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Energy Security Insights

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Editorial

India is a 'solar' rich country. It has been estimated that even if only 1.25% of its geographical area is used, the available solar energy would be nearly 26 times the commercial energy consumption. But somehow, solar energy was never accorded the importance, commensurate with the potential we have - until recently. With an aim to address energy security and climate change concerns, India embarked on a very ambitious journey by launching Jawaharlal Nehru National Solar Mission (JNNSM) towards building Solar India. Though the country has been actively working on a variety of renewable energy technologies for about three decades now, in terms of vision and scale, JNNSM is truly path-breaking, and transformational.

Here it is worth mentioning that the canvas of solar energy utilization in the country is pretty vast. This indigenous resource can be used to meet the requirements of thermal energy as well as electricity in domestic, industrial, and commercial sectors. On the applications side, at the high end there are megawatt level solar thermal power plants whereas at the lower end there are domestic appliances such as solar cooker, solar water heater and PV lanterns. And in between these two ends of the spectrum are applications such as industrial process heat, desalination, refrigeration and air-conditioning, drying, large scale cooking, water pumping, domestic power systems, and passive solar architecture.

Given the ambitious goals set under JNNSM, the main challenge lies in translating the intents in to practice i.e. the implementation strategy. It is not that we are starting from a clean slate. As a result of efforts made during the past two decades, a significant infrastructure has emerged for the manufacture of different solar energy systems/components including solar PV cells and modules; solar collectors; solar water heating systems; and solar parabolic dish. Some of these have also been exported to the USA, Asian countries, Europe and Latin America albeit sporadically. However, to quickly capitalize on the momentum, the emphasis has to be on creating a policy and regulatory framework that facilitates, on one hand the demand creation and on the other hand, enables the industry to take up the challenges and fulfill the defined goals.

Since achieving grid parity is one of the stated purpose of the Mission, rapid indigenization through technology transfer, research and development, as well through ramping up local manufacturing base is imperative. This also calls for, among others, a vibrant and mission-mode R&D.

Of course, in order to move forward in an earnest way, that too in a time bound fashion, the approach would have to be radically different from that of doing things in a business-as-usual manner, including embarking on a new institutional framework that is nimble, and is receptive and responsive to new ideas.

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Energy security and national solar mission

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Introduction

It is well-known that the long-term energy security of India is in peril. Two-thirds of India's electricity generation comes from fossil fuels, of which 53% is from coal, which may run out as early as in the next 50–100 years; and with 78% of its oil and petroleum requirements being imported, most of it from one particular region of the world, that is, West Asia. This is the situation when India's per capita electricity consumption is one-fifth of the world's average and when roughly half of the 1.16 billion people are deprived of a basic lifeline electricity connection. Despite valiant efforts, the government has failed to reach the laudable target of electricity for all. Power supply is short of demand by at least 10%, peaking to 15%. The urban–rural divide in India is brought into sharp focus when it comes to electricity. The rural areas, where 70% of the population live, get a raw deal in electricity distribution. Of the 600 000 villages in India, some 100 000 officially do not have access to electricity. This is when the definition of electrification is liberal enough to include in its ambit any village where just 10% of the houses have an electric connection. Majority of the rural population still use the most primitive methods of fuel use for cooking, that is, by burning wood and biomass.

Against this backdrop, there is an urgent need for India to find additional sources of energy. If these happen to be clean and green, so much the better! It is true that with its large population and a rapidly growing economy, India is already one of the biggest polluters in the world, although the per capita emissions of CO_2 are amongst the lowest in the world. However, we have committed ourselves to reducing the intensity of carbon emission by 25% by 2020 starting with 2005 as the base year. That ambitious goal has to be achieved in the backdrop of an economy that requires to grow at 8%–10% per annum and without touching the agricultural sector in this context. How then will India achieve that target?

Promise of solar

Fortunately India is situated in the sunny region of the world and receives abundant sunshine almost throughout the year. India is blessed to be located between 8°4' N to 37°6' N in the northern hemisphere of the earth. This places the country uniquely in the tropical/temperate zone in such a way that most parts of the country receive sunlight almost throughout the year. With about 300 clear sunny days in a year, India's solar power reception is about 5000 trillion kWh/year. The daily average solar energy incident over India varies from 4 to 7 kWh/m^2 with about 2300–3200 sunshine hours per year, depending upon the location.

Solar energy can be harnessed in different ways and used in many day-to-day applications like lighting homes or streets, heating water or air, to power industry furnaces and foundries and in the use of large scale solar cookers. The most exciting avenue for utilising solar energy is through the use of PV (photovoltaic) cells as it generates electric power that is more versatile. The crystalline silicon has been the mainstay of the solar industry over the last two decades and the emergence of other technologies such as concentrated solar power or PV thin film remains to be established at a commercial scale. As and when that happens, the size of the market will only grow further.

The main reason why solar has been slow to start in India is the fact that unlike in the rest of the world, India did not have a grid-connect solar policy until 2009. The solar industry has therefore grown in the off-grid mode, marketing solar home lighting systems, solar lanterns, etc. The cost of solar equipment entails a one-time high cost followed by negligible or zero running cost over a long life of the product over 20–25 years. The cost of solar power products is competitive with conventional power products even at current prices, provided a life cycle cost comparison is made. The trouble is that except for well-informed individuals and institutions, this approach is avoided by most people who look at only the first time

* Views expressed in this article are personal.

cost and hence dither from going solar. Costs will certainly come down with economies of scale and technological developments.

