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Indian Solar Cities Programme: An Overview of Major Activities and Accomplishments

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ABSTRACT

The government of India's Ministry of New and Renewable Energy (MNRE) has created a Solar City Programme, which supports 60 Indian cities in the development of energy efficiency (EE) and renewable energy (RE) projects and aims to reduce conventional energy demand by 10% by 2013, compared to 2008 energy use levels. Under the programme, each city must develop a master plan which provides projections for energy demand and supply for five and ten year periods (for 2013 and 2018) and includes annual targets for energy conservation, renewable energy addition, and greenhouse gas (GHG) abatement along with an action plan for implementation and identification of potential sources of funding.

The U.S. had a similar program, called Solar America Cities, which ran from 2007-2010 and provided funding and technical support to 25 American cities. The goal of the American program was support cities in their plans to remove market barriers and encourage the adoption of solar energy by residents and businesses.

The support and expertise provided to the American cities has applicability to Indian cities, and staff from the National Renewable Energy Laboratory (NREL) have been tasked with supporting MNRE in the development and implementation of the Solar City Programme, similar to support that NREL provided to American cities. This paper details the Indian Solar City Programme, provides an overview of one city's master plan and implementation progress, describes NREL's support of the Indian Solar City Programme, and outlines synergies and differences between the Indian and American programs including unique challenges and opportunities India is facing.

Keywords: India; solar cities; Ministry of New and Renewable Energy (MNRE); Solar America Cities

1. BACKGROUND

India's energy consumption has been increasing at one of the fastest rates in the world. This is attributed to population and economic growth, urbanization, and increasing access to energy. As an example, commercial primary energy consumption in India has grown by about 700% in the last four decades.[1] Aside from this staggering growth in energy use, an existing energy supply-demand imbalance poses a hurdle for future increased economic growth. Also, despite this growth, over half of the citizens have no access to energy.[2]

Renewable energy technologies have the potential to improve the quality of life in India by helping to meet the growing demand for energy and reducing the reliance on fossil fuels, thus reducing associated GHG emissions. Thus, MNRE has been actively promoting renewable energy sources in the country. An overview of the potential for renewable energy technologies as well as the installed capacity and renewable energy targets for India is presented below.

TABLE 1: ESTIMATED RENEWABLE ENERGY POTENTIAL, INSTALLED RENEWABLE ENERGY CAPACITY AND TARGETS IN INDIA[3]

Renewable Energy Source	Estimated Potential (MW)	Installed Capacity (MW)1	2007-2012 Target (MW)
Wind	48,500	13,184	9,000
Small Hydropower	15,000	2,953	14,000
Biopower2	23,700	2,673	1,780
Solar Power	20-30 MW/square km	32	50

[1] As of January 31, 2011

[2] Includes biomass power, bagasse cogeneration, urban and industrial waste to energy.

The government is aiming for 14,000 megawatts (MW) of renewable energy technology installation during the years 2007-2012.[4] Furthermore, the government of India recently launched a National Solar Mission, which seeks to facilitate the deployment of 20,000 MW of grid-connected solar power by 2022 as well as 2,000 MW of off-grid solar applications.[5] One component of India's aggressive renewable energy goals is the Solar Cities Programme.

2. INDIA SOLAR CITIES PROGRAMME

India's MNRE has created a Solar City Programme, which supports 60 Indian cities in the development of EE and RE projects. At least one city in each state, to a maximum of five cities per state, will be supported. The programme aims to reduce conventional energy demand by 10% by 2013, compared to a baseline year of 2008. Support is provided to municipal corporations for the preparation and implementation of a master plan, or road map, to develop their cities as Solar Cities.

The objectives of the programme are:

- to enable/empower urban local governments to address energy challenges at a city-level;
- to provide a framework and support to prepare a Master Plan including assessment of current energy situation, future demand and action plans;
- to build capacity at the urban local bodies and create awareness among all sections of civil society;
- to involve various stakeholders in the planning process; and
- to oversee the implementation of sustainable energy projects through public-private partnerships.

