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PROSPECTS OF USE OF SOLAR ENERGY IN PAPER INDUSTRY.(R)

Abstract

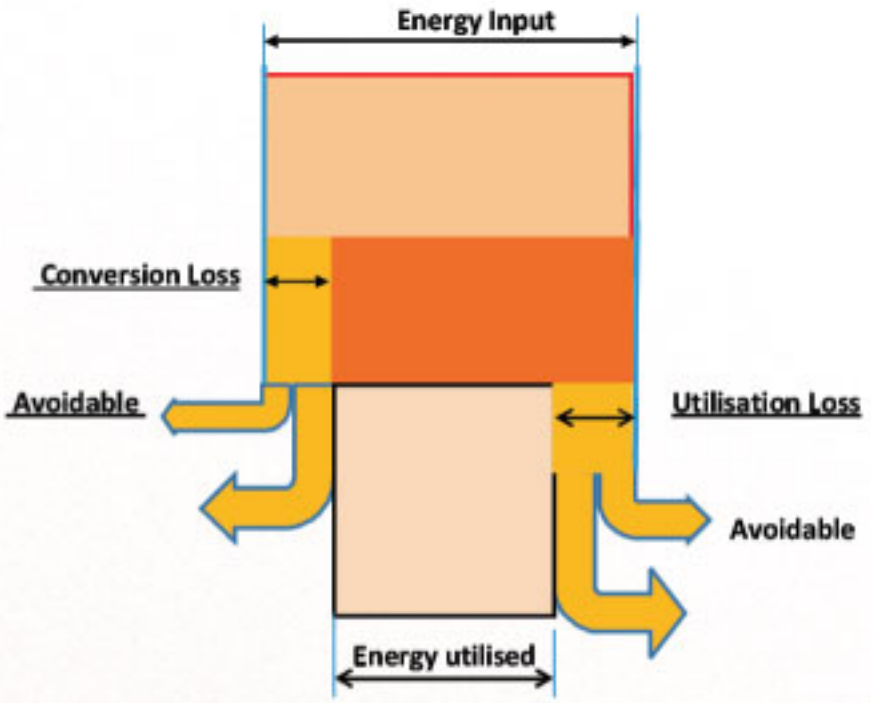
Increasing energy needs with depleting fossil fuel reserves and environmental concerns have led to Global focus on renewable sources. Due to several advantages, "Solar" is the most favoured. It is mainly harnessed as electricity though PV cells & heat through Thermal Collectors and Receivers. Use of PV electricity has crossed 3000 MW in India. Some Thermal power plants have already come up in Gujarat and Rajasthan.

It is ideally suited for use in paper plants as they use both electricity and heat in substantial quantity and also have a lot of open land for installation of collecting panels. With availability for about 8 hours/ day for 300 days in a year, for use in paper plants it has to be integrated (Hybrid) with other permanent sources like grid power and captive generation. Paper mills in general can however benefit by using solar energy for non continuous operations. Besides savings in consumption and cost there will be benefit of reduced air and land pollution by harnessing solar energy.

1. Introduction

The estimated decrease in the turnovers of Indian companies due to power shortage is approximately 7% . Energy intensive industries like textiles, cement, paper, sugar, ceramic etc. have been mainly affected. This is in spite of use of energy efficient equipment, devices & processes. Steps are on to reduce the avoidable losses. Governments in India are trying to overcome the energy shortage by encouraging use of nonconventional and non-polluting Renewable sources like solar.

Figure –1 : SHANKEY Diagram, Simplistic Energy Audit.



2. Advantages of Solar over other Non-conventional Energies.

Clean. Solar produces no carbon footprint or harm full emissions. Installing a 500KW solar power generation system prevents the emission of carbon dioxide equivalent to that sequestered by 124 acres forest. **Bio-fuels considered to be carbon neutral are really not so, as substantial quantity diesel is burnt in cultivating, harvesting, transporting & handling.**

Distributed & abundant. Unlike hydro , tidal & geothermal powers, solar energy is available every where and is not dependent on location. India receives solar energy sufficient to set up a 20 MW power plant per square kilometer land area.

Safe & environment friendly. The construction of dams on rivers for harnessing hydro power has often caused ecological disasters and submergence of large land areas with displacement of human habitations. Accessing the earth's energy and using it as geothermal power source may cause seismological disasters.

Independent of external sources. Collection & storage of solar energy will reduce or eliminate dependence on both the electrical grid and stand-by generator sets.

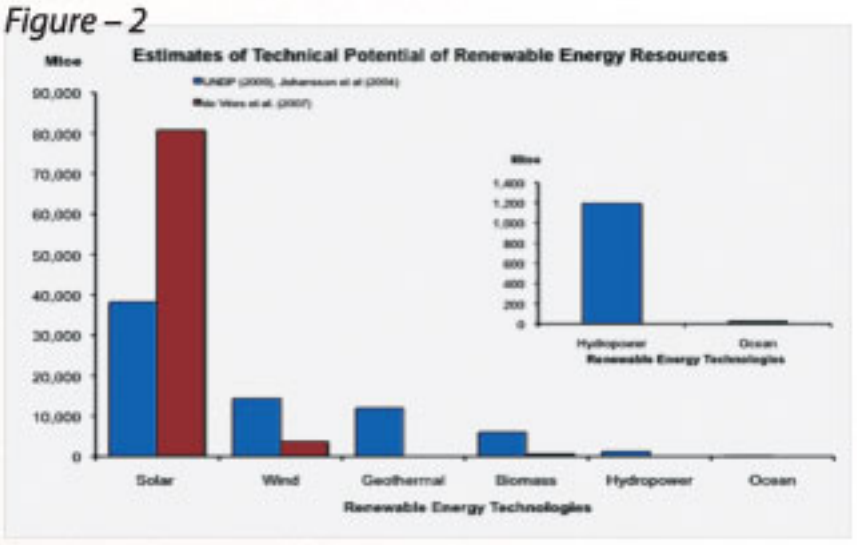
Cost effective Solar energy systems have experienced phenomenal growth in recent years due to technological developments as well as falling price of solar panels.

No transmission & distribution losses, since solar power is generated at site.

Incentives & Subsidies. The Ministry of New & Renewable Energy provides financial support through 30% subsidy and/ or 5% interest bearing loan for off-grid solar power projects. In addition, a capital subsidy of 90% of the benchmark cost is available for off-grid solar applications in identified States. There is also accelerated depreciation benefit. **Another major incentive is the existing carbon market instruments like the Clean Development Mechanism of the Kyoto Protocol & Renewable Energy Certificate (REC) which can be traded in the market.**

Nuclear, once considered to be promising is being abandoned by many countries like Germany after the Fukushima nuclear disasters & also waste disposal problems. In the U.S.A, the White House has honoured ten " **Solar Champions of Change** ", who are driving policy changes at the local level to expand energy choices for Americans, grow jobs, and add new clean energy to the grid. It has named Indian-American professor Dr. Rajendra Singh as one of the ten who are taking the initiative to spur solar deployment across America.

