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GOOD PRACTICE AND SUCCESS STORIES ON ENERGY EFFICIENCY IN INDIA

INDIA ENERGY EFFICIENCY SERIES

GOOD PRACTICE AND SUCCESS STORIES ON ENERGY EFFICIENCY IN INDIA

INDIA ENERGY EFFICIENCY SERIES

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EDITED BY

Prof Amit Garg
Indian Institute of Management, Ahmedabad

Dr. Subash Dhar
UNEP DTU Partnership, Copenhagen

Mr. Bhushan Kankal
Indian Institute of Management, Ahmedabad

Mr. Pankaj Mohan
Energy Efficiency Services Limited, Delhi

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Fabrice Belaire Infographie

COPENHAGEN CENTRE ON ENERGY EFFICIENCY

UNEP DTU Partnership

Marmorvej 51
2100 Copenhagen Ø
Denmark

Phone: +45 4533 5301

www.energyefficiencycentre.org

Email: c2e2@dtu.dk

This book can be downloaded from www.energyefficiencycentre.org

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FOREWORD

Energy efficiency improvements will be absolutely critical for achieving the ambitious goals of the Paris Agreement under the UN Framework Convention on Climate Change, where the stated objective is to keep the global temperature increase well below 2 degrees by the end of the century.

Energy efficiency, beyond being a key mitigation option, has many potential co-benefits, for example in the form of increased employment, reduced local air pollution and simple cost savings. Energy efficiency options in most cases provide cost effective opportunities from a societal point of view, therefore, it is in the interest of countries to promote energy efficiency, overcome market imperfections and institutional barriers, and realise the full potential of energy efficiency opportunities.

In terms of the future growth of energy and related greenhouse gas emissions, China and India stand out from other countries, due to their rapid economic development, large size, high population combined with rapid urbanisation, and large industrial sectors. While paying necessary attention to the fact that economic growth is essential for reducing poverty and unemployment, and achieving other developmental goals, both countries have focussed on decoupling energy use from economic growth, which in turn decouples greenhouse gas emissions from economic growth. In their Intended Nationally Determined Contributions submitted under the Paris Agreement, both countries have included strategies to pursue improved energy efficiency across the main sectors of their economies.

The High Impact Opportunities studies that UNEP DTU Partnership has supported in China and India is an effort to engage national stakeholders, research institutions and practitioners in the identification of good practices and the necessary priorities for enhancing energy efficiency in the future.

The Report on Good Practices and Success Stories on Energy Efficiency in India assesses what has been achieved so far in different key sectors. The study documents a variety of approaches that have succeeded across sectors. In a majority of cases, policies and regulations have been used to promote a technology. However, using policies to create a level playing field for different technologies has also been successful. The replication of these successes in India has been very positive so far but can be further scaled up. Moreover, these experiences can be used in other developing countries.

A number of national experts and practitioners have written the 11 success stories -- their names and affiliations are noted in the relevant chapters. I would like to congratulate them on their efforts. I am sure that the book will be of interest to policymakers, practitioners and researchers, and will pave the way for further efficiency gains.

John Christensen
Director
UNEP DTU Partnership

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Amit Garg

Subash Dhar

Bhushan Kankal

Pankaj Mohan

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ABBREVIATIONS

3CSEP	Centre for Climate Change and Sustainable Energy Policy
AC	Air Conditioner
AGDSM	Agriculture Demand Side Management
AMUL	Anand Milk Union Limited
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Limited
APMIP	Andhra Pradesh Micro-irrigation Plan
APSPDCL	Andhra Pradesh Southern Power Distribution Company Limited
BEE	Bureau of Energy Efficiency
BESCOM	Bangalore Electricity Supply Company Limited
BLY	Bachat Lamp Yojana
BPO	Business Process Outsourcing
C2E2	Copenhagen Centre on Energy Efficiency
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CEU	Central European University
CFL	Compact Fluorescent Lamp
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPWD	Central Public Work Department
DC	Designated Consumers
DELP	Domestic Efficient Lighting Programme
DENA	Designated Energy Auditors
DG	Diesel Generator
DISCOM	Electricity Distribution Companies
DMRC	Delhi Metro Rail Corporation
DPR	Detailed Project Reports
DSM	Demand Side Management
DTU	Technical University of Denmark
ECA	Energy Conservation Act
ECBC	Energy Conservation Building Code
EDGE	Excellence in Design for Greater Efficiencies
EEPS	Energy Efficient Pump Sets
EESL	Energy Efficiency Services Limited
EJ	Exa Joule
ELCOMA	Electric Lamp and Component Manufacturers
EPI	Environmental Performance Index
ESCERTS	Energy Saving Certificates
ESCO	Electricity Supply Company
EU	European Union
EV	Electric Vehicles
FDS	Family Drip Systems
GBPN	Global Buildings Performance Network
GDP	Gross Domestic Product
GGRCL	Gujrat Green Revolution Company Limited
GHG	Greenhouse Gas
GNCTD	National Capital Territory of Delhi
GOI	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment
GTKM	Goods Tonne Kilometre
GW	Giga Watt
HC	Hydro Carbon
HESCOM	Hubli Electricity Supply Company
HIO	High Impact Opportunity
HP	Horse Power
HPSV	High Pressure Sodium Vapour
HVAC	Heating, Ventilation and Air Conditioning
IA	Implementing Agencies
ICAR	Indian Council on Agricultural Research
ICL	Incandescent Lamp
ICS	Improved Cook Stove
IDE	International Development Enterprises
IIMA	Indian Institute of Ahmedabad
IMI	International Management Institute
INDC	Intended Nationally Determined Contributions
INR	Indian Rupees
JBIC	Japan Bank of International Cooperation
JICA	Japan International Cooperation Agency
JVVNL	Jaipur Vidyut Vitran Nigam Limited
KCAL	Kilo Calorie
KTOE	Kilo Tonne of Oil Equivalent
KV	Kilo Volt

KWH	Kilo Watt Hour
LED	Light Emitting Diode
LEED	Leadership in Energy and Environment Design
LPG	Liquefied Petroleum Gas
LPS	Large Point Sources
M&V	Monitoring and Verification
MANIT	Maulana Azad National Institute of Technology
MJ	Mega Joule
MNRE	Ministry of New and Renewable Energy
MOP	Ministry of Power
MRT	Metro Rail Transport
MRTS	Mass Rapid Transit Systems
MT	Million Tonne
MT	Metric Tonne
MTOE	Million Tonnes of Oil Equivalent
MW	Mega Watt
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NBCI	National Biomass Cook stoves Initiative
NBFC	Non-Banking Financial Company
NBMMP	National Biogas and Manure Management Programme
NCEF	National Clean Energy Funds
NCPA	National Committee on the use of Plastics in Agriculture
NCPAH	National Committee on Plasticulture Agriculture with the Horticulture
NGO	Non-governmental Organisation
NHB	National Housing Bank
NITI	National Institution for Transforming India
NMEEE	National Mission on Enhanced Energy Efficiency
NMT	Non-motorised Transport
NOX	Oxides of Nitrogen
NPBD	National Project on Biogas Development
NPIC	National Programme on Improved Chulhas
NSGM	National Smart Grid Mission
NSSO	National Sample Survey Organisation
O&M	Operation and Maintenance
PAT	Perform, Achieve and Trade
PKM	Passenger Kilometre
PM	Particulate Matter
POA	Programme of Activities
PPP	Public Private Partnership
PV	Photo Voltaic
PVC	Polyvinyl Chloride
PWC	PricewaterhouseCoopers
REC	Renewable Energy Certificates
RITES	Rail India Technical and Economic Service
S&L	Standards and Labelling
SAFL	Sustainable Agro-commercial Finance Ltd
SDA	State Designated Agencies
SDGY	Saansad Adarsh Gram Yojna
SEFORALL	Sustainable Energy for All
SEC	Specific Energy Consumption
SECI	Solar Energy Corporation of India
SERC	State Electricity Regulatory Commission
SLNP	Street Lighting National Programme
SPC	Special Project on Cook stoves
SPV	Solar Photo Voltaic
SUMUL	Surat Milk Union Limited
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited
TANHODA	Tamil Nadu Horticulture Development Agency
TBU	Technical Backup Unit
TEDA	Tamil Nadu Energy Development Agency
TERI	The Energy Research Institute
TFL	Tubular Fluorescent Light
TJ	Tera Joules
TSSPDCL	Telangana State Southern Power Distribution Company Limited
TV	Television
TWH	Tera Whatt Hour
UCA	Unnat Chulha Abhiyan
UJALA	Unnat Jyoti by Affordable LEDs for All
ULB	Urban Local Bodies
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VGF	Viability Gap Funding
WHRB	Waste Heat Recovery Boilers

EXECUTIVE SUMMARY

The growing per capita income in India is expected to increase the demand for various energy-consuming products and services among Indian households. Enhancing energy efficiency remains one of the cheapest options to "produce" energy in India, as the efficiency of many energy systems has a large scope for improvement, and as this option plays an important part in enhancing India's energy security.

This report is part of the Study on High Impact Opportunities for Energy Efficiency in China and India project that aims to identify high impact opportunities (HIOs) in the two countries for energy efficiency enhancement across sectors until 2030, delineate existing policies and measures that support these HIOs, and highlight success stories from each country. This report focuses on success stories from India and presents a few successfully implemented initiatives (policy/programme) that have the potential to significantly enhance energy efficiency in relevant sub-sectors. The report covers a number of sub-sectors and, in all, 11 success stories have been presented (see Table A). A stakeholder consultative process was adopted for selecting these 11, out of the approximately 70 case studies.

TABLE A: Success stories covered in this report

SUB-SECTOR	SUCCESS STORY
Industrial and agricultural processes	Perform, Achieve and Trade (PAT) Scheme
	Energy Efficiency in agricultural pump sets
Buildings and Appliances	Efficiency Enhancement in the Building Sector
	Programmes for enhancing LED penetration in Domestic & Municipal Sectors
	Standards and Labelling Programme for Electrical Appliances
Distributed Electricity Solutions	Solar Rooftop Systems in Residential and Industrial Sectors in Tamil Nadu, India
Modern Cooking Appliances and Fuels	Improved Cooking Stove (ICS) using Biomass fuel
	Village-level Biogas Plant and Gobar Bank in Gujarat
Transportation	Technology Shifting from 2-stroke to 4-stroke engines in two-wheelers in India
	Improving Public Transport: A Case Study of Delhi Metro
Cross cutting	Coal Cess in India

Each success story is explained in terms of a short introduction, followed by why the policy was initiated, what was done, effects of the policy, challenges experienced in implementing the policy and its replicability.

The success stories highlight that there are varied approaches to achieving the improvements in energy efficiency. In some of the success stories, the government identified a priority technology, ensured that technology was made available to end users at subsidised costs, and supported it through capacity building and training on the technology use. This approach has given good results for LED lighting, Solar Rooftop Systems, Biogas Plants, agricultural pump sets and cook stoves. In the case of PAT schemes, a market-based approach has been used to incentivise more efficient technologies within the identified industries, and it has yielded positive results. The technology choice in this case was left to the companies within the industries. In the case of the buildings and appliances sector, the overarching focus is on standards/codes and labelling, respectively, to provide information about the technology.

Some success stories have already been replicated in India -- e.g. the PAT scheme is going into its second phase, more appliances are being added to the standards and labelling programme, more cities are being added to the metro programme, etc. Replication in other countries, however, would need an understanding of their enabling frameworks before deciding on a course of action.

INTRODUCTION

Amit Garg
Subash Dhar
Jyoti Painuly
Bhushan Kankal
Pankaj Mohan

BACKGROUND

The Copenhagen Centre on Energy Efficiency (C2E2) is a part of the UNEP DTU Partnership, and collaboration established between the Denmark Government, the UN Environment and the Technical University of Denmark (DTU). The C2E2 serves as the Energy Efficiency Hub of the Sustainable Energy for All (SEforALL) initiative.

The Sustainable Energy for All (SEforALL) initiative is a multi-stakeholder partnership between governments, the private sector, and civil society. The SEforALL initiative was launched by the United Nations Secretary General in 2011 to achieve three interrelated goals by 2030:

1. Ensure universal access to modern energy services;
2. Double the share of renewable energy in the global energy mix;
3. Double the global rate of improvement in energy efficiency.

In order to facilitate the realisation of the SEforALL goal on energy efficiency, C2E2 provides capacity building, analytical, and knowledge support to countries in their actions on energy efficiency improvement.

This report is a part of the project "A Study on High Impact Opportunities for Energy Efficiency Improvement in China and India", which was initiated to identify high impact opportunities (HIOs) for energy efficiency enhancement across sectors, and facilitate measures, including policies, to achieve the objectives. This study is part of the C2E2 to build capacity and provide a platform for analytical work, and is being implemented with the help of the Indian Institute of Ahmedabad (IIMA) and Energy Efficiency Services Limited (EESL), New Delhi, in partnership with International Management Institute (IMI) Kolkata and Maulana Azad National Institute of Technology (MANIT) Bhopal. Delineating existing policies and measures that support these HIOs, and highlighting success stories in each country are also a part of the overall study. The study requires appropriate modelling of the energy systems at a reasonably detailed level, scanning the policy landscape, and interacting with business and practitioners to ascertain what has and has not worked in the case of high impact opportunities in the recent past. This report, titled *"A report on Good Practice and Success Stories"*, is an outcome of this exercise.

China and India are important players in the global energy arena and are among key countries in any global energy scenario. They are, therefore, of great significance to the realisation of the SEforALL energy efficiency objectives. The existing international studies on the future energy pathways of these two countries are often from the perspective of climate change mitigation and so far, the focus has been on their contribution to greenhouse gas emissions reductions with the aim of achieving the target of keeping global warming below 2 ◦C above pre-industrial levels. In these studies, energy efficiency is one of multiple options for GHG emission reduction, and is therefore not given sufficient attention in modelling and policy assessment. Moreover, in the modelling for climate change mitigation, the timeframes are usually until 2050 or 2100, which are much longer than the SEforALL target period of until 2030.

China's economic growth of the past few decades has been driven by export, investment and domestic consumption. With the increases in per capita income and growing urbanisation, the role of domestic consumption has been increasing, and is expected to become the most important driving force for economic growth in the coming decades. China is, therefore, gradually transforming from the world's manufacturing hub to a large market for consumer goods. This transformation means a growing final demand for housing, lighting, heating, transport, appliances, etc. The rising household demand for products and services poses challenges for climate change, high peak demand for electricity, energy security, traffic congestion in cities, and air pollution.

India's economic growth has been slower than China's, but it has accelerated recently and growth expectations for the coming decades are higher. India, however, has seen a relatively slow urbanisation. About two thirds of the population still live in rural areas and UN population projections show that even in 2050 the urbanisation levels will be close to 50% the current levels in China. However, per capita incomes are expected to grow both in rural and urban areas in India, resulting in increased demand for energy-consuming products and services in the coming decades. Despite a relatively slower urbanisation, Indian cities are struggling to cope with growing pollution and traffic congestion.

Enhancing energy efficiency remains one of the cheapest options to "produce" energy in India, as the efficiency of many energy systems has a large scope for improvement and it is an important option to enhance energy security for the country. Indian energy needs are large and increasing. India's imports are rising significantly since energy production has not been able to keep pace with the demand. India imports 83% of its crude oil, 29% of coal and 68% of natural gas. The high dependence on imports puts considerable pressure on its foreign exchange reserves, despite low energy prices in the recent past offering a respite. With significant reserves, coal is the mainstay of Indian energy system, and this has consequences for local pollution as well as GHG emissions. India has taken various measures over the years, and is doing so currently, to enhance energy efficiency across many sectors. This report examines some of the successes achieved in this area.

SELECTION OF GOOD PRACTICES AND SUCCESS STORIES

In this study, success stories are taken as implemented initiatives (policy and/or market mechanisms) that have the potential to significantly enhance energy efficiency in a specific sector / sub sector /application. In terms of sectoral coverage, the stories range from households to buildings, transport, industry and electricity supply. In the case of households, though, both total energy demand and potential for energy efficiency improvement are high, making it challenging to address since the demand is fragmented over a large number of smaller energy users. Energy efficiency of the building and transport sectors, to a large extent, is influenced by the design and quality of the buildings and the infrastructure, respectively. Once in place, it is expensive and difficult to improve the energy efficiency in these sectors due to a 'lock-in' effect. Therefore, these sectors require appropriate policies and measures in the early stages to curtail long-term energy demand.

The success stories are noted in sub-sectors or sectoral action areas identified by SEforALL[1] (Table 1). The sub-sectors have also been used for the identification of future High Impact Opportunities.

1 *Sustainable Energy for All: A Global Action Agenda, April 2012 http://www.un.org/wcm/webdav/site/sustainableenergyforall/shared/Documents/SEFA-Action%20Agenda-Final.pdf, Downloaded on March 31, 2015.*

TABLE 1: Sub-sectors and High Impact Opportunities

SUB-SECTOR (OR SECTORAL ACTION AREA)	HIGH IMPACT OPPORTUNITIES
Modern Cooking Appliances and Fuels	• Building sustainable local value chains for clean and efficient cooking solutions; • Building market demand by raising awareness of their health, economic, environmental, and gender benefits; • Investing in the infrastructure and local distribution supply chains required for cleaner fuels (e.g. ethanol and LPG); • Developing tiered standards for efficiency, emissions and safety; designing cooking appliances, etc.
Buildings and Appliances	• Public / residential / commercial buildings, cool roofs, building integrated solar PV, and small-scale renewables such as rooftop solar and solar hot water; • Sectoral efficiency labels and performance standards; • Well enforced building codes; • Demand-side management programmes and advanced technologies to enable energy-saving behaviour and shift demand over time; • Advanced lighting, space cooling and heating, refrigerators, etc.
Transportation	• Efficiency programmes for internal combustion engines and vehicle design; • Alternative fuel vehicles, including flex-fuel, hybrid, and electric vehicles (EVs); • Fuel efficiency and fuel quality standards; • Overall transportation demand reduction; • Eco-driving programmes; • Expanded and more efficient public transport; • Electrification of rail systems; • Freight mode shifting (e.g. from trucks to trains), etc.
Distributed Electricity Solutions	• Clean energy mini/micro-grid solutions for rural and targeted industrial applications, using both renewables and conventional sources; • Locally appropriate regulatory frameworks to incentivise and support commercially viable investments in decentralised electricity solutions, etc.
Grid infrastructure and supply efficiency	• Strengthening transmission and distribution networks to reduce losses and improve reliability; • Regional interconnections to improve performance; • Improving the efficiency of existing conventional energy generation and interaction between fossil and non-fossil fuels; • Smart grid technology solutions and grid-scale storage, etc.
Industrial and agricultural processes	• Eliminating gas flaring and developing local gas markets; • Variable-speed motors; • Energy management practices and systems (e.g. in cement and steel industries); • Cogeneration systems (combined heat and power); • Energy efficient irrigation pumps; • Energy-smart agriculture, etc.

A general criterion for selecting success stories requires analysing the technological, economic, social, and policy implications of an initiative. The technological implications of the intervention include reduction in energy consumption (which, in the case of electricity, may lead to reduction in peak energy and avoided capacity addition), ease of implementation, maturity of the technology and low probability of obsolescence in the near future, and increase in current and expected future penetration levels. The economic implications include low energy costs, energy cost savings and relatively easy financing. In the case of electricity, it includes reduction in consumption, reduction in normal and/or peak requirement which in turn may lead to capital savings due to avoided capacity addition. The social implications include generation of local employment, acceptability of the technology as represented by rising penetration levels, and benefits from reduced pollution. In the case of policy interventions, a success story can be an enabling policy that becomes an HIO and has low replication challenges.

Around 70 case studies were discussed in the Indian context across all sub-sectors. Their detailed assessment across the four dimensions - technological, economic, social, and policy implications is available as supplementary information for interested users.

The following eleven success stories (Table 2) were selected out of the 70 case studies, representing the recent thrust in Indian energy efficiency initiatives. A stakeholder consultative process was adopted to select the success stories.

TABLE 2: Selected success stories included in the book

SUB-SECTOR	SUCCESS STORY
Industrial and agricultural processes	• Perform, Achieve and Trade (PAT) Scheme • Energy Efficiency in agriculture pump sets
Building and Appliances	• Efficiency Enhancement in the Building Sector • Programs for enhancing LED penetration in Domestic & Municipal Sectors • Standards and Labelling Programme for Electrical Appliances
Distributed Electricity Solutions	• Solar Rooftop Systems in Residential and Industrial Sectors in Tamil Nadu, India
Modern Cooking Appliance and Fuels	• Improved Cooking Stove (ICS) using Biomass fuel • Village level Biogas Plant and Gobar Bank in Gujarat
Transportation	• Technology Shifting from 2-stroke to 4-stroke engines in two wheelers in India • Improving Public Transport: A Case Study of Delhi Metro
Cross cutting	• Coal Cess in India

SEforALL has identified a unique approach to unlocking the high impact energy efficiency opportunities through the "energy efficiency accelerators". Accelerators are public-private partnerships around specific opportunities to support energy efficiency actions in countries and cities. Currently, accelerator exists for lighting, appliances, buildings, district energy, and vehicle fuel economy. The accelerators are collectively referred to as Global Energy Efficiency Accelerator Platform, which is one of the flagship programmes of the SEforALL on energy efficiency.

STRUCTURE OF THE STORIES

Each success story is explained in terms of a short Introduction, followed by why the policy was initiated, what was done, effects of the policy, challenges experienced in implementing the policy and its replicability. Each story is presented as a separate chapter. The case studies reflect a mix of opportunities; some case studies required development of an enabling policy framework, some were driven by low cost considerations, while in some cases, technologies had arrived. National circumstances played an important role in each story, which also highlights the challenges and barriers for replicability in other geographical regions.

1

PERFORM, ACHIEVE AND TRADE (PAT) SCHEME

Saurabh Kumar
Pankaj Mohan
Saket Shukla
Bhushan Kankal

1.1 INTRODUCTION

Perform, Achieve & Trade (PAT) is an instrument to reduce specific energy consumption in energy intensive industries, with a market-based regulatory mechanism. The Perform Achieve Trade (PAT) is an innovative market-based trading scheme announced by the Government of India in 2008, under its National Mission on Enhanced Energy Efficiency (NMEEE) in National Action Plan on Climate Change (NAPCC). It aims to improve energy efficiency in industries by trading in energy efficiency certificates in energy-intensive sectors.

