ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 12, June 2013

Solar Energy Availability and Utilization in Nagpur, Maharashtra, India

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Abstract- Well-functioning public lighting improves a city's quality of life, but contributes also significantly to its energy consumption and greenhouse gas emissions (GHG). The use of renewable energy (RE) and energy efficiency (EE) measures in Public Street lighting, present opportunities to reduce energy demand, to harvest financial savings from reduced electricity use and to reduce related GHG emissions. Many options exist for local governments to explore, such as: 1) energy conservation and efficiency (i.e., reducing operation hours, the number of lights and power); 2) stand-alone photovoltaic (PV) powered lighting; 3) grid-interactive PV-powered lighting; or 4) procurement of RE for lighting. Local governments often incorporate more than one of these options, depending on the local priorities and circumstances, as well as policy contexts. The cases of Nagpur, India, are examples of local governments choosing suitable options for public lighting. In Nagpur, PV-powered street lighting systems have been installed and significant energy and emissions savings are also being recorded.

I. INTRODUCTION

With the increasing demand of energy via *greener* methods and the gradual depletion of fossil fuels, solar energy conversion has regained the spotlight of the global energy activities. Our planet receives 160,000TW solar energy, while the present global energy demand is about 16TW. While the solar resource is virtually unlimited, conversion of solar energy to readily usable form is too expensive to be commercially successful at present. Furthermore, reliable solar technology has to be complemented by energy storage system to accommodate the daily and seasonal variations in the solar radiation. From this perspective, many countries have formulated their long term solar energy utilization roadmap. Well-functioning public lighting improves a city's quality of life. It contributes to an increased sense of safety, prevents crime and allows for longer use of public spaces for recreational and economic activities. Street and public lighting are among the core services a local government provides, or can influence. Public lighting also significantly contributes to a city's energy consumption. The use of RE and EE measures in public street lighting provide opportunities to reduce energy demand, harvest financial savings from reduced electricity use and reduce related GHG emissions. RE solutions can be an easy option for providing lighting in areas that do not have an electricity infrastructure. This can be especially relevant in rapidly urbanising areas or in under-developed areas of a city. Local governments can implement a variety of actions to improve public lighting for streets, pathways, roadways, parking lots, gardens and lawns across a city. While some of the applications can be used within an integrated programme, others can only be used independently (*e.g.* stand-alone vs. grid-integrated PV; changes to installations can be difficult to revert). Principal opportunities a local government can explore include:

Promote energy conservation and efficiency:

Energy can be reduced by revising operation hours, the number of street lights, and power. This does not require any additional expenditure. A further step would be to replace existing lighting with more energy efficient lighting systems (*e.g.* LED lights).

Stand-alone PV powered lighting:

Stand-alone solar street lights are self-contained systems that do not consume energy from the electricity grid. An advantage of this technology is the relative simple installation. Next to saving conventional energy, this technology can also reduce maintenance and running costs compared to grid-interactive street lights (see below). Solar lights are also considered reliable. Furthermore, they operate at low voltages and hence a safe option for workers.

Grid-interactive PV powered lighting:

Grid-interactive lights contribute to the electricity grid by day and draw from it by night. In contrast to stand-alone lights, this system ensures that all energy produced is utilized, and avoids possible lighting failure due to energy shortages. Lighting can feature as part of a smart grid, which uses information and communication technology to gather and act on the information (e.g. the light only switches on when natural day light falls below a certain threshold level). Grid-interactive PV powered lighting systems may however not be suitable in many situations. Nevertheless, the benefit of being connected to an electricity grid, is that it can draw upon RE generated elsewhere (e.g. solar power plant, wind farm, etc.).

Procurement of renewable energy for lighting:

By purchasing the equivalent amount of electricity and feeding it into the general electricity grid, street lighting can be fed from remote RE sources. This could have the additional benefit of supporting local or regional renewable electricity production, as well as being part of a wider shift of local government operations to RE. Local governments often incorporate more than one of the above, depending on

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local priorities and circumstances. The main differences depend upon the pre-existing regulatory framework, infrastructure, initial installation costs, and available investment. Local government actions may, however, be restricted where streets and their lighting are in the responsibility of state or national agencies. The case of Nagpur, Maharashtra, India, are examples of local governments choosing their most suitable options. In both cities, the local government took action to reduce GHG emissions and energy costs, as well as address energy security issues, by changing their approach to public lighting. Different local and regional conditions including the varying policy contexts, lead to diverse solutions. In Nagpur, PV-powered street lighting systems have been installed.