National solar mission

The Prime Minister announced the National Action Plan on Climate Change (NAPCC) on 28 June 2008 which enumerates steps that promotes our development objectives while also enabling us to deal with climate change effectively through adaptation and mitigation measures. Of the eight national missions mooted under this plan, the first and foremost is a National Solar Mission. The Jawaharlal Nehru National Solar Mission, launched on 19 November 2009, lays out an ambitious vision and a broad framework to make India a world power in the use of solar energy and fixes an ambitious target of generating 20 000 MW of solar power by 2022. From the current installed solar power base of less than 200 MW, this would mean growing the Indian solar market 100 times over during the next 12 years. The mission targets will be achieved in three phases with Phase I ending in March 2013 and Phase II in 2017. The immediate challenge is to reach the target of 1100 MW of grid-connected and 200 MW of off-grid installations, which has been set out for the first phase up to March 2013. The solar mission is also slated to launch a major research and development (R&D) programme on solar energy with international cooperation. As mentioned in the solar mission document, R&D will 'enable the creation of more affordable, more convenient solar power systems and to promote innovations that enable the storage of solar power for sustained long term use'. The Prime Minister of India, Dr Manmohan Singh, stated while launching the solar mission: 'Our success in this endeavour will change the face of India. It would also enable India to help change the destinies of people around the world'.

The National Solar Mission targets can be achieved if the mission receives the political leadership and policy direction that it deserves. All the ingredients in terms of demand and supply are present for the expansion of the solar energy market in India in a major way. What is needed is a policy push, backed by budgetary support to help the market grow in the initial phase, until a critical mass is reached.

Assessment of the National Solar Mission

With the launch of the National Solar Mission (NSM) with a target of generating 20 000 MW of solar power by 2022, the Indian solar industry is moving into the globally established grid-connected mode whereby electric power generated by solar photovoltaic panels is fed into the grid. Phase I of the solar mission is targeting a setting up of 1000 MW of grid-connected solar power plants to come up by March 2013. The main driver of solar power generation will be the feed-in tariff which is being fixed by the Central Electricity Regulatory Commission through a consultative process. The idea is that private power developers will invest and set up these plants and recover their investments by selling power to the state transmission utilities through an arrangement fixed by the government. The plan is that with private investment coming in, the government will not have to directly invest in the solar power plants but will pay for the same by purchasing the power thus generated at a cost which is determined on cost-plus basis and is higher than the cost of the conventional (thermal/hydro/nuclear) power. The most well established and successful technology uses crystalline silicon cells which could be mono- or multi-crystalline.

Under the NSM, the government has appointed a wholly owned subsidiary of National Thermal Power Corporation (NTPC), namely the NVVN (NTPC Vidyut Vyapar Nigam) as the nodal agency for the purchase of power from the solar power developers and for the onward sale of the same to the state utilities. The NVVN will be mandated to bundle solar power with the unallocated (surplus) power from the NTPC stations and sell the same to the distribution utilities.

The centre piece of this plan is the generic tariff which is determined by Central Electricity Regulatory Commission (CERC) for solar power. In its latest regulation, CERC has taken the normative capital cost of a one-megawatt solar power plant as Rs 16.9 million/MW. They have assumed a capacity utilization factor (CUF), which is akin to plant load factor (PLF) in conventional plants as 19% and have assumed a normative return on equity as 19% pre-tax returns for the first 10 years and as 24% pre-tax returns for the 11th to the 25th year. They have assumed that a 1 MW solar plant will generate 1.66 million units per year. Based on these assumptions, they have worked out the levellised tariff over the 25 year life of the plant and come to the conclusion that it should be fixed at Rs 17.91 /kWh for the whole duration of 25 years.

The assessment is that the normative capital cost mentioned above is in line with the current costs, but the generic tariff calculations are off the mark for two critical reasons. One, the CUF actually achieved on the ground is 16%–17% (and not 19%) and this will have an impact on the total power output. Two, the CERC tariff is silent about the 'de-rating' of solar panels which is bound to happen @0.5%–1% per annum (1%–2% in the first 1–2 years). Power output will be around 90% at the end of 10 years and 80%–85% at 25 years, in line with global norms. This should be factored into the calculations. In fact, the draft guidelines for the grid-connected projects mention that the modules used must be able to generate 90% output at the end of 10 years and 80% at 25 years. However, CERC calculations ignore the de-rating and arrive at output figures which are not possible in actual practice.

Where do we stand today?

The Ministry of New and Renewable Energy (MNRE) and Ministry of Power (MoP) organised an interactive session on 1 April 2010 at Vigyan Bhawan where the draft guidelines for the 1000 MW grid-connected projects of Phase I (as well as for the off-grid projects) were discussed. MNRE has announced that 50% of Phase I projects will be done using solar PV and 50% through solar thermal technology, which means 500 MW of solar PV and solar thermal projects each by March 2013. The assessment is that solar thermal technology is not yet established and reliable and has no manufacturing or industrial base in India. Therefore it is unlikely to hit the figure of 500 MW in the next 2–3 years. In fact, the sense is that the government should not get into the selection of technologies and leave that choice to market players based on project economics, technology risks, bankability, and technical viability considerations.

Current market indications point to the fact that the government will receive applications far in excess of 500 MW for the PV projects in Phase I. Even after eliminating some of the proposals on financial criteria like net worth of Rs 20 million/MW and bank guarantees of 5 million/MW and the arrangements in place for at least 50% of the required land, etc., it is likely that far more than 500 MW projects will stay in queue. It remains to be seen how the government selects the projects for the first 500 MW. Our recommendation is that the government should actually select all the projects as long as they meet the basic eligibility criteria. After all, the larger target is not 1000 MW of Phase I alone, it is 20 000 MW by 2022. Therefore, it is better if the government takes a bold and decisive step to allow all eligible projects to go ahead. After all, the investors are putting in their own resources to set up projects. Tariff is only paid when solar power is generated. Hence, risks for the government are minimal and they should let market forces play out to establish solar power as a viable source for grid-scale power.

