Solar Energy Future in India

Abstract: *Solar energy, the fastest growing renewable energy, can deliver at least half the world's energy needs by 2050. In fact, one estimate suggests the solar energy may actually meet the entire capacity requirement of the whole world by using less than 1% of earth's land area. Photovoltaic energy is no longer too costly. It is already on par or cheaper than diesel, and will economically overtake thermal energy from coal in a few years. Governments all over the world are promoting solar energy and many countries including India are offering attractive schemes to make solar viable. Solar energy can be used by photovoltaic (PV) and concentrated thermal power (CSP), apart from the use for hot water and kitchens. PV power also is used on small scale as rooftop panels for home and on small and medium scale in-house consumption, while small and large power plants up to a few MW range are in operation. Building designs are incorporating PV panels in their designs (BIPV) CSP is being developed for medium and large scale generation using different methods. India has schemes like JNNSM and others which are changing lives of remote villages, and states are enforcing their own policies within overall framework to promote solar energy. .India has vast potential for solar, as it has one of the highest incident natural solar energy at its disposal. With costs heading downwards, solar energy may well become a major source of energy in near future. In fact, this source has the potential to meet the entire global energy requirements in just a few years!*

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1. INTRODUCTION

Globally, solar generation is the fastest growing source of energy, seeing an annual average growth of 35% over the past few years. Japan, Europe, China, U.S. and India are the major growing investors in solar energy. Renewable energy can deliver at least half of the world's energy needs by 2050. In fact, it may be possible to solely rely on renewables by that time, going by the pace of development. A report 'Energy Revolution: A Sustainable India Energy Outlook' by European Renewable Energy Council (EREC) [20] shows that a massive lift to renewable energy sources is technically and economically feasible.

India's electricity generation in 2010 was over 10% energy from renewable sources [1], McKinsey & Company, in its survey ended in May 2009, stated that India has one of the world's highest solar intensities with an annual solar energy yield of 1,700 to 1,900 kilowatt hours per kilowatt peak (kWh/KWp) of the installed capacity [2]. However, our efforts in realizing the potential have been abysmal all along.

Germany, the world leader in photovoltaic, plans to derive all its electricity from renewable energy by 2050 [29] and become the world's first major industrial nation to get rid of fossil fuel dependence for power, according to their Federal Environment Agency. This is despite the fact that it gets only sixty sunshine days in a year! Around 300,000 renewable energy jobs were created in Germany in the last decade. The country has also announced its intention to dismantle all its nuclear power plants in a few years. In fact WWF report says world's entire projected demand for energy needs in 2050 could technically be met by only photovoltaic solar energy utilizing less than 1% of world's land [30]. It says we need not compromise with environment conservation goals when PV power plants are well planned.

India Consumes 3.7% of the world's commercial energy, making it the 5th largest consumer of energy globally [33]. In terms of space, scope and facilities for renewable energy expansion, India ranks fourth in the world. In the last six decades, India's energy use has increased 16 times and the installed electricity

capacity by 84 times, to 210.95 GW in Dec 2012 (renewable energy capacity forms 11.45%). Still, India suffers from significant electricity deficit and faces 15% shortfall during peak hours.

The Indian Solar Industry has immense potential where around 45% of households, mainly rural ones, do not have access to electricity, according to the "Indian Solar Energy Market Outlook 2012" [3]. The industry has witnessed rapid growth over the past few years and is projected to grow further in future. The Indian Gross Domestic Product (GDP) is targeted to grow at 8% over the next ten years. Power demands may rise from 120 GW in 2010 to 315-335 GW by 2017. Consumer demand is projected to grow at 14% over the next 10 years — much faster than the GDP rate! The number of solar water heating systems is projected to grow at a CAGR of about 22% between 2011 and 2020.

2. APPLICATIONS OF SOLAR ENERGY

2.1 Off Grid-Solar Applications

New Keringa is a model village in Southern Orissa, India, with 47 families. It is the first village in Orissa to be lit by solar energy, thanks to the unique joint initiative of 'D light and Beyond Solar', an American nonprofit organization with Southern Orissa Volunteer Association (SOVA), a local NGO that has sponsored the solar installations [24], These people are alienated from the mainstream, lack the basic infrastructure and the roads to development has been abysmal.

In Gudda, a village in Rajasthan with 100 families, residents had never seen light after dark, except from the moon. There are no real roads that lead to the tiny village. There is no electricity — power lines don't exist here. Water is scarce, too. Solar light has transformed Gudda. Villagers now can play music at night. Children can study well past sunset. People have started using solar cookers for making food [21].