II. PV-POWERED STREET LIGHTS

The option of PV-powered street lights was not selected due to a number of identified drawbacks. The cost of the installation of solar streetlights, when the grid and the street light network already exist, was estimated to be higher than other options. The selection of the PV panels was problem-atic, with so many available options. There was also concern that companies would not exist for the duration of the warranty. The full-life cycle of the batteries for stand-alone solar installations, their production, maintenance and disposal, were difficult to assess from an environmental perspective. As such, for Sydney, the costs outweighed the benefits for stand-alone or grid connected solar street lighting.

III. SOLAR STREET LIGHTING SYSTEMS IN INDIA

A solar street lighting system (SSL) is an outdoor lighting unit used to illuminate a street or an open area and consists of a compact fluorescent lamp (CFL) fixed inside a luminaire, which is mounted on a pole. The PV module is placed on top of the pole and a battery is placed in a box at the base. The module is mounted facing the south to receive optimal solar radiation throughout the day without being exposed to a shadow. A typical SSL uses a PV module of 74-Wp capacity, a 12 V flooded lead-acid battery, 75 Ampere-hour, and a CFL of 11-W. This system is designed to operate from dusk to dawn. The CFL automatically lights up when the surroundings become dark.

IV. SOLAR CITIES PROGRAM

The Indian MNRE approved the Solar Cities programme under the 11th Five Year Plan devised in 2008. One of the objectives was to support Urban Local Bodies to prepare a road map toward RE cities or solar cities. The objectives of the programme include: Enabling/empowering urban local governments to address energy challenges at the city-level.

Providing a framework and support to prepare a master plan, including the assessment of the current energy situation, future energy demand and action plans. Building capacity in the urban local bodies and creating awareness within the society.

- Involving various stakeholders in the planning process.
- Overseeing the implementation of sustainable energy options through public-private partnerships.

V. RENEWABLE ENERGY FOR STREET LIGHTING IN NAGPUR, INDIA

In India, local governments face great challenges in providing adequate utility services to their populations. Unstable energy supply and the increasing energy demands of a rapidly growing population can often lead to a weak electricity grid. As a result, most cities and towns are facing severe electricity shortages. Municipal corporations can ameliorate these strains through targeted interventions to reduce energy consumption from municipal operations in street lighting and water supply. The local government (the Nagpur Municipal Corporation - NMC) consumes energy in operations such as water treatment and supply, sewage treatment and pumping, street lighting, transportation and hot mix asphalt plants (diesel operated), as well as in its own buildings. Nagpur is renowned as the first model Solar City in India. In 2007, the local government set RE and EE targets for 2012: a 3% reduction in conventional energy consumption across the city and a 20% reduction in conventional energy consumption in municipal operations and facilities (with 2005 as the baseline year). The focus of the activities is on the promotion of RE applications with the goal of meeting 10% of the city's primary energy consumption with RE sources.

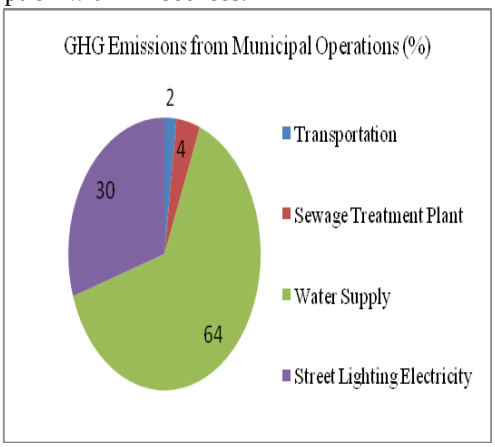

Fig 1: Nagpur GHG Emissions from Municipal Operations

VI. LOCAL RENEWABLES PROGRAMME IN NAGPUR RAISES AWARENESS

The NMC took part in ICLEI's *Local Renewable Programme* starting in 2006, in order to reduce its own energy consumption and to switch to RE. The project was created to mobilize a wide variety of key partners to become the first platform linking local governments and institutions to pursue the generation of RE and EE at the local level. The concept of RE was very new in Nagpur and the benefits had to be explained to the NMC staff. Also, the NMC did not

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have the financial resources to engage in a large scale project and RE was not considered a priority.