MNRE provides support to the cities for:

- Preparation of the master plan and oversight of its implementation – The master plan is a road map for the city to envision and implement renewable energy and energy conservation strategies.
- Setting up a solar cell in the city – The solar cell is set up within the city council to provide support for project planning and implementation. It includes the senior administrator and city engineers. A Solar City Stakeholders Committee is also set up for advisory support, and includes representatives from the local municipal bodies, research and academic institutions, resident welfare associations, industries and corporate organizations, non-government organizations (NGOs), state nodal agencies, and other relevant stakeholders.[6]
- Organizing promotional activities – Promotional activities such as training programs, workshops, business meetings, and awareness campaigns will be organized for stakeholders such as elected representatives, municipal officials, architects, engineers, builders, developers, financial institutions, NGOs, technical institutions, manufactures, and suppliers.

Financial assistance from MNRE is also potentially available for installation of various RE devices as well as support for other activities. In January 2011 the programme was modified to also provide financial support for the establishment of ten cities to be developed as Pilot Solar Cities and for developing four cities as Model Solar Cities. MNRE's 2010-2011 Annual Report states that a total of 48 cities have been selected for the programme, and draft master plans have been prepared for 11 cities.[7]

3. MASTER PLANS

The cities' master plans provide total and sector-wide baseline data for 2008 for energy use and associated GHG emissions for the city. The master plans also contain projections for energy demand and supply for the coming 5 and 10 year periods. It then outlines annual targets for energy conservation, RE addition, and GHG abatement and an associated action plan for implementation. The reduction associated with these actions must equate to at least a 10% reduction in the projected total demand of conventional energy at the end of five years (end of 2013). The plans also outline potential sources of funding, such as funding from MNRE, the Ministry of Urban Development, or the Bureau of Energy Efficiency as well as income from the sale of carbon credits.[8]

4. SAMPLE MASTER PLAN: AGRA

The master plan for the city of Agra was written by ICLEI South Asia. The city of Agra was one of the first cities to finalize its master plan. Agra is located in the northern state of Uttar Pradesh, at an altitude of 169 meters above sea level. Agra is situated on the bank of Yamuna River and is home to the Taj Mahal. As of the census in 2011, Agra had a population of 4,380,793. This population number represents a 20.96% growth from the 2001 census.[9]

The maximum temperature in the summer is 45°C and the minimum temperature is about 21.9°C; in the winter the maximum temperature is 31.7°C and the minimum temperature is about 4.2°C. Agra has a good average annual solar resource (insolation incident on a horizontal surface) of approximately 5 kilowatt hours (kWh)/meter $(m)^2$/day – this is the equivalent of the solar resource in the central

United States.[3] Good quality wind resource data is not readily available; the average annual wind resource is estimated to be 3.17 meters per second (m/s) at 50 m. Biomass resource data for the city is not available; however, data is available at the district level. The potential of power generation from biomass is estimated to be 6 MW for the entire district, but there is relatively little potential of power generation from biomass within Agra. No estimate of energy potential is available for solid or liquid waste; however, annual quantities of waste are available. In 2007-2008, 235,390 metric tonnes of solid waste and 90.25 million liters per day (MLD) of liquid waste were generated in Agra.[10]

Agra's master plan provides an overview city profile which includes the city's current energy demands and also outlines the municipal corporation services which are driving the city's growing energy demand.[11] It also includes a detailed analysis of electricity, petrol, diesel, kerosene, and liquefied petroleum gas (LPG) consumption in the city, as well an estimate of the future conventional energy demand, calculated by interpolating the past energy consumption data and accounting for population growth data.

The master plan provides strategies for annual energy efficiency and renewable energy technology installations for the residential, industrial, commercial, and municipal sectors. Surveys of sample buildings were conducted to understand the current energy use and existing deployed EE and RE technologies. This was done for all sectors and served as a basis for generating EE and RE savings estimates. Also, for each technology a 'target percentage' is provided for the number of systems and capacities of the systems to be replaced or installed.