1.2 WHY THE POLICY WAS INITIATED

Electricity generation and industry account for 50% of total energy consumption in India (Table 3). Some of these industries use state of the art technologies and performance management, while some plants are close to being obsolete. Thus, there is a wide range of energy efficiency performance at the plant level. The PAT scheme was initiated with the purpose of bringing the energy efficiency of energy intensive industrial sectors in India to a higher level of performance as measured through their specific energy consumption (SEC). SEC is energy consumed to produce one unit of output by a plant. It was envisaged that a total saving of 4.05%[1] in total energy consumption would happen across the eight sectors --Thermal Electricity Generation, Iron and Steel, Cement, Aluminium, Fertiliser, Paper and Pulp, Textile and Chlor-Alkali from 01 April 2012 to 31 March 2015.

TABLE 3: Energy consumption in various sectors in India

SECTORS	MILLION TONNES OF OIL EQUIVALENT (MTOE)	PERCENTAGE OF TOTAL NATIONAL CONSUMPTION
Electricity Generation	179.29	25.3%
Industry	179.09	25.3%
Transport	74.79	10.6%
Residential	182.88	25.8%
Commercial & Public Service	20.55	2.9%
Agriculture	23.75	3.4%
Non Energy Use	47.26	6.7%
Total	**707.61**	

1 *ESCerts Trading under PAT Scheme, Downloaded https://beenet.gov.in/(S(yhl43obb1iky1halghmhnegl))/GuideLine/Introduction%20to%20ESCerts%20Trading%20under%20PAT%20Scheme.pdf*

1.3 WHAT WAS DONE

The PAT Scheme is being implemented in three phases -- the first phase (PAT cycle I) ran from 2012-2015, covering 478 facilities from eight energy-intensive sectors. These eight sectors account for roughly 38% of India's total primary energy consumption. It targeted energy consumption reductions of 6.686 million tonnes of oil equivalent (mtoe) but have achieved reduction of 8.86 mtoe in 427 of the 478 covered facilities.

The targets were set by carrying out the baseline audits in the PAT cycle I. The baseline audits were carried out by BEE empanelled agencies having certified energy auditors and energy managers. The audits were carried out to assess the potential of energy efficiency and what the consumption was at the time. This audit was termed as baseline audit, and based on them the targets were set for the Designated Consumers (DCs) in PAT cycle I.

Participation in the scheme is mandatory for DCs under the ECA. It is being administered by the BEE, which sets targets for specific energy consumption within larger, energy-intensive facilities. Main elements of the PAT scheme are presented in Box 1.

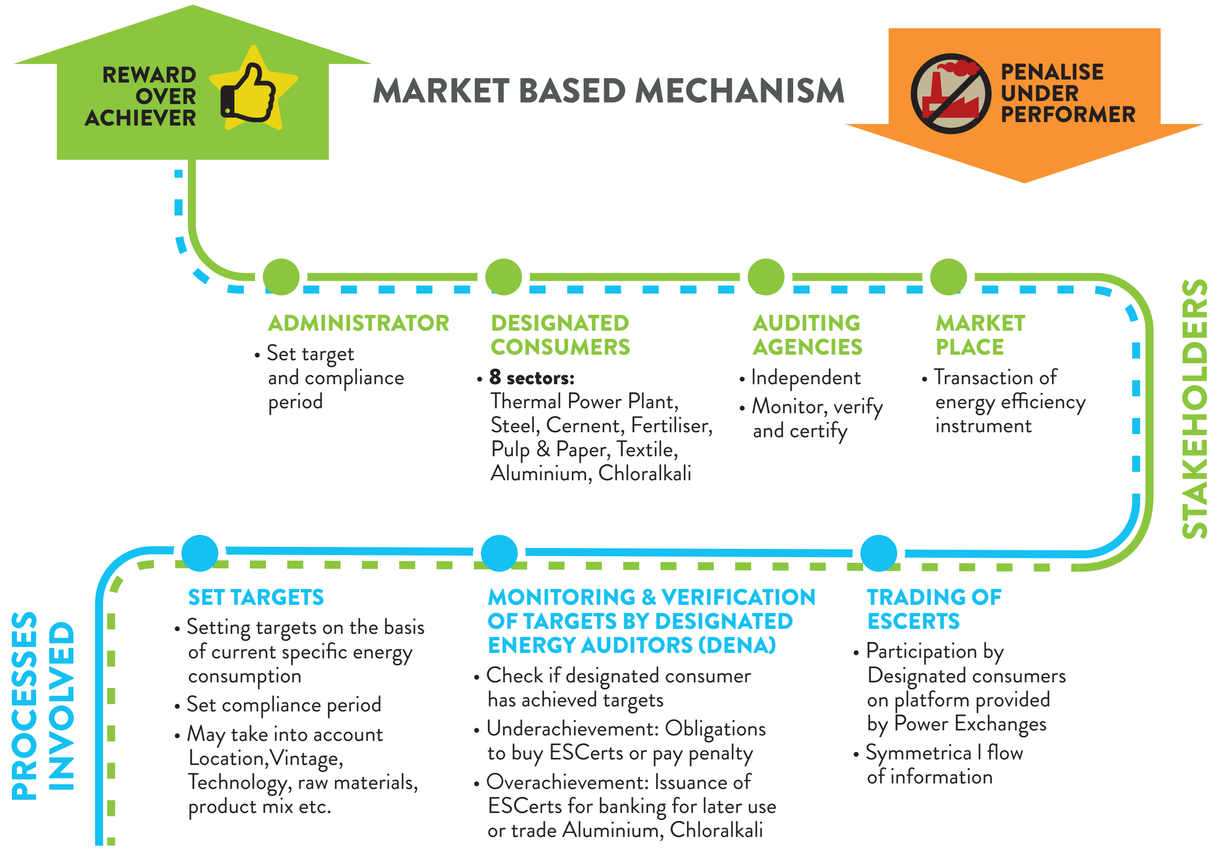
BOX 1.
MAIN ELEMENTS OF THE PAT FRAMEWORK

1. Methodology for setting specific energy consumption for each DC in the baseline year.
2. Methodology for setting the target to reduce the SEC by the target year from the baseline year.
3. The process to verify the SEC of each DC in the baseline year and in the target year by an accredited verification agency.
4. The process to issue energy savings certificates (ESCerts) to those DCs who achieve SEC lower than the specified value.
5. Trading of ESCerts.
6. Compliance and reconciliation of ESCerts
7. Cross-sectoral use of ESCerts and their possible synergy with renewable energy certificates.

Source: 12th Five-year Plan

The 2010 amendment to the Energy Conservation Act (ECA) was carried out to provide a legal mandate to the PAT mechanism. The PAT framework and institutional arrangement is based on providing incentives for over achievers and penalising the under achievers (see Figure 1), and consists of three processes: i) Setting Targets, ii) Monitoring & Verification of Targets, and iii) Trading of ESCerts.

FIGURE 1: PAT Framework



SET TARGETS

The Bureau of Energy Efficiency (BEE) has prepared Sector Specific Form-1 (annual energy return form) along with sector specific normalisation factors to streamline the monitoring and verification (M&V) process. The sector/sub-sector specific normalisation factors were developed to neutralise the effects on specific energy consumption (SEC) in the assessment year and the baseline year so that undue advantages or disadvantages could not be imposed on any DCs while assessing the targets. For the development of such factors, committees/sub-committees were formed for each sector/sub-sector, with representation from DCs as well. Several rounds of meetings were held to identify and develop normalisation factors.

MONITORING & VERIFICATION OF TARGETS

The BEE has put in place a process of accreditation of Energy Auditors who were engaged to execute the M&V process of DCs to assess their performances. The BEE has successfully conducted 15 National Certification examinations for Energy Managers and Energy Auditors. India now has 12,228 Certified Energy Managers, out of which 8,536 are additionally qualified as Certified Energy Auditors to date. This is further supplemented by the accreditation of energy auditors through recommendations of the “Accreditation Advisory Committee”. Accredited energy auditors would undertake mandatory energy audits in energy intensive industry as mandated in EC Act. To date, there are 150 accredited energy auditors.

TRADING OF ESCERTS

Development of ESCerts trading infrastructure is in progress, in collaboration with the Central Electricity Regulatory Commission (CERC).

PAT CYCLE II

The second phase of the PAT Scheme (PAT cycle II) runs from 2016-2019, covering 707 units from the 11 energy intensive sectors (Table 4). PAT cycle II focuses on deepening and widening PAT cycle I - i.e. the inclusion of 61 new DCs from the existing 8 sectors, and the addition of 170 DCs from 3 new sectors, namely: Railways, Refineries, and Electricity distribution companies (DISCOM). This would expand the coverage from 38% to 70% of total primary energy consumption. There are around 188 units from four sectors (Cement, Pulp & Paper, Iron & Steel, and Textiles), and around 130 units from the remaining four sectors - Aluminium, Fertilisers, Chlor-alkali and Thermal Power Plants. The new sectors - Railway, Refineries and DISCOM - include around 170 units to date. More DCs are under identification, which would bring the total to approximately 707.

TABLE 4: **The targeted savings for PAT Cycle I and PAT Cycle II**

S. NO	SECTORS	UNIT OF SEC	PAT CYCLE I		PAT CYCLE II	
			Number of DCs	Targeted Savings (mtoe)	Number of DCs	Targeted Savings (mtoe)
1.	Power (Thermal)	Kcal/kWh	144	3.21	154	3.13
2.	Iron and Steel	toe/tonne of product	67	1.47	71	2.28
3.	Cement	toe/tonne of product	85	0.82	111	1.12
4.	Aluminium	toe/tonne of product	10	0.46	12	0.47
5.	Fertiliser	toe/tonne of product	29	0.48	37	0.45
6.	Paper & Pulp	toe/tonne of product	31	0.12	29	0.15
7.	Textile	toe/tonne of product	90	0.07	99	0.09
8.	Chlor-Alkali	toe/tonne of product	22	0.05	24	0.10
9.	Petroleum Refinery	Million British Thermal Unit per Thousand Barrel per Energy Factor	-	-	20	1.11
10.	Railways	Litres/1000 GTKm	-	-	100	na
11.	DISCOMs	% of Transmission and Distribution losses	-	-	50	0.94
	Total		**478**	**6.686**	**707**	**18.00**

For the majority of the sectors (for the new DCs), the last financial year of the three-year reported data would be considered the baseline year in PAT Cycle II. For the new sectors, proper workshops will be first given to the empanelled agencies for filling up Data in the Pro-forma and Target Fixation methodology. This will be carried out by BEE for the three new sectors included in PAT cycle II -- i.e. Railway, Refineries and DISCOMs.

The PAT cycle II targets for individual DCs have been notified by the Ministry of Power on 31 March 2016 (BEE, 2016a). The notification clearly mentions that any entity that has consumed 30 ktoe in a year would be a Designated Consumer. Detailed methodologies for measurement and verifications are also provided through a Performance Assessment Document (*BEE, 2016b*). The gazette of PAT cycle II mentions that the Designated Consumers shall comply with the energy consumption norms and standards specified against their names by the target year 2018-2019, a period of three years from 1 April 2016 until 31 March 2019.

1.4 EFFECTS OF THE POLICY /PROGRAMME

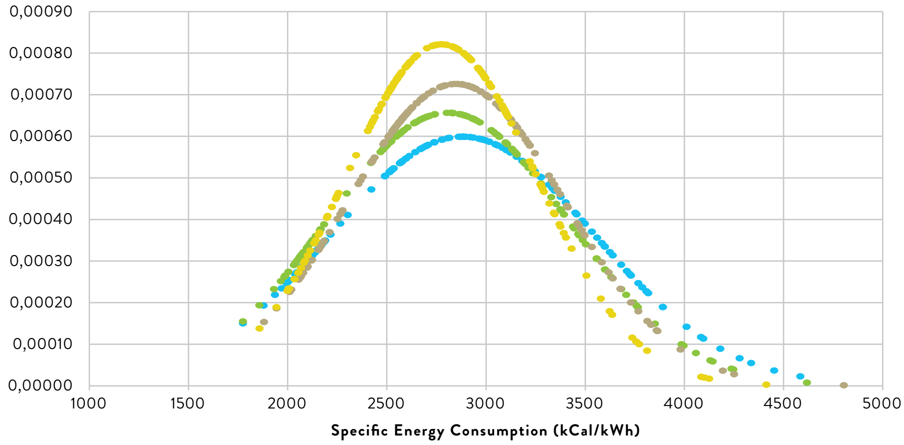
PAT II targets energy savings of approximately 18.0 mtoe in the 707 covered facilities under 11 sectors. Figure 2 (a-d) provides a comparative assessment of PAT cycle I and PAT cycle II on specific energy consumption (SEC) for power, iron and steel, cement and textile sectors using a normal distribution. The specific energy consumptions are plotted on the x-axis, and the probability distribution function values are plotted on the y-axis. It is to be noted here that SECs are specific to an industry and do not have a common unit. The figures indicate a gradual shift towards the left - i.e. a reduction in specific energy consumption in each industry from PAT cycle I to PAT cycle II. It is also observed that plants with extremely high SECs are targeted to reduce much faster than plants that have low SECs.

The savings in energy have reduced the carbon footprint of the output and also provided cost reductions. For example, energy savings under the PAT scheme in cement manufacturing have resulted in a reduction in CO_2 emissions by 25 kg CO_2/tonne of cement, and a 15% reduction in power cost.

FIGURE 2: **A comparative assessment of PAT cycle I and PAT cycle II on SEC for power, iron and steel, cement and textile sector**

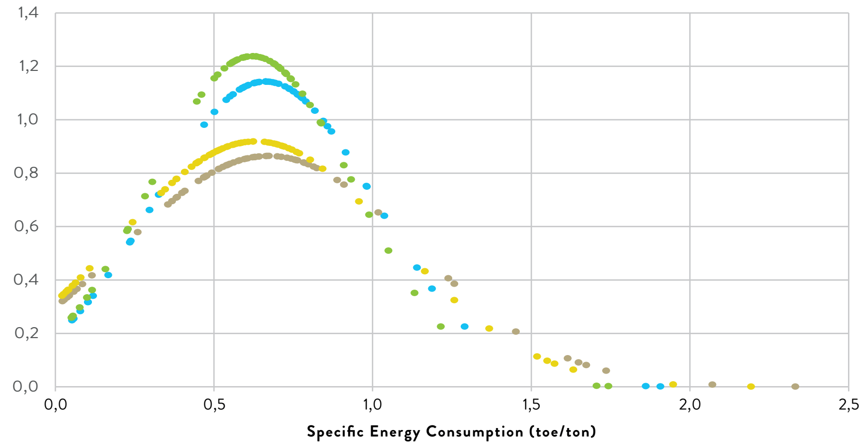
Power

	n	μ	σ
PAT Cycle I - Baseline	144	2881	666
PAT Cycle I - Target		2807	608
PAT Cycle II - Baseline	125	2849	550
PAT Cycle II - Target		2776	486



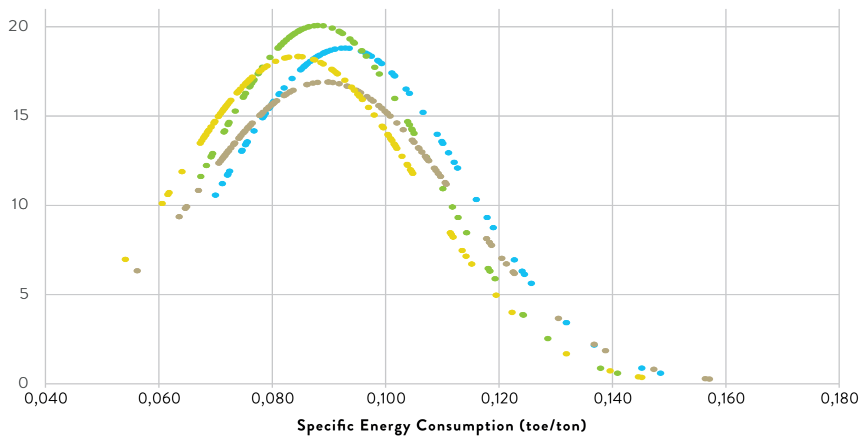
Iron and Steel

	n	μ	σ
PAT Cycle I - Baseline	66	0,66	0,35
PAT Cycle I - Target		0,62	0,32
PAT Cycle II - Baseline	71	0,67	0,46
PAT Cycle II - Target		0,63	0,43



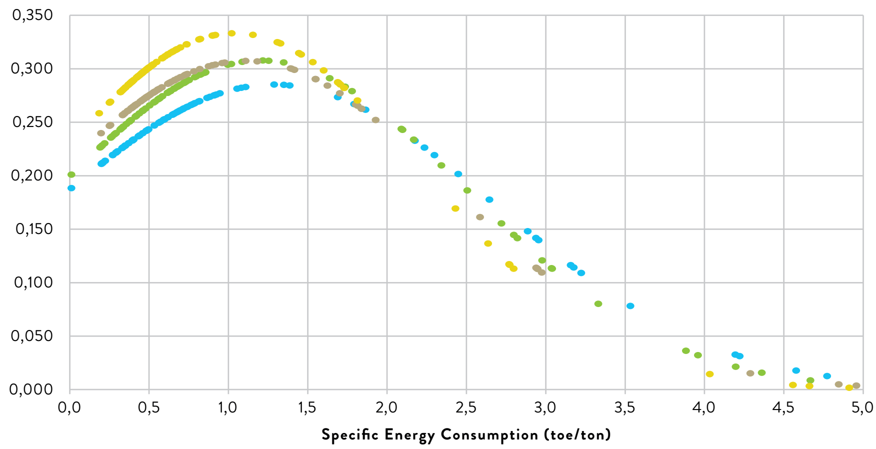
Cement

	n	μ	σ
PAT Cycle I - Baseline	85	0,093	0,021
PAT Cycle I - Target		0,088	0,020
PAT Cycle II - Baseline	111	0,089	0,024
PAT Cycle II - Target		0,084	0,022



Textile

	n	μ	σ
PAT Cycle I - Baseline	90	1,284	1,398
PAT Cycle I - Target		1,206	1,296
PAT Cycle II - Baseline	99	1,111	1,298
PAT Cycle II - Target			1,197



1.5 CHALLENGES EXPERIENCED

The following challenges were experienced in the implementation of waste heat recovery systems in two industries - i.e. Iron & Steel and Cement industries.

High initial capital cost: The capital cost to implement a waste heat recovery system may outweigh the benefits gained in heat recovered. It is necessary to put a cost to the heat being offset. The cost implications for only installing waste heat recovery boilers (WHRB) and other accessories is around USD 0.75 million. The cost of installing whole units along with waste heat recovery in large plants is USD 22.23 million – as in an Iron & Steel plant. The cost implication in the Cement industry is approximately USD 11.25 million.

Quality of heat: Often, waste heat is of low quality (temperature). It can be difficult to efficiently utilise the quantity of low quality heat contained in a waste heat medium. Heat exchangers tend to be larger to recover significant quantities, which increases the capital cost.

Maintenance of equipment: Additional equipment requires additional maintenance cost.

1.6 REPLICABILITY

The PAT scheme has been successful in India, and PAT cycle I has already been extended to more industries under PAT cycle II. The PAT scheme is replicable in any country or province, although due diligence is required by the host government to audit historical SEC of targeted designated consumers in that country, and set up appropriate legal framework to implement PAT. Sectoral targets in the PAT scheme require specific interventions, such as raw material management, process improvement, installation of new systems such as waste heat recovery, reducing output wastages through better quality control, etc. These vary for industry and at the plant level. For instance, around 40 to 50% of units in the Iron & Steel and Cement sectors across India have gone for waste heat recovery projects. The process, notifications and expertise gained by BEE and empanelled accredited energy auditing firms could, thus, be utilised for the benefit of other countries desirous to replicate the Indian PAT scheme in their own countries. The existing scheme could also be expanded to include GHG emission reductions and carbon and environmental trading markets.

2 PROGRAMMES FOR ENHANCING LED PENETRATION IN DOMESTIC & MUNICIPAL SECTORS

Saurabh Kumar
Pankaj Mohan
Saket Shukla

2.1 INTRODUCTION

LEDs have emerged globally as a more efficient source of lighting. EESL has reviewed that a 60W incandescent lamp (ICL) can be replaced by a 9W LED; a 40W ICL can be replaced by a 5W LED, and so on. On 5 January 2015, Hon'ble Prime Minister launched 100 cities National Programmes on: (i) Domestic Efficient Lighting Programme (DELP) [now renamed UJALA (Unnat Jyoti by Affordable LEDs for All)] to provide LED bulbs to domestic consumers, with a target to replace 770 million incandescent bulbs with LED bulbs, and (ii) Street Lighting National Programme (SLNP) to replace 35 million conventional street lights with smart and energy efficient LED street lights by March 2019. Electricity distribution companies and municipalities are important stakeholders for these energy efficiency programmes that the Ministry of Power and BEE have been promoting.

2.2 WHY THE POLICY WAS INITIATED

Energy efficiency assumes national significance in the current environment of shortages and climate change concerns. Lighting, itself, accounts for approximately 20% of total electricity consumption in India. A significant proportion of lighting needs are met by the use of incandescent bulbs, which are extremely energy inefficient as over 90% of electricity is wasted as heat. Promoting efficient lighting in the household sector alone can reduce electricity consumption by as much as 50 billion kWh every year, at the national level. Additional savings can come from commercial, industrial and street lighting. This will also benefit consumers by way of reduced electricity expenditure.

There is a significant untapped potential of energy efficiency in the country. The government enacted the Energy Conservation Act 2001 to provide a regulatory and policy framework to catalyse market-based energy efficiency implementation. The Act has empowered the government to unveil a combination of regulatory and policy measures to help unlock the potential for energy efficiency in the country. BEE has taken several initiatives in this regard in the 11th (2007-2012) & 12th (2012-2017) Plans to stimulate implementation of energy efficiency in these sectors i.e. Domestic and Municipal.