What is required?

At present, a potential project developer must have financial arrangement at Rs 17 million/MW and arrangement for the land at 5 acres/MW. The land should preferably be non-agricultural wasteland proximate to a grid line and/or substation to save on costs for laying a new power line. In India, practically all places receive adequate insolation (sunshine) for PV systems to work well. In fact, what is gained in high insolation in some places may be lost in high temperatures since PV systems deteriorate incrementally in performance with rise in temperature above a certain temperature. In addition to nearness to electric substations, it would be better if the selected location is close to a paved road. Availability of water for drinking and for cleaning the panels would be required. Ensuring safety and security of the installation throughout the life of the project is also important.

What should the developer do?

The emerging policy regime in India provides for a power purchase agreement (PPA) to be signed between the solar power project developer and the utility (or the NTPC Vidyut Vyapar Nigam in case of Phase I of the NSM) to be of 25 years. Such a long duration means the quality and reliability of performance of solar modules will be the single most important factor driving the success of the solar projects. Therefore, the importance of getting a 25-year warranty on the solar modules will be crucial in getting the projects off-ground.

There will be other critical issues such as the robustness of the electricity infrastructure including substation and the connectivity to the grid whether at 33 KV or above. The performance quality of the inverters will also play a significant role in optimum performance of the system. The structures must be designed and engineered to withstand natural forces of sun, wind, rain, hailstorms, dust, etc., for 25 years. Not only do the individual parts like solar panels, inverters, wires and cables, structure, transformers, etc., need to be of required specifications and standards, but also the system integration must be of the highest standards.

The equipment supplier, Engineering, Procurement and Construction (EPC) contractor and project developer must all work in a coordinated fashion to achieve the required systems performance over the long term. Operations and maintenance should be handled by qualified personnel. At all stages, the highest levels of safety standards must be strictly maintained to ensure there is no accident, especially during installation and commissioning.

In light of the above, it becomes imperative for prospective project developers to select companies with long-term experience with the highest standards. The success of the project depends on them.

Conclusion: the key component for success

Solar power projects are long term bets lasting for 25 years or more. The main component is the solar cell, which make up the PV modules that constitute roughly 60%–65% of the cost of the plant. Therefore, it is of utmost importance that the project developer selects cells and modules which are guaranteed to perform for 25 years.

The second most important factor is to look at the 'derating' factor. Derating in the case of Crystalline Silicon is 0.5%–1.5% per annum varying from one manufacturer to the other. The buyer must look at the guaranteed output at the end of say 10 years, and certainly at the end of 25 years. For example, BP Solar/Tata BP solar offers a guaranteed output of 93% over 12 years and 85% over 25 years. This would compare better than other manufacturers which might offer say 80% over 25 years. The buyer must compare the offers not only on the basis of the initial cost but on life-time cost and delivered value basis. A company offering cheaper modules which under-perform should be avoided. Another factor is the enforceability of the guarantees, warranties and performance contracts. It is recommended to choose an Indian manufacturer that is expected to last the lifetime of the warranty, that is, 25 years.

Prospective solar power project developers must work with globally competitive suppliers who have the technical experience and expertise, strong balance sheets, trained manpower that can offer life-long post sales support, and believe in working in partnership rather than just making a sales. After all, this is an affair which has to last for 25 years!

India's solar energy offensive: what can India learn from Germany?

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Introduction

The world is hurtling towards two major crises: serious energy shortages and accelerating climate change. Together, they threaten to torpedo the prospects of sustainable economic development. Solutions to both the crises are interlinked: diversification of the fuel base and adoption of emerging clean and green alternatives for energy production. While fortunately, such clean and diverse alternatives have emerged on the technology horizon, barriers to their adoption are widespread, especially in the developing world.

Solar energy is one eternal source of energy whose widespread adoption is no longer shrouded in doubt. Globally, it is the fastest growing source of energy with an annual average growth of 35%, as seen during the past few years. By the end of 2008, the cumulative installed capacity of solar photovoltaics (PV) had crossed 6 500 MWP which is projected to increase to 433 000 MWP by 2025, with an investment value of US $102 billion. Similarly, solar thermal power installations are expected to catapult from the current global capacity of 355 MW to 36 850 MW in 2025, with investment volumes of US $16.4 billion per year. Solar energy is thus one of the major emergent sources of sustainable energy.

While the world is racing ahead for a place in the sun, solar energy development in India has been tardy. The only area where discernible achievements have been made is solar water heating. Cumulative installation of solar PV in India remained stagnant at around 16 MWP, whereas power from solar thermal concentrating technology was practically nil. The Solar Generation Report 2008 (EPIA and Greenpeace 2008) predicts cumulative installation of 24 729 MWP of solar PV and 1500 MWP of solar thermal power by 2025 for India. This is based on a business-as-usual scenario. Compare this to China which is projected to have 86,100 MWP of solar photovoltaics and 1,500 MWP of solar thermal power by 2025 – almost four times as much photovoltaic power than India by 2025.

Besides policy and mindset barriers, solar energy development has been hindered by lack of awareness and proper understanding about the technology, its commercial potential and viability. The global growth of the sector was the result of innovation in policy, regulation, financing, market development and awareness creation, besides continued research and development.

This paper will highlight Germany's best practices in all of these areas. Learning from global best practices and the Indian experience, an innovative and forward looking policy package will be needed for policymakers to enact. Proposed also is the exploration of regulatory avenues for market expansion through the state electricity regulatory commissions.