The report then provides resource information on financing, capacity building, and awareness campaigns for successful implementation of the sustainability measures. A risk analysis describing the risks associated with implementing RE projects, and potential mitigation strategies, concludes the report.

4.1 Agra Master Plan Findings

The main sources of energy in the city are electricity, petrol, diesel, LPG, and kerosene, with minimal energy provided by compressed natural gas (CNG) and solar water heating (SWH). A breakdown of energy consumption data for Agra for 2008 is presented below; it can be seen that the bulk of energy use is electricity.

[3] Solar resource data: 4.91 kWh/m2/day (NASA SSE Satelite) or 5.09 kWh/m2/day (MNRE Solar)

TABLE 2: ENERGY USE IN AGRA IN 2008[12]

Source	Consumption	Unit	Consumption in Million kWh (MU)
Electricity	1206.43	MU	1,206.43
LPG	10413.52	MT[4]	151.39
Petrol	50857.28	kL	469.38
Diesel	53468.52	kL	608.5
Kerosens	32405.76	kL	325.75
CNG	902362.9	Kgs	13.12
SWH	218	Nos.[5]	0.76
		Total	2,775.32

Petrol and diesel consumption data are not available for all sectors. Therefore only the energy usage for electricity, LPG, and kerosene is considered for defining the energy baseline and target. The total energy use in 2008 was 1,683.57 million kWh. Based on historical growth in consumption levels and population growth projections, the energy consumption in Agra in 2013 is predicted to be 2,484.82 million kWh. This gives the city a 10% reduction goal of 248.48 million kWh.[13]

TABLE 3: ENERGY CONSUMPTION IN AGRA CITY IN 2008 AND ENERGY USE PROJECTIONS FOR 2013 AND 2018 IN MILLION KWH[14]

Year	2008	2013	2018
Electricity Consumption	1,206.43	1,804.771	2,423.666
LPG	151.3865	213.4092	275.34
Kerosene	325.7515	466.6413	607.9797
Total	1,683.57	2,484.82	3,306.99

Electricity consumption represents approximately 72% of the baseline energy use and is therefore the focus of most of the energy conservation and demand side management measures in the master plan. A breakdown of electricity use by the four sectors – residential, commercial, industrial, and municipal – is presented below. The residential sector consumes 78% of the electricity.

[4] Metric Tonnes

[5] Number of Units

TABLE 4: ELECTRICITY CONSUMPTION IN AGRA, BROKEN DOWN BY SECTOR[15]

Electricity Consumption (MU)					No. of Consumers
Year	'04-'05	'05-'06	'06-'07	'07-'08	
Residential	499.46	549.9	585.36	691.3	217,975
Commercial	210.55	242.22	271.94	267.33	56700
Industrial	110.6	125.23	142.76	190.05	4045
Municipal		54.61	54.76	57.75	
Total	820.61	946.73	1,027.06	1,206.43	278,720

4.1.1 Renewable Energy Findings

As a requirement of the Indian Solar City Programme, a minimum of 5% of the energy reduction goal is to be achieved through RE measures. Those measures deemed most feasible for Agra are SWH, solar PV devices, biogas systems, and solar cookers. Considering the high capital costs of solar equipment in India, SWH has proved to be the least costly option compared to other solar equipment.

Agra's master plan sets a target of installing:

- 5.82 million litres per day (LPD) capacity SWH with a collector capacity of 0.116 million square meters (sqm)
- 12.40 MW cumulative solar PV systems
- 7,553 cubic meters (CuM) biogas systems
- 5.12 MW waste to energy projects
- 4,592 solar cookers. (101)

A breakdown of the quantities proposed for each system is provided in Table 5.