2.3 WHAT WAS DONE

During the 11th Five Year National Plan of India (2007-2012), BEE developed an innovative scheme to promote energy efficient lighting in the household sector, called Bachat Lamp Yojana (BLY). The scheme helped to overcome the upfront high cost barrier by providing compact fluorescent lamps (CFL) at the rate of incandescent lamps (ICL). The difference in cost was recovered through Carbon Finance. To get the carbon finance, BEE developed a Programme of Activities (POA) and registered it with UNFCCC.

Now EESL is following the BYL scheme model under the Domestic Efficient Lighting Programme (DELP) to increase the sale of domestic LEDs by providing LED bulbs at the cost of ICLs. The cost difference between ICLs and LEDs is recovered through equal monthly instalments included in the electricity bill of the consumer. The cost difference may also go through the carbon finance route, and is still under consideration. EESL distributed more than 103 million of domestic LED bulbs until 09 May 2016.

BEE has also funded the preparation of detailed project reports (DPRs) of more than 130 municipalities/urban local bodies (ULBs) in India for the replacement of street lights with LEDs under the street lighting national programme (SLNP). The prepared DPRs have highlighted the fact that energy cost accounts for a significant portion of the total expenditure, and identified many interventions for the savings. The current lighting fixtures that are commonly installed on street light posts range from ordinary fluorescent lamps of 40W with electromechanical choke to High Pressure Sodium Vapour (HPSV) lamps having a rated capacity from 70W to 400W. Up to 50% energy savings can be achieved if these fixtures are replaced with LEDs that provide the same level of light output. The resultant energy savings and the associated monetary savings provide a business model. The lower running cost is a significant benefit for the State Governments, Discoms and ULBs, particularly for ULBs that are supported by State Government budgets. EESL has, till 13 Dec 2016, installed 1,448,166 street lights .

Initially, 100 cities have been taken up for coverage under the street lighting national programme (SLNP) and Domestic Efficient Lighting Programme (DELP). For DELP, as per the statistics of the Electric Lamp and Component Manufacturers (ELCOMA), about 770 million incandescent bulbs were sold in 2013-14. If all these are replaced by LEDs, the total reduction in connected load in the country is estimated to be 20,000 MW and energy savings of 100 billion KWh every year. The total saving in electricity bills of consumers will be about USD 6 billion every year, considering average tariff of 0.06 USD per kWh. The total cost charged to consumers by EESL is about 1.5 USD (based of applicable VAT/Octroi in a state) and the payback is less than one year. The LED bulb will function for more than 25,000 hours and the savings achieved after one year is of the consumer only. For the street light programme, the expected reduction in installed street light load by replacing conventional lights with LED based street lights will be about 1500 MW. These replacements can lead to savings of approximately 9 billion KWh of energy and cost saving of USD 800 million to municipalities annually, considering an average tariff of 0.089 USD per KWh.

2.4 EFFECTS OF THE POLICY/PROGRAMME

As of 13 December 2016, 183 million LED bulbs were sold under UJALA, which has had a major impact on energy use and CO_2 emissions. The energy saving from these LED bulbs is around 19,273,422 kWh per day, and avoided peak demand is approximately 4,764 MW, assuming they replace incandescent bulbs over which LEDs are 85% more efficient The cost saving would be around INR 95 billion (USD 1.45 billion) per day, considering a unit price of INR 4 per kWh (USD 0.059[1] per kWh) and GHG emission reductions of 29,712 tCO_2 per day. The impacts of the LEDs through DELP was checked in five cities by a third party. Table 5 shows the findings of the survey, and a variation in impacts is observed; nevertheless, the impacts are real.

1 *Exchange rate: 1 USD = 67 INR*

TABLE 5: Energy savings and CO2 reduction in different regions

SR. NO.	REGION	NO. OF BULBS DISTRIBUTED	UNITS SAVED FOR THE OVERALL PROJECT (MILLION KWH)	PEAK LOAD REDUCTION (MW)	EMISSION REDUCTION (THOUSAND TCO2)
1	Puducherry	338	80.95	15.81	65.57
2	Anantapur	240	150.06	29.36	121.55
3	Guntur	240	249.33	48.70	201.96
4	Srikakulam	240	142.04	27.87	115.05
5	W. Godavari	240	214.1	41.82	173.42

The above impacts can be undermined if the LEDs are not operational; therefore, in these five cities, the failure rate was also checked by a third party. A total of 1,298 bulbs were distributed during the survey, out of which 1,280 i.e. 98.61% of bulbs were found to be operational. This shows that the estimations of impacts from the LED programme are correct.

The implications of the Street Light National Programme (SLNP) on energy use and GHG emission reduction, to date, are mentioned in Table 6. The energy savings is 0.363 kWh per light per day, which resulted in a total saving of 525,684 kWh per day for 1,448,166 street lights, installed as of 13 December 2016. The GHG emission reduction per day is 436.36 tCO_2, and avoided capacity generation is 47.79 MW.

TABLE 6: Installation of LED street light by EESL in 5 cities and third party checks carried out by PricewaterhouseCoopers (PWC) Private Limited

NAME OF CITY	NUMBER OF LED INSTALLED	NO. OF DEFECTIVE LED STREET LIGHTS	ANNUAL ENERGY SAVINGS (MILLION KWH)	AVOIDED GHG EMISSION (THOUSAND TCO2)	PEAK LOAD REDUCTION (MW)	% OF DEFECTIVE LED STREET LIGHTS
Varanasi	947	21	1.56	1.278	0.39	2.22%
Jhalawar	2449	21	0.37	0.303	0.09	0.86%
Mount Abu	1807	38	0.65	0.53	0.16	2.10%
Vizag	91775	884	23.54	19.302	5.05	0.96%
Agartala	34200	425	3.9	3.2	0.97	1.24%
Total (For 5 Cities)	**131178**	**1389**	**30.02**	**24.613**	**6.66**	**1.06%**

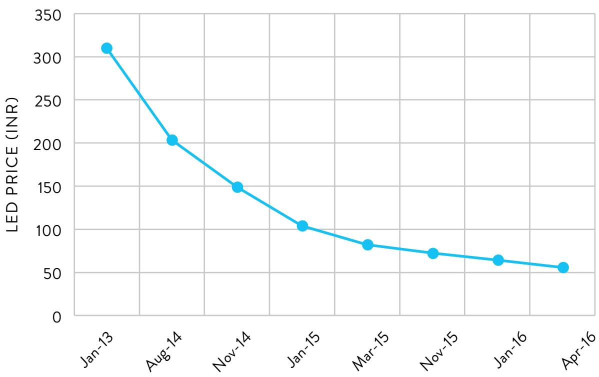
Percentage failure rate as per findings: It was found through a third party that most of the street lights installed were in working condition, and only 1.06% (Table 6) of the installed street lights were observed to be non-working. Based on discussions with the officials of the municipal corporation and local suppliers in these cities, it was found that line faults were the major reason for the non-working LEDs.

FIGURE 3: LED street light installation in Varanasi

2.5 CHALLENGES EXPERIENCED

The challenge in the domestic sector was that of awareness and the changing mind-set of the people towards energy efficiency. What is the impact of the energy efficient appliances on their daily budgets and life? Energy Efficiency Services Limited (EESL) took this challenge and started the national programme Domestic Efficient Lighting Program (DELP). The second challenge was the initial high cost of the LED bulbs as perceived by domestic consumers. As already mentioned, the LED lamps were provided at well below the prevailing market prices due to huge economies of scale in the programme by EESL. This also brought down the market price of LEDs, eventually in close range with those offered by EESL -- from INR 310 (USD 5.22) to INR 55 (USD 0.82), in one and a half years (Figure 4), which is shown in the graph below. The consumers were also attracted to the scheme since they could pay for LED lamps in easy monthly instalments. The energy saved per month through LED use almost offset these instalments.

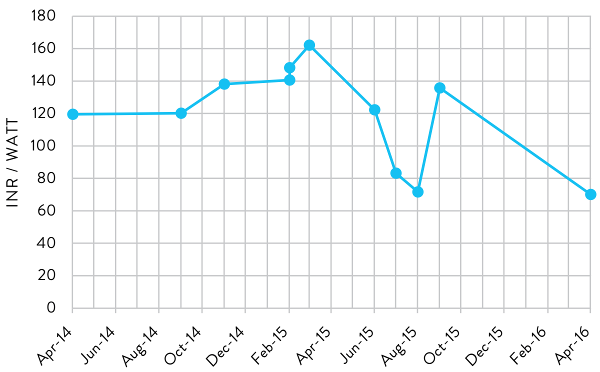
FIGURE 4: Trend in LED bulb prices



The major challenge experienced by the municipalities and urban local bodies (ULBs) was the selection of ESCOs to implement the energy efficient street lighting. Municipalities/ULBs issued the tenders for selecting the ESCOs for implementing the projects, but they did not materialise due to a variety of reasons like problems in setting the baseline, conditions of the contracts, availability of funds, data inadequacy and challenges associated with monitoring and verification of the data. Energy Efficiency Services Limited (EESL) made the same observation and evolved an annuity-based model that ensures the best available technology leading to overall cost saving to the municipalities/ULBs. In the street light case, as well, the cost of LED street lights was reduced from INR 162 (USD 2.4) per watt to INR 68 (USD 0.99) per watt (Figure 5).

To date, EESL has invested USD 1.2 billion in energy saving investment in the street lighting and domestic lighting sectors, and through these investments they are present in 151 cities with their street lighting investments and 240 cities with their domestic lighting investments. The funds are being arranged through a combination of equity from promoter companies, and loans from bilateral & multilateral agencies and banks.

FIGURE 5: Prices of the street lights per Watt



2.6 REPLICABILITY AND SCALING UP POTENTIAL

Replicability of the Ujala programme is proven by the fact that the programme used the Bachat Lamp Yojana scheme architecture and the DSM regulations to create a viable business model to promote large-scale replacement of incandescent lamps with LEDs. The replicability is also demonstrated by the fact that, to date, EESL has distributed more than 100 million LEDs in India with the help of DISCOMs and State Designated Agencies (SDAs).

EESL has evolved a service model whereby it works with electricity distribution companies (DISCOMs) through a benefit sharing approach. The Ujala programme obviates the need for DISCOMs to invest in the upfront cost of LED bulbs; EESL procures the LED bulbs and provides them to consumers at a rate of 1.5 USD each, against their market price of 5 USD. The upfront investment made by EESL is paid back in two different ways:

On Bill Financing (OBF): Cost recovery from consumers by deduction of easy instalments of 0.15 USD every month for 8-12 months. The entire cost of the LED bulbs, including the awareness, distribution and cost of capital is recovered from consumer bills.

Annuity Model: EESL replaces the conventional street lights with LEDs at its own costs (without any need for municipalities to invest), and the consequent reduction in energy and maintenance cost of the municipality is used to repay EESL over a period of time. The contracts that EESL enters into with municipalities are typically of a seven year duration, where it not only guarantees a minimum energy saving (of typically 50%) but also provides free replacements and maintenance of lights at no additional cost to the municipality. The service model enables the municipalities to go in for state-of-the-art street lights with no upfront capital cost, and repayments to EESL are within the present level of expenditure. Thus, there is no additional revenue expenditure incurred by the municipality for change over to smart and energy efficient LED street lights.

Replicability of the National Street Lighting Programme and the Domestic Energy Efficient Lighting Programme (Now UJALA) are also proven by the fact that the Programme has been developed on the principles of BLY. EESL has installed more than 0.763 million LED-based street lights and distributed more than 103 million bulbs in the country. This proves the replicability of the programme and the business models.

3

STANDARDS AND LABELLING PROGRAMME FOR ELECTRICAL APPLIANCES

Amit Garg
Bhushan Kankal

3.1 INTRODUCTION

The ownership of assets that consume electricity at the household level in India has increased across both urban and rural households (Figure 6). These appliances are of different manufacture dates, makes and models, and have different usage patterns across households. The usage also depends on region and season, as well as time of day. Some researchers have estimated profiles of these appliances in India (Garg et al., 2011). These indicate that scope exists for reducing the energy consumption of these appliances per unit of service delivery. Prima facie, the energy savings of a device is expected to offset the additional capital expenditure of the high performing device. However, despite negative marginal costs, most energy efficient devices do not automatically penetrate in a developing country due to a myriad of existing barriers, such as market imperfections, weak institutional support, quality and reliability of electricity and energy efficient appliances, high upfront capital costs, high interest rates, low awareness, behavioural inertia to change, and other dynamic barriers e.g. changing tax and subsidy regimes (Garg et al., 2014). Along similar lines, Almeida et al. (2003) had identified that the most common barriers for application of energy efficient technologies were split budgets (different budgets for capital and operations), risk of failure, lack of internal incentives and market structure. A combination of educational tools, standards and labelling, promotional activities and financial incentives could be the most successful way to promote energy efficient technologies.

Standards and labelling programmes for electric appliances have existed in developed and some developing countries for some time now. For instance, USA had the star labelling programme for refrigerators since 1979, Canada since 1990, European Union (EU) since 2010, China since 2010, Brazil (for electric equipment) since 1985, Japan since 2006, etc.

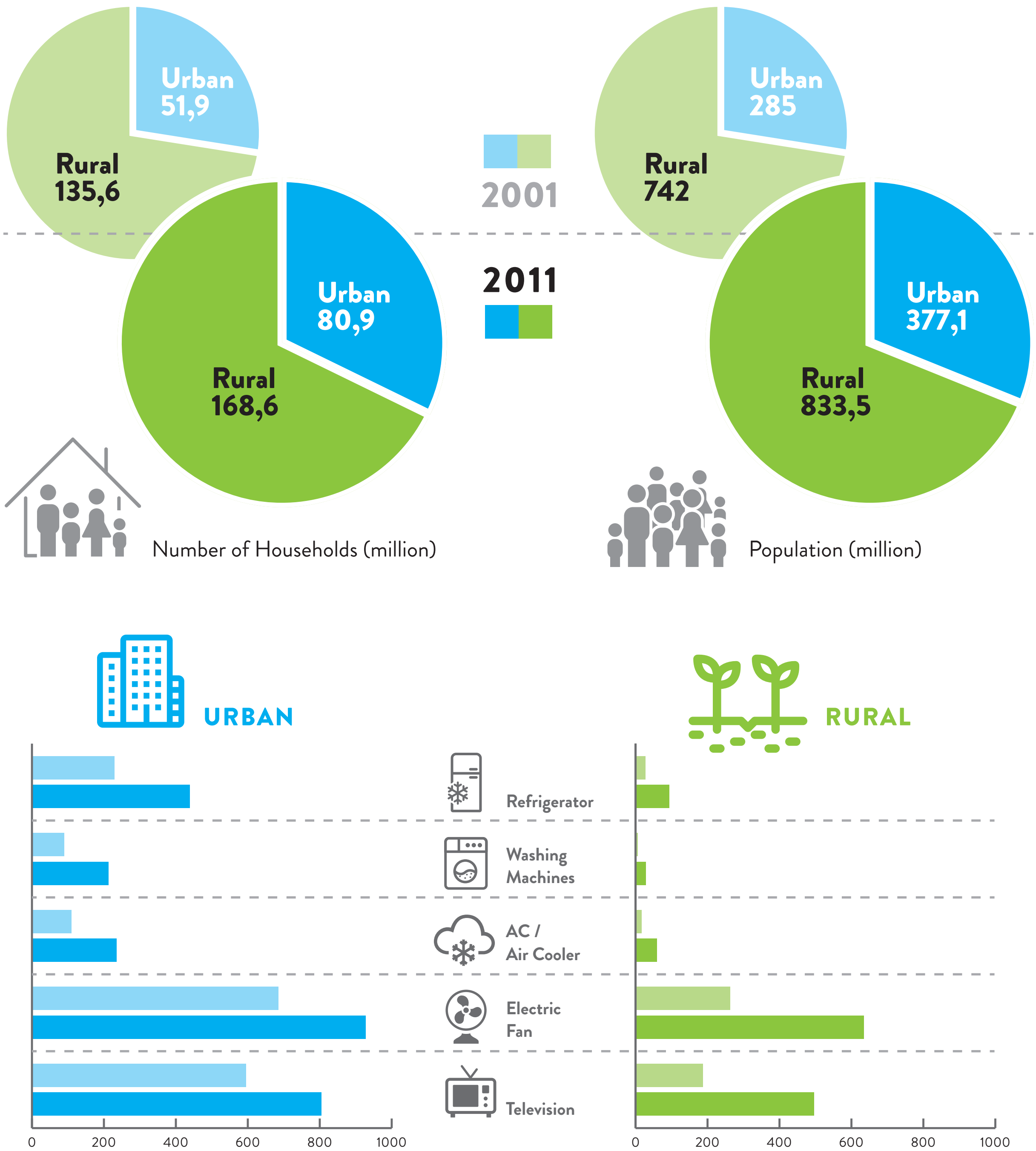
3.2 WHY THE POLICY WAS INITIATED

The Indian government has instituted several measures to lower the transaction costs for higher penetration of EE appliances. These could be through mandatory standards and labelling wherein devices sold on the market have to follow these standards. There are also schemes such as UJALA and SLNP wherein efficient devices are pushed on the market through a programme. BEE has developed a mandatory Standards and Labelling (S&L) scheme for air conditioners, refrigerators, tubular fluorescent lights (TFLs), and distribution transformers, and a voluntary scheme for ceiling fans, washing machines, TVs, direct cool refrigerators, storage type water heaters, domestic gas stoves, and various types of water pump sets. These schemes require display of energy performance labels on the end use equipment and appliances, and lay down minimum energy performance standards (BEE, 2016). The Electricity Act (2003) provides an overarching framework for enhancing energy efficiency in the residential sector, among others.

3.3 WHAT WAS DONE

BEE is undertaking the Standards & Labelling Programme to provide consumers information about the energy saving and, thereby, the cost saving potential of household goods and other equipment. The appliances are rated with one to five stars, with five stars indicating the most energy efficient model. The labels note the amount of electricity consumed by the appliance and its energy efficiency. This is expected to impact energy savings in the medium and long run, while at the same time positioning the domestic industry to compete in markets where norms for energy efficiency are mandatory.

FIGURE 6: Indian household profile (number per 1000 households).



Source: National Sample Survey Organisation, Fifty-Fifth and Sixty-Eighth round documents, Government of India.

The programme was launched in May 2006, and is currently operational for the following equipment and appliances: room air conditioner, ceiling fan, colour Television, computer, direct cool refrigerator, frost free refrigerator, distribution transformer, domestic gas stove, general purpose industrial motor, mono-set pump, open well submersible pump set, stationary type water heater, tube light florescent ballast, solid state inverter, office automation products, diesel engine driven mono-set pumps for agricultural purposes, diesel generator set, LED lamps, and inverter AC. Their individual energy ratings are available on the BEE website (*https://www.bee-starlabel.com/*).

The ratings are proposed by the BEE and have been made mandatory for five different equipment in India since January 2010. The equipment are mandated to have star labelling, and include room air conditioner, frost free refrigerator, tubular fluorescent lamp, distribution transformer and cassette type air conditioner. The five star ratings decided by BEE for the different equipment are provided in Appendix A.

This equipment cannot be sold on the market without the star labelling. Furthermore, their standards are revised periodically, for example, the standard for ACs has been revised three times since 2010. There are another 16 voluntary equipment, other than these five mandatory ones, which are going to come under the mandatory star labelling programme in the coming years (one to two equipment every year). These voluntary equipment are: direct cool refrigerators, general purpose motors, ceiling fans, agricultural pump sets, colour TV, electric water geysers, laptop & notebook, washing machine, LPG stoves, ballast, inverters, office equipment, DG sets, DG pump sets, variable capacity (inverter) ACs, and LED lamps.

3.4 EFFECTS OF THE POLICY/PROGRAMME

Every year, an independent evaluation is carried out which assesses the penetration of starred products using the data from such evaluations; penetrations of different starred products have been worked out. Also, BEE periodically revises its rating system to reflect best global technologies. Using information for households from India's official data agency, National Sample Survey Organisation (NSSO), BEE has attempted a calculation of energy savings made from the star labelling scheme of four common energy consuming appliances in households (ACs, ceiling fans, refrigerators, colour TVs). From the labelling of these four appliances, the estimated saving of electricity consumption by households in the year 2030 is 136.8 billion units (or 24%). Table 7 illustrates these potential savings. BEE has stipulated a reduction of approximately 30% for household electricity consumption, inclusive of both lighting and appliances for the year 2030.