India's national solar mission

The Indian government has reacted to global demands for climate protection and sustainable energy production. Before the Copenhagen Climate Summit in December 2009, it announced ambitious plans – the so-called 'National Solar Mission' – to accelerate the growth of electricity generation through solar energy in the country. In the present UN-climate regime, India bears the official status of 'developing country'; but the country also presents itself as an emerging economic power with great potentials. Despite huge domestic challenges like combating widespread poverty and securing access to electricity and clean cooking fuels for hundreds of millions of people, India will have to learn to assume responsibility also for global issues such as climate change. After all, it is in India's own national interest to combat the negative effects on agriculture and its cities. Promoting renewable energy (RE) sources such as wind and solar power and caring for energy efficiency at all stages of production and distribution are part of the policy package to guide sustainable economic development.

The German case: a global model or a specific situation?

Germany is one of the world's leading nations in promoting solar energy, despite the fact that the country is not blessed with abundant sunshine. In 2008, German manufacturers of solar cells and modules held a share of 20% in world production. This placed them second in the ranking list behind China's PV industry which accounted for every third product sold on the world market. Nonetheless, Germany is still considered to be one of the world leaders in green technology.

Germany's successful feed-in-tariff-law, called Renewable-Energies-Law, which was first enacted in 1991 and later successfully amended several times, has served as a model for almost 50 countries worldwide. Its aim is to promote renewable energies basically for electricity generation, especially wind and solar power, by granting them privileged access to the central distributing grid. Wind power accounts already for a large part of the total 16% share of RE (renewable energy) based electricity in Germany, surpassing in importance traditional water power generation. Solar power by means of PV modules, however, contributes only 1% to the national electricity supply, and that at comparatively high costs. Private investments for roof-top PV units (at a price of some 12 000 euros, or approximately US $15 000) have been booming, because high feed-in-tariffs promise excellent returns on investments (8%–10% annually) for a period of up to 20 years.

The feed-in-tariff instrument served the national economy well to help build up technologically-oriented small to medium-size companies in the PV branch as producers of solar cells and modules. It has created new sustainable jobs, promoted technological innovation and favoured exports of German solar products to the growing world market. However, the price tag for these benefits is exceedingly high and the consumer pays for them with his electricity bill. The solar boom in Germany, as evidenced on hundreds of thousands of roof tops of private and public buildings all across the country, has created in the long run a high and mounting solar debt. With every new installation, indirect subsidies paid to local producers of roof-top electricity fed into the central grid, are accumulating to an amount of 10 billion euros annually, guaranteed for a period of 20 years. It is estimated that every German household now already pays 150 euros (US $200) per year extra with its utility bill in order to offset the costs of PV electricity generation, with no alleviation in sight.

Germany is still the biggest single market for PV cells and modules. It is no longer supplied exclusively by German companies. Increasingly, Chinese PV companies are selling their cheaper products there. They have bought German production technology and equipment to be fit for the high-tech export business, competing successfully with quality products at lower prices. Since their products are sold at 60% of the average German price tag, they find an open market, especially after the crash of the lucrative Spanish market. There, for a while, the feed-in-tariffs for PV-electricity were even more generous than the German ones, provoking a giant construction boom, until the Spanish government was forced to put a lid on solar subsidies. The combined effect of Chinese competition and the collapse of the PV market in Spain led to an over-supply and a sharp decline of prices for solar cells and modules. The former sellers-market had suddenly turned into a customer-oriented market with discounts of up to 30%. Grid parity, when prices for solar generated electricity equal those of power from conventional fuels, is already seen on the horizon, possibly by 2015.

Solar subsidies in Germany (actually, levies paid by the consumers at large) are under constant review and are now in the process of being cut substantially, provoking wild protests from the PV industry and its powerful lobby organizations, including a wide-flung coalition with active party-led support. They claim that 50 000 jobs are being threatened by the proposed cuts and that Germany's ambitious climate protection goals (40% reduction of national CO_2 emissions) need to be met. The likely political compromise, to be passed into law soon, is a 15% annual degressive rate applied to feed-in-tariffs for PV electricity, offset by the new financial incentive of a self-use consumption rate for private households.

The legislation favouring renewable energies in the electrical generation sector has been contested ever since its initiation by large utility companies because it is threatening their privileged position in the coal and nuclear-power based industry. Especially after a new coalitional government has been in power in Germany, the political issue of abandoning or living with an exit strategy with regard to nuclear power is heavily contested. It boils down to the systemic question of whether or not nuclear power is compatible with a speedy build-up of potential for renewable electricity generation. One side claims that German industry still needs the nuclear power option for a prolonged period of time in order to bridge the gap (some 25% of power generating capacity) which the renewables (basically wind and solar power) are scheduled to fill within a decade or two. The other side, especially the respective RE lobby, maintains that renewable energies can substitute coal and nuclear power much faster than generally anticipated, under the condition that RE is given absolute priority and certain prerequisites are met. This implies technological advances in storing electricity, building smart transnational super-grids and providing gas-fired back-up plants, to offset fluctuating input from electricity generated by wind turbines and solar panels. It is also a question of maintaining a centrally supplied power system with monopolist utilities or creating a decentralized form of electricity generation with a great number of new independent providers. The new German government has proposed to solve this quandary by commissioning expert studies to advise a comprehensive national energy strategy. The deadline has been set for October 2010.