TABLE 5: TARGET QUANTITIES OF RE SYSTEMS FOR AGRA6,[7,8,9]

Renewable Energy Devices	
100 LPD Solar Water Heating	46,429
1000 LPD Solar Water Heating	1,178
Solar Cookers (Box and Dish)	4,360
Community Solar Cooker	233
Solar Lanterns	12,207
Solar Home Systems (SHS)	12,207
250-500W PV System for Inverters	17,176
10 kWp PV Power Plant for Diesel Abatement	331
10 CuM biogas system from Organic/Food Waste	755
Solar Street Light	6,392
Solar PV Traffic Lights	20
Solar Blinkers (37Wp)	60
Road Stud	5,688
Solar PV Pumps	20
Solar Hoarding	300
Waste-to-Energy Power Plant	3

4.1.2 Energy Efficiency Findings

A variety of EE and demand side management measures were considered for each of the sectors. Table 6 details these measures.

TABLE 6: POTENTIAL ENERGY EFFICIENCY AND DEMAND SIDE MANAGEMENT MEASURES BY SECTOR

EE Measure	Residential	Commercial	Industrial	Municipal
Replace incandescent lamps with compact fluorescent (CFL) bulbs	X	X	X	
T5 fluorescent light and electronic ballast to replace T12/T8 fluorescent light and magnetic ballast	X	X	X	
Efficient ceiling fans to replace conventional ceiling fans	X	X	X	
Replacement of conventional air-conditioners (ACs) with	X	X	X	

[6] A solar home system (SHS) is a fixed indoor lighting system and consists of solar PV module, battery and balance of systems. Capacity of such system could be of 18Wp, 37Wp, and 74Wp for different configurations.

[7] Blinkers are flashing lights placed on barriers, barricades, and cones.

[8] Road studs are raised pavement markers/reflective lane markers.

[9] A hoarding is an advertisement, similar to a billboard.

EE star rated ACs[10]				
Replacement of conventional refrigerators with EE star rated refrigerators	X	X		
Replacement of conventional water pumps with EE water pumps	X	X		
Energy efficiency in motors, furnaces, boilers, etc.			X	
Replacement of 150 watt HPSV with LEDs				X
Replacement of 40 watt T8/T12 tube lights with T5 tube lights				X
Sensors for automatic on/off of street lights				X
Proper pump-system design (efficient pump, pumps heads with system heads				X
Installation of variable speed drivers				X
Power saver installation in pump house				X
Plugging of leakages in the water supply system and use of efficient pumps and motors				X

[10] Star rating is a system initiated by India's Bureau of Energy Efficiency (BEE) to determine the energy efficiency of an electronic product.

The estimated potential of energy savings in the residential sector through EE measures is 87 million kWh per year; this equates to 35% of the target of 248.48 million kWh in electricity reductions by 2013 in Agra. Replacement of incandescent bulbs with compact fluorescent light (CFLs) and replacing T12/T8 fluorescent lights and magnetic ballast with T5 fluorescent lights and electronic ballast present the highest potential for energy savings. A summary of these findings is in Table 7, below.

TABLE 7: SUMMARY OF EE STRATEGIES FOR RESIDENTIAL SECTOR[16],

	Target Capacity	Investment[11]	Energy Saved (MU)	Emissions reduced (Tonnes)
Replacing 100W incandescent bulbs	277,543	416	27	22,155
Replacing T12/T8	305,828	1,529	10	8,318
Replacing Fans	146,397	2,196	2	1,708
Replacing AC	61,142	9,171	21	16,938
Replacing Refrigerator	49,589	2,975	24	19,039
Installing EE Water Pump	244,13.2	244	3	2,165
Total		16,532	87	70,323

The commercial sector is comprised primarily of offices, shopping malls, markets, hotels, and restaurants; some of these are conditioned and some are not. The largest energy-consuming equipment in this sector is air-conditioning and lighting. Thus, the focus for energy conservation and efficiency measures for the commercial sector is enhancing efficiency levels and deploying conservation options for lighting and air conditioning. Replacing 60 watt (W) incandescent bulbs with 15W CFLs present the largest opportunity for reductions. The estimated energy savings potential for the commercial sectors from EE measures is 14 million kWh per year, which is almost 6% of the target of 248.48 million kWh in energy reductions by 2013 in Agra. A summary of these findings is in Table 8, below.

