-free polysilicon production process** are the following:

1.Thereaction of metallurgical-grade silicon with alcohol proceeds at 280°C in the presence of a catalyst:

Si + 3 C2H5OH catalyst Si(OC2H5)3H + H2 .---------------------------- (1)

2. The disproportion (i.e., simultaneous oxidation and reduction) of triethoxysilane in the presence of a catalyst will lead to the production of silane and tetraethoxysilane:

4 Si(OC2H5)3H catalyst SiH4 + 3 Si(OC2H5) ------------------------- (2)

3. Dry ethanol and such secondary products as highpurity SiO2 or silica sol can be extracted by hydrolysis of tetraethoxysilane. The alcohol will be returned to Stage 1.

Si(OC2H5)4 + 2 H2O ----- SiO2 + 4 C2H5OH -- (3)

4. Silane is decomposed pyrolytically to pure silicon andhydrogen at a temperature of about 900°C:

SiH4 -850° - 900°C Si + 2 H2 .-- (4)

5.2 Distributed Power Plant

Distributed Solar Power Plant is just the opposite of centralized power plant. In centralized power plant, electricity is generated at central power plants that central powerplants that are located hundred miles away from the load centre. Thermal power plant is set up near coal mines& nuclear power plants are set up far away due to safety reasons. Central power plant essentially needs extra high tension power transmission. As a result, these involve a high transmission loss. Distributed power generation can be done in a small area with the locally available sunlight. So huge loss in transmission can be eliminated by this process. Grid connected multi megawatt solar firms at 11kV and above not only suffer from usual distribution loss of 15% but also a loss during stepping up process. Distributed solar power plant can use existing low voltage transmission in a local substation.

VI CONCLUSION

There is an urgent need for conversion from petroleum based energy systems to one based on renewable resources to reduction requirement on developing assets of fossil fuels and to moderate climate change. An importance of presenting the real picture of massive renewable energy prospective, it would be possible to attract foreign investment to herald a green energy revolution in India.Solar energy is perfectly suited for India as compared to many other sunlight starved countries. The government has made a start by fixing an ambitious target of 22 GW solar capacities by 2022.One key to the development of any photovoltaic technology is the cost reduction associated with achieving economies of scale. This has been evident with the development of crystalline silicon PVs and will presumably be true for other technologies as their production volumes increase. Given the vast potential of photovoltaic technology, worldwide production of terrestrial solar cell modules has been rapid over the last several years, with China recently taking the lead in total production volume. Fortunately India is both densely populated and has high solar insolation, providing an ideal combination for solar power in India. The Government of India is planning to electrify 18,000 villages by year 2012 through renewable energy systems especially solar PV systems. This offers tremendous growth potential for Indian solar PV industry.

There are always two sides of coin – while solar energy is considered the safest and most cost effective renewable energy,its production process is energy intensive. However at the cell level the pollution is minimal and at the module level the pollution is negligible to near-zero. As per present estimate, coal availability on a global average is expected to last only for 60 years. The switch to solar energy is must to achieve the target, to save this planet and to leave a cleaner world for future generation.

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