TABLE 7: Energy saving potentials by appliances in 2030

HOUSEHOLDS	APPLIANCE	TOTAL NO. OPERATED MILLIONS	LIFE IN YEARS	STAR RATED	ENERGY SAVING (KWH/ PRODUCT/ YEAR)	ENERGY SAVING BY STAR RATED APPLIANCES (MILLION KWH)	ENERGY USED BY NON-RATED APPLIANCE (MILLION KWH)	ENERGY SAVED (PER CENT)
Bottom 5	AC	4	7	2*	415	1660	10400	16
	Refrigerator	26	10	3*	283	7358	18720	39
	Colour TV	60	7	0	0	0	24000	0
	Ceiling Fans	94	10	0	0	0	21996	0
Top 5	AC	52	10	3*	567	29484	135200	22
	Refrigerator	161	10	5*	411	66171	115920	57
	Colour TV	247	7	4*	71	17537	98800	18
	Ceiling Fans	585	10	4*	25	14625	136890	11
All						**136835**	**561926**	**24**

Source: BEE, Adapted from LCC Final Report, 2016

TABLE 8: Shares of BEE labelled air conditioners sold

STAR RATING	2007-08	2008-09	2009-10	2010-11	2011-12
1 Star	17.10%	14.50%	16.20%	8.50%	1.70%
2 Star	74.50%	56.50%	39.00%	40.40%	34.80%
3 Star	3.50%	24.80%	31.00%	31.80%	39.60%
4 Star	3.70%	3.30%	3.20%	3.70%	2.50%
5 Star	1.20%	0.90%	10.60%	15.60%	21.30%

Source: BUR 2016

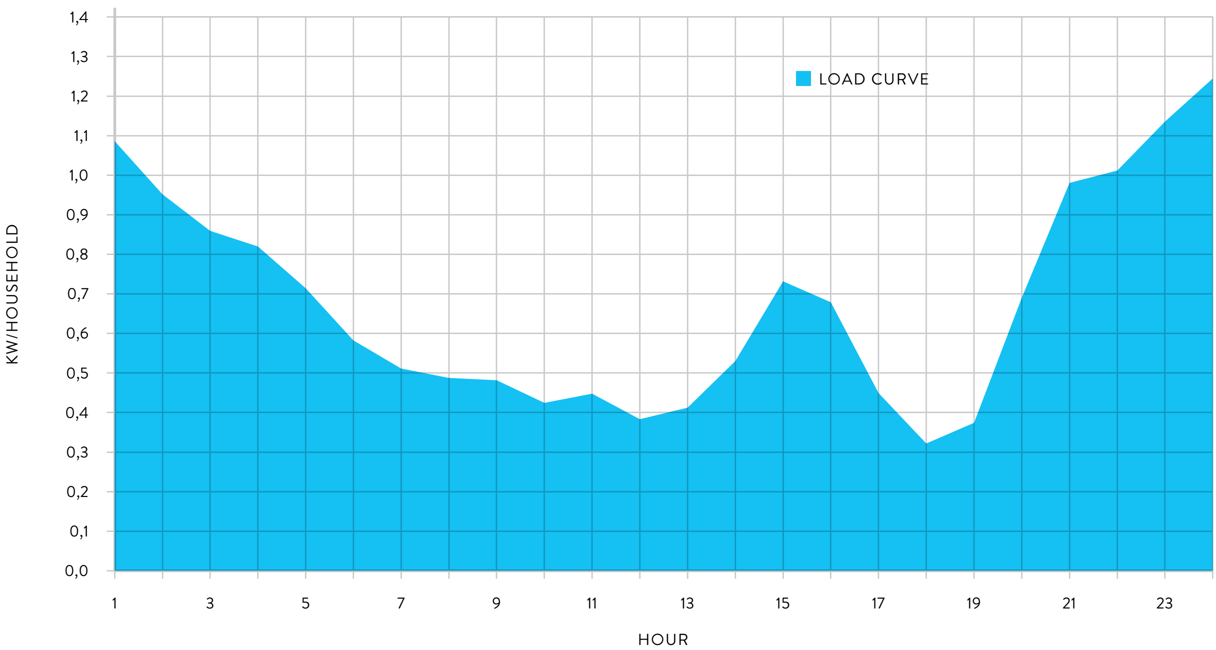
TABLE 9: Shares of BEE labelled frost free refrigerators sold

STAR RATING	2007-08	2008-09	2009-10	2010-11	2011-12
1 Star					
2 Star					
3 Star	100.00%	100.00%	11.50%	14.70%	7.50%
4 Star			47.90%	27.80%	23.20%
5 Star			40.60%	57.50%	69.30%

Source: BUR 2016

Results indicate that up to 7.9 TWh of electricity can be saved per year in Gujarat state, with 6.7 Mt-CO_2 emissions mitigation at negative or very low CO_2 prices of USD 10/t-CO_2 (Garg et al. 2014). The old and new load curve arrived at by using some technology transitions is depicted in Figure 7. The shaded portion is the load removed due to usage of energy efficient appliances. Most of the power savings result from energy efficient refrigerators, ceiling fans and air conditioners. Although air conditioners save more power per unit of operation, the total number of fans and refrigerators is very high, resulting in a higher contribution in power saving. Energy efficient ceiling fans are not a focus of present labelling and standards programmes, even though some star labelled fans have become available on the market recently. Lighting contributes only marginally, also during the evening peak.

FIGURE 7: Load curves showing savings by various EE appliances in summers



3.5 CHALLENGES EXPERIENCED

The implementation of the standards and labelling programme required a considerable amount of technical and financial resources. The following challenges were experienced for the implementation of this programme (Jose, 2011):

- Aggregation of baseline data;
- Lack of established testing protocols for EE;
- Strengthening of nationwide testing capacity;
- Unorganised market for several appliances plays key role in regional markets;
- Institutional challenges for upscale of such a nationwide scheme;
- Sustainable and robust model for monitoring and verification;
- Continuous and strategic media campaign;
- Public procurement and payback-based purchases in terms of EE appliances;
- Incentive-based promotion for manufacturers in addition to the market-based promotion;
- Technical and manpower support for further enlargement.

3.6 REPLICABILITY AND SCALING UP POTENTIAL

The standards and labelling programme was started in India in May 2006. It focused on air conditioners to begin with, and slowly frost free refrigerators, tubular fluorescent lamps, distribution transformers and cassette type air conditioners were brought in. In light of the significant success of this programme, there are proposals to continue and extend the appliance-labelling programme for presently uncovered appliances. Some standards were moved to the compulsory scheme, wherein every product manufacturer had to follow these to sell their respective products in Indian markets. Another category of the voluntary scheme was introduced subsequently, whereby it is optional to follow these standards. Manufacturers that decide to follow these standards may use them as a strategic marketing advantage to sell their products.

It is apparent that new standards and labelling are brought as voluntary schemes initially. As the production matures and the penetration level increases, these are made into compulsory schemes, and the performance levels are also enhanced (Tables 8 and 9).

The manufacturers, therefore, get time to adjust their production processes over a period and prepare for enhancing their product performance. This also provides leverage to market more energy efficient products to the consumers. In other words, efficient products are initially "pushed" through standards and labels and then the customers "pull" them, as reflected in market demand for more efficient products.

As already mentioned, standards and labelling is a time-tested mechanism for enhancing energy efficiency of electrical appliances all over the world. However, more measures are still needed to realise the full economic and environmental potential of energy efficient devices, especially from the household sector. Perhaps there is a scope for energy service companies (ESCOs) in distributed household sector. However, mechanisms for the same have to evolve in India, such as cost, benefit and risk sharing arrangements between power utilities, appliance manufacturers and households.

4 SOLAR ROOFTOP SYSTEMS IN RESIDENTIAL AND INDUSTRIAL SECTORS IN TAMIL NADU

Tirthankar Nag

Renewable energy technologies are ideally suited to distributed applications, and they have substantial potential to provide a reliable and secure energy supply as an alternative to grid extension or as a supplement to grid-provided power. Over 400 million people in India, including 47.5% of those living in India's rural areas, still have no access to electricity. Because of the remoteness of much of India's un-electrified population, renewable energy can offer an economically viable means of providing connections to these groups. Some of the renewable energy technologies that are used in villages and rural areas as decentralised systems are:

- Family-size biogas plants
- Solar street lighting systems
- Solar lanterns and solar home lighting systems
- Solar water heating systems
- Solar cookers
- Standalone solar/biomass based power generators
- Akshay Urja / Aditya solar shops
- Wind pumps
- Micro-hydro plants

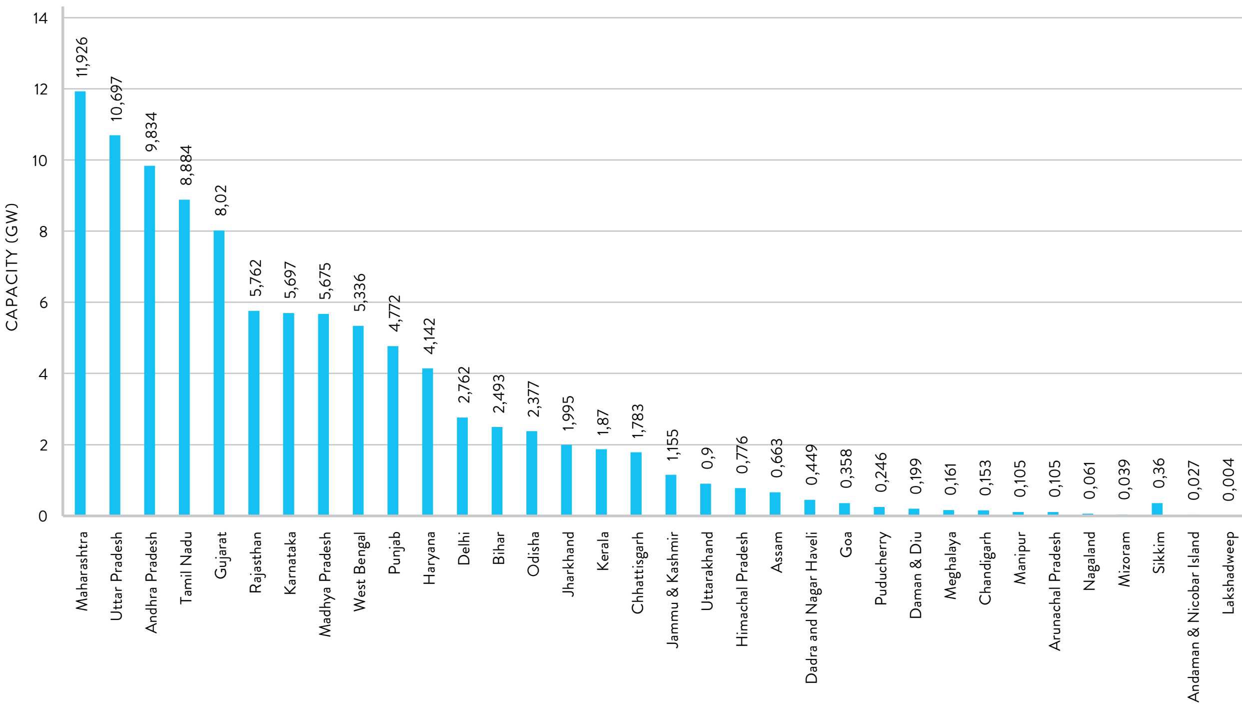
Many of these systems have also been found useful in urban and semi-urban areas to conserve the use of electricity and other fossil fuels. Solar water heating systems have helped in demand side management of electricity in various cities and towns during peak hours. Standalone rooftop SPV systems are getting popular for daytime diesel abatement in areas where power cuts are very high.[1]

Solar home systems are particularly convenient for rural homes where grid connectivity is not available/reliable. Solar home systems provide around four LED lights, one fan and two mobile charging points. They have a small battery backup that can support these facilities for up to four hours.

The government of India has announced an ambitious target for solar power under their intended nationally determined contributions (INDC) at the Paris Climate Change Convention in 2015. The solar electricity capacity target of India under the Jawaharlal Nehru National Solar Mission (JNNSM) has been set at 100 GW by 2022 (Figure 8 gives a state-wise breakdown of this target). This capacity will include 40 GW Rooftop and 60 GW through Large- and Medium-Scale Grid Connected Solar Power Projects. These projects have been allocated capital subsidy under Viability Gap Funding (VGF) based projects to be developed through the Solar Energy Corporation of India (SECI) and for decentralised generation through small solar projects. This 100 GW is expected to abate 170 million tonnes of CO_2 over its life cycle (PMI, 2015).

1 *http://www.mnre.gov.in/schemes/decentralized-systems/*

FIGURE 8: State-wise solar power generation capacity targets in India (GW)



Twenty-six states have set up regulations for gross/net metering facilities for solar rooftop installations. Some of the states, for example Tamil Nadu in the southern parts of India, have been encouraging both the residential and industrial sectors to adopt rooftop solar systems. Two case studies from each of these sectors are provided below.

CASE A: SOLAR ROOFTOP SYSTEMS AND STREET LIGHTING SYSTEMS SERVING RESIDENTIAL CONSUMERS

4.1A INTRODUCTION

The Government of Tamil Nadu, one of India's southern states, has launched a programme for solar powered homes in rural areas and solar street lighting systems. The programme is known as the Solar Powered Green House Scheme. The plan under this scheme involved constructing 300,000 houses with solar powered lighting systems over a period of five years, from 2011-12 to 2015-16. In each of those years, 60,000 such houses have been planned for the rural areas for people living below the poverty line (GoTN, 2015) ....

The Rural Development and Panchayat Raj Department is the implementing agency for construction of houses, and the Tamil Nadu Energy Development Agency (TEDA) is the implementing agency for installing the solar systems. These houses are constructed by replacing existing dwellings or on land owned by the beneficiaries, thus bypassing issues of land acquisition.

4.2A WHY THE POLICY WAS INITIATED

The policy was introduced to provide rural housing with solar lighting to people below the poverty line in rural areas of the state of Tamil Nadu in India. With limited household-level access to electricity, decentralised electricity generation using solar panels was chosen.

4.3A WHAT WAS DONE

For the years 2011-12 to 2014-15, 240,000 homes, each measuring 300 square feet, had been fitted with solar power lighting systems. The various aspects of the project are provided below.

KEY FEATURES OF THE POLICY/PROGRAMME

Economic and Financial Aspects: The cost of house construction is USD 2,650 and the cost of installing solar equipment is USD 440, including CFL/LED lamps. The Rural Development and Panchayat Raj Department deposits USD 440 with TEDA for each house (TEDA, 2015). TEDA is responsible for setting up the solar lighting system and claiming the applicable subsidy from the Ministry of New and Renewable Energy, which is then passed on to the Government of Tamil Nadu. Any savings and interest accumulated are also passed on to the Government of Tamil Nadu. An estimated subsidy of USD 6.3 million and USD 5.8 million for the first two years has been allocated from the Ministry of New and Renewable Energy. These houses have been provided with 49,650 CFL and 10,350 LED-based solar power lighting system for each year. On average, the balance of system and module cost is USD 9.8 per W, with 45 W planned for each house.

Technology Aspects: The solar lighting system consists of hybrid solar inverter/PCU, which is a mature technology based on solar PV and battery storage. The modular design makes it easy to install, and the systems have been functioning well with the five-year comprehensive annual maintenance contract by the supplier. There is a high scope for obsolescence of PV module with the thinning of films. The battery has to be replaced at regular intervals. All the components, except the polysilicon and the solar panels, are made in India and installed by Tata Solar (TPS, 2015), Su-Kam and others.

The solar lighting system consists of five CFLs/LEDs - one in the living room, bedroom, kitchen, bathroom and veranda. These systems can be operated for five hours per day. Figure 9 depicts a rural house with a solar lighting system.

The solar home lighting system with grid backup has the following features:

1. Comprehensive annual maintenance contracts of the systems by the supplier for five years.
2. Smart power conditioning unit to charge the battery from the grid only on rainy or cloudy days when solar power is insufficient.
3. The solar system has a three-day autonomy i.e. even if it rains for three days the system will work as the required energy for three days is generated by the panel and stored in the battery. Provision of grid backup avoids the requirement of autonomy for more than a day. Hence, additional capacity of battery and SPV panel required for more autonomy is reduced, resulting in huge capital savings.

Social Aspects: There is a high acceptance of the programme at the local level. An estimated 250 people are employed for installation every year. An estimated 100 people are employed every year for maintenance of the solar systems.

Policy Aspects: This programme is driven by state government policy. It may face replication challenges due to the involvement of the subsidy component. However, market mechanisms can also be structured to take care of these challenges.

The government of Tamil Nadu has also planned to implement 100,000 street lights in village panchayats through solar power over a period of five years until 2016, i.e. 20,000 each year. A cost of USD 7.4 million is estimated, out of which the Ministry of New and Renewable Energy provides the subsidy of USD 1.2 million. A photograph of the street lighting system is provided in Figure 10.

The street lights are installed through solar power in three categories:

1. Per year 18,000 existing street lights with 40W incandescent bulbs or tube lights are replaced with 20W LED lights and powered from centralised Solar Photo Voltaic (SPV) power plants through the existing distribution line of Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO), with grid backup.
2. Per year 1000 new LED-based street lights from centralised SPV power plants.
3. Per year 1000 new LED-based standalone street lights are powered by SPV.

4.4A EFFECTS OF THE POLICY/PROGRAMME

Assuming 300,000 installations, avoided generation would amount to 13.5 MW peak load capacity for the state of Tamil Nadu. With full use, the power supply requirements fulfilled in rural areas would approximately be 24.6 million kWh per annum. The carbon dioxide saved is estimated at 18.7 thousand tonnes per annum.

FIGURE 9: Houses with solar lights

FIGURE 10: Solar street lighting

4.5A CHALLENGES EXPERIENCED

One of the major constraints is the budgetary support of the state, since the entire cost was fully funded by the state and central governments. The second challenge is maintenance of the solar systems after five years when maintenance contracts with the supplier ends. Maintenance procedures have also been communicated to the users, which can be a major step towards curbing this challenge. An important constraint of maintenance and user buy-in was overcome by ensuring that the principal user also works for implementing the project i.e. there is some sort of sweat equity contribution from the user.

4.6A REPLICABILITY AND SCALING UP POTENTIAL

Such projects driven by state policy and financial support are good examples of mass scale distributed renewable electricity generation and use. Replication through market mechanisms may pose issues, although later projects using partial subsidy coverage are working fine. The technological progress of solar PV leading to decrease in cost would contribute to making such projects less costly to replicate.

However, recent policies for grid connected solar rooftops and capital subsidies in residential, government, social and institutional (hospitals, educational institutes) sectors will encourage the penetration of solar rooftop systems. The budget for solar rooftop systems has been scaled up from around USD 0.1 billion to USD 0.7 billion until 2020, covering the support for installation of 4,200 MW of solar rooftop systems. Thus, the replicability potential of such projects is high in the present scenario.

This project is available until 2016. The state government has moved towards a partial subsidy mechanism in subsequent projects for solar rooftops, where users need to pay USD 640 to USD 880 for a 1 kW supply. Even these prices are well below the market rates, and the implementing agency is witnessing the rapid growth of these projects.

CASE B: ROOFTOP SOLAR ELECTRICITY IN INDUSTRY: THE CASE OF MURUGAN TEXTILES

4.1B INTRODUCTION

Murugan Textiles, a textile plant in Palladam, Tirupur district of Tamil Nadu state of India, installed rooftop solar to supply electricity to the spinning machines at their mills. Slowly, some industries are exploring renewable energy options for meeting their captive needs. Aside from captive consumption, the solar energy plant in Palladam is also connected to the grid through a dedicated feeder at 11 kV to obtain Renewable Energy Certificates[2] (REC) (EAI, 2015).

4.2B WHY THE PROJECT WAS INITIATED

The industrial area used to suffer from a shortage of electricity from the grid. Batch processing industries like textile have to rely heavily on assurance of continuous supply of quality power as supply shortages lead to the entire batch in process to be discarded. In addition, the firms operations are working capital intensive as they use open-end spinning machines, which are more power intensive than conventional machines. Previously, these plants relied heavily on diesel-run generators, which is a costly source of electricity. The use of solar energy as the primary source by a textile mill was prompted by the introduction of Renewable Energy Certificates and the decreasing capital cost of solar power installations, which made such projects feasible and efficient in a supply deficit region. The mill is grid connected through an 11 kV feeder to take care of exigencies in renewable energy generation. Such conditions exist in many industrial clusters across India where renewable energy solutions can pose feasible alternatives to grid-based electricity supply. The rooftop solar installation of the mill is shown in Figure 11.

2 *1 REC is equivalent to 1 MWh of electricity generated from renewable sources and can be traded.*

4.3B WHAT WAS DONE

To meet their daily operational energy requirements, Murugan Textiles has adopted renewable energy sources like solar and wind (ToI, 2015). The rooftop solar system is built on top of the existing spinning mills and warehouse.

Key features of the policy/programme

Economic and Financial Aspects: The cost of the plant is nearly USD 2 million (Solar PV costs are estimated at USD 0.92 million per MW). The company estimates a break-even period of six years, and since this is much lower than the lifespan of the technology the project was found financially viable.

Technology Aspects: The system is designed as a hybrid model of renewable energy consumption, using both solar and wind energy so that the entire power demand can be met from renewables. The solar system is designed to generate 2 MW peak power. The total roof area covered is 18,850 square meters. The Solar Power Plant is configured as 700 kW on one rooftop, and 650 kW, each, on two rooftops. The solar system has crystalline modules of 245 W and 250 W supported by 57 numbers of inverters for the entire system (TERI, 2013).

Social Aspects: Murugan Textiles, at present, powers nearly all of its machinery on renewable energy. They generate 25% of their electricity requirement through solar, and the rest though wind energy. The benefits include projected cost savings of USD 1.6 million in 25 years.

Policy Aspects: This project has not been driven through any subsidies from the government; rather, it is market-based. It makes use of existing government regulations that allow captive power plants to supply electricity into the grid and renewable energy policies that enable the plant to earn renewable energy certificates and get paid a higher price for electricity, using feed in tariffs.

4.4B EFFECTS OF THE POLICY/ PROGRAMME

The solar plant will result in an estimated energy generation of 3 million kWh per year (Bloomberg, 2015) and CO_2 savings of 2,567 tonnes per year, as reported by the company and Tata Power Solar, the installation contractor for this project.

4.5B CHALLENGES EXPERIENCED

Dedicated rooftop and financing requirements: The project, which started as a green initiative, has expanded to take over the conventional grid connected power supply of the mill. The only constraints are the requirement of a dedicated area, and financing of the capital cost of the project. Murugan Textiles solved the problem of area by dedicating their entire rooftop to solar installations.

Capital cost: One of the challenges in the face of falling oil prices is the capital cost of solar power in industries, though mechanisms like feed in tariffs will lead to some benefits. Thus, short-term direct benefits are absent for industries, although taking long-term scenarios into account, this may seem comparable.

4.6B REPLICABILITY AND SCALING UP POTENTIAL

This project may be replicated across other industries, especially since it is working well in a batch processing industry, which needs a constant source of electricity. With the government mandate of spending 2% of profits for certain class of companies, this amount can be harnessed for shifting to a green alternative.

Renewable Energy Certificates, higher feed in tariffs in Tamil Nadu, and the decreasing capital cost of solar power installations may have played a role in encouraging such installations.

In batch processing industries, especially, the damage cost of load shedding or having low quality power is quite high. Therefore, many industries might want to replicate this case, if not for full reliance than for partial backup power.