[11] 1 lac = 100,000; 1 US dollar = 49.5908 INR on March 4, 2012. (http://www.exchange-rates.org/Rate/USD/INR)

TABLE 8: SUMMARY OF EE STRATEGIES FOR THE COMMERCIAL SECTOR[17]

	Target Capacity	Investment	Energy Saved (MU)	Emissions reduced (Tonnes)
Replacing 60W incandescent bulbs	86,887	130	7	5,701
Replacing T12/T8	81,648	408	2	1,825
Replacing Fans	38,081	571	1	432
Replacing AC	5,605	841	2	1,553
Replacing Refrigerators	4,034	272	2	1,549
Installing EE Water Pump	6,350	64	1	463
Total		2,286	14	11,522

Agra's electricity utility (Uttar Pradesh Power Corporation Ltd. (UPPCL)) has around 4,000 industrial customers; these customers consume about 16% of the total electricity in Agra. A survey of energy use in the industrial sector in Agra revealed that almost all customers used incandescent bulbs for lighting; there is a great potential for electricity savings associated with replacing incandescent bulbs with CFLs. EE measures in the industrial sector of Agra can save at least 6.52 million kWh of electricity per year. This equates to about 3% of the target of 248.48 million kWh in energy reductions by 2013 in Agra City. Table 9 outlines recommended EE strategies for the industrial sector.

TABLE 9: SUMMARY OF EE STRATEGIES FOR THE INDUSTRIAL SECTOR[18]

	Target Capacity	Investment	Energy Saved (MU)	Emissions reduced (Tonnes)
Replacing 100W incandescent bulbs	24,785	50	5.35	4,336
Replacing T12/T8	20,495	102	.72	585
Replacing Fans	7,923	119	.15	123
Replacing AC	842	130	.29	233
Total		401	6.52	5,278

The bulk of energy savings for the municipal sector result from outdoor lighting measures. The electricity savings potential through EE measures in the municipal sector is 22.60 million kWh per year; this equals about 9% of the total target.

TABLE 10: SUMMARY OF EE STRATEGIES FOR THE MUNICIPAL SECTOR[19,12]

Areas	EE Measures	Target	Investment	Electricity Saved	Emissions Saved
Outdoor Lighting	Replacing T8/T12 tube lights with T5	7,215	36	0.73	586
	Replacing 250W HPSV with 112W LED	8,027	4,415	4.85	3,930
	100% timer-based operation and power saver	30,772	169	4.8	3,888
Water Supply	Efficient pump system design	81		2.92	2,365.2
	Installation of variable speed drivers	81		0.73	591.3
	Standard/ recommended condition	81		2.19	1,773.9
STP	Efficient pump system design	15		3.19	2,583.9
	Installation of variable speed drivers	15		.8	648
	Standard/ recommended condition	15		2.39	1,935.9
			4620	22.6	18,305

4.1.3 SUMMARY FINDINGS

The master plan presents a summary of annual goals for energy savings through the implementation of RE and EE measures. The goal is a minimum 10% reduction in the projected total demand of 2484.82 million kWh by 2013; these reductions are to be achieved through EE measures

[12] STP = sewage treatment plant

and generation from RE installations. The master plan sets a goal of total savings of 296.53 million kWh with 166.38 million kWh from RE installation and 130.16 million kWh from EE measures; this would be a 12% reduction in energy use from the 2008 baseline. The table below presents a summary of annual EE and RE goals.