Figure – 2



(Mtoe – million ton oil equivalent)

Availability of renewable energy is shown in **Figure -2** above and solar is far in excess of the other sources. **The energy in twenty days of sunshine falling on Earth is the same as that of all the coal, oil, and natural gas known to humans.**

The total solar installations in the world is now over 200 GW. The electricity generated in India at present from different sources:

Energy Source.	% Share in installed capacity.
Fossil.	67.85
Nuclear.	2.14
Hydro (large)	17.68
Renewable sources.	12.33

(Reference : EAI)

3. Use of solar energy in India

It is rapidly growing in India with states setting up MW scale electricity generations. Even roof top solar panels & solar water pumps is a common sight. For example, as part of its green power initiative, Southern Railway has begun to tap solar power for its energy requirements to reduce dependence on conventional sources. Starting with the National Solar Mission in 2010, solar power, specially solar PV has crossed 3000 MW by end 2014. Germany, which receives just 50 per cent of the sunshine that India receives, has already installed over 32,000 MW of solar power, whereas India, called as the 'Sun Belt of the World' has only 3000 MW.

Annexure I. Details of Major Solar Power Plants in India.

India's largest photovoltaic (PV) power plants

Name of plant	Peak power. MW	Notes
Charanka Solar Park – Charanka village, Gujarat.	221	Commissioned in April 2012
Welspun Energy Neemuch, Rajasthan.	151	Commissioned in February 2014

State wise Grid connected PV power generating capacity.

STATE	MWp	%
Andhra Pradesh	41.75	3.18
Chattisgarh	4.0	0.30
Delhi	2.50	0.19
Gujarat	654.80	49.90
Haryana	7.80	0.59
Jharkhand	4.00	0.30
Karnataka	9.00	0.69
Madhya Pradesh	132.00	9.15
Maharashtra	20.00	1.38

STATE	MWp	%
Odisha	13.00	0.99
Punjab	9.00	0.69
Rajasthan	510.25	38.89
Tamilnadu	15.00	1.14
Uttar Pradesh	12.00	0.91
Uttarakhand	5.00	0.38
West Bengal	2.00	0.15
Total	**1442.10**	**100.00**

Figure – 3.

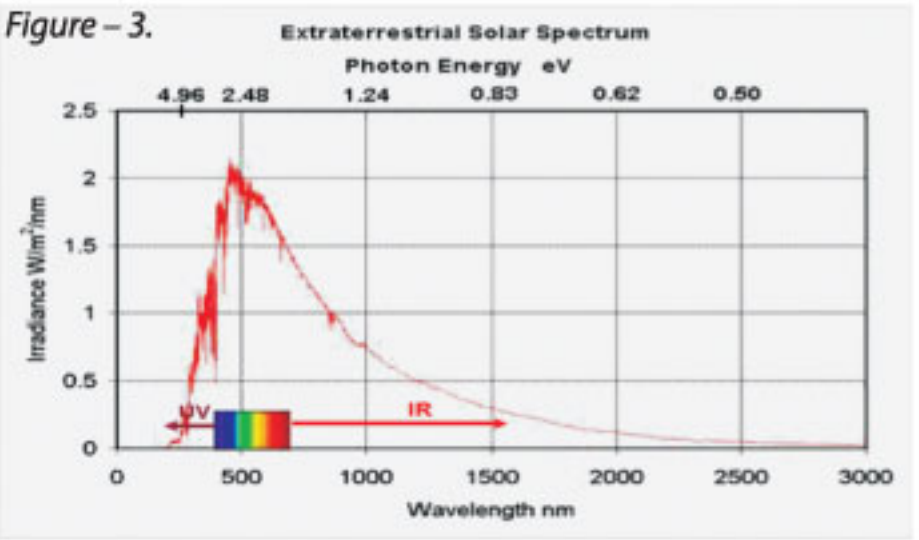
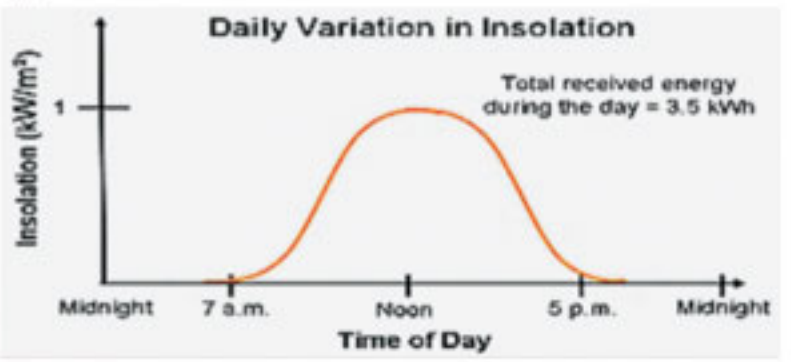
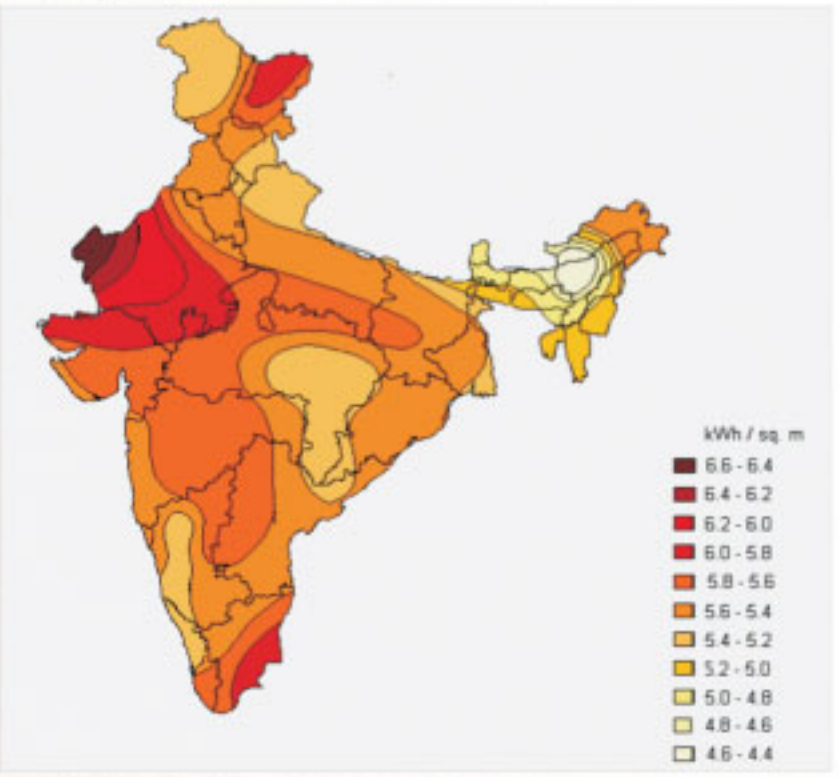


Figure – 4



The total energy received over the 10 hours of daylight will be 3.5 Kwh/ Sq. mtr.