Devagiri and Lalagatti, two sleepy villages in Dharwad made news recently for becoming 100 per cent solar villages [37]. Thanks to Karnataka Vikas Grameena Bank, which has taken up funding the project of energizing the villages with solar power, all the households, numbering over 150 in these two villages have been installed devices to get solar energy.

Across India, thousands of homes are receiving their first light through small companies and aid programs that are bypassing the central electricity grid to deliver solar panels to the rural poor. When people who live day-by-day on wage labor and what they harvest from the land choose solar, they are not doing it to conserve fossil fuels, stop climate change or reduce their carbon footprints. To them, solar technology presents an elegant and immediate solution to powering everything from light bulbs and heaters to water purifiers and pumps. Tripura alone has 80,000 solar lanterns distributed among poor, and over 66,000 small and medium hot water plants have been installed across state [28].

Off-Grid Solar applications have tremendous potential in reaching out to people in rural and remote areas, by providing lighting and other basic energy services. These include small solar plants, roof-top solar power applications, solar lights and solar lanterns, solar thermal heating applications such as water heaters for residential, commercial, institutional and industrial applications, etc.

Centuries-old practices of passive solar design have received revamp. Double-glazed windows facing predominantly sunny side, skylights, and insulated walls are examples of harnessing passive solar energy. Solar roof shingles, solar paint and solar nanotechnology also make their contributions to energy efficient home design. Renewable energy is getting cheaper as components are mass-produced and the price of fossil fuels increases.

The cost of photovoltaic cells (PV) has been dropping for years. A PV solar module today costs half of what it did in three years back. Breakthroughs in technology and manufacturing, combined with an increase in demand and production are contributing to the decline in price of solar power steadily.

2.2 Solar Heat- community Kitchen

Any heat energy use of solar does not get counted in electricity generation capacity, but thermal energy used for solar cookers, water heating, space heating and community kitchens is very substantial, and reduces electricity and fuel requirement in a massive way. For example, the world's largest solar kitchen, operative in Tirumala Tirupathi Devasthanam, prepares meals for over 70,000 people every day [11] as in Fig. 1. The temple has also a windmill, solar lights, and water recycling system. Similar one at Shirdi serves 50,000 people [12], and such kitchens on different scale operate at several locations.

Smaller kitchens serving 100 to 1000 people are becoming common. Bakeries, café' and restaurants use solar kitchen in several countries all over the world.

Fig. 1. World's largest solar cooking system at Tirumala Tirupathi Devasthanam

2.3 Solar cooker:

The household box type solar cooker as in Fig. 2 has become common in villages and cities alike. While the cost of these cookers is still beyond the reach of poor in developing countries, people can do with Kyoto cooker [7], which won the award for cheapest and effective solar cooker recently. With these developments, solar cooking should become the most preferred way to cook.

Fig. 2. Box type solar cooker

The Kyoto Box as in Fig. 3 is targeted at people who currently use firewood, a fuel that takes the rural poor hours of hard labor per day to collect, and can cause health problems when the fumes from the often primitive stoves are breathed in the home. It cost under $5 to make. The DATS (Double Angle Twelve Sided) cooker [13] is another yet cheaper solar cooker as in Fig. 4. Inventions such as these make life of poor people easier, and save them from associated health problems. Use of such cheap cookers may be spread among villagers and tribal communities.

Fig. 3. Kyoto solar cooker

Fig. 4. DATS solar cooker

2.4 Solar water heaters:

Solar water heaters as in Fig. 5 & Fig. 8 are made compulsory in all new buildings in Bangarulu and Pune, and more cities are on way to introduce such systems. Industries and hotels use solar systems for process heating and hot water. By using solar water heating over gas water heater, a family will save 600 Kg of pollution each year. About 25% of energy is used for water and space heating.

Water and space heating load consumes 25% of domestic electrical energy. This may be easily converted to solar heating. A passively heated home uses 65- 70% of solar energy falling on its walls and windows. As per Centre for Renewable Resources, a well-designed passively heated home may reduce electricity bill by as much as 75% at an additional construction cost of 5-10%.

Fig. 5. Rooftop solar heater

2.5 Solar Lighting:

Solar Street Lights as in Fig. 6 with CFL lamps can be used everywhere, in villages and cities alike, to save on power as also to improve reliability, since these are not subject to power failures. With the distribution of 10 million solar lanterns in remote areas and to nomadic populations, India could save 500 million liters of kerosene a year!