TABLE 11: ANNUAL ENERGY SAVINGS TARGETS OVER A FIVE YEAR PERIOD

RE and EE strategy for Agra	Energy Savings Target over 5 years					% of Savings target to achieve	Emission Reduction /year
	1st Year	2nd Year	3rd Year	4th Year	5th Year		
RE Residential	11.42	28.54	51.37	79.91	114.15	45.94	84761
RE Commercial	0.6	1.49	2.69	4.19	5.98	2.41	3486
RE Industrial	1.25	3.13	5.63	8.76	12.52	5.04	11094
RE Municipal	.24	9.5	13.18	33.02	33.73	13.57	27322
Total RE Strategy	16.64	41.59	74.87	116.46	166.38	66.96	126664
EE Residential	8.68	21.70	39.70	60.77	86.82	34.94	70323
Ee Commercial	1.42	3.56	6.4	9.96	15.23	5.72	11522
EE Industrial	0.65	1.63	2.93	4.56	6.52	2.62	5278
EE Municipal	2.26	5.65	10.17	15.82	22.6	9.09	18305
Total EE Strategy	13.02	32.54	58.57	91.11	130.16	52.38	105429
RE and EE Combined	29.65	74.13	133.44	207.57	296.53		232092
	12%	30%	54%	84%	119%		

5. SYNERGIES WITH SOLAR AMERICA CITIES

In 2007 and 2008 the U.S. Department of Energy (DOE) designated 25 major U.S. cities as Solar America Cities and provided financial and technical assistance to help the cities develop comprehensive, city-wide approaches to accelerate the adoption of solar energy technologies. The Solar America Cities partnerships represented the foundation of DOE's larger Solar America Communities program.

Unlike India's Solar City Programme – which includes support for the development of EE and RE technologies – the Solar America Cities program promoted only solar technologies. These included photovoltaics (PV) and concentrating solar power as well as solar water and space heating and cooling.[20] Technical assistance was provided by DOE, its national laboratories, and other experts in areas such as city planning, technology selection, project financing, building codes, architecture, and community outreach. Support provided to the cities fell into these categories:

- Organizing and strategizing a local solar effort
- Making solar energy affordable for residents and businesses
- Updating and enforcing local rules and regulations
- Improving utility policies and process
- Creating jobs and supporting economic development
- Educating and empowering potential customers
- Leading by examples with installations on government properties.[21]

NREL staff provided technical assistance to numerous cities as part of the Solar America Cities program. This support included: on-line solar map development; solar project financing guidance and development; curriculum development; code official training; and community outreach and education.

6. NREL STAFF SUPPORT FOR INDIA SOLAR CITIES

The support and expertise provided to the U.S. cities has applicability to Indian cities, and staff from NREL have been tasked with supporting MNRE in the development and implementation of the Solar City Programme, similar to support that NREL provided to the American cities.

Drawing upon the experiences of the Solar America Cities program, partnerships between U.S. and Indian cities will be established to support India's new Solar Cities program. U.S. city representatives have already supported their Indian counterparts by sharing lessons learned and best practices,

and Indian city representatives attended the annual Solar America Cities meeting.

NREL staff attended a meeting of India Solar Cities stakeholders in 2011 and based on that meeting have been working to outline future support. Input from that meeting helped NREL to define the following future technical assistance support needs:

- Developing city plans
- Implementation support for overall program development
- Capacity building and training activities in the following areas:
  - Technology-Focused
  - Policy-Focused
  - Financing-Focused
  - Curriculum Development.

7. CONCLUSION

The Indian Solar Cities Programme has the potential to drastically reduce energy consumption in cities across India. Through partnerships with numerous stakeholders, cities are identifying the most promising opportunities for EE and RE technology installations. By acting on these findings and installing these measures, the cities can help the government reach its aggressive goals to install 14,000 MW of RE technologies during the years 2007-2012 and to deploy 20,000 MW of grid-connected solar power by 2022 as well as 2,000 MW of off-grid solar applications through the National Solar Mission.

8. ACKNOWLEDGMENTS

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