The company is expanding its project from 2 MW to 3 MW. In the future, other companies may also follow the same model. Similar examples of industry using distributed renewable sources of electricity are numerous in India, for example, oil distribution companies, retail banks in rural areas, etc.

FIGURE 11: Murugan Textiles, Tamil Nadu

5

IMPROVING PUBLIC TRANSPORT: A CASE STUDY OF DELHI METRO

Amit Garg
Bhushan Kankal

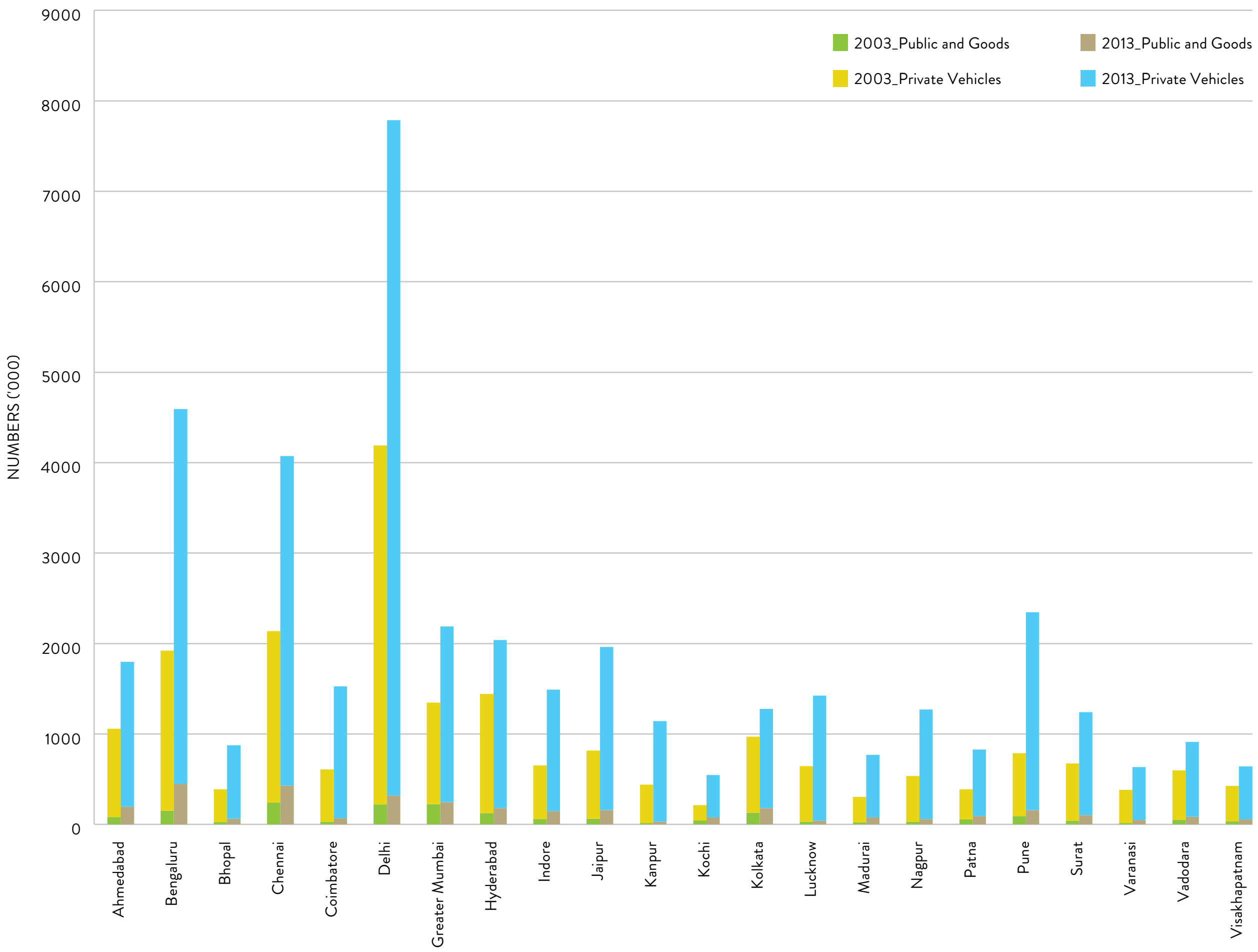
5.1 INTRODUCTION

The number of private transport vehicles has been increasing at a high rate in Indian cities over the last decade (Figure 12), though on a per capita basis the level is still significantly below developed countries. Public and paratransit modes still provide a larger share of demand for passenger transport in urban areas (Dhar & Shukla, 2015, and Table 15), however the growth in private vehicles is expected to make it the dominant mode of transport in the future. Private transport has, on a per passenger km basis, higher fuel consumption, takes up more road space leading to congestion on the roads, results in more accidents and has higher emissions of local and global pollutants. In aggregate, therefore, increased private vehicles means higher oil imports[1], more accidents, increased pollution[2] and more congestion in cities. It also means more CO_2 emissions. An efficient public transport system is, therefore, necessary for shifting the demand from private to public transport.

1 *India imports over 75% of its oil, which is a large outflow of foreign exchange for India.*

2 *Indian cities dominate the list of most polluted cities, and a larger number of cities have a concentration of $PM_{2.5}$ -- way beyond the permissible levels.*

FIGURE 12: Population of vehicles in Indian cities



Source: Indiastat, 2016

The Government of India initiated metro rail systems in Kolkata (1984), Chennai (1995 and 2015), New Delhi (2002), Bengaluru (2011), Gurgaon (2013), Mumbai (2014), Jaipur (2015), Hyderabad (2016), and Kochi (2016). Overall, 15 large cities in India currently have on-going metro projects, and it is considered a mitigation option within the INDC of India.

Delhi was the first city in India to go for a metro rail project in a big way. It also created high standards of execution and performance, including earning two CDM projects on regenerative braking and modal shift. This case is analysed in detail.

TABLE 10: Passenger billion km among various categories of cities (2005)

CITIES	2 W	3 W	CARS	JEEPS	TAXIS	BUSES	TOTAL	PUBLIC/ PARATRANSIT	PRIVATE
Mumbai	3.08	3.65	2.86	0.82	2.54	24.60	37.55	30.79	6.75
Delhi	15.44	5.72	13.43	2.80	1.77	69.41	108.57	76.91	31.67
Kolkata	1.21	0.60	2.01	0.00	2.08	19.22	25.12	21.90	3.22
Chennai	4.39	1.83	2.11	0.18	1.35	20.89	30.74	24.07	6.67
Bangalore	5.63	2.95	2.97	0.15	1.32	33.81	46.83	38.08	8.75
Hyderabad	5.67	2.61	1.6	1.13	0.57	13.21	24.8	16.39	8.41
Ahmedabad	4.26	2.14	1.93	0.38	0.73	22.71	32.16	25.58	6.57
Pune	4.24	3.31	1.19	0.53	0.74	17.85	27.85	21.89	5.96
Surat	3.29	2.16	0.78	0.21	0.12	2.71	9.27	5.00	4.28
Kanpur	2.14	0.08	0.58	0.26	0.05	4.46	7.57	4.59	2.98
Jaipur	3.82	0.45	0.98	0.39	0.41	11.97	18.03	12.83	5.20
Lucknow	3.09	0.34	0.81	0.52	0.26	7.36	12.37	7.95	4.42
Nagpur	3.17	0.78	0.5	0.37	0.04	9.92	14.79	10.75	4.04
Patna	1.00	0.79	0.27	0.68	0.14	9.87	12.75	10.79	1.96
Indore	1.63	0.38	0.38	0.08	0.76	8.58	11.8	9.71	2.09
Vadodara	2.65	1.05	0.43	0.23	0.25	6.79	11.4	8.09	3.31
Bhopal	1.50	0.41	0.25	0.05	0.54	6.04	8.79	6.99	1.81
Cochin	0.53	0.55	0.32	0.12	0.56	9.63	11.70	10.74	0.97
Coimbatore	3.31	0.44	0.77	0.16	0.44	10.39	15.52	11.27	4.24
Visakhapatnam	1.57	0.56	0.24	0.21	0.19	3.02	5.79	3.77	2.02
Ludhiana	4.13	0.37	1.01	0.20	0.09	4.49	10.29	4.95	5.34
Varanasi	1.59	0.26	0.16	0.18	0.05	3.75	5.99	4.06	1.93
Madurai	1.47	0.27	0.15	0.08	0.46	8.87	11.29	9.60	1.70
Total	**78.80**	**31.70**	**35.70**	**9.70**	**15.40**	**329.60**	**501.00**	**376.70**	**124.30**
All India	**297.80**	**133.60**	**66.30**	**71.60**	**92.60**	**2476.60**	**3138.50**	**2702.80**	**435.70**

Source: Reddy and Balachandra (2010)

5.2 WHY THE POLICY WAS INITIATED

Delhi is the capital of India, and has grown quite rapidly since the Independence of India. In 2011, Delhi had a population of more than 16 million people. The growing population and traffic, especially private vehicles, is leading to congestion and air pollution. However, for a shift from private modes of conveyance to public transport, an improvement in public transport is essential. The Delhi government, therefore, proposed to initiate a Mass Rapid Transport System (MRTS).

The first significant mention of an MRTS for Delhi emerged from a 1969 traffic and travel characteristics study. Since then, many official reports by a wide variety of government departments have been commissioned to explore the issues related to technology (underground rail, surface rail, light rail, bus based, etc.), route alignment, and whether urban mass transit is ultimately the jurisdiction of the National Government or the Delhi Union Territory Government. In 1984, the Delhi Development Authority and the Urban Arts Commission came up with a proposal for developing a multi-modal transport system, which would consist of constructing three underground mass rapid transit corridors, as well as augmenting the city's existing suburban and road transport networks. Following that, the Government of National Capital Territory of Delhi (GNCTD) commissioned Rail India.

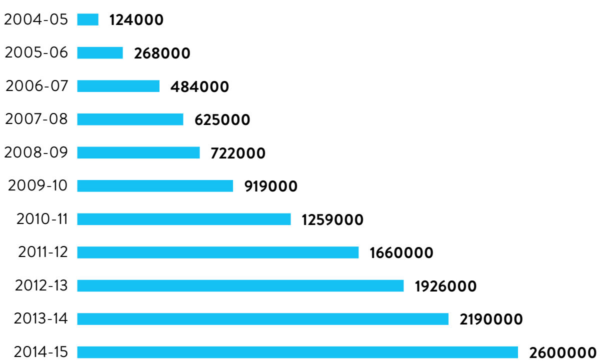
In 1988–89, Rail India Technical and Economic Service (RITES) Limited was appointed to study the feasibility of introducing an Integrated Multi-Modal Mass Rapid Transit System for Delhi. The study was completed by RITES in 1991, and recommended a 198.5 km predominantly rail-based network (GoD, 2015). In July 1994, the Central Cabinet gave the go-ahead, in principle, for the MRTS for Delhi and directed the GNCTD to take up the preparation of a Detailed Project Report (DPR). In May 1995, RITES finalised the DPR for a 55.30 km MRTS comprising rail and metro corridors, for completion by March 2005. The Union Cabinet sanctioned the Delhi MRTS Phase I (Project) of 55.30 km in September 1996, at a total cost of USD 971 million – at April 1996 prices (UNEP, 2014).

5.3 WHAT WAS DONE

The metro system was planned to serve Delhi and connect its satellite towns of Faridabad, Gurgaon, Noida and Ghaziabad in the National Capital Region. The project was divided into phases. Phase I comprised of 58 stations and 65.0 km of route length, of which 13.0 km was underground and 52.1 km was surface or elevated, and was completed in 2006. Phase II of the network comprised of 124.6 km of route length and 85 stations, and was completed in 2011. Phase III of the network comprises 103 km of route length and 69 stations, and is under construction. Phase IV is in the planning phase.

The Delhi Metro has been registering a continuous increase in ridership since its inception. When metro services were introduced in 2002, the average ridership was 80,000 passengers per day, while, as of 2015, daily ridership has risen to 2.6 million (Figure 13).

FIGURE 13: Daily average ridership of Delhi Metro



Source: UNEP, 2014

For the Delhi Metro, the average ridership is 11,450 passengers per km per day. Table 11 shows its ridership per km over the years. The revised projection of the ridership of 2,000,000 passengers per day for 190 km of network, gives 10,500 passengers per km.

TABLE 11: The ridership of Delhi Metro per km

YEAR	NETWORK LENGTH (KM)	PASSENGERS PER KM PER DAY
2006	33	14,900
2007	65	9,550
2008	68	11,300
2009	76	11,600
2010	156	9,900
Average		**11,450**

Source: UNEP, 2014

5.4 EFFECTS OF THE POLICY/ PROGRAMME

The Delhi Metro is a system that runs mainly on electricity. It has electricity consumption from traction – running of trains – and non-traction purposes, such as lifts and escalators, air-conditioning of underground stations, lighting of stations, etc. Approximately 60% of the electricity generation is from coal, which has a higher fly ash content. The heat rate of an Indian power plant is around 2,500 kcal (10464 KJ) per kwh for coal-based plants and 2,000 kcal (8372 KJ) per kwh for gas-based plants (CEA, 2014). The Delhi Metro has no direct emissions from its operation, but contributes to carbon emissions at power plants during the generation of electricity used for its operation. Delhi also has a mix of vehicles used for commuting. Table 12 gives an overview of different modes of transport prevalent in Delhi.

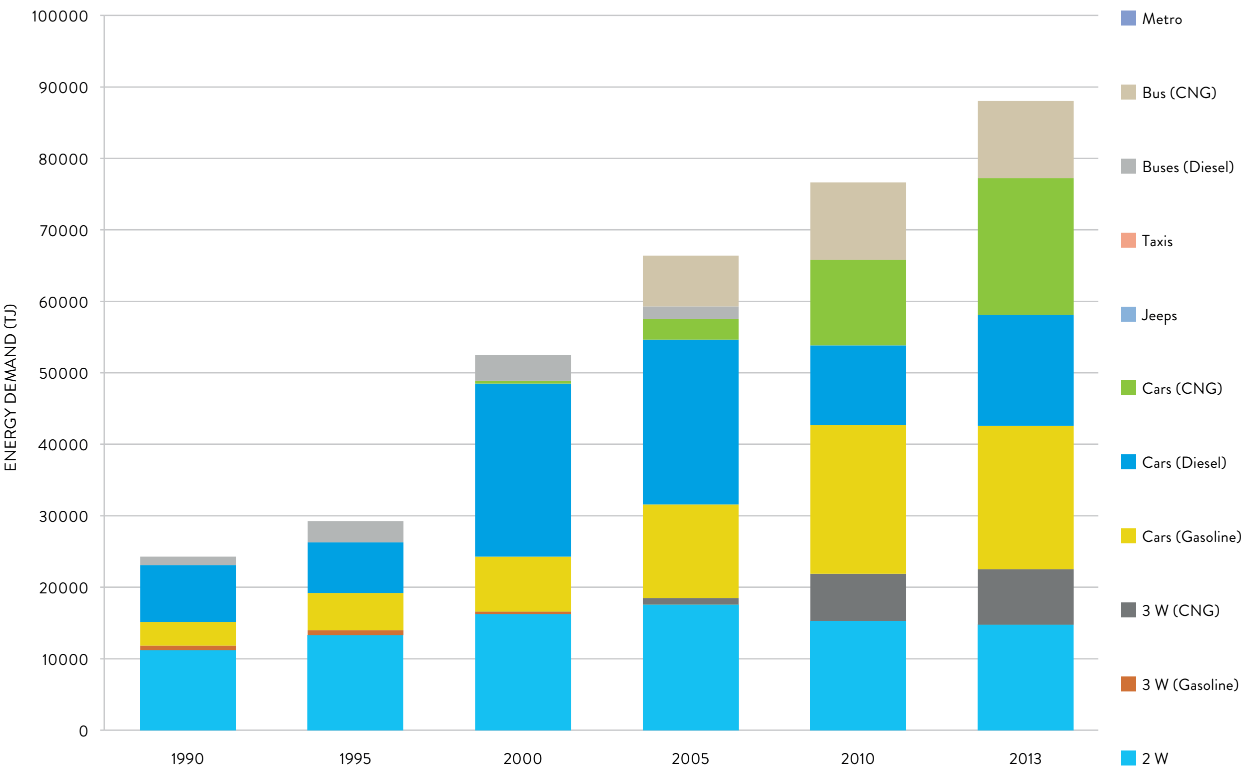
TABLE 12: Energy consumption for various modes of transport for vehicles in Delhi

TRANSPORT MODE	OCCUPANCY (PERSONS/ VEHICLE)	MAIN FUEL	FUEL TYPE (MJ/PKM)			
			1997	2005	2010	2011
2 W (Scooter/Motor bike) – 2 stroke	1.5	Gasoline	0.54	0.55		
2 W (Scooter/Motor bike) – 4 stroke	1.5	Gasoline	0.37	0.45	0.47	0.41
3 W – 2 stroke	1.75	Gasoline	1.00	0.98		
3 W – 4 stroke	1.75	Gasoline		0.78		
3 W – 4 stroke	1.75	CNG	0.68	0.70		1.23
Car	2.5	Gasoline	1.43	1.27	1.87	0.97
	2.5	Diesel	1.61	1.37	2.34	0.28
	2.5	CNG	0.64	1.02	2.29	0.14
Bus	50	Diesel	0.31	0.20	0.21	
	50	CNG	0.30	0.30		0.516
Metro		Electricity			0.09	
BRTS (AC bus)					0.55	
BRTS (Non-AC bus)					0.22	
Suburban train	800	Electricity		0.02		0.16
Diesel locomotive		Diesel			0.11	
Electric locomotive		Electricity			0.05	

Source: Teri (2006), Teri (2012), Das and Parikh (2004)

Looking at the energy consumption pattern of the different modes of transport a shift in energy consumption can be seen in Delhi after the introduction of the metro in 2004, and with the completion of different phases by 2008 (Figure 14).

FIGURE 14: The shift in energy consumption pattern in Delhi



Source: Compiled from Kokaz et.al. (2000), MoPNG (1995, 2000, 2005) and Neilson (2013)

5.5 CHALLENGES EXPERIENCED

Revenue: The fare box contributes less than 50% of the total revenue of the Delhi Metro.

Implications: It has a significant implication on the self-sustainability of metro systems. This leads to the metro systems' dependence on real estate development and, hence, a permanent change in the city's structure.

Costs: Phase I of the project was developed with a total investment of USD 2.1 billion, at an average cost of USD 32 million per km. Of this, the Japan International Cooperation Agency (JICA) funded approximately 60%. The DMRC has a current debt of USD 3 billion, while the annual interest and financial charges reached more than USD 36 million in 2011, despite the fact that the JICA loan is provided at a concessional interest rate of 1.2%.

Implications: With the increasing cost of operations and debt repayment, and an expanding network size, the cost burden of the Delhi Metro is going to rise significantly.

Ridership: Actual ridership of the Delhi Metro is, at most, one-fourth of the projected ridership, leading to an overestimation of the benefits (and unfair justification) of the metro system in the DPRs, during the planning phase. Despite adding track km per kilometre, ridership has stagnated.

Implications: Future planning of metros in other cities should address this issue, and the travel demand models should be improved in order to provide a realistic projection of the demands, and, thus, the benefits of metro systems.

Availability of cycle rickshaws or 3-wheelers: Cycle rickshaws are an important feeder mode for metro users. Nearly 27% to 38% of metro trips depend on rickshaws for their last-mile connectivity. At present, there are 15% rickshaw users due to restrictions posed on use of 3-wheelers in many parts of Delhi (UNEP, 2014). This would discourage some segment of passengers to use metro transport. If rickshaw usage is permitted to ply all over Delhi, metro ridership can be significantly augmented. Rickshaw parking places near metro stations is also required to facilitate the use of 3-wheelers for access and egress trips to metros.

Availability of Non-Motorised Transport (NMT) infrastructure: Safe pedestrian and bicycle paths and crossing facilities do not exist near metro stops. This makes access to metro stops difficult.

Implications: A focus on NMT infrastructure improvement in the city has a great potential to increase access to metros and, hence, metro ridership.

Transport policies for private motor vehicles: The UNEP (2014) report shows that an improvement of the speed of cars and two-wheelers, i.e. by transport policies like flyovers, road widening, and increased parking, leads to a significant reduction in metro ridership.

Implications: Transport policies like flyovers, road widening, and increased parking may lead to a reduction in the ridership of public transport, in general, and metro use, in particular.

5.6 REPLICABILITY AND SCALING UP POTENTIAL

The metro rail project is being replicated in other Indian cities, and is under construction in Mumbai, Bengaluru, Hyderabad, Chennai, Jaipur and Kochi. Moreover, it is proposed for the cities of Pune, Chandigarh, Ahmedabad, Kanpur, Ludhiana, Bhopal, Indore and Nagpur. However, financing metros remains a challenge for expanding and replicating such public transport projects. Major portions of the cities are already congested; therefore, metro lines must go underground, resulting in high capital investment. The fares, although recovering revenue expenditure, are not able to recover the capital expenditure quickly. The break-even period may be 25-30 years. Therefore, such large infrastructure projects have to be seen holistically, and their co-benefits accounted in a social return-on-investment framework. Governmental support is a prime requisite for reliability of metro projects in any city.

6

ENERGY EFFICIENCY IN AGRICULTURAL PUMP SETS

Saurabh Kumar
Pankaj Mohan
Saket Shukla

6.1 INTRODUCTION

The agricultural sector in India is the second highest contributor to direct greenhouse gas (GHG) emissions (17.6%). Additionally, it adds another 9% to GHG emissions as indirect emissions since it accounts for one-fourth of the country's electricity demand. The agricultural sector is responsible for 514 million tonnes of CO_2 equivalent emissions (334 directly, and around 180 indirectly through electricity consumption), while the croplands absorb only 208 Mt of CO_2 (INCCA, 2010). Being the second-highest contributor to greenhouse gas emissions, a sizeable reduction in emissions within the agricultural sector would have significant implications for India's commitment to climate mitigation. The agricultural sector has the potential to save 27.79 billion units of electricity, which is 30% of the sectoral consumption, and more than 36% of total energy savings potential (Patel, 2016).