Figure – 5 : Solar Radiation Map of India



4. Availability of solar energy.

Sunlight comes in many colours (energy levels), as shown in the attached graph (**Figure – 3**). The total energy in the spectrum (not just visible light) falling each second on a 1 square metre perpendicular plane outside Earth's atmosphere is equal to 1367 Watts/ sq.mtr. Due to 25 to 30 %e absorption by the Earth's atmosphere the incident solar radiation **(Insolation)** is about 1000W/ sq.mtr..

5. Harnessing Solar Energy

Solar energy is mostly converted for use through 2 different routes i.e.:

Electric (photovoltaic or PV).

Thermal i.e. heat.

In the photovoltaic system, electricity is produced through PV cells, usually made of silicon as shown in Figure—6

Figure –6 Solar PV electricity generation

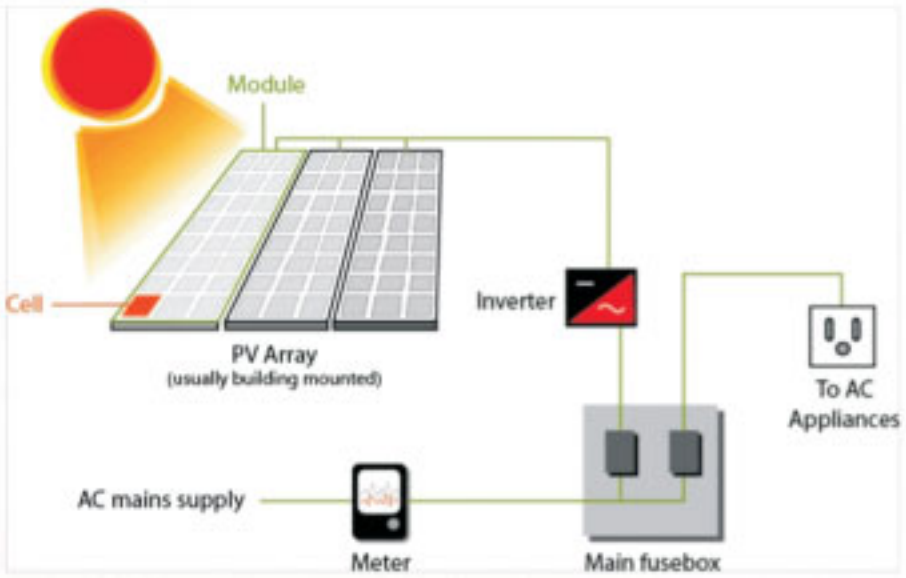
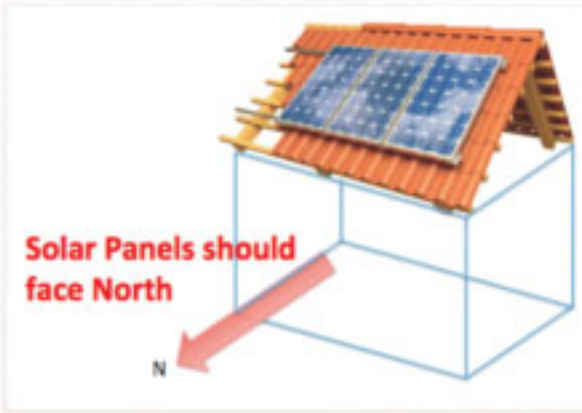


Figure – 6A : Roof top Solar panel installation



The ideal direction to point your solar panels in India is: North. This is because the sun rises in the East then moves North until midday when it heads West to set.

In the **thermal** route the solar energy is converted into heat with the help of mirrors (collectors) & receivers as shown in **Figure – 7** . This thermal energy is classified in to:

Low grade : Up to 100°C , as used in water heaters, air heaters, cookers, dryers etc. for both domestic & industrial applications.

Medium grade: From 100° C to 300° C , used for producing hot air, fluids, & vapour (steam) for industrial heating & drying.

High grade :Above 300° C mainly used for heating fluids (Heat Transfer i.e. Thermic) & producing steam for industrial use including generating electricity.

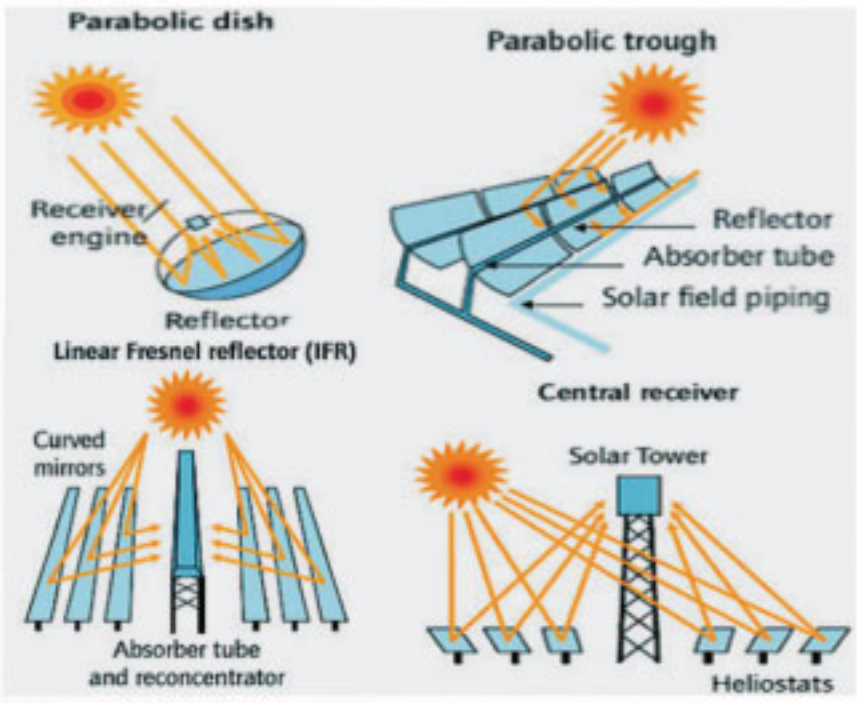
For low temperature applications, non- focussing solar collectors are used whereas, for medium & high temperature applications focussing (concentrating i.e **CSP**) types are used. Parabolic trough **(PT)** is the most commonly used **CSP** technology. Conversion of sun light to electricity in PV cells is about 12% only where as, with a thermal collector it can be up to 70%. The lower efficiency of the PV system is due to loss of energy as heat. Hence, comparatively large land area is required for PV system.