Fig. 6. Solar Street light

Fig. 7. Solar lantern

Similarly, the solar lantern as in Fig. 7 can go a long way towards providing lights in rural area without waiting for Govt. plans for rural electrification. There is no need of grid or generation capacity, and no delays in implementation. Today a good number of NGOs are doing this work credibly, and also thereby providing employment in this business. Rural people buy the lanterns, or just hire them, and the NGO centre arranges for charging of the batteries of these lamps on solar power at nominal cost. This eliminates the need for kerosene lamps, while giving a better light quality. Further, some of these lanterns are provided with facility to charge mobile phones as well. These lamps being safe and portable, are being increasingly used everywhere.

Fig. 8. Typical solar water heating system

Solar home-lighting solutions are the stepping stones of an Indian green rural energy revolution. Rural India wishes to be part of the economic growth but is restricted by resource crunch and an energy solution that is both green and cheap. $10 million was spent in 2010 for purchasing solar lanterns and installing solar home lighting systems in villages around India.

However, NGOs and volunteering organizations can make real difference, and accelerate the advent of solar age in villages and towns. Public & private corporations can adopt villages or hamlets as part of their Corporate Social Responsibility (CSR) and support solar lighting, heating and cooking applications to bring about a change in the life of people. This will work faster than any Govt. initiative for these areas.

A 2 MW PV power plant at Awan, Punjab (the first privately owned, utility scale power plant in the Asian subcontinent) became operational in December 2009 [4]. The 2MW plant has an anticipated working life of over 40 years, & is connected to grid. This experiment would be soon replicated in entire border belt of Punjab with three solar power plants of 10 MW each in each border district.

3. NEAR FUTURE PROJECTIONS:

MNRE envisages setting up of 20,000 MW of solar power by 2022, and 100,000 MW by 2030. Solar cost will reach parity with coal-fired electricity latest by 2030. (It is already cheaper than D.G. Sets, and on par with nuclear energy today.) Technical breakthrough and scale of economics will make solar far more competitive in six years. Both thermal and electrical power can be effectively harnessed. Indian Government targets 1000 KW energy per capita by 2012, which works out to 1.2 trillion KWh per year. Solar energy potential in India is 4000 times the present need for electricity!

However, going by trends, and with more and more companies taking commercial interest, KPMG estimates that India will meet the target thrice over to produce 68,000 MW of solar power by 2022 [23]. This seems possible considering ambitious plans being undertaken by Gujarat and Rajasthan, as also the importance being given to solar by most states. Govt. of India has plans to make 60 cities from all over India as solar cities [28], and Nagpur is slated to become first solar city, with Gurgaon and Faridabad following suit. Solar energy systems, including street & garden lights, traffic lights, hoardings & solar heaters will be installed in the city. Green buildings will be promoted on a large scale. The objective is to reduce dependence on fossil fuel, expensive oil and gas for energy and to promote increased use of renewable energy.

It is often argued that solar energy is too costly. Not anymore. A practical study on a 100KW in-house system for a commercial building showed the following Table on comparison with D.G. Sets [22]:

Table 1. PV power Vs. DG sets

	D.G. Set 100 KW	**PV system 100KW**
Diesel price	Energy cost Rs/KWH	Energy cost Rs/ KWH
Low @ Rs. 29.37	7.4	
Med @ 37.19	10.01	10.65 w/o subsidy
High @45.00	15.18	8.04 with subsidy

Diesel power is considered cheaper because of subsidies on fuel. On the other hand, once the cost of solar installation is recovered, there is no recurring cost for a grid connected system. Any excess power generated by such installation can be sold to utilities at higher rates, as per Govt. policies. The unit rate of Rs 4 to 6 per KWH of electricity charged in different states contains a huge subsidy borne by the Govt. Hence it buys the solar or wind energy at higher rates which reflects actual cost of diesel powers generation.

Gujarat, in cooperation with Clinton foundation, is considering development of world's largest solar project [18]. It will be an integrated solar city with a generation of 5000 MW. The plant cost will be 70% less – about 2000 crores, compared to conventional generation plants. Thermal energy costs Rs. 10-11 per unit, while power in this solar city will cost just Rs 4 per unit, due to technology and scale. Of all the Indian state governments, Gujarat has taken bold steps towards 'solarizing' the state – the government is even offering 25-year fixed-rate tariff contracts, and 35,000 sq. km. area of Thar Desert has been set aside for solar power projects.