The agricultural sector consumes approximately 173.2 billion units a year, which is equivalent to around 18.45% of total national electricity consumption in India. As per the Central Electricity Authority there are around 20.27 million electrical pump sets installed in the agricultural sector (EESL, 2015). The average efficiency level of inefficient no-star rated pump sets are in the range of 25-30%, and the efficiency level of star rated energy efficient pump sets is 40-45%. Therefore, the energy saving potential of 25% is estimated to results from the mere replacement of inefficient pump sets with star rated one, and by considering the reduction in specific energy consumption (Kw/lps), which could lead to an additional 5-10% energy savings. This would also reduce repair and maintenance costs for farmers.

6.2 WHY THE POLICY WAS INITIATED

To accelerate Demand Side Management (DSM) measures in the agricultural sector, the Government of India approved a scheme on Agricultural Demand Side Management (AgDSM), implemented by the Bureau of Energy Efficiency (BEE), Ministry of Power. The objective of the scheme is to create appropriate framework for market-based interventions in the agricultural pumping sector by facilitating a policy environment to promote Public Private Partnership (PPP) to implement the project. The BEE has provided resources to create a shelf of bankable detailed project reports (DPRs) in the agricultural sector to mainstream the scheme.

In the Energy and Power sectors, AgDSM consists of activities, methodologies, awareness, policies and technologies that influence consumer (farmers) behaviour, and changes their consumption patterns. The objective of the AgDSM programme is to reduce peak demand, shift the time during which electricity is consumed to off-peak hours, and to reduce the total quantum of consumption. The AgDSM programme would replace inefficient agricultural pump sets with BEE star rated high efficiency pump sets to reduce the amount of electricity needed to pump water in the agriculture sector, and benefit economically.

6.3 WHAT WAS DONE

The BEE facilitated and initiated the implementation of the first AgDSM pilot project in Sholapur circle of Maharashtra where 2,209 old inefficient pumps were replaced with star rated Energy Efficient Pump Sets (EEPS), and provided free operation and maintenance for installed pump sets throughout the project duration. The cost of pumps were however borne by the farmers. In order to accelerate the implementation of the BEE AgDSM scheme, Energy Efficiency Services Limited (EESL) had taken a step forward in implementing the AgDSM project throughout India. The status of different BEE projects is given in Table 13.

TABLE 13: The BEE projects completed or under progress

PROJECT NAME	NO. OF PUMP SETS	STATUS
Hubli Electricity Supply Company Limited (HESCOM)	11,013	Completed
Bangalore Electricity Supply Company Limited (BESCOM)	13,864	Completed
Andhra Pradesh Eastern Power Distribution Company Limited (APEPDCL)	2,496	Completed
Jaipur Vidyut Vitran Nigam Limited (JVVNL)	1,966	Completed
Telangana State Southern Power Distribution Company Limited (TSSPDCL)	3,299	Under progress
Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL)	5,013	Under Progress

6.4 EFFECTS OF THE POLICY/PROGRAMME

The intervention led to lower energy supply on the feeder. This study demonstrated that capital subsidy through efficient pump sets could lead to a reduction in revenue subsidy on cheaper electricity for farmers, resulting in a lower overall subsidy to be paid by the State Government after most of the pumps have been replaced. EESL conducted the survey for implementation of AgDSM and found benefits like reduction in energy consumption and costs, improved power quality, and various social benefits due to this scheme.

The GHG emission reduction from the two completed projects of HESCOM and APEPDCL (Table 13) is estimated to be 7.108 $MtCO_2$ per annum. The potential for energy savings, and therefore GHG mitigation, is huge since there are almost 21 million grid-connected pumps.

6.5 CHALLENGES EXPERIENCED

Despite the huge potential for energy savings in the agricultural sector, the progress to implement energy efficiency measures in the agricultural pumping sector has been slow. Although the electricity distribution companies (DISCOMs) have taken steps to implement the energy efficiency measures, they were unsuccessful due to the following reasons:

a. Inadequate baseline data
b. Lack of performance contract standards
c. Lack of access to finance
d. Lack of monitoring and verification protocols
e. Lack of awareness
f. Farmers are reluctant to reduce their existing pump horse power (HP)
g. Farmers are afraid of metering of their pump sets
h. Farmers are reluctant to give back old pump sets
i. Farmers do not want to sign contracts with Electricity Supply ESCO
j. Low voltage and availability of power supply
k. Low cost or free electricity
l. Institutional barriers and market-based barriers like lack of fiscal incentive for DISCOMs to initiate DSM investments and delayed recovery of capital for ESCO

The investment expected in agricultural pumping is in the range of INR 85000 million (USD 1.24 billion), to replace all 21 million agricultural pump sets.

6.6 REPLICABILITY

The AgDSM programme uses the same architecture as the BEE, while also taking into consideration the DSM regulations to create a viable business model to promote the large-scale replacement of inefficient agricultural pumps with energy efficient ones. To date, around 5,000 energy efficient agricultural pumps in ESCO mode have been installed in India. EESL is also planning to replicate this across India and has evolved an annuity-based model to ensure the best available technology, leading to overall cost savings to DISCOMs. Approximately 2,00,000 old pumps have been replaced with energy efficient ones in Andhra Pradesh, resulting in the decrease in pump costs, due to economies of scale, while also creating awareness among farmers. EESL will invest 100% of the pump cost, and the maintenance of the pumps will be free for five years.

7
IMPROVED COOKING STOVES (ICS) USING BIOMASS FUEL

Manmohan Kapshe

7.1 INTRODUCTION

The Ministry of New and Renewable Energy (MNRE) implemented a National Programme on Improved Chulhas[1] (NPIC) from the financial year 1983-84 to 2002-03. The scheme was later transferred to State Governments, in 2003-04. A variety of models were developed and deployed under the NPIC. The initial success of the programme could not be continued, as the efforts were not sufficient for commercialisation and sustenance of improved chulhas in the country after the discontinuance of NPIC.

Looking at the possibility that the improved cook stoves could yield enormous gains in health and welfare for the weakest and most vulnerable sections of society, the Government of India launched the National Biomass Cook stoves Initiative (NBCI) to develop next-generation cleaner biomass cook stoves and deploy them to all Indian households that currently use traditional cook stoves. The initiative has set itself the lofty aim of providing energy service comparable to clean sources such as LPG, but using the same solid biomass fuels commonly used today. MNRE, through a Special Project on Cook stoves (SPC) during the year 2009-10, initiated the process of consultations under its Core Group on cook stoves to ascertain the status of various types of biomass improved cook stoves being developed and promoted by various organisations, NGOs, entrepreneurs and industries in the country. The core group was also asked to identify ways and means for the development and expansion of the deployment of improved biomass cook stoves. The consultations indicated that biomass cook stoves have the potential to directly address health and welfare concerns of the weakest and most vulnerable sections of society. The core group observed that the cleaner combustion in these devices would also greatly reduce greenhouse pollutants.

As a result of the above consultations, a National Biomass Cook stoves Initiative (NBCI) was launched by MNRE on 2 December 2009, with the primary aim of enhancing the use of improved biomass cook stoves in India. The initiative stressed the setting up of state-of-the-art testing, certification and monitoring facilities and strengthening R&D programmes. The aim was to design and develop the most efficient, cost effective, durable and easy to use device.

As a follow up to the NBCI, the Ministry initiated a new proposal for promoting the development and deployment of Unnat Chulhas (Improved Cook stoves) in the country during the 12th Plan Period from 2012-17. Accordingly, the Administrative Approval with detailed Guidelines for the Unnat Chulha Abhiyan (UCA) were formulated and issued on 27 June 2014. The Guidelines are available on the MNRE website.

1 *Chulha is a Hindi word commonly used for the conventional three stone cook stove using biomass.*

7.2 WHY THE POLICY WAS INTRODUCED AND IMPLEMENTED

In India, the burning of biomass in Chulhas (three stone stoves) for cooking food has been done for generations. Even today, more than 60% of the rural population of India depends on biomass fuel for cooking. The Chulha is a very inefficient device and only 10-20% of heat is consumed for cooking. The burning of biomass in open stoves results in the release of smoke and high concentration of particulate matter. These air pollutants are harmful for women and small children who are very often present in the kitchen for longer hours. Due to the wastage of energy, the time required for cooking is also high. Very often, the biomass is collected from nearby forests and requires long hours of labour. If the biomass is purchased then it is a big burden for the household budget. Thus, a policy was initiated to improve the efficiency of cook stoves. The improved cooking stove consumes less fuel and requires less time for cooking. These stoves also emit less smoke and compared to traditional stoves improve indoor air quality by releasing harmful gases via the chimney.

7.3 WHAT WAS DONE

First the National Programme for Improved Chulhas (NPIC), introduced by the Government of India in 1983, provided a minimum subsidy of 50% to households that purchased the improved cook stove. Under this programme, more than 60 designs of natural draft fixed and portable models of improved chulhas for family, institutional and commercial applications were developed. From 1983 to 2000, approximately 35 million improved stoves of various types were distributed, and a 1995–1996 survey showed that perhaps 60% of stoves distributed up until that point were still in use (Sinha, 2002). It may be noted here that one-time subsidy had its use as an incentive for a rural householder to move from the age-old traditional stove to an improved one. While acknowledging this, it must be pointed out that the one-time subsidy would have been a worthwhile expenditure if, and only if, the beneficiary preferred to buy an improved stove when the time came for replacing their existing one. Such a decision would be governed not only by their satisfaction with the improved design but also by the availability of improved stove models in the open market and the unsubsidised price of these models (Hanbar and Karve, 2002). Under NPIC, there was no assessment of what fraction of the NPIC beneficiaries continued to use improved stoves by buying these models in the open market, without subsidy. As a result, no quantitative data is available for judging whether NPIC succeeded in creating a culture of improved stove use, and to what extent. The

numbers provided in various reports have likely declined significantly since then, given the lack of continued government support and, later, the withdrawal of the programme in 2004.

Recently the programme has been revived under the implementation of the Unnat Chulha Abhiyan (UCA) Programme, during the year 2013-2014. During the remaining period of the 12th Five-Year Plan, until 2017, some more initiatives are being taken.

The initiatives under UCA include, but are not limited to:

- Establishing test centres for supporting research, development, demonstration and testing to develop efficient and cost effective improved biomass cook stoves/*unnat chulhas*, including related technology for processed biomass fuel and development of standards and test protocols.
- Distributing improved biomass cook stoves/*unnat chulhas* to provide cleaner cooking energy solutions on a large scale, including providing after sales service.
- Monitoring and evaluation of the programme to ensure it is implemented in accordance with pre-defined objectives.
- Carrying out studies regarding the socioeconomic impact of improved cook stoves/*unnat chulhas*, their effect on fuel saving, emissions and resulting indoor air quality at the place of cooking, and on climate change mitigation by reducing carbon and other emissions resulting from burning biomass for cooking. This includes ensuring Clean Development Mechanism (CDM) benefits to suppliers/programme implementers to improve the affordability of biomass cook stoves/*chulhas* for the user.
- Awareness and publicity programmes for generating demand, and user and service staff's training and orientation programme.
- Creating an enabling environment for large-scale production of cook stoves/*chulhas* processed biomass fuel, network of dealers, entrepreneurs and supply chain.
- Field performance monitoring and evaluation to study the impact and further steps required for promoting the use of cook stoves.

7.4 EFFECT OF THE POLICY/PROGRAMME

The Kitchen Performance Test conducted on the functioning of both the improved and traditional chulhas in the field showed a wide variation in the energy consumed across households. Improved chulhas performed better, with their average daily energy consumption being 27.4 MJ, whereas for the traditional chulha it was 34.2 MJ (Sadaphal et al., 1993).

Based on many experimental results, Gusain (1990) concluded that smokeless chulhas could easily be made to burn biomass fuels with efficiencies in the range of 20-30% in the laboratory and 15-25% in the field. At a burning rate of 1.0 kg of wood/hour, the thermal efficiency of the two pot chulha, developed by Technical Back up Unit (TBU), New Delhi, is reported as 29%. A comparison of the efficiencies of the three models, namely single pot, double pot and triple pot chulhas developed by the TBU of Baroda, revealed that the single pot chulha had a thermal efficiency of 20-22%, while the two pot and three pot fixed models performed with an efficiency of 25% or more (George, 1988).

Many studies carried out for measuring thermal efficiency of the chulhas indicated that the thermal efficiency of a portable single pot mud chulha ranged from 20-22%, 30-45% for single pot metallic chulhas (Antika, 1989), and 22-40% for a two pot improved chulha (Bhogle and Anand, 1985; Maiti and Gupta, 1993). For three pot chulhas, the efficiency has been reported as high as 45% (Kumar et al., 1990). Replacement of the traditional three stone single pot open chulhas having an efficiency of 10-15% with three pot smokeless chulhas having double or higher thermal efficiency is, thus, an economic investment which is expected to bring down the fuel requirement, and contribute to GHG mitigation.

Despite widespread global efforts to promote clean cook stoves to achieve improvements in air and forest quality, and to reduce global climate change, surprisingly little is known about the degree to which these actually reduce biomass fuel consumption in real-world settings. In India, too, there was no formal monitoring of the use and performance of stoves in practice, therefore, making it difficult to objectively evaluate the programme's achievements and overall impact.

7.5 CHALLENGES EXPERIENCED

Independent evaluations of the programme have questioned the success in meeting objectives, largely because of the low durability, usage and performance of the stoves in the field. The NPIC also relied on government subsidy-based delivery mechanisms without the provision of maintenance/repair services, leading to poor user adoption rates of the delivered technology (Kishore and Ramana, 2002). Numerous problems, including fragmentation of effort and insufficient attention to scalability and sustainability, have prevented such operations from expanding to serve a larger customer base (Edwards and Hulme, 1992; Uvin et al., 2000). The programme had varying degrees of success in different regions in the country. Some models had better acceptability than others in specific regions. Users in certain regions showed greater enthusiasm for adopting new designs. For a variety of reasons, the programme brought a mixed bag of experiences (IITD, 2010).

One of the major problems faced by the programme was the absence of any kind of performance standards. In India, BIS standards were developed in 1991 for a particular kind of cook stove. Even today the performance standards are very limited in scope, and the testing protocols have thermal efficiency as the main focus. There are limited testing facilities, which also need updating and expansion. Recent developments in technology, and focus on health related issues and GHG mitigation aspects call for a close look at the above challenges.

7.6 REPLICABILITY AND SCALING UP POTENTIAL

Globally, the efforts to popularise use of improved stoves have not yielded desired results. Technologies are reasonably well established for 'improved cook stoves' that burn biomass more cleanly and efficiently, and could thus help mitigate the above problems (Hulscher, 1998; Masera et al., 2007). However, after more than three decades of effort, largely by governments and NGOs, less than a third of the total biomass-using population has adopted an improved stove (UNDP/WHO, 2009). Looking at the historical evidence on the lack of success of the improved biomass Chulha, it could be wrongly concluded that the programme has no future. It is important to note that the National Programme for Improved Chulhas (NPIC) was initiated in a completely different context wherein fuel efficiency was the major criterion, as the full benefits of clean combustion were not well understood and the stove technologies to achieve it were not well developed (Venkataraman et al., 2010). Although the NPIC was formally closed in 2004, the need for improved cook stoves to reach rural and semi-urban households in India has persisted. The awareness of adverse health impacts due to unclean combustion of biomass has increased with a need to take effective steps to improve indoor air quality in rural households by providing cleaner cooking options. Moreover, with increasing concerns about climate change and outdoor air quality, it is no longer considered sufficient to remove the smoke from the kitchen using a chimney. There is a widely felt need to provide biomass burning cook stoves with cleaner combustion at very low levels of emissions and at an affordable price (IITD, 2010).

While the government of India has many other schemes that envisage the provision of improved cooking devices and alternate fuels, such as LPG, the large rural population in India will continue to depend on biomass in the foreseeable future. This is primarily due to the lack of affordability of the rural poor in India. The international price of LPG, being a petroleum product, will most likely continue to increase faster than rural incomes, thus making the transition to modern household fuels difficult without any government subsidies (Venkataraman et al., 2010). This adds to the attraction of deploying advanced biomass stoves that provide high performance using local renewable resources while relieving the government of the cost of fuel subsidies.

The Government of India has undertaken steps for the commercialisation of biomass-burning improved cook stoves, through standardisation of designs and performance parameters, promotion and marketing of quality stoves by manufacturers and other marketing networks throughout the country. The users' financial involvement is also being gradually increased, depending on the status of the beneficiaries, their responses, and the level of awareness already achieved.

Presently, dissemination of ICS by the government is being carried out under the Unnat Chulha Abhiyan programme, which was launched in June 2014. The programme has a target to disseminate 2.4 million household-level improved cook stoves and 3.5 million community sized stoves by the end by 2017. A budget of INR 2940 million (Approximately USD 44 million) has been earmarked to meet the programme objectives (MNRE, 2014).

A target of 2.75 million improved cook stoves/chulhas will be disseminated / installed in the remaining period of the 12th Plan Period, as listed in Table 14.

TABLE 14: Physical target for the Unnat Chulha Abhiyan (UCA) Programme for 12th Five Year Plan Period

SL. NO.	YEAR	PHYSICAL TARGETS		
		FAMILY TYPE OR HOUSEHOLD COOK STOVES#	COMMUNITY SIZE COOK STOVE	
			DHABAS/CANTEEN, INDUSTRY	ANGANWADIS/ ICDS/ MDM/TRIBAL HOSTELS/FOREST REST HOUSES, ETC.
1	2012-13	Nil	Nil	Nil
2	2013-14	100,000	5,000	5,000
3	2014-15	750,000	25,000	75,000
4	2015-16	750,000	40,000	75,000
5	2016-17	800,000	50,000	75,000
Total		**2,400,000**	**120,000**	**230,000**

 # The total numbers also include earthen cook stoves. The breakup of target between earthen and family type portable cook stoves will be done by MNRE on the basis of demand for each type and availability.

The Ministry of New and Renewable Energy, Government of India action plan for the New Initiative for Development and Deployment of Improved Cook stoves has concluded that the new cook stove programme must incorporate lessons learned from the successes and failures of past and on-going dissemination programmes. The key elements of an effective cook stove initiative have to include technology research and development, performance standards, demand generation, mass production and distribution channels, selection and training of retailers, financing, user education, cook stove servicing, and evaluation. In order to penetrate the hard to reach rural markets as much as possible, opportunities for collaborations to take advantage of existing dissemination networks should be explored. With these factors taken into consideration, the initiative of disseminating the improved cook stoves can be effectively implemented, even in remote rural areas.

8

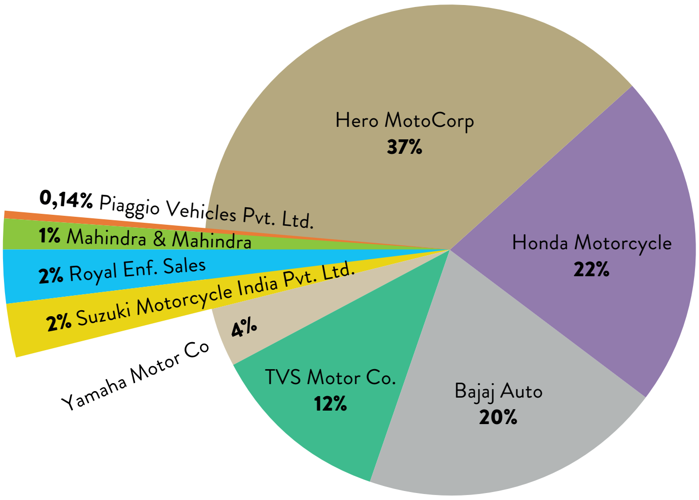
TECHNOLOGY SHIFTING FROM 2-STROKE TO 4-STROKE ENGINES IN TWO-WHEELERS IN INDIA

Amit Garg
Bhushan Kankal

8.1 INTRODUCTION

Two-wheelers have been a very important mode for transportation in India. Almost 75% of the vehicles sold comprise of scooters, motorcycles and mopeds. Traditionally, the motorcycle market has been the biggest segment of the two-wheeler market. Hero MotoCorp, Honda Motorcycles, Bajaj Automobiles Ltd and TVS Motor Company are the major players of the two-wheeler industry, collectively occupying 91% of the market share (Figure 15).

FIGURE 15: Company wise market share in 2-wheeler industry in 2014



Source: CAPITALINE, 2015

These companies produce motorcycles (73.5%), scooters/ scooterettes (22.6%) and mopeds (3.8%) for the two-wheeler market. The two-wheeler engines are either four-stroke engines or two-stroke engines. In two-stroke engines, the lubricating oil is mixed with the fuel itself. The advantages of this technology are low cost, excellent torque and power, mechanical simplicity, lighter and smaller engines, greater operating smoothness and lower nitrogen oxide emissions. However, it has higher particulate matter (PM) and hydrocarbon (HC) emissions, lower fuel economy and high noise levels.

8.2 WHY THE POLICY WAS INITIATED

During the 1990s, the number of two- and three-wheelers increased substantially in India, worsening the air quality in Indian cities. Approximately 94% of the two- and three-wheelers in the country were powered by two-stroke engines in the 1990s. The conventionally designed two-stroke engines combust fuel more inefficiently than their four-stroke counterparts. The average mileage of two-stroke engines was approximately 30% lower than four-stroke engines (Table 15). They also have higher levels of hydrocarbons in exhaust emissions i.e. 5,500 parts per million (ppm), compared to 850 ppm for four-stroke engines (Table 16). The policy to convert all two-stroke two-wheelers into four-stroke two-wheelers was, therefore, initiated to control local air pollution, with energy saving as a co-benefit.