6. Storage of Solar Energy

The most common storage of solar electricity is through **batteries.** Solar heat can be stored through water at high temperature & pressure in **steam accumulators.** However, due to the size & cost these are viable only for lower capacities. Another possibility is to pump water to higher altitude & reclaim the energy through water turbine.

Large scale hi-tech storage systems (like through molten salts & graphite stored at high temperatures in towers and phase changing materials) are in use in large scale power generating units & it is now possible to generate uninterrupted electricity for 24 hours in solar power plants. On July 4, 2011 Torresol's 19.9 MW concentrating solar power plant in Spain, became the first ever to generate uninterrupted electricity for 24 hours straight, using a molten salt heat storage.

Figure – 7 : Solar Thermal Collectors



7. Feasibility of use of solar energy in paper industry.

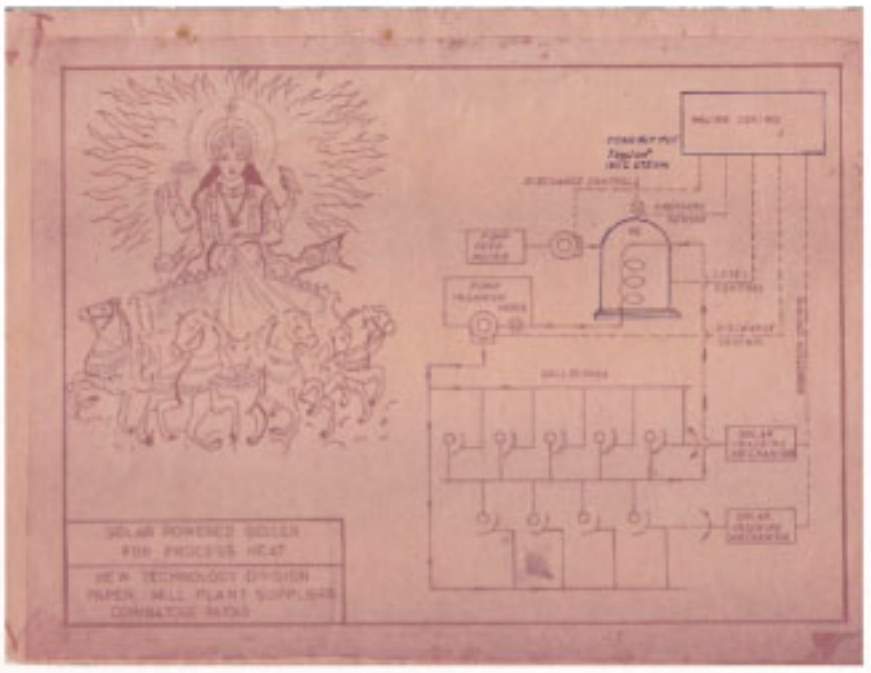
Unlike other sources like hydro & wind it is not dependent on location, is free from hazards and can be produced at site. Hence, it is ideally suited for use in paper mills as well as, paper converting units as:

a. **They use both electricity & heat in substantial quantity.**

b. **A lot of open land used for storage, material movement, lagoons etc. & even roof tops are available for installation of solar panels & collectors. (1KW of solar panels require about 10 SqM of shade-free space & will generate about 4 KWh per day on average.)**

Even as early as the 1980's Mr. R. Kandavelu, President of PMPS, Coimbatore had stressed on the use of solar energy for producing steam for paper production in their company's brochure.

Annexure II. Reproduction from PMPE Brochure.



The main constraint is that solar energy is available for only 8 to 10 hours in a day for about 280 to 300 days in a year. Hence, in continuous operating plants, it can be utilised to substitute conventional sources partly (up to 25%), both to reduce dependence and cost. **However, more relevant is that there will be corresponding reduction in air & land pollution.**

Solar energy can be effectively utilised in industries with single shift operation like sun dried board mills & some conversion units. For utilisation in continuously operating plants it's generation has to be integrated (Hybrid) with other permanent sources as detailed later, so that, they supplement each other. Plants in general can however, reduce electricity and fuel consumption by using solar energy for :

Hot water for process & boiler make up.

Hot air for dryers.

Space heating & cooling.

Paper conversion.

Repair shop.

Lighting & ventilation (With battery backup)

Water pumping.

Charging of battery operated fork lifts , vehicles & equipment.

Effluent treatment. (Aeration, sludge dewatering etc.)

Concentration of effluent by evaporation.

Electricity off take in a 50 Tons/ day Kraft paper mill (abt. 18000 Kwh/ day) can be reduced by at least 10% with installing 300 KW solar PV panels at a cost of Rs. 1.5 Crores. Similarly fuel can be saved by using solar thermal systems. Also, paper mills in states like Tamilnadu, where electricity off-take from the grid is rationed can meet the shortfall through solar power instead of purchasing from private sources or generating by DG sets at exorbitant rates. While setting up new plants, the roofs should be designed for installation of solar panels.

The Energy & Research Institute (TERI) has carried out detailed study on the feasibility of using solar energy in different industries including paper. In one of their publications (Solar thermal energy technologies for industrial applications - India's experience by Sri Shirish Garud, Fellow,) the operations in paper manufacture where solar energy can be utilised have been identified.

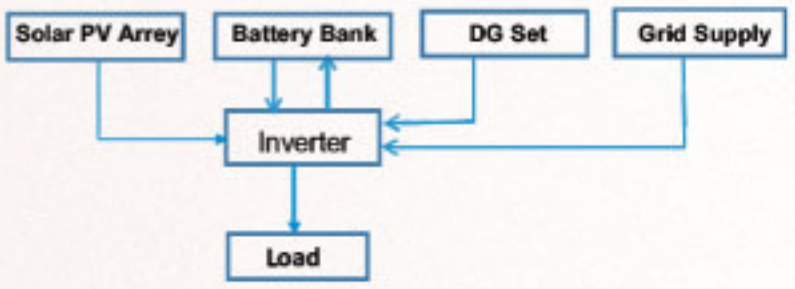
8. Hybrid Concept

The hybrid power system integrates solar generation with other energy sources, using controls to manage the system operation. Some typical Hybrid Concepts :

Electricity.