10,000 - 12,000 MW of solar power generation is planned in Rajasthan in the next 10-12 years under National Solar Mission (NSM) [39]. Small-scale & roof-tops, Captive plants as well as for power sale are being encouraged. Units of 50MW plants could be common. Both PV and thermal plants are envisaged. Solar parks of over 1000MW capacity are identified in Jodhpur, Jaisalmer, Bikaner & Barmer. Rajasthan has large barren land, which can be exploited to meet state's demand, and excess energy can be supplied to other states.

Speaking of big numbers and energy consumption, every month 8-10 million new mobile phones are connected in India. This is an interesting market segment for solar PV as well: thousands of new GSM poles will be needed across the country. Most mobile towers are supplied from D. G. Sets. A comparison of mobile tower supply shows PV system to be more economical and reliable compared to D.G. sets.

4. BUILDING INTEGRATED PHOTOVOLTAIC (BIPV)

Rabi Rashmi Abasan shown in Fig. 9 in Kolkata is India's first completely green housing complex [10]. The 58 kilowatt project consists of 26 photovoltaic systems comprising 464 units of C125W solar modules. The solar modules were customized to fit on the building roofs. This is also India's first building integrated photovoltaic project.

The houses will have both passive solar architecture and active solar energy features. The passive solar features will make houses cool during summer; ensure natural light, and better air circulation inside the house. The active solar energy elements include the solar water heating system. Other sustainable features include garbage management system, solar street lights, and a solar-heated swimming pool. The complex has been conceived, designed, engineered and built by West Bengal Renewable Energy Development Agency (WBREDA) and Bengal DCL

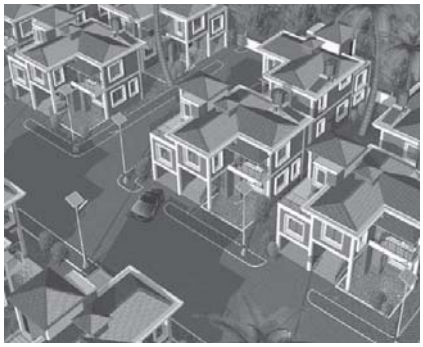

Fig. 9. Rabi Rashmi Abasan- India's first green project

Building Integrated Photovoltaic (BIPV) is making appearance all over the world, where the PV system is incorporated in the building architecture itself. 805 BIPV modules cover 360 sq. m. of the famous Mozart Tower in the south of Paris, with power output of 30 KWp [31] as in Fig. 10. The glass-glass solar modules integrated in the roof of this building also cover the terraces above office spaces. Skyscraper of CIS

Fig. 10. Mozzart Tower (Paris)

Insurance building in Manchester as in Fig. 11is powered by 390 KW from BIPV system [32]. Georgetown University building as in Fig. 12 has a PV array of 337 KWp from 4464 power modules [35]

Fig. 11. BIPV, Manchester

Fig. 12. 390 KW Georgetown University BIPV

5. CONCENTRATED SOLAR POWER (CSP):

Most large scale applications are making use of concentrated solar power, by use of reflectors to focus solar heat for heating steam, which in turn is used for power generation. This has got the benefit of better efficiency, and several methods are available to use the heat. The heat may even be stored for later use.

Focus in the solar world is on Photovoltaic (PV) power, but the fastest-growing segment of the solar market is the solar thermal market [6], which will expand by a factor of 37 from 2009 to 2014, compared to just a six-fold rise for PV during the same period, according to an estimate. The economies of scale of CSP plants dictate that systems of tens of megawatts in size must be constructed to obtain competitive costs.

CSP is generally cheaper than photovoltaic for large scale, and most large power projects are made around them. These systems allow storage of heat in the form of molten salt or steam, for use when needed.

CSP uses arrays of hundreds of mirrors to concentrate the sun's rays to temperatures between 400 and 1,000° C (750-1,800° F) to provide energy to run a power plant. With advanced development and high levels of energy efficiency, concentrated solar power could meet up to 7 percent of the world's power needs by 2030 and one quarter by 2050, employing 2 million people in the process *[European Solar Thermal Electricity Association (ESTELA)* [9]. CSP is a preferred alternative energy source, and in power towers, it commonly uses salt (NaCl) in a liquid state to keep turbines moving. It is estimated that by 2020 the cost of CSP will drop low enough to make it the more cost-effective renewable energy generation methods as can be seen in Fig. 13.