In the meantime, the political battle between differing lobby groups will continue in a typically German fashion, often with ideological connotations. Potential investors will wait to see what political framework might emerge, before making their respective business decisions. It is notable, though, that relevant political decisions concerning measures to guarantee energy security and climate protection are no longer taken exclusively at the national level, for example, in Berlin, but increasingly in Brussels by respective institutions of the European Union (EU). Economic actors are learning to adapt to this special political environment: often their field of operation is no longer restricted to an individual country, rather they look at the European playing field, both in the traditional energy sector and in expanding RE branches.

What can India learn from Germany?

India and Germany are quite different in size, wealth and status for a comparison. Nonetheless, there are common challenges that the countries face and there exist lessons to be learned for the sake of not repeating the mistakes. Technological leapfrogging cannot result only from international transfer of know-how, joint ventures and foreign investments; it has to find political leadership and national elites at all levels to prepare the requisites necessary for such an ambitious undertaking. International cooperation is needed.

India is working towards becoming a global leader and a hub of solar power, something developed nations like Germany, Japan, Spain and the US were recognized for. This has arisen from a report called the National Solar Mission which the Government of India is working on. India plans to add 20 000 MW of solar power generation capacity by 2020. Furthermore, the plan envisages 100 000 MW by 2030 and 200 000 MW by the middle of the century. India is focusing on solar energy to make a major contribution to the country's electricity generation. Meanwhile, India's PV manufacturing sector is developing fast. This is because it has been recognized that the country's scientific, technical and managerial talents need to be pooled with sufficient financial resources in order to develop solar energy to power the economy. It also has the advantage of permitting decentralized production and distribution of electricity, thereby helping to empower millions of poor people in the countryside by gaining access to it through projects of rural electrification.

Although India as a tropical country is blessed in most parts with abundant sunshine (long hours per day and in great intensity), the sun only shines at day-time and thus PV solar energy needs to be complemented with an intelligent mix of numerous renewable and traditional energy sources. The hybrid and off-grid nature of decentralized electricity production can best be guaranteed by a combination of wind and solar power with natural gas or biogas. This allows for an uninterrupted day-and-night energy supply. When the chosen technology is apt to be handled with local technical skills it can save money and procure jobs where they are most needed, thereby reducing poverty and empowering the people to use electricity not only as a commodity but as an indispensable production factor for small business and local commerce. This is an experience which Germany witnessed more or less a century ago during the Second Industrial Revolution with the revolutionary impact of urban and rural electrification. Hundreds of millions of Indians living in rural villages are 'still waiting' for electricity, as Greenpeace India has titled its recent report on energy injustice in the country (Greenpeace 2009).

Another solar technology, namely concentrated solar power (CSP), a promising field in which German manufacturing and construction companies hold great expertise, can be used successfully for large-scale electricity production in countries such as India where solar radiation is intense. They have just completed two demonstration plants (Andasol I and II) in southern Spain where electric power is generated by steam-driven turbines on a day-and-night basis because of a saline storage facility.

Research and development in this field is being actively undertaken at a newly opened, state-financed German research facility (Jülich).

Today India can leapfrog backward technological development and with the help of green technologies begin right at laying foundations for a so-called Third Industrial Revolution. Many observers believe this to be necessary for sustainable economic development with cleaner fuels for energy generation in order to comply with the requisites of climate protection. The present fuel mix to generate electricity in India as well as in Germany is still dominated by coal (52% vs. 43%). The share of nuclear-produced electric power in Germany is much larger than in India (23% versus 3%), despite the fact that there this clean power source (free of carbon dioxide) finds only limited public acceptance and will play no role in future considerations. Surprisingly in this comparison, India leads the RE statistics with an overall share of 35% as compared to Germany's modest 16%. This is due to the fact that almost a quarter of India's electricity supply is produced by hydro power; in Germany water turbines produce only 3% of national electric power. However, wind turbines account for 6% and with significant offshore capacities in the planning, this share is likely to rise in the future. Solar power through PV occupies a niche in Germany with a share of 1% which due to climatic conditions will not increase significantly. In this respect, India has a clear advantage: it can use modern solar power technologies, both PV and solar thermal applications, in an optimal way to generate electricity in large scale.

What needs to be done in India is to create a favourable political and economic environment for private and public investments in solar technologies. Building 'Solar India' is precisely the goal of the Jawaharlal Nehru National Solar Mission. It seeks 'to promote ecologically sustainable growth while addressing India's energy security challenge'. And the mission will also constitute 'a major contribution of the country to the global effort to meet the challenges of climate change'.

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The environmental benefits of solar lighting alternatives over kerosene: an input–output approach

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Overview of lighting sources in India

Even today, electric lighting remains a luxury for a sizeable share of households in India. 55% of rural households in India continue to depend on kerosene as the primary source of lighting (NSSO 2007).[1] This high reliance on kerosene for lighting can be attributed to two reasons: one, the fact that electricity is yet to reach 96 023 villages (Ministry of Power 2010) in India and two, rural areas continue to suffer from frequent blackouts.

Although the Government of India has committed to the electrification of all villages in India by 2012 through the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), it is unlikely that electricity would be available to all without any shortages within this time-frame (Deshmukh, Gambhir and Sant 2010). Kerosene lanterns associated with low quality illumination, indoor air pollution and the ubiquitous issue of misdirected subsidies, are therefore expected to remain an important solution to fulfil the lighting needs of many over the next few years. Apart from the air pollution and safety-related aspects of kerosene lanterns, there is concern about the increasing under-recovery on kerosene subsidies which have increased from Rs 37.51 billion in 2003–04 to Rs 282.25 billion in 2008–09 (Government of India 2010). Moreover, estimates indicate that around 50% of the PDS kerosene does not reach the targeted households (UNDP/ESMAP 2003). From the imports perspective, India currently imports 70% of its crude oil requirements with estimates suggesting that this figure may reach 85% by 2012 (Financial Express 2007). Therefore, from an energy security perspective, solar lanterns could play an important role, by providing a clean and affordable lighting solution to these rural households.