Solar—Grid Supply Hybrid. Grid supply compensates short fall or absence of solar power. (A 400 kW Solar Power Plant has been installed on roof of Chinnaswamy Stadium. Pegged as a first for any stadium in the country, the bi-directional net metering project under the Bescom grid-connected solar rooftop scheme is connected to the power utility's 11 kV substation.)

Solar- DG set hybrid. DG set as standby for both solar & grid power, reduces reliance on diesel to the extent possible. About 7000 MW electricity is being produced in India through DG sets of different capacities. The use varies from housing & office complexes, agricultural pumps & MW scale consumption in factories. The consumption of diesel can be substantially reduced (at least 10%) by integrating solar PV system with DG set. A typical system is shown in the diagram below.



Solar – Wind hybrid is another approach by adding a wind turbine to a PV system to provide complementary power generation, where feasible.

Steam and Power

Bio/ fossil fuel hybrid : Combining bio-mass/ fossil fuel & solar thermal energy systems complement each other, both seasonally & diurnally, to overcome the individual drawbacks. **Figure – 8.** shows thermic fluid heating for producing hot air & water used in many converting units like coating, laminating plants.

Figure –8 : Solar heat collection

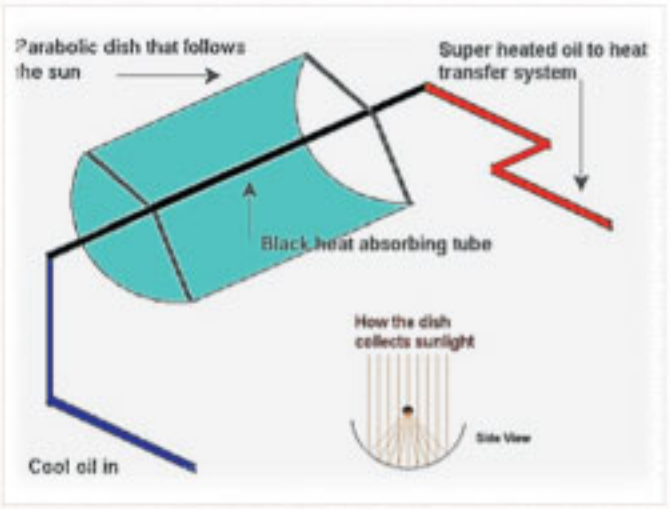
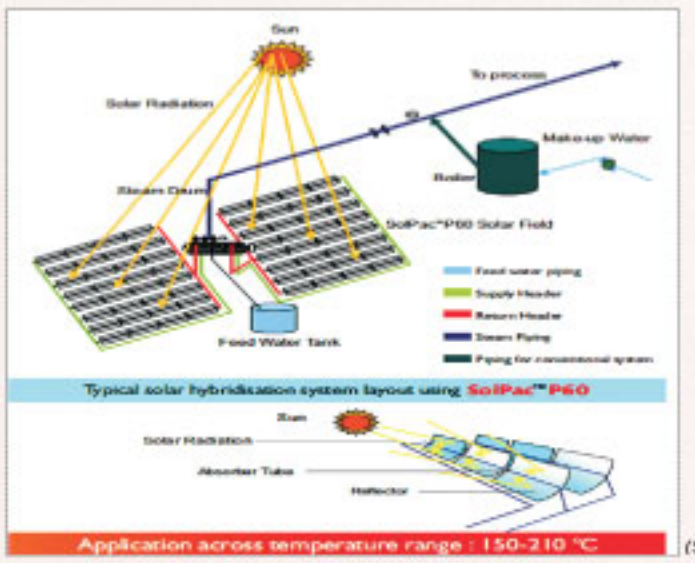


Figure 8a : Combined solar & fuel Thermic Fluid heating

Major solar thermal hybrid integration options for steam generation :

For medium pressure (up to 210*C) & lower quantity steam generation a simple design direct solar steam generation (DSG) is integrated with the conventional boiler (**Figure – 9**). Multiple rows of mirrors (Linear Fresnel Reflector LFR) focus solar radiation to pipes filled with water to generate steam.

Figure 9 : Direct Hybrid Solar – Biomass / Fossil Fuel Steam Generation



(Source : Thermax)

To produce higher temperature steam for captive electricity generation, the water is heated to saturation temperature at the required pressure by solar energy & further superheated and expanded in the conventional steam cycle. (Figures-- 10 & 11.) . From the Enthalpy of steam at 450° C & 40 atm. given in Figure 12 it will be noted that 80% of the energy is in the saturated stage. Even when solar radiation is available, the conventional boilers operate at about 50% capacity (for reasonable efficiency) & part of the furnace is shut off.