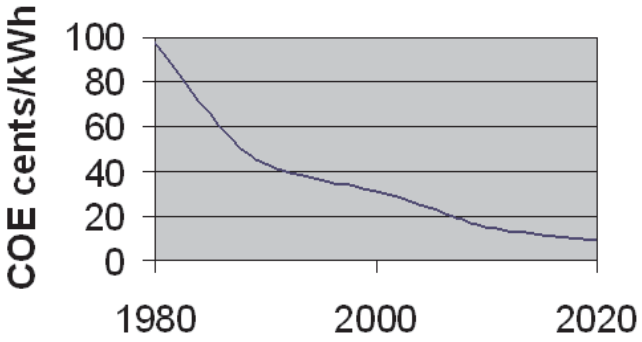

Fig. 13. Decline of CSP energy cost over years (Source: U.S. Dept. of Energy) [18]

CSP can be deployed through a number of technologies, each having its own benefits [26]:

- **Parabolic Trough** is the most proven, reliable and widely used system. This consists off parabolic reflectors which focus light on to central receiver tubes in focal line, and work at temperatures up to 400°C.

- **Linear Fresnel Reflector** has very low capital cost and is in initial development stages. It deployed multiple thin flat mirrors (instead of parabolic mirrors) which focus light on receiver tubes filled with working fluid. Higher reflection area than the parabolic system gives it higher

efficiency and cost advantage. However, there are no large scale plants in operational as of now.

- **Stirling Dish** is a scalable and efficient system, similar to parabolic, but inbuilt receptor for each dish, creating standalone units handling temperatures from 250 to 700°C. This technology uses gas for heat transfer. However, it does not offer economy of scale.

- **Power Tower** is highly efficient, most popular system and offers large energy storage. However, it is less advanced than parabolic system. It consists of array of heliostats reflecting heat to a central receiver located on a high tower and works in temperature range of 500-1000°C.

Fig. 14. 11-MWt power tower outside Seville, Spain [36]

Its main drawback is dependence on a single receiver, which can impact the entire plant. Economic viability depends on long- term performance of receiver at such high temperatures and the heat transfer medium-water, molten salt or HTF.

Large Scale Energy Storage

Although sun provides power only during the day, 70% of energy demand is during the daytime! Till satisfactory solutions are found, traditional methods may be used for night time. Further, systems for large scale energy storage are under different stages of development and already in use, and the day is not far when enough storage capacity will be available for night use. Then part of energy produced during day may be preserved for night as well. For example, New York State has installed array of 2MWH batteries to store energy from solar and wind, and energy is available 24 hours.

The transportation sector is the single largest user of petroleum, consuming approximately two thirds of the total. New generation batteries and fuel cells offer a power source that produces electrical energy from fuel and oxidant that produce little or no emissions. These could be recharged using solar devices.

6. SOLAR ENERGY FUTURE

There is a renewed focus as more and more people see the advantages of solar energy and as it becomes more and more affordable. Governments across the world offer financial assistance. Solar electric systems are now used to power many homes, businesses, holiday cottages and even villages. We see solar cells powering anything from household appliances to cars.

Rooftop solar can now compete effectively in price with any form of renewable energy, including wind. Solar panel prices have dropped by half over the last three years and keep dropping. MNRE**,** Govt. of India has schemes to promote rooftop solar for abatement of diesel and other fuel oil [23]. Birla Surya Limited announced in June 2011 [14] that the company will invest approximately Rs. 5,400 crores over the next five years to build India's first largest integrated facility for fabrication of multi crystalline silicon wafers and processing of solar photovoltaic cells. Solar PV panel prices have come down from $3.7 per W in 2007 to $1.8 per W in 2010, and prices are falling rapidly. World photovoltaic capacity has grown from 7.5 GW to 18.2 GW in 2010, a growth of 139%! The five year growth rate from 2007 to 2011 was approximately 70% per year!

Solar cells are becoming increasingly cost-effective as more distributors enter the market and new technologies continue to offer more choice and new products. We might even see the end of the combustion age in our lifetime.

Screen-printed solar cells are expected to drive prices down even more. Roofing shingles are capturing the sun's rays and turning them into electricity! Solar panels are being mounted to the sides of houses when roof space is not an option. Pools are being heated with solar energy for a fraction of the price of conventional heaters.