TABLE 15: Energy consumption for 2-stroke and 4-stroke engines

MODE	TECHNOLOGY	VINTAGE[e]	MILEAGE[f] (KM/L)
Scooter	2-Stroke	>15 years old	35.37
		10-15 year	36.63
		5-10 year	37.84
		<5 years old	38.57
	4-Stroke	>15 years old	30
		10-15 year	35.36
		5-10 year	41.93
		<5 years old	44.66
Motorcycle	2-Stroke	>15 years old	55
		10-15 year	33
		5-10 year	58.33
		<5 years old	-
	4-Stroke	>15 years old	53.33
		10-15 year	45.7
		5-10 year	52.24
		<5 years old	53.36

Source: Agrawal and Jain, 2014

TABLE 16:
Emissions from 2-stroke engines

TWO- AND FOUR-STROKE ENGINE EMISSIONS (AS PERCENTAGE OF TOTAL EMISSION)		
POLLUTANT	2-STROKE	4-STROKE
Carbon monoxide	3	3.4
Hydrocarbon (hexane)	0.55	0.085
Nitrogen oxides	0.015	0.1

Source: DtE, 1993

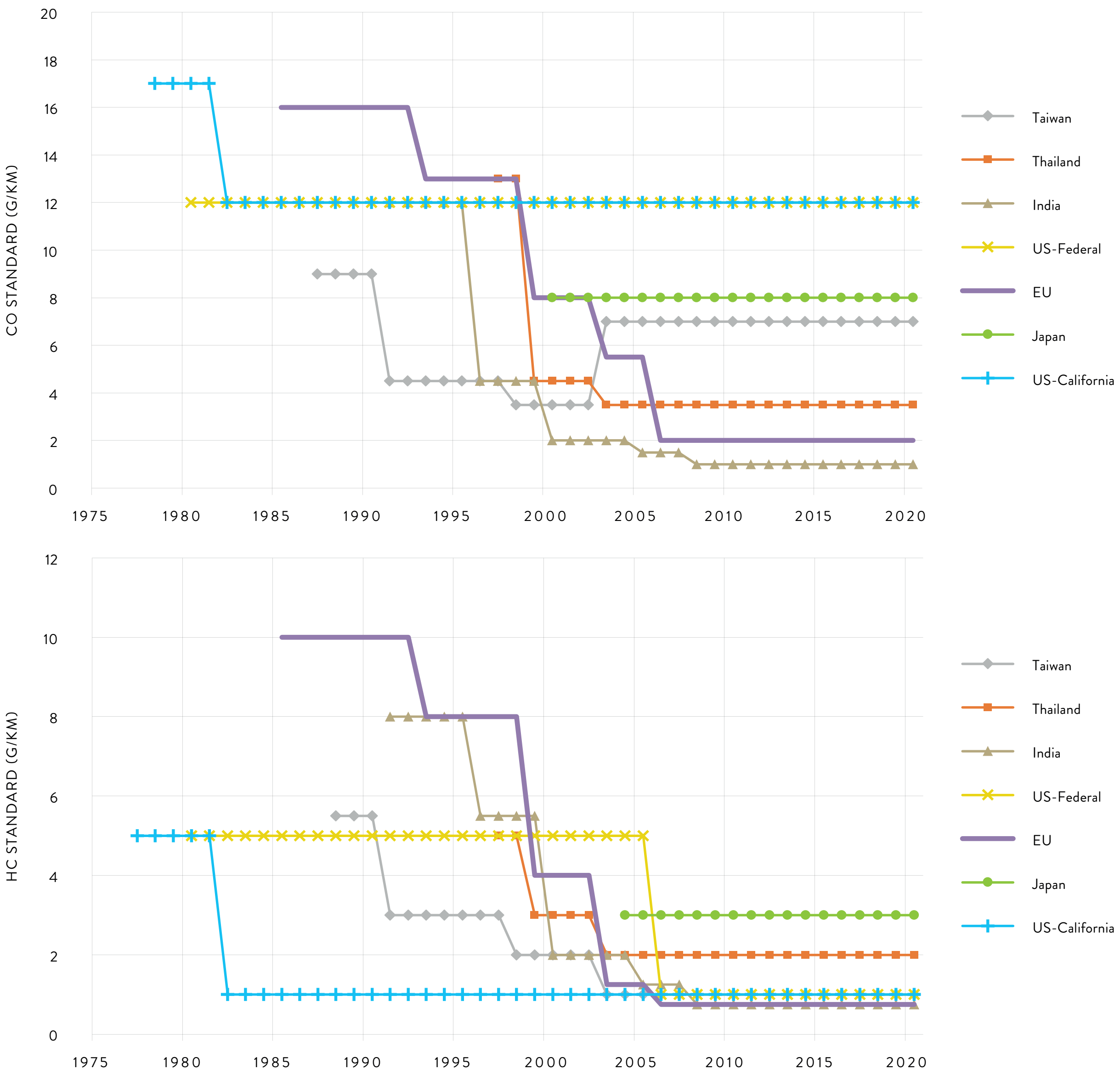
Another factor contributing to the worsening air quality was growth of four-wheeler vehicles, which mainly run on diesel or gasoline.

8.3 WHAT WAS DONE

The shift from two-stroke to four-stroke technology was mainly a result of judicial interventions to combat air pollution. In July 1998 the Supreme Court of India mandated several measures affecting two- and three-wheelers in Delhi (GTZ, 2009). These included measures that were directed towards reducing emissions from on-road two-stroke vehicles, removing older vehicles, and putting down emissions regulations for vehicles.

1. Banning the sale of loose 2T oils at filling stations and service garages, effective December 1998.
2. Improving specifications of 2T oil for two-stroke engines with respect to smoke throughout the country, effective April 1999.
3. Mandating that filling stations mechanically meter lubricant to be mixed with gasoline at the point of gasoline sale for two-stroke engine vehicles, effective December 1998.
4. Mandating the replacement of all pre-1990 autos and taxis with new vehicles using clean fuels, effective March 2000.
5. Introducing financial incentives for replacing all pre-1990 automobiles and taxis with new vehicles using clean fuels, effective March 2001.
6. Introducing more stringent emission norms (standards) for two-stroke engine two-wheelers and three-wheelers (Figure 16). After April 1996, production had to stop on two-stroke engines not meeting the norms. The emission standards and roadmap for the future was finally put in place within the Autofuel policy.

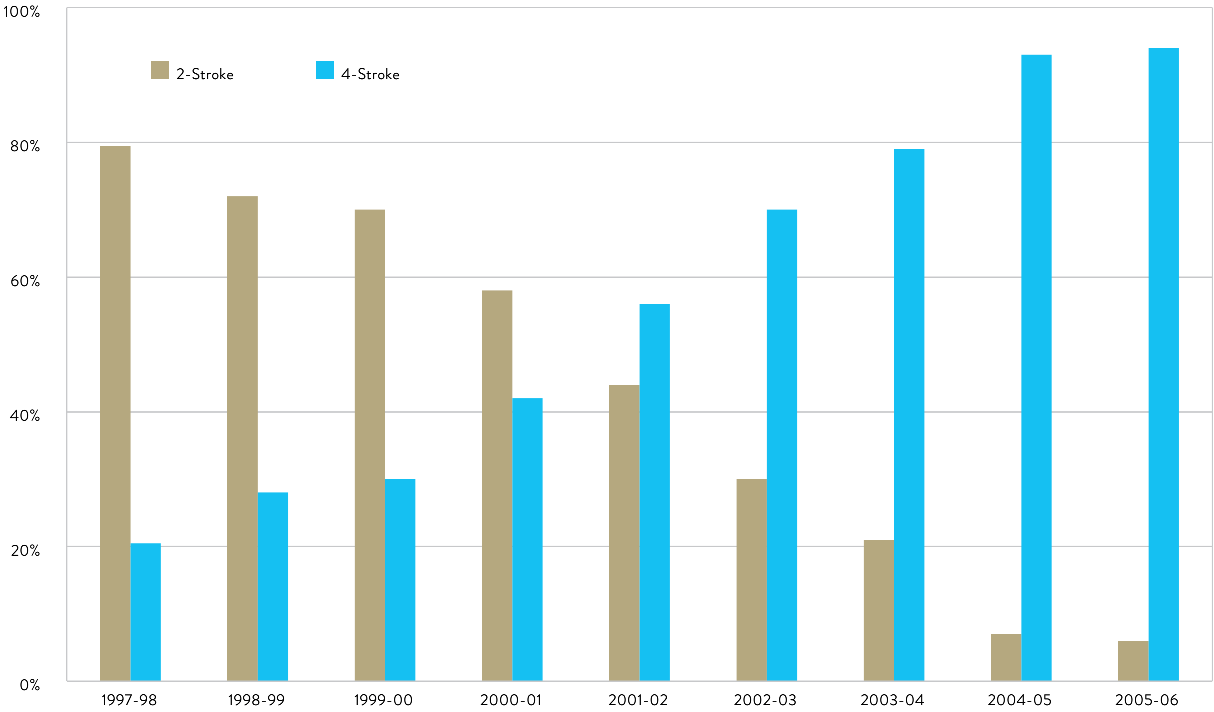
FIGURE 16: Change in CO and HC emission standards for 100cc 2-Stroke motorcycles (2-wheelers) in India



Source: ICCT, 2007

Several technologies are available to reduce emissions from two-stroke two-wheelers. These include: (1) catalytic converters for both two- and four-stroke two-wheelers, (2) direct injection technology for two-stroke two-wheelers, (3) the replacement of two-stroke with four-stroke technology, and (4) fuel-injection technology for four-stroke motorcycles (Iyer, 2012). The Indian two-wheeler industry responded to the emission standards by using catalytic converters and introducing more four-stroke vehicles, resulting in the share of two-stroke engines declining from 80% in 1997-98 (Figure 17) to 3.8% in 2014 (CAPITALINE, 2015).

FIGURE 17: Progressively increasing proportion of 4-stroke 2-wheelers in India

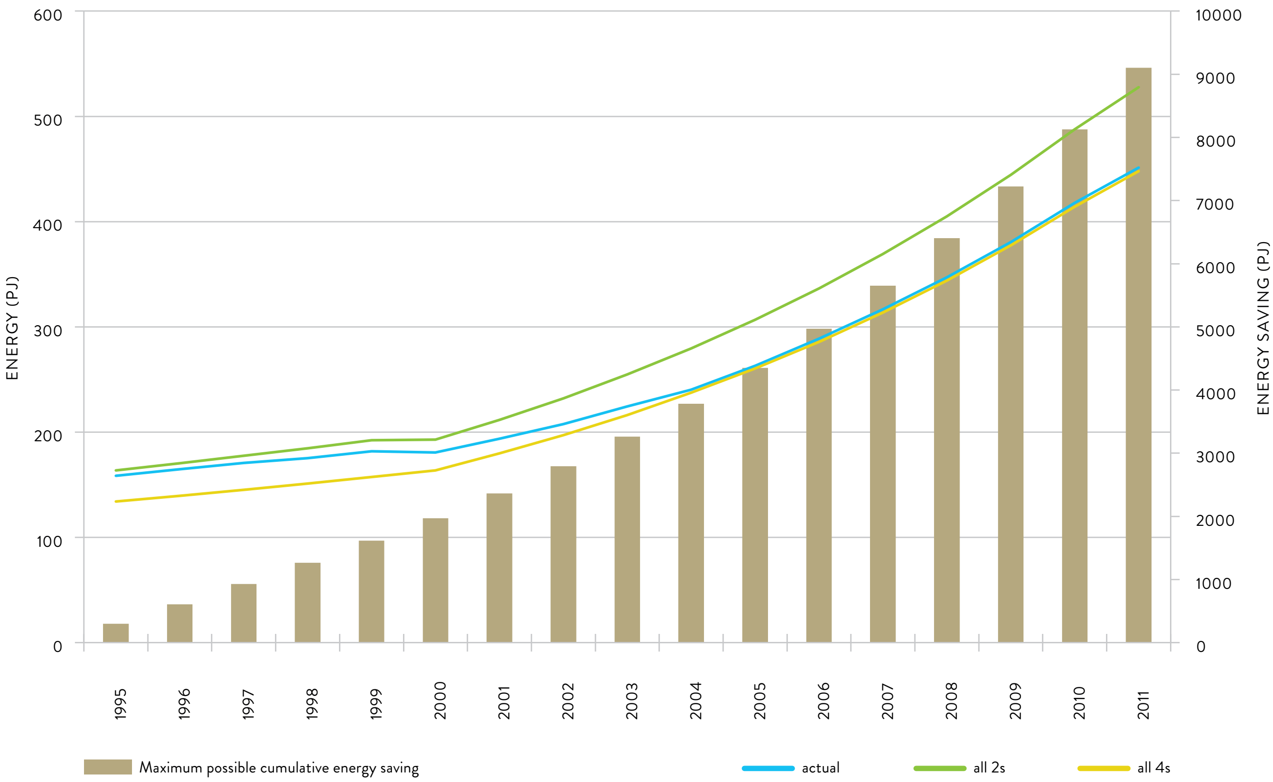


Source: GTZ, 2009

8.4 EFFECTS OF THE POLICY/PROGRAMME

Two-stroke engines have higher fuel consumption (Table 15), higher emissions of HC and PM, but lower emissions of NOx, and similar emissions of CO. Higher fuel consumption translates into increased carbon emissions and, ultimately, increased GHG emissions. A major shift from two-stroke to four-stroke engines was witnessed due to stricter emission norms. Figure 18 provides annual energy consumptions based on the actual mix of two- and four-stroke technologies, and the cumulative savings if this transition had not taken place. Here, the assumption is that none of the vehicles sold were retired.

FIGURE 18: **Energy consumption if all 2-wheelers were 2-stroke, 4-stroke, and actual pattern**



Source: compiled from SIAM (2001, 2006 and 2011), Singh (2006) and Reddy and Balachandra (2010)

8.5 CHALLENGES EXPERIENCED

The phasing out of two-stroke two-wheeler vehicles was brought about mainly by the auto fuel policy of the Government of India, which laid down a roadmap for emission norms. However, bringing in this policy had been a major challenge. The producers were opposed since they had to change the production process, while having to provide maintenance for two-stroke vehicles in the market for some years - a sizable stock exits even now. The oil companies opposed the policy since they had to make changes within the refineries to supply cleaner fuels. The policy also needed to create a market wherein consumers were willing to pay a higher price for four-stroke two-wheelers. It should be noted here that there was no ban on using two-stroke two-wheelers, but there was a ban on selling new two-stroke two-wheelers. Therefore, no separate monitoring system was established to check vehicles on the road. Each vehicle had to undergo a pollution check to receive a PUC (Pollution Under Control) certificate which is technology agnostic. The emission standards for various pollutants coming out into the atmosphere are tightened regularly.

8.6 REPLICABILITY AND SCALING UP POTENTIAL

The policy has already been implemented nationwide in India. The main producers of four-stroke two-wheelers are Bajaj Auto Limited, Suzuki Motorcycle India Pvt. Ltd., Hero MotoCorp, Mahindra & Mahindra, TVS Motor Co., Piaggio Vehicles Pvt. Ltd., Honda Motorcycle, Yamaha Motor Co., etc. They also export to neighbouring countries like Bangladesh, Nepal, Pakistan and Sri Lanka, indicating that the effects of this success story are also being felt in other parts of the world.

9

VILLAGE LEVEL BIOGAS PLANT AND GOBAR BANK IN GUJARAT

Amit Garg
Bhushan Kankal

9.1 INTRODUCTION

India's overall energy production is considerably less than its overall energy consumption. The country's energy demand is increasing, and its inability to step up production to meet demand has increased India's reliance on costly imports. The gap between consumption and production is projected to widen into the next century, as demand for energy is expected to grow at an annual rate of around 5% - one of the highest in the world. In an attempt to stem the projected deficit between production and consumption, particularly for the rural sector, the government is pursuing alternative measures of energy provision. Renewable energy potential is high on the subcontinent (Nasery, 2011).

The Government of India started the National Project on Biogas Development (NPBD) of the Ministry of Non-Conventional Energy Sources (MNES) in 1981-82 for the promotion of family type biogas plants, the current potential of which is estimated at 12 million plants, to provide clean alternate fuel to the rural masses, and enriched organic manure for agriculture. The implicit objective of the programme is to reduce the use of non-renewable fuels and fuel wood (Planning Commission, 2002). The programme was renamed the National Biogas and Manure Management Programme (NBMMP) in 2003-04, which enables the setting up of Family Type Biogas Plants mainly for rural and semi-urban households (MNRE, 2016). A family type biogas plant generates biogas from organic substances, such as cattle dung, and other biodegradable materials such as biomass from farms, gardens, kitchens and night soil wastes, etc. The scheme has been undergoing regular revisions. The current objectives of the scheme are as follows:

1. To provide clean gaseous fuel, mainly for cooking purposes, and organic manure to rural and semi-urban households through family type biogas plants;
2. To mitigate drudgery of rural women, reduce pressure on forests, and accentuate social benefits;
3. To improve sanitation in villages by linking sanitary toilets with biogas plants;
4. To provide bio digested slurry (liquid/semi-solid and dried) as an upgraded source of enrichment for manure to reduce and/or supplement use of chemical fertilisers, by linking biogas digested slurry with enrichment units such as wormy-composting plants and other organic enrichment facilities of slurry;
5. To meet 'lifeline energy' needs for cooking as envisaged in the "Integrated Energy Policy" report of the Planning Commission;
6. To help combat and reduce causes of climate change by preventing emissions of carbon dioxide and methane into the atmosphere.

The government provided financial support ranging from INR 1,200 to 15,000 (USD 17.9-223.9) for a 1 cubic meter plant, and from INR 1,200 to17,000 (USD 17.9-253.7) for a 2-6 m^3 plant. In addition, technical support for installation of these plants was also provided, and as a result half a million plants have been installed so far across India (MNRE, 2015). However, one of the major drawbacks has been lack of maintenance and, therefore, survival of active biogas plants. Biogas is produced by bacteria, which are living organisms. Thus, they must be fed regularly, the temperature has to be maintained in a predefined range, and the feed has to be mixed well. If the plant becomes non-operational, the process has to be started again. Consequently, the lack of maintenance support has made many of these plants non-operational.

The easy availability of dung, and need for a cleaner fuel has resulted in some innovative solutions across India that have tried to go beyond the mandate of NBMMP. A case study for the village of Bhintbudrak of Tapi district in Gujarat, India is presented. This village is one of the richest in dairy products, and almost each family has up to six buffalos (SDP, 2015). With the high availability of dung in this village, Surat Milk Union Limited (SUMUL) dairy started a community biogas plant, with a network of pipeline grid through the village, supplying cooking biogas to the village. The slurry output from the plant was vermin-composted to produce organic fertiliser, and sold. Villagers received cooking gas for two hours in the morning and two hours in the evening (Jadhav and Rao, 2014). The sale of the organic fertiliser made the whole process economically feasible.

9.2 WHY THE PROGRAMME WAS INTRODUCED AND IMPLEMENTED

The idea of the biogas plant was brought about in order to have a proper disposal system for the cow dung. Before the establishment of the biogas plant, the dung was collected from households, streets and empty spaces. This dung was sold to an external contractor, who would only collect it once a year, which resulted in dung being piled up in large quantities. This was an unhygienic practice and raised health concerns. The health hazard was further emphasised by a subsequent outbreak of bird flu in Navapur. Thus, these public health and sanitation issues were the main contributing factors for the construction and smooth functioning of the plant.

9.3 WHAT WAS DONE

The institutional involvement for developing this plant was provided by SUMUL dairy. Although the health hazards of mismanaged cow dung, and the array of benefits from the biogas plant was intuitive to the villagers, it had to been reinforced by someone who had knowledge, authority and power (Nasery, 2011).

After collecting all the information related to the concept of cattle dung-based biogas production and distribution in Bhintbudrak village, several programmes, mentioned below, were conducted:

- Awareness programme for the active leaders of the village;
- Awareness programme for all animal rearing family;
- Key objectives of the project;
- Role and responsibility of the villagers and structure formation for successful implementation of the project;
- Merits and demerits of the project.

After a detailed study, the construction of a biogas plant of 300 m^3 per day capacity was decided (Detailed Technical Parameters in Table 17). It was designed to supply biogas to households, with an additional facility for enrichment and bottling of biogas. The bottled gas was for running tractors. The cost parameters for the plant are as follows (Vijay, 2015):

- Capital cost: INR 2,800,000 (USD 70,000)
- Operational cost: INR 1,500,000 (USD 37,000)
  - Fixed operational cost: INR 300,000 per annum (USD 7,500)
  - Annual running cost: INR 1,200,000 per annum (USD 30,000)
- Annual income generated by selling biogas and slurry = INR 2,200,000/- (USD 55,000)
- Operating profit = INR 700,000 (USD 17,500)

FIGURE 19: Community Biogas Plant at Bhintbudrak Village at Surat, Gujarat

TABLE 17: Overview of the plant

SR. NO.	PARAMETER	DESCRIPTION
1	Ownership	Village Co-operative Society
2	Number of beneficiaries	121
3	Operational since	2004
4	Feedstock	Cattle dung
5	Capacity	4000-4500 kg per day
6	Size of digester	2*85 m^3
7	Digester type	Floating dome
8	Auxiliary systems	Mechanised mixing of dung and water, pressure regulating tank, network of pipes for distribution, water supply from nearby tank, emergency diesel generator, vermin compost sheds
9	Input rate	3.5 tonnes per day
10	Water	1:1
11	Slurry	Vermi compost made out of a fraction of total output slurry of 2.5 tonnes per day
12	Gas supply	Underground pipes from the plant to the beneficiaries
13	Gas availability	2 hours each in the morning & the evening

9.4 EFFECTS OF THE POLICY/PROGRAMME

The reduction in GHG happens due to the conversion of methane (CH_4) into cooking fuel. Further, this clean fuel helps in the prevention of deforestation for firewood. It is estimated that the plant can generate carbon credits worth INR 266,000 (USD 3,900) annually, at around USD 10 per tonne CO_2 (Nasery, 2011).

9.5 CHALLENGES EXPERIENCED

The major challenges experienced during the project were:

1. Community participation in dung collection and storage, since the residents of some religion would not collect cow dung or want dung slurry around their house premises;
2. Siting of the plant and storage of dung was a concern since no one wants to have it around their home;
3. Laying out the pipeline since it should not go beneath houses;
4. The plant is in a rural area and the electricity needed to run the plant is not available 24 hours;
5. Many households have been using LPG for cooking, however, the burners need modification for the biogas;
6. Lack of technical capacity for running the plant in the village, e.g. to ensure a proper dung mix for plant;
7. Economic challenge was faced at the plant and, therefore, it became funded 80% by government, 10% by entrepreneurs and 10% by villagers. The plant was allowed to sell voluntary carbon credits.