Figure 10 : Solar feed water pre- heating

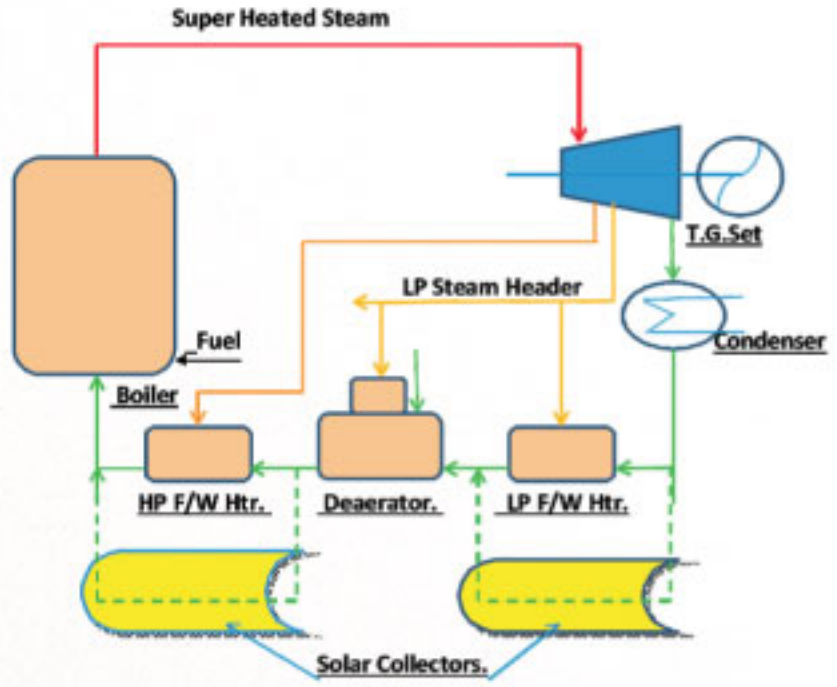


Figure 11 : Hybrid CSP Steam & Electricity Generation

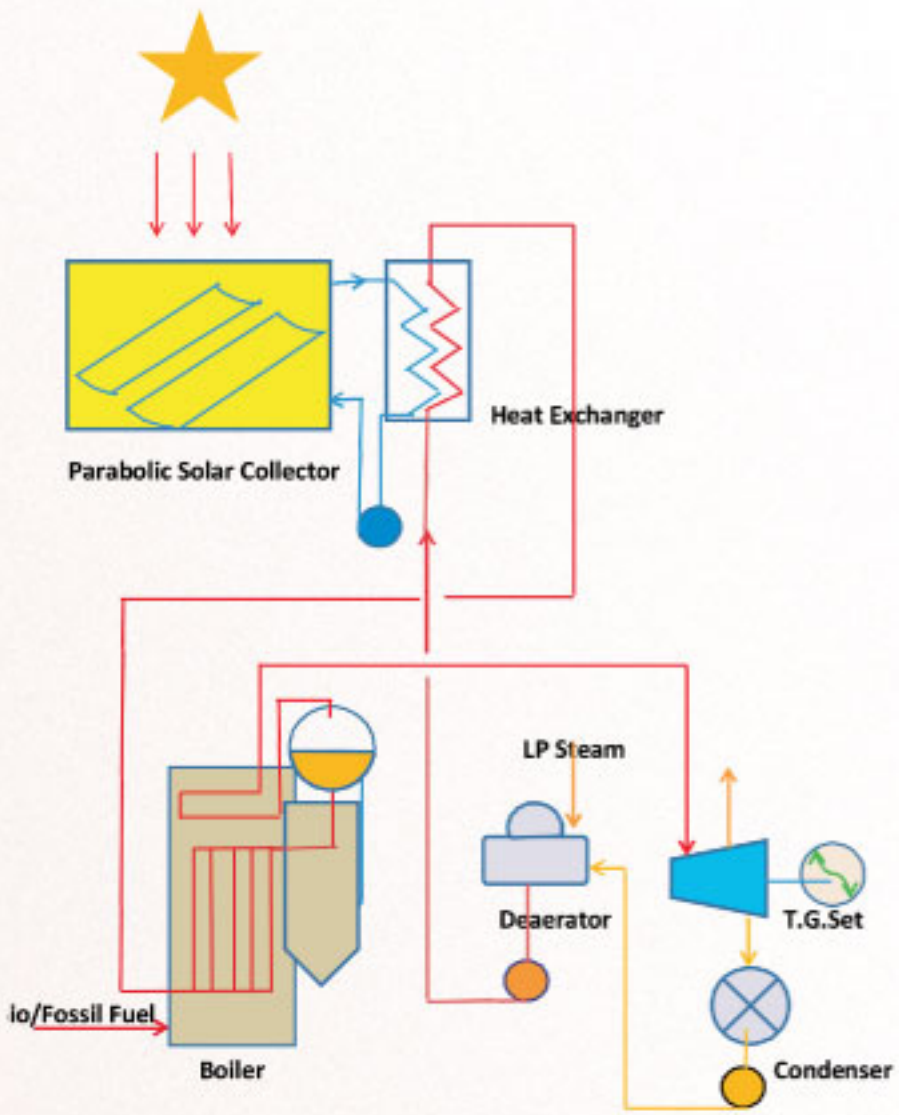
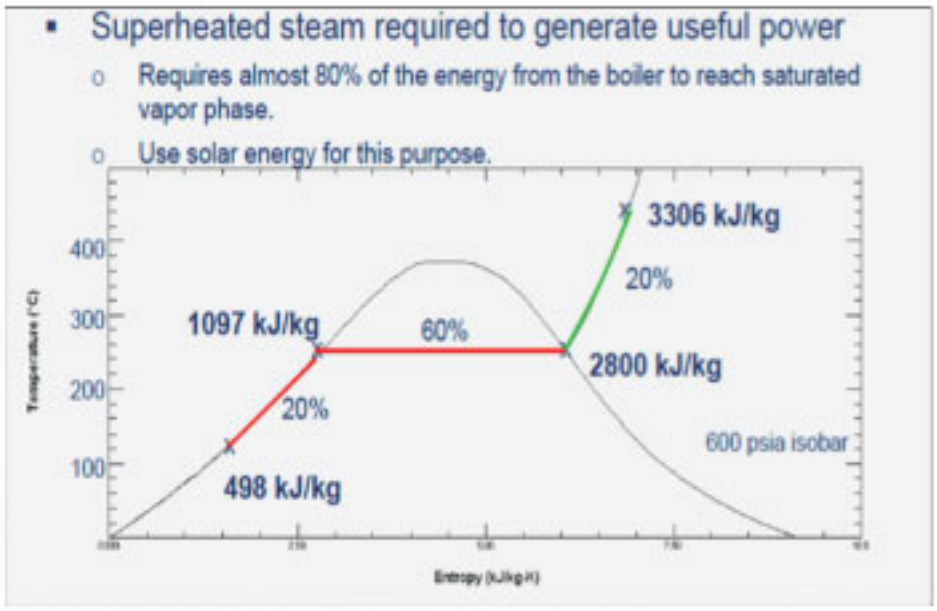


Figure 12 : Enthalpy of steam @ 41 ato & 440*C



Advantages of solar bio/ fossil fuel hybrid solution :

–Reduces the usage of biomass/ fossil fuel.

–Increases the capacity utilization factor of the plant.

- Increases the carbon footprint by not burning the fuel.

–Efficient solar thermal energy conversion.

Some instances of use of solar heat is detailed in **Annexure III.**

The Godawari 50+MWe Plant is India's first commercial CSP plant rated to produce 130 Gwh green electricity annually in the Jaisalmer District of Rajasthan..

Annexure – III. Some solar thermal systems already in use in industry.

GFCL Ltd, Kakinada : 120,000 Ltrs / day Boiler feed water pre-heating.

The system was installed in 1997 through soft loan from IREDA and it recovered its cost in four years. (GHG saved : 700 tons CO2/ day. Energy saving : 22GJ/ day)

Another system installed at textile factory in Gurgaon with a capacity of 50,000 litters per day has been working since October, 2007 and has recovered the cost in two years. Many more such systems have been installed in various industries and are functioning satisfactorily.