The manufacture of solar modules is an energy intensive process and it is estimated that the cost of power and fuel for the crystalline silicon value chain itself is above 10% of the cost of the production and manufacture of solar cells and modules (Indian Semiconductor Association 2008). Accordingly, there is a concern whether the solar lantern consumes much more energy and is associated with higher emissions when compared with the kerosene lantern in terms of a life cycle approach to emissions. This paper uses a macro approach to examine whether the solar lantern is in fact actually 'cleaner' and 'cheaper' than the kerosene lantern, when compared in terms of its life cycle costs and emissions.

Methodological approach

This paper uses the Input–Output (IO) approach to determine the carbon emissions associated with the production and use of a solar lantern vis-à-vis a kerosene lantern, on an annual basis. To trace the entire network of the supply chain to produce one unit of solar lantern, a lot of information and data is required about the 'cooking recipe' of the products related to solar lantern production. While the specifications of lanterns vary, for purposes of this paper, the comparison is conducted for a particular specification of solar and kerosene lanterns. For example, an aluminium frame is an integral part of every solar module considered in our specific solar lantern. Bauxite, electricity and other inputs are indirectly required to produce one unit of aluminium frame. Further, specific amount of fuels are needed to generate electricity required to produce the aluminium frame. Using the mathematical model of the IO analysis, one can trace the complex interdependent production system in the economy.

The Indian Input–Output table published by Central Statistical Organization every five years, represents the inter-dependence of each sector of the economy on the other, and makes it possible to estimate the indirect consumption of various goods by the different sectors of the economy. This has been

[1] 2004/05 figures

appropriately transformed into an Environmental Input–Output (EIO) matrix for India in collaboration with Keio University (TERI 2010).[2] The ability of being able to estimate the indirect emissions from the manufacture and use of resources is one of the advantages of the EIO approach. While EIO matrices have not been developed and applied in the Indian context earlier, it has been used a number of times in the past to conduct comparative carbon emissions analysis (Hendrickson, Lave, and Mathews 2006).

The sector-wise indirect carbon emission per unit consumption is given by the following equation.

$$CO_2 = a_c(I-(I-M)A)^{-1}) \begin{bmatrix} 1 \\ 1 \\ . \\ . \\ 1 \end{bmatrix}$$

where:
M is the diagonal matrix of import coefficients
A is the input coefficient matrix by industry technology assumption
a_c is the matrix of carbon emissions

Data and assumptions

The solar lighting technology is based on using the modules to charge a battery which is then used at night to power an electric bulb. The lantern either uses a Compact Florescent Lamp (CFL) or a Light Emitting Diode (LED) as these sources of lighting have a higher watt per output as compared to the ordinary General Lighting Service (GLS) bulbs. The lighting device is housed in a plastic encasing and it is possible for individual modules to be connected to all the lanterns or to have centralized charging stations where a number of lanterns can be brought to be charged together.

This paper assumes a configuration of a single module charging a battery that will power a single lamp after dark. For the case of CFL lanterns, the paper has considered a module capacity of 10Wp with a CFL of capacity 7W. For the case of LED lanterns, a module capacity of 3Wp has been taken with a LED of output 2.5W. It should be noted that this is not the exclusive combination that may be possible for module capacity and lantern output but this combination has been chosen keeping in line with the required time for the output of the lantern. Table 1 gives the costs of the different components of the solar lantern as well as the lifetime of the different components as assumed in this paper.

Table 1 Costs and lifetime of components of solar lantern

	LED (2.5 W)		CFL (7W)	
	Cost per component (Rs)	*Lifetime (years)*	*Cost per component (Rs)*	*Lifetime (years)*
LED/CFL	350	25.7	70	5.1
Battery[31]	170	2.6	640	5.1
PCB	180	10	200	10
Housing	150	20	190	20
Total	850		1100	

Source Chaurey and Khandpal 2009

In the case of modules, data was procured based on consultations with members of the solar module production industry. Table 2 gives the size and unit cost of materials that are consumed in the construction of 3 Wp and 10 Wp modules. The consumption of electricity and the cost of machinery (capital cost) for the production of solar modules have been taken after consultations with members from the solar module production industry.

Table 2 Quantity and cost of components of solar modules

	3 Wp module (LED) Size	10 Wp module (CFL) Size	Cost (per unit)
Frame	0.82 m	1.4 m	Rs 150/m
Glass	0.04 m^2	0.13 m^2	Rs 600/sq. m.
EVA Sheet	0.04 m^2	0.14 m^2	Rs 750/sq. m
Tedlar Sheet	0.04 m^2	0.14 m^2	Rs 800/sq. m

Source Manufacturers Websites. Cost data has been determined from the web and interaction with sector experts.
Note
(i) Although there are a number of different modules of 10 Wp available, all with different dimensions, the module that has been considered in our analysis is mid-range.
(ii) It should also be noted that the area of glass, EVA and Tedler sheet have been taken to be 1%, 6% and 7% more than the area of the model in line with de Wild-Scholten and Alsema 2005.

Since most of the cells and wafers are imported from Japan or Germany, and the cell and wafer

[2] This paper is based on the EIO model developed jointly by Prof Kazushige Shimpo (Keio University, Japan) and the Modelling and Economic Analysis team at TERI during 2008–10. The model can be used in various life cycle emission studies for India.
[3] In the case of CFL lanterns, the battery will be 12V, 7Ah whereas in the case of LED lanterns the capacity of the battery is 6V, 4.5 Ah.

manufacturing industry is still at a very nascent stage, the carbon emissions from this sector have been considered to be similar as in the Japanese sector. These are summarized in Table 3.