9.6 REPLICABILITY AND SCALING UP POTENTIAL

Since it is a community-based programme, it can be replicated at places where there are proper dung collection and community participation. Anand Milk Union Limited (AMUL) has decided to implement this concept in 50 more villages under its co-operative network. The tribal development department of Gujrat has also followed AMUL and plans to establish 20 such plants. The business model of the project links input and output products. The input (dung) is provided by the farmers, while the output (biogas and slurry compost) is provided by the plant operator to the farmers. The pricing mechanism ensures that if farmers increase the price of their dung, the price of biogas supplied to them would proportionately increase. The business model, therefore, always stays in a stable equilibrium.

The present central government has initiated programmes that could be linked to such Gobar Bank projects. These include: Clean India Mission, Biogas Mission, Saansad Adarsh Gram Yojna (SAGY) for 950-odd Indian parliamentarians to adopt one village each, as a model village, and India's National Sanitation and Hygiene Programme for Rural India.

10 EFFICIENCY ENHANCEMENT IN THE BUILDING SECTOR

Saurabh Kumar
Pankaj Mohan
Saket Shukla

10.1 INTRODUCTION

The last couple of decades have seen a significant increase in the share of the services sector in the Indian economy. Consequently, demand for office space in India has also seen astronomical growth. What started in metropolitan cities, and in Central Business Districts, has now expanded into the suburbs of metropolitan, as well as to tier-II and tier-III, cities in India. Modern office buildings in newly developed areas enable higher quality standards of working conditions that are essential for sectors like Information Technology, financial services, etc. from the point of view of attracting customers and employees. However, the energy performance index (EPI) of such spaces ranges from 200 to 400 kWh/m²/year, whereas similar buildings in developed nations have an EPI of less than 150 kWh/ m²/year.

The encouraging aspect, however, has been the importance attached to energy efficiency by the government, corporate and individual consumers. Apart from an urge to develop a sustainable environment, the need to reduce cost of energy has also been a motivator for various stakeholders in this direction. This is true for both buildings and appliances.

The BEE has developed an Energy Conservation Building Code (ECBC) that enables new commercial buildings to reduce their energy use. The Energy Conservation Act 2001 gives the power to central and state governments to mandate this. Efforts are being made to encourage states to make reductions mandatory for any new commercial construction, and to have them significantly enhanced.

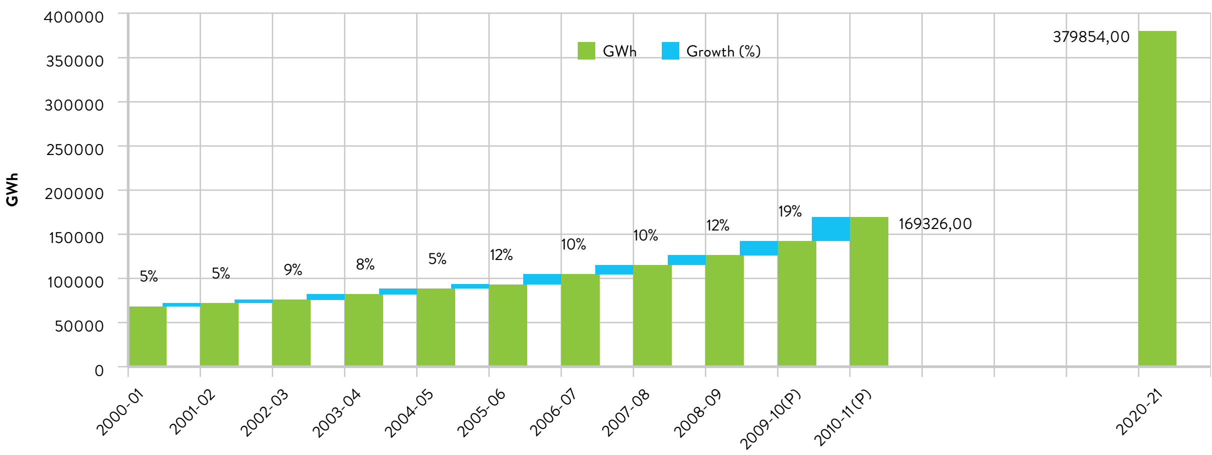
10.2 WHY IT WAS INITIATED

Buildings account for over one third of India's total electricity consumption, which is mainly in the residential and commercial sectors. Energy consumption in the building sector is function of the type of construction, usage pattern, the climatic region and the energy consuming devices installed in the buildings. Different types of energy end-use in buildings such as lighting, space heating, space cooling, plug-in loads and appliances all account for the overall energy consumption pattern of the building. Energy consumption is not only dependent on the type of end-use appliances but also on the operational efficiency and maintenance of these end-use appliances. Building design and material can have a significant impact on the energy consumption levels of a particular end-use application. For instance, the overall energy consumption pattern of a typical home depends heavily on appliance efficiency. In a commercial building, the overall energy consumption of the building is significantly affected by the design and selection of the building material and glazing, along with the choice of appliances and HVAC systems.

ELECTRICITY CONSUMPTION IN RESIDENTIAL SECTOR:

The residential sector consumes 24% of the total electricity consumption of India. As per estimates, electricity consumption of the residential sector may increase by more than two times by 2021 (Figure 20). In this sector, lighting and cooling requirements take up 75% of the total electricity consumption (Figure 21). These requirements are project to grow by 260% by 2021 (Figure 22).

FIGURE 20: Annual growth in electricity consumption by residential sector



Source: World Bank, 2008

FIGURE 21:
Electricity consumption pattern in residential buildings

Source: Planning Commission, 2015

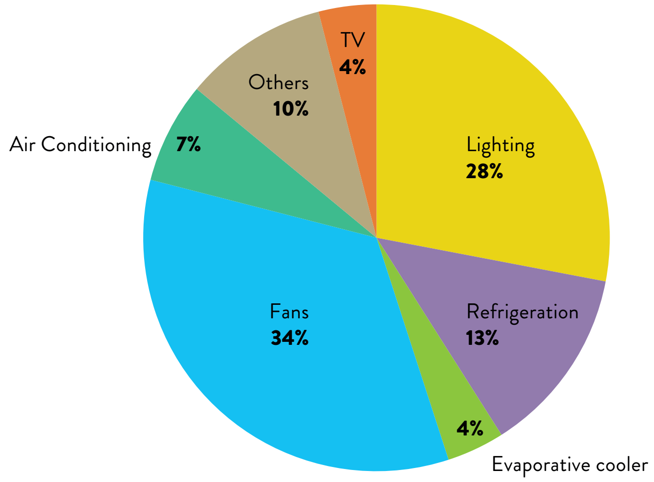
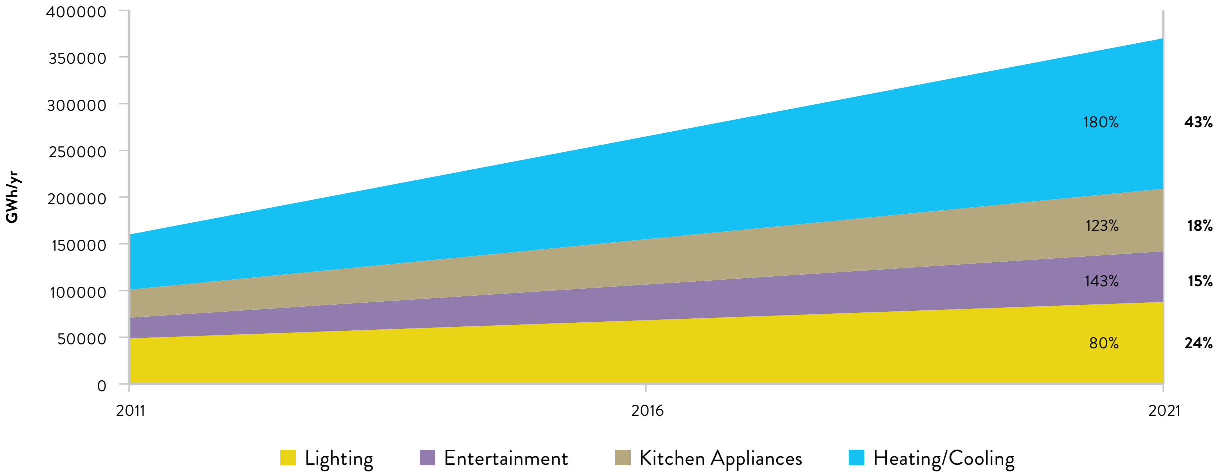


FIGURE 22: Projected growth in electricity consumption by appliances in residential sector



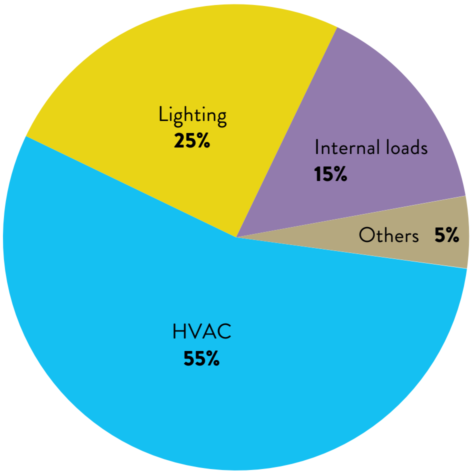
Source: World Bank, 2008

A study on greenhouse gas emissions from electricity use in buildings in urban India by TERI estimates that a mandatory phasing out of conventional appliance coupled with mandatory use of star labelled appliances - such as fans, tube lights, air conditioners and compact fluorescent lamps, in order of priority and cost effectiveness by 2020 will help avoid up to 51% of emissions from this sector alone. Further savings can be achieved by focusing on more efficient design strategies, daylight integration and low-energy cooling strategies.

ELECTRICITY CONSUMPTION IN COMMERCIAL SECTOR:

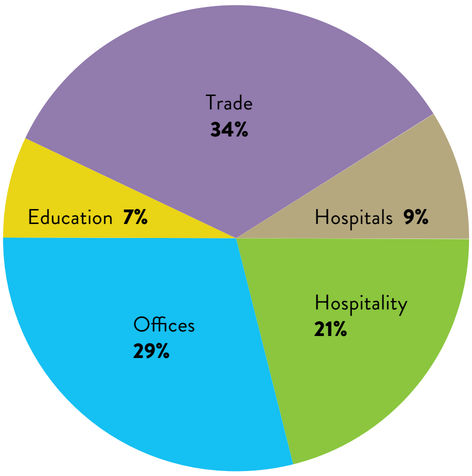
It is estimated that 70% of the commercial sector has yet to be built, given the fast urbanisation trends of the country. The sector is witnessing a high annual growth rate in electricity consumption. Almost 55% of energy consumption in the commercial sector is due to heating, ventilation and air conditioning (HVAC) (Figure 23). Trade and hospitals are the major consumers of electricity in commercial buildings (Figure 24), accounting for more than 50% of total electricity consumption in the building sector. The HVAC market has increased from USD 843 million in 2005-06 to USD 1.53 billion in 2008-09 – nearly double in four years.

FIGURE 23: Energy consumption distribution in commercial buildings



Source: Planning Commission, 2015

FIGURE 24: Contribution of different categories of commercial buildings to electricity consumption in 2010-11



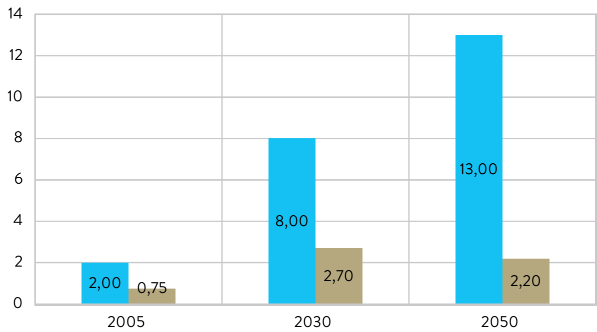
Source: TERI, 2015

Although the use of energy-consuming appliances is increasing, energy consumption due to building envelope characteristics is expected to remain a significant element in total energy consumption. The building envelope, which consists of external walls, fenestration and roofs, plays a major role in making buildings comfortable -- both thermally and visually. When a building does not meet comfort criteria, occupants rely on mechanical and electrical comfort and lighting systems. Reliance on energy driven systems can only be reduced when the building envelope responds favourably to the local climatic context.

A scenario analysis, commissioned by Global Buildings Performance Network (GBPN) and produced by the Centre for Climate Change and Sustainable Energy Policy (3CSEP) of the Central European University (CEU), estimates that India could easily experience an increase in building energy consumption and CO_2 emissions of around 700% by 2050, compared to 2005 levels.

India's constructed floor area is projected to increase by around five times, from 2005 to 2030, or more than 400% by 2030. By 2050, 85% of floor space use will be residential, while 15% will be of commercial purposes (GBPN, 2014).

FIGURE 25: India's moderate efficiency scenario projected energy consumption of India's buildings in 2030 and 2050; percentages represent the ratio of residential and commercial buildings



Source: GBPN (2014)

India has begun the gradual introduction of energy efficiency solutions in the building sector. In 2001, the Indian Government introduced the Energy Conservation Act. As an outcome of this act, a first generation building code, the Energy Conservation Building Code (ECBC), came into effect in 2007. Currently, ECBC applies to buildings that have a connected load greater than 100 kW, or contract demand greater than 120 kVA. In practice, ECBC requirements are generally only applied to buildings with air-conditioned floor areas of over 1000 m^2.

In principle, the ECBC also applies to large residential complexes, when their connected load or contract demand exceeds the thresholds. However, the current national policy priority is to enforce the code at the state level for large commercial buildings only. The Bureau of Energy Efficiency introduced the Energy Conservation Building Code (ECBC), with effective adoption and enforcement, as commercial energy use is predicted to grow from 0.656 EJ in 2005 to 2.648 EJ in 2030.

10.3 WHAT WAS DONE

There are a number of measures such as building codes, policy interventions, labelling/rating systems, appliance standards, etc. to streamline efforts to promote energy efficiency in the buildings sector. Building rating systems are a popular tool to add momentum in achieving energy efficiency in buildings. These help in assessing the level of performance of the building, and provide opportunities in reducing the O&M costs of the building, in addition to creating a market pull towards environmentally sustainable buildings. Most green rating programmes are based on design intent and do not rate the energy performance of existing buildings through a systematic evaluation process.

In order to enable rapid transformation towards energy efficiency in buildings, policies and measures that create a "supply push" (such as codes and standards) need to be supplemented by policies and measures that simultaneously create a "demand pull" as well. This "demand pull" attracts building users to energy efficient buildings, thus creating a preferential market demand. On the "supply push" side, the ECBC is currently a voluntary programme with a number of states adopting it as a mandatory requirement. Furthermore, both LEED (Leadership in Energy and Environment Design) and GRIHA (Green Rating for Integrated Habitat Assessment) rating systems have adopted ECBC as a minimum compliance requirement.

ECBC enables new commercial buildings to reduce their energy use. The Energy Conservation Act gives the power to central and state governments to mandate this. Efforts are being made to encourage states to do the same, and this needs to be significantly enhanced. A combination of regulatory push and market pull need to be structured, as suggested below.

IMPLEMENTATION METHODOLOGY:

a. Mandating ECBC for commercial buildings: All new commercial buildings need to have energy performance based on ECBC standards within a specified time period. The Ministry of Power / Ministry of Urban Development and BEE decide on the timeframe, in consultation with states. Similar energy efficient guidelines/designs for large housing colonies also need to be evolved.

b. Excellence in Design for Greater Efficiencies (EDGE) Building certification/labelling: A system of certification and labelling of EDGE buildings need to be developed based on energy performance standards set by ECBC. BEE could develop these certificates and labels to be granted to commercial buildings.

c. Financial incentives for EDGE buildings: Developers of EDGE certified/labelled buildings may be given interest subsidies through financial institutions. A small pilot project is under implementation by the National Housing Bank (NHB) through a bilateral line of credit. This needs to be scaled up.

d. Other incentives: In order to create a market pull, EDGE certified/labelled buildings could be given a discount in electricity tariff by the state electricity regulatory commissions (SERCs), discounts in registration fee by states, etc.

e. Monitoring and verification: BEE will undertake, with State Designated Agencies (SDAs), periodic monitoring and verification of energy performance of EDGE buildings. This could be done by evolving transparent protocols and processes.

This programme rates office buildings in terms of specific energy usage in kWh/m^2/year on a 1-5 star scale, with 5 star labelled buildings being the most efficient. The scheme is in use on a voluntary basis, and labels provided under it are applicable for a period of five years from the date of issue. The star-rating programme provides public recognition to energy efficient buildings, and creates a "demand side" pull for such buildings. Various categories of buildings, such as office buildings (day use and BPOs), shopping malls, hotels, hospitals and IT parks in the five climatic zones, have been identified under the scheme.

Additionally, energy audits were carried out in the buildings mentioned above. This resulted in the implementation of energy efficiency measures suggested by certified energy auditors.

10.4 EFFECTS OF THE POLICY/PROGRAMME

Energy-conscious building designs have been shown to reduce EPI to 180 kWh/m²/year (Indian benchmark) and are considered ECBC compliant, which means buildings that meet the code are considered energy efficient. Some examples are mentioned below in Table 18.

TABLE 18: Energy efficiency measures in various sectors

S. NO.	SECTORS	SUCCESS STORY	COST SAVING/ANNUM	ENERGY SAVING IN KWH/ANNUM	PAYBACK PERIOD (YEARS)
1)	Commercial Building				
a)	Hospitals	Regional Cancer Centre, Thiruvananthapuram	USD 61.57 thousand/ annum	0.87 million kWh/ annum	1.4
		Government Medical College Hospital, Kozhikode	USD 48.16 thousand/ annum	0.64 million kWh/ annum	1
b)	Office Building	Vikas Bhawan, Thiruvananthapuram	USD 16.67 thousand / annum	0.14 million kWh/annum	1.6
c)	Hotels	Mascot Hotel, Thiruvananthpuram	USD 37.51 thousand/ annum	0.19 million kWh/annum	2
d)	Govt. Building & Municipal Offices	Yojna Bhawan	USD 75.25 thousand/ annum	0.06 million kWh/ annum	1.6

Source: EMC, 2010

The GHG emission reductions resulting from the examples of the five buildings mentioned in Table 18 is 1.55 MtCO2 per annum.

10.5 CHALLENGES EXPERIENCED

Although the savings potential of each option may vary with building typology, climate zone, space conditioning needs and the initial base design proposed by the client/designer, on average it is estimated that the implementation of energy efficient options would help achieve around 30% electricity savings in new residential buildings and 40% savings in new commercial buildings (TERI, 2015). The biggest challenge India faces is achieving the net zero energy building target for new construction -- for existing buildings it is more far-fetched. An empirical study carried out for a typical daytime office building using best available technology for four climatic zones of the country shows that the best performance case gives an Environmental Performance Index (EPI) of nearly 50 and a height of 12 floors.

The major challenge is making the ECBC codes mandatory for new constructions in all states and union territories (UTs) of the country. To date, only seven states have made ECBC norms mandatory in the country. Also, the challenge is in the retrofitting of energy efficient appliances and in creating norms for the retrofitting of buildings. At present, there are no norms for the retrofitting of buildings. There are several other barriers that slow down the process. Stakeholders, such as architects, developers, and state and local governments, lack awareness of building energy efficiency and do not have enough capacity and resources to implement ECBC. Most jurisdictions have not yet established effective legal mechanisms for implementing ECBC; specifically, the ECBC is not included in local building by-laws in most jurisdictions or incorporated into the building permitting process. There is no systematic approach to measuring and verifying compliance and energy savings, and thus the market does not have enough confidence in ECBC.

Energy efficient buildings require a higher investment of INR 29,500 (USD 428) per square metre, as compared to INR 19,000 (USD 276) per square metre for a non-energy efficient building, but offer substantial savings in energy consumption. For a 10,000 square metre hotel with a life expectancy of 30 years, an energy efficient building will consume 300 kWh/m^2 as compared to a non-energy efficient building that will need 500 kWh/m^2 of energy. The net present value is calculated to be positive at INR 8.1 million (USD 0.12 million), with an electricity tariff rate of INR 6 (USD 0.09)/kWh and a discount rate of 10%.

10.6 REPLICABILITY AND SCALING UP POTENTIAL

In a developing economy like India, improved energy efficiency is a primary goal that could be achieved through promotion of higher performance in buildings. Building rating and verification systems are an effective measure to encourage building owners to go beyond the minimum, and creating an awareness of these systems would add substantial momentum to promote energy efficiency in buildings. The buildings sector is the largest energy consumer of all end-use sectors, accounting for one third of total energy demand. The good practices mentioned above could be replicable in the buildings, which would result in a substantial amount of savings, as well as GHG emission reductions.

EESL has carried out the implementation of energy efficiency measures in many government buildings like Yojna Bhawan and NITI Ayog, and achieved around 20% savings. EESL is also implementing the changes according to the ECBC norms in other buildings. Moreover, EESL has signed a MoU with the Central Public Work Department (CPWD) for 1,000 government buildings for implementation according to ECBC norms; implementation in 18 buildings has already started. This clearly shows that measures implemented earlier in buildings have both replicability and scaling up potential.

11 COAL CESS IN INDIA

Amit Garg
Bhushan Kankal

11.1 INTRODUCTION

The Indian energy system is dominated by coal. Large domestic resources, easy availability, cheaper prices and established path dependencies, have ensured that this dominance would continue for some years to come. However, the worldwide consensus on limiting global warming to 1.5 °C makes future growth of coal for energy difficult. India is keen to reduce its dependence on coal and has announced one of the most ambitious renewable energy programmes in the world, with a target of 175 GW of renewable energy capacity by 2030 (INDC, 2016). The Government of India introduced a Clean Energy Cess on coal in 2010, and the revenues from this are being partly used to give incentives for renewable energy.

The Clean Energy Cess has resulted in substantial amounts of revenue in the last few years (Table 19).

TABLE 19: The total Clean Energy Cess collected during the years