Hotel Fisherman's cove, Chennai : 20,000 Ltrs/ day hot water production.

M/s Raghav Woollen Mills, Ludhiana, Punjab : Drying of garments in their tumbler dryers It has replaced the cool ambient air of about 30°C with solar pre heated air of 55 – 65°C which is further raised by diesel fired hot air generator to 100 – 110 °C for drying the garments. With the result, they have been saving 25% of their fuel consumption amounting to around Rs.1.50 lacs per annum. The payback period has been reported to be two years and system is expected to last more than 15 years.

Tapi food industries, Gujarat: A system of 100 sq. m dish area at their food & fruit processing unit . This system installed in 2006 is also hooked up with their wood fired boiler and has been generating 400 kg of steam/ day at 6 bar pressure. The savings have been reported through reduced firewood and labour cost which comes to around Rs. 2.45 lakhs/ year. It has also paid back the cost in 3 yrs with depreciation benefit and MNRE subsidy.

Men - Tsee - khang Pharma, Dharamsala : Drying of 100 Kgs / day herbs to 4% moisture.

Alpine Knits (Tirupur, Tamil Nadu) : The spinning mill commissioned a 1MW roof top, grid connected, DG synchronised solar plant in March 2013. Construction time was 2 months.

Besides the above, solar dryers are being effectively used for fish processing, tea leaf drying & other purposes with resultant fuel saving & CO2 reduction. For example, a 500 Kgs solar fish drying unit is operating at Vishakhapatanam since 1999. The system generates hot air from 60 Sq m. of roof mounted solar collectors which is sent to recirculation dryers running on electricity. A typical system with 100 sq m. of flat plate collector costing Rs. 5 to 6 lakhs could save up to 6000 liters of fuel oil in a year.

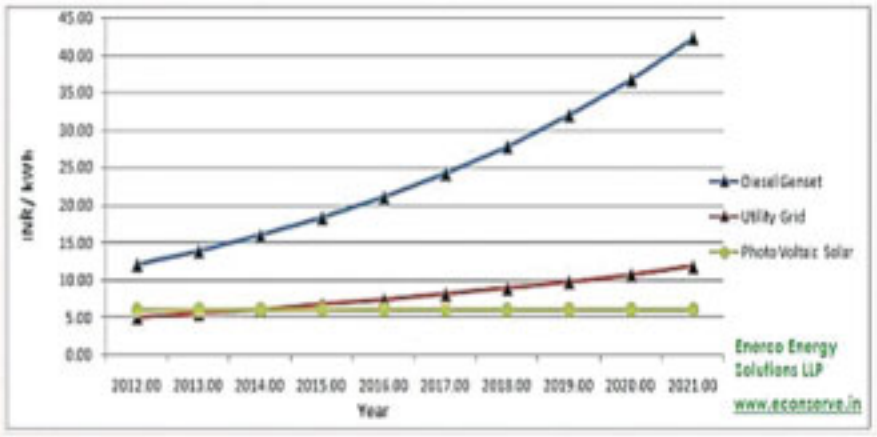
9. Economics of using solar energy

PV Electricity. Due to substantial decrease in the cost of PV panels, in many cases, solar electricity is comparable with or cheaper than the grid supply.. A 100KW (peak) solar panel (after subsidies & depreciation benefits) will cost about Rs 50.0 lakhs. With battery back up it will be about Rs 70.0 lakhs. The space requirement would be 1200 Sq. mtrs. free from shade. The electricity generation about 400 KWh in a day, will reduce the annual electricity bill by about Rs 7.5 lakhs. Besides, there will be earnings through Carbon trading. What is more important is that about 120 Tons coal (or equivalent bio fuel) will be saved in a year.

A graph depicting analytical comparison of the cost of electricity (Rs / KWh) from different power sources i.e. PV solar, Utility grid and D.G. set carried out by

M/s Enerco Energy solutions is reproduced in **Annexure IV**. KWh. A study conducted by Tata Power Solar, points out the cost of one KWh of solar power has come down to Rs. 1.8 in 2014 from Rs. 7 in 2011. In Madhya Pradesh, the BSE - listed M and B Switchgears Ltd, sell power directly to large consumers at around Rs 4 a unit. Mr. Vikalp Mundra, Director, says that it works out profitable for the solar plant owners even if only 20 percent of the RECs they acquire are sold in the market.

Annexure IV



(Above Diagram taken from Solar Energy Report)

Levelised cost of electricity (LCOE) of Grid connected small size (1 to 10 MW) Solar PV generation against different grid tariffs has been worked out in **Annexure – V.**

Electricity Tariff in different states for industrial use.(Rs/ KWh.) (Average values)

Andhra Pradesh.	7.00
Gujarat.	5.00
Karnataka.	5.75
Maharastra	7.00
Tamil Nadu.	6.00

Annexure - V

Levelised cost of electricity (LCOE) of Grid connected small size (1 to 10 MW) Solar PV generation

Basis :

a. Without solar tracker, Project cost : Rs 6.35 Crores/ MW,
   Generation (@ 18% CUF): approx.16.0 lakh Units/ MW/annum.
b. With Solar tracker, Project cost : Rs 6.75 Crores/ MW,
   Generation(@ 21% CUF): approx. 18.4 lakh Units/ MW/ annum.
   Interest rate: 12% pa., Generation Loss: 3%

Optimal electricity tariff for project IRR of about 13% & DSCR of about 1.30.

All data in Rs/ KWh

	With Trackers		Without Trackers	
	LCOE	TARIFF	LCOE	TARIFF
Pessimistic Assumptions	5.97	6.75- 7.00	6.62	7.50- 7.75
Acceptable Assumptions	5.33	6.25- 6.50	6.08	6.75- 7.00
Optimistic Assumptions	4.77	5.50- 5.75	5.18	6.00- 6.25

Not surprisingly, the LCOE and the tariff for good IRRs, are far more favourable for projects with than for without trackers..

Usually projects of the scale of 1-5 MW takes around for 4-5 months for completion.

Hybrid Solar Thermal. Solar water heating is a well established technology and is in promotion world wide. It can be used in industries for boiler feed applications in raising water temperature from 25° to 90° C and thereby saving a substantial amount of fuel being used in boilers. A 10,000 liters per day capacity system may cost between Rs.15-18 lakhs and can save around 14,000 liters of fuel oil (or equivalent quantity coal/ bio mass) per year for a period of about 20 years, the life of the system. The largest system installed is of 1,20,000 liters per day capacity at M/s Godavari Fertilizers and Chemicals Ltd., Kakinada, Andhra Pradesh.