Table 3 Emissions from solar cell and wafer manufacture

Component	g-C/w	g-C/3w	g-C/10w
Sillicon and ingot-wafers process	8.21	24.62973	82.09909
PV cells	4.38	13.13182	43.77273
PV modules	6.55	19.64536	65.48455
Total	19.14	57.40691	191.3564

Source Yamada and Komiyama (2002)

It should be noted that where there was scope of any ambiguity in data, caution has been taken and a conservative estimate of the higher side of costs for solar modules has been considered. In case of an LED solar lantern, the life of the lantern is assumed to be 10 years and that there will be four changes of batteries during this period. In case of a CFL lantern, the life of the lantern is again assumed to be 10 years with the battery and the CFL being changed twice. The lifetime of the module is assumed to be 20 years.

In terms of consumption levels, it is assumed that a household would use two kerosene lanterns per year, each costing Rs 50 and that each household consumes 36 litres of kerosene in a year.

In the case of CFL and LED lanterns, the light sources tend to provide a higher quality of light as compared to the standard kerosene based hurricane lantern. However, this paper does not consider the increased luminosity from shifting to solar lanterns, although this would be an additional inherent benefit.

Findings

Figure 1 provides the comparative life cycle emissions from a solar CFL lantern, a solar LED lantern and a kerosene lantern (using around 36 litres of kerosene annually) based on the EIO approach.

On an annual basis, the LED lantern could result in a saving of 93 kg CO_2, while a CFL lantern could save 89 kg CO_2 compared to a kerosene lantern.

In terms of the manufacture of solar lanterns as a whole, the largest share of emissions is on account of the solar modules (as high as 80%–88% of the emissions is attributed to the total emissions from the solar lantern as considered in this study).

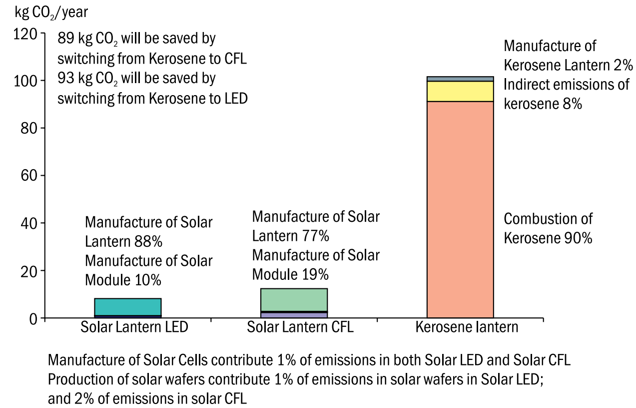

Figure 1 CO_2 from various lighting sources
Source TERI Analysis

Although the costs of solar modules and lanterns continue to be significantly higher than those for kerosene lanterns and fuel; costs for modules continue to decrease as developments take place in this field. Also, economies of scale can significantly reduce the cost and energy consumption for the production of solar modules.

Solar lighting devices provide an important alternative to kerosene lanterns. This paper demonstrates that there is significant reduction in carbon dioxide emissions with the adoption of either a CFL or LED based solar lantern as against a kerosene based lantern. There would be a significant reduction in the energy consumption when compared in terms of a life cycle approach. Accordingly, the adoption of solar lanterns have a role to play in terms of increasing the energy security of India as the country currently imports majority of the crude oil. A shift away from kerosene would lead to reduction in the petroleum subsidy apart from providing a clean and safer lighting solution.

Although the solar lanterns are an attractive option for the mitigation of emissions of CO_2, there are a number of barriers that stand in the way of widespread adoption of solar lanterns and modules. The main factor is the high capital cost of the solar modules as compared to the kerosene lanterns. However, it should be pointed out that the distribution of solar modules and lanterns could have a more targeted subsidy reach than kerosene.

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Solar energy – policy requirements

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The climate change deliberations have brought global attention to solar energy. Despite low CO_2 emissions by India – 11 324 Mt of CO_2 with cumulative annual growth of 5% versus 6071 Mt of CO_2 in China at 6% CAGR, India is also paying great attention to solar energy development.[1] The Jawaharlal Nehru National Solar Mission has a target of deploying 20 000 MW grid connected solar capacity in the next 12 years (by 2022). According to initial assessment and as reported in newspapers, the 20 000 MW plan envisaged a budget of Rs 2700 billion and to provide Rs 17.50 per MW feed-in tariff to solar power generators for 20 years. Out of this, Rs 5.50 will be paid by the utilities and the Central Government will pay the balance.[2] The Finance Ministry is unable to fund this much and the target is likely to be reduced to 4000 MW, at a cost to government of Rs 900 billion over 20 years. The annual radiation the country receives ranges from 1600 to 2200 kWh/m^2 which is equivalent to annual generation of 6000 million GWh versus the electricity generation of 0.7 million GWh from all resources (2008–09).[3] To put matters in context according to the Integrated Energy Policy 2006 with an annual GDP growth of 9%, we will need 2043 million tones of oil equivalent (MTOE) of total primary energy supply (TPES) in 2031–32 against 550 in 2006–07.[4] The solar targets are a small fraction of our requirements.

State governments have laid down the percentages to be procured from renewable energy which vary between 1% in Delhi to 10% in Haryana though the actual generation is miniscule.[5] The national tariff policy recognizes that solar energy is relatively more expensive unlike wind and regulators have allowed higher prices. When it comes to grid connected energy, solar has so far been practically a non-starter.

However, the budget speech for 2010–11 of the central government announced 'concessional customs duty of 5% to machinery, instruments, equipment and appliances required for the initial setting up of photovoltaic and solar thermal power generating units'. There is also exemption from central excise duty. However, there is no mention of the concessions that were awaited, namely – tax concessions and fiscal incentives to encourage investment in solar energy.

An important incentive announced in the solar mission which will allocate up to 1000 MW (in the first phase) of centrally unallocated power to states that have new solar generation capacity of 1000 MW. If a state bundles these together, the cost of solar power of the developer of Rs 13 per KWh and the NTPC power at Rs 2 per KWh, will bring the bundled power cost down to an acceptable Rs 4.75 per KWh.[6] This is close to and at times even below the cost of power bought in the market exchanges.

However, this can at best be a limited solution since there is a limit on available unallocated power. Other incentives have to be developed. One interesting development is the announcement of Renewable Energy Certificates (RECs), which will be issued to the renewable energy developers who can trade them with those in the country who are short of the quota of renewable energy set in each State. This will be an additional income and can therefore

*Inputs provided by Ms Nidhi Maurya, Research Associate, TERI

[1] Calculation based on data provided in IEA Key World Energy Statistics 2009 and UNFCC website (http://unfccc.int/di/DetailedByParty/Event.do?event=go) accessed in March 2010

[2] <http://www.thehindu.com/2010/01/10/stories/2010011055 581300.htm> 'Solar energy mission target may stand reduced' January 10, 2010

[3] Grid Connected solar Power-Time to Act: Mercados, 2010

[4] Integrated Energy Policy: Report of the Expert Committee pp. 28

[5] Report on Development of Conceptual Framework for Renewable Energy Certificate Mechanism for India submitted to Ministry of New and Renewable Energy (Government of India) prepared by ABPS Infrastructure Advisory Private Limited (June 2009)

[6] Ranjit Deshmukh, Ashwin Gambhir and Girish Sant, Prayas Energy Group 'Need to Realign India's National Solar Mission, March 2010' submitted to the Economic and Political Weekly for publication.

reduce the cost of solar energy. However, clarification is still required on how and when the RECs can be issued since the issuing State has to first meet its renewable energy quota. SERCs have to issue their regulations and recognize RECs as valid instruments for discharging mandatory obligations.

Wind power capacity creation took off when 80% accelerated depreciation was allowed at one time. Many high net worth individuals and profitable businesses added capacity. However, till December 2009 there were no generation-based incentives to promote actual generation of power. A similar incentive structure on capacity creation could help solar energy capacity also to develop.

The imperative however is to lower the costs for solar power, both thermal and photovoltaic. This will come through new technologies, cheaper financing, economies of scale, and fiscal incentives. There must also be payment security to the seller. These are in addition to assistance in acquiring enough land at affordable cost, for water to be available at affordable costs and a transmission network that can evacuate power to the grid.

While there is little work going on in new technologies in India, there is considerable activity in the United States and in Europe on substituting the expensive semiconductor material with a cheap optical system. Other technologies under scaled-up experimentation include low-cost mechanics, optics for concentration of solar radiation (a very promising approach), central tower technologies, and dish stirling solar chimney technology.[7] Clearly, access to these developments is essential for India to move speedily ahead on solar and thereby reduce the use of coal. This is the crux of the argument by India for some years on technology access at affordable costs from the developed world, which has yet to be accepted. Cheaper financing for solar is yet to come about. Accelerated depreciation for solar energy investments, more flexible debt equity ratios, even lower interest rates (to be recovered by lenders from other businesses), might be worth examining. Already costs of solar panels and photovoltaics have reduced drastically, though they are still expensive as compared to conventional power. Scale will bring costs down further. The objective of fiscal and other incentives must be to rapidly scale-up production and generation so that cost reduction becomes possible. The 2010 budget has made coal-based electricity more expensive, with a Rs 50 per tonne cess on domestically produced as well as imported coal (raising costs by about 2.5 to 3 paise per unit), while the development of power markets through the exchange has brought power prices closer to market conditions. Power prices are especially higher in the summer months. As the price of coal based thermal generation increases, solar energy might become more feasible and economical.

As stated earlier, the mandate of the National Solar Mission is to deploy 20 000 MW of solar energy capacity in 12 years. However, the high costs would make this impossible. So the goal was reported to be reduced to 4000 MW, which would cost the government Rs 900 billion over 20 years from the day the mission kicks off, providing for substantial subsidies to the generators and cross-subsidies by raising average power costs. The Hon'ble Minister for New and Renewable Energy Dr Farooq Abdullah has announced the ambitious goals of installing 20 million solar powered lights and 20 million square metres of solar panels by 2022! This would mean more than 20 000 MW of solar power for India. Even these ambitious goals for solar energy, necessary as they are, will meet only a fraction of the overall energy demand of India. There are other developments that are possible that need government's intervention through regulation and policy-making. For example, solar cell laminates could replace roofing tiles and combine roofing with solar power generation. There could be penalties for not using solar panels in buildings, or for distribution companies not buying solar power in a given proportion, or buying tradable RECs in their place. Fiscal incentives must have penal provisions if the capacity is not available within a specified period.

On balance, solar power can alleviate the carbon emissions from burning coal but to a limited extent. It must be encouraged as must other forms of renewable energy.

[7] Presentation by Mr Pradip Vesvikar, Head, Centre For Solar Energy 'Grid Connected RE (PV & CSP) Advances in Technology and Market Trends RE Regulation India 2010, 4–5 February 2010, Pune

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