Table 1: Performance of solar public lighting and energy efficiency measures in Nagpur between 2006-2007

Measure	Investment (Rs)	Energy Savings (ekWh/ Year)	Savings in Emissions (CO2e/Year)	Financial Savings (Rs)
20 Solar Lights installed in NMC premises	103820	1051	0.85	5220
20 Solar Lights installed in NMC premises of High Court	103820	1051	0.85	5220
60 Solar Lights installed in Garden, Parks etc.	311750	3154	2.55	14500
42 solar blinkers installed (37 Wp)	654820	2331	1.89	10440
Conversion of 12000 of 70 watt HPSV* to 50 watt HPSV lights	49888700	240	0.19	1044
TOTAL	**51065520**	**7827**	**6.34**	**36540**

*HPSV - High Pressure Sodium Vapour lamp

The Local Renewable Programme included:

- Establishing a renewable resource centre to raise awareness.
- Identifying relevant stakeholder groups.
- Providing training programmes and awareness-raising events to different stakeholder groups.

To ensure the successful implementation of the project, the NMC appointed a staff member to work and train for the project. The project also sought suggestions and approval from the elected local representatives, holding meetings with local stakeholders. In 2006, the location, design and estimates for the Resource Centre were identified. It was opened to the public in November 2006 to provide information and a point of exchange for RE and EE.

The improved awareness led to support from local politicians and other actors for a new approach to urban energy, which resulted in local policies on RE and EE. The greater awareness amongst politicians, staff and companies on these issues was instrumental to a relatively fast decision-making process. Nagpur was amongst the first Indian cities (in parallel with the same process in the city of Bhubaneswar) to adopt comprehensive sustainable energy policies. Based on the successes of Nagpur, the city was selected by the Ministry of New and Renewable Energy (MNRE) as one of India's Solar Cities. The status *Model Solar City* made Nagpur eligible for additional national funds. Nagpur also benefited from India's *Jawaharlal Nehru National Solar Mission*, which was initiated in 2010 and targets the installation of 20 million solar lighting systems in homes and streets across the country. In some places, street lights are installed on the outside of houses, while residents keep the batteries of the street lights indoors to prevent theft.

VII. SOLAR LIGHTING IN THE STREETS, IT CAN BE DONE!

Consuming more than 22 gigawatt hour of electricity, street lighting represented the second highest source of electricity consumption for local government operations in 2005-2006 (37% of the total). The initiated RE policies and programmes provided an opportunity to reduce electricity consumption, while increasing the availability of street lighting. Between 2006 and 2007, NMC installed PV powered streetlights across the city following a lifecycle cost-benefit analysis. Solar lights and EE light bulbs were tested and compared against each other in different parts of the city. Although the implementation costs were found to be higher for solar lights than for EE lighting systems, as a whole, the benefits of solar lights outweighed those for EE lights. The factors that encouraged NMC to select solar lighting included:

- Compared to other Indian cities, Nagpur is relatively affluent in solar radiation, with more than 300 sunny days a year.
- NMC received additional funds from MNRE (INR 95 million, almost USD 1.8 million) for promoting RE in the city.

VIII. RESULTS

Since being part of the Local Renewables Programme in 2006, the local government has implemented a variety of actions, including an analysis of the city's energy performance, and initiated the City Lighting Improvement Project (CLIP) to improve the illumination levels in the city. The city already features approximately 72,000 street lights. The new system has energy-saving devices, automatic switch-on/switch-off arrangements, closed luminaries/lighting device (to protect against humid or dusty environments), etc. The measures and results (expressed in energy and carbon savings) are presented in table 1.

IX. CONCLUSION

Different solutions tailored to local resources and conditions Local governments' choices in their public lighting installations are based on the pre-existing regulatory framework, available technology and infrastructure, and the initial installation costs and available funds. Each city needs to determine the most suitable technological and economic solution for street lighting within its policy, resource and energy context. In certain cities, this process could lead to

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EE lighting combined with RE. The benefits of this strategy can be in terms of cost and a quicker payback for local governments with existing infrastructure and RE electricity supply. In cities where a pre-existing grid is absent or energy supply is not secure, the assessment may conclude, for example, that installing new stand-alone RE sourced public lighting systems, which may or may not be connected to a grid, is cost-effective.

Fig 2: Solar Street Light in Nagpur

Fig 3: Lighting Arrangement with 50 Watt Sodium Vapor Lamps

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