Savings by Solar water heater.		
Qty of water heated in a day. Ltrs.	10000.00	
Temperature rise (90 - 25)	65.00	
Heat gain Kcal.		650000.00
Heat input/ Kg Husk, Kcal	2100.00	
Husk consumption/ day Kgs		309.52
Savings/ year Rs. Lakhs @ Rs. 3.5/ Kg of Husk		**2.93**

In case of direct process steam generation **(DSG),** for generating 1000 Kgs/ hr steam @ F & A 100° C in combination with a conventional coal/ bio-mass boiler, the additional capital investment will be approx. Rs 600 Lakhs of which Rs 150 Lakhs will be available as subsidy. Considering effective solar steam generation for 8 hrs. in a day & 270 days/ year, the annual saving of fuel will be about 13.5 %.(i.e 325 Tons bio-mass). With cost of bio-mass (husk) @ Rs 3500/ Ton, this works out to Rs.11.4 Lakhs. Hence, the payback period even after considering the incentives & 20% annual escalation in fuel costs, will be 10 years.

(Source : Thermax)

Based on data available from solar panel manufacturers, investment in parabolic trough solar panels (**2.5 MW**) suitable for combined steam & power generation in a 100 TPD waste paper based writing printing paper mill (25 TPH & 3.5 MW) is estimated in **Annexure VI**. The payback period on the investment of Rs 210 million also worked out there–in, will be within 8 years if the benefits of lower interest rates & appreciated depreciation is considered.

Annexure VI

Economics of Solar combined Steam & Electricity Generation

100 TPD Writing printing paper prodn. with recycling waste paper, (3.5 TPH, LP steam & 650 KWh electricity/ Ton paper.)

Fuel : Paddy husk, 14000 KJ/ Kg @ Rs. 3.5/ Kg.

Boiler/ T.G. efficiency : 80/ 90 %.

Optics.

Primary mirror surface	2053.30 Sqm
Primary mirror aperture	9.7 (2 x 4.85) m
Mirror length	211.68 m
ETFE transparency	92%

Single Collector Performance	
Ground coverage	0.5-0.7 ha
Water usage for 1 cleaning session**	1.2 m^3
Solar-to-thermal efficiency at normal incidence (typical)	60%
Solar-to-thermal efficiency, yearly average***	37% - 47%
Peak thermal power at normal Incidence, 1.000W/m2 DNI	1.3 MWth

Return on Investment.	**Unit**	
Processsteam consumption/ day (4 ato)	Tons	350.00
Electricity generation/ day	KWh	65,000.00
Bi-product electricity generation / day.	KWh	24,500.00
Electricity from condensed steam / day.	KWh	40,500.00
Steam to condenser @ 5 Kgs/ Kwh.	Tons/ day	202.50
Total steam generation. (41 ato, 410*)	Tons/ day	552.50
Enthapy increase in boiler for producing steam.	KJ/ Kg	2,800.00
Husk consumption without solar support.	Tons/ day	153.47
- Do –/ Year (330 days)	Tons	50,645.83
Savings in husk consumption with solar/ year (18% for 270 days)	Tons	7,458.75
Savings/ year.	Rs, million	26.11
Payback of Rs 210 million investment	**Years**	**8.10**

10. Conclusion

The cost of **PV solar panels** has come down substantially in recent years and consequently the cost of electricity generated through them in most cases is lower than that of grid supply and even in some cases by captive generation through steam turbine. Hence, for reasons discussed in detail, it is profitable and desirable for paper mills to utilise the same as far as practicable. However, the generation will be restricted due to the large space requirement. **"Give us your rooftop and we will give you cheap solar power"** - this is the model being used by many solar power companies to

rake up their rooftop solar installation capacities. Industrial establishments, commercial buildings, malls and large communities are the target for these operators who would set up solar rooftops for free and sell you power at rates that are cheaper than the local utilities.

Solar thermal systems can be profitably used for producing hot air, boiler feed water etc. to reduce fuel consumption. It must however, be pointed out that although solar thermal installations for steam & electricity generation are economically viable, even with the present subsidies they are capital intensive and the investment is beyond the limit for most entrepreneurs.

The Government has to play a more important role by increasing subsidies & providing interest free loans. Of course, with increased local manufacture, the cost of solar thermal systems will come down. India Ratings in an analysis has said it believes that the viability gap funding (VGF) model for these projects needs the support of financial engineering techniques to enable timely debt service. The equipment costs, debt structure and the size of the viability gap funding (VGF) will drive the credit quality of these projects. The decrease in customs and excise duty for solar power components should make these products more competitive and encourage the clean power sector. In addition, the government has tapped state-owned company Vidyut Vyapar Nigam (NVVN) – the trading arm of the state-owned electricity giant NTPC -- to accelerate the solar rollout and help meet the targets set by the solar mission.

As the Chief Minister of Gujarat, Mr. Narendra Modi oversaw the creation of over 900 MW of solar power capacity in the State, which is nearly a third of the total capacity in the entire country. A number of agencies both National & International are engaged in research & development activities for efficient & economic utilisation of solar energy. While, some of them have been referred above in relevant contexts, a few of the other major ones are :

The Jawaharlal Nehru National Solar Mission (also known as the National Solar Mission) www.indianpowersector.com/nationalsolar mission.

IRENA–www.irena.org.The International Renewable Energy Agency (IRENA) is an intergovernmental organization dedicated to renewable energy.

IEA-ETSAP- www.etsap.org. The Energy Technology Systems Analysis Programme (ETSAP) is an Implementing Agreement of the International Energy Agency (IEA),

TERI –The Energy & Research Institute, mailbox@teri.res.in

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2. Making Renewable Power Sustainable in India by Hon. Minister Sri Piyush Goyal, (Govt. of India publication)
3. Hybrid Solar–Biomass Plantfor Power Generation. Techno – Economic Assessment. by J.Servert, G.San Miguel, D.Lopez. (Global NEST Journal, vol 13, No: 3)
4. Hybrid Solar – Biomass power plant without Energy storage. By T.Srinivas, B.V.Reddy. (Case Studies in Thermal Engineering, vol.-4, March 2014)
5. Hybrid Solar Thermal Integration at Existing Fossil Generation Facilities. by Kevin Miller, Manager Engineering, Black & Veatch, South Africa.
6. Renewable Energies India Pvt. Ltd. (AREVA , Chennai & Rajasthan)
7. India Roof Top Solar Guide – 2014, (Energy Alternatives India, **EAI** publication.)
8. Clique Solar Brochure. (info@cliquesolar.com/www.cliquesolar.com)
9. Solar Mango Global News App. (ramya@solarmango.com)