Chakrana Village in Patan Dist. In Gujarat has 2966 acres are covered with PV panels [40] generating 214 MW every day- more than China's 200MW Golmund Solar Park! Solar parks are present at 13 other locations spread over 2375 acres of non-arable land. Gujarat introduced solar policy in 2000, even before NSM came into existence. State buys energy from these plants @ Rs. 15 per unit for 4 years, and Rs. 5 for next 13years (actual production cost will be just 15 paise per unit after capital recovery)..Investors will recover capital in 8 years, and then it is all profit!

This means that once capital cost is recovered fully, cost of solar power generation can as well be just 15 paise per unit- unimaginably cheap by today's standards. It appears the solar energy is set to change the whole cost scenario of power, and power subsidies will be a thing of the past.

7. SYSTEM FLEXIBILITY

In the event of a war or cyber-attack, our electrical grid is quite vulnerable, and a few co-ordinated attacks in a few rural grassy fields, where major transformers are located, can cause major blackouts. Grid vulnerability means that should a failure occur, our water, sewage, phone, and transportation systems, medical and most of our basic economic functions would cease within a very short time.

A vast majority of homes and businesses may stay connected to the grid, but would run on renewable energy sources for their normal power needs. It is just enough to simply build into our existing distribution grid the capability to isolate into micro-grids when need be. By building resilience into our current grid, we could have both the benefits of a national grid system and the flexibility of distributed, independent generating capacity.

Way ahead

Grid connected roof-top solar power is planned in a big way in second phase of JNNSM. Govt. envisages adding 3 GW to the current capacity of 1.1 GW, and investments up to Rs. 1000 billion are expected in this phase Schemes for off-grid solar applications, solar thermal and roof-tops are to be covered by incentives [25].,

The average intensity of solar radiation received on India is 200 MW/km. Only 12.5% of the land, amounting to 0.413 million sq. km. can, in theory, be used for solar energy installations. Even with 10% of this area, the available solar energy would be 8 million MW, which will replace 5 909 mtoe (million tons of oil equivalent) p.a. [19].

As we are aware, roughly 40 percent of residences in India are without electricity. In addition, blackouts are a common occurrence throughout the country's main cities. A large number of Indian businesses believe that unreliable electricity is one of their primary impediments to doing business.

According to recent study by Hiremath Mitavachan and Jayaraman Srinivasan of Divecha Centre for Climate Change of IISc, Bangalore, 4.1 percent of the total uncultivable and waste land area in India is enough to meet the projected annual demand of 3,400 terawatt-hour (TWh) by 2070 by solar energy alone (1 terawatt-hour per year equals 114 megawatts). The land area required will be further reduced to 3.1 percent if we consider other potential renewable energy sources of India [34]. Their calculations are based on present-day solar photovoltaic (PV) technology and do not include higher efficiencies achieved by new solar cells. Neither have they considered roof-top PV systems that can be established without any need for additional land.

Atul Chokshi of the IISc Department of Materials Engineering and an expert on solar energy calculates that a three kilowatt rooftop solar panel system on the 425 million households can generate a total energy per year 1900 TWh - half of the projected energy demand by 2070 [34].

While the climate in India is conducive, there is a high dependence on foreign oil; there is an opportunity for innovation in the solar industry to meet very high domestic demand with relatively low capital requirements. India is attracting solar equipment manufacturers and power plant developers from around the world. The country's national and state governments have incentives in place to entice solar energy development,

One of the major constraints in popularizing renewable energy is its high production cost compared to coal. As coal is a non-renewable resource, its price will increase, and so will that of thermal power over time. By the current trend, by 2015, cost of thermal power will go to Rs. 8 / KWh, and by 2030, it may well be Rs. 15 /KWh as coal reserves deplete. By 2040, renewable energy sources are expected to dominate [38].

It has been observed that over that past decade, solar PV market has shown sturdy annual growth of 39% globally. This means that in coming 15 -20 years, solar energy could possibly meet the entire requirement of the planet earth. Add to this the wind energy, hydro power and biomass power, it may well be possible to totally get rid of fossil fuels, and depend solely on renewables in 12- 15 years!

One possible obstacle to achieving this goal is the necessity of storing this huge amount of energy, usable when sun and / or wind are low, or when rivers supplying dams dry out. New technologies of energy storage are coming up and proving to be quite promising and practical, with some large scale energy storage devices already in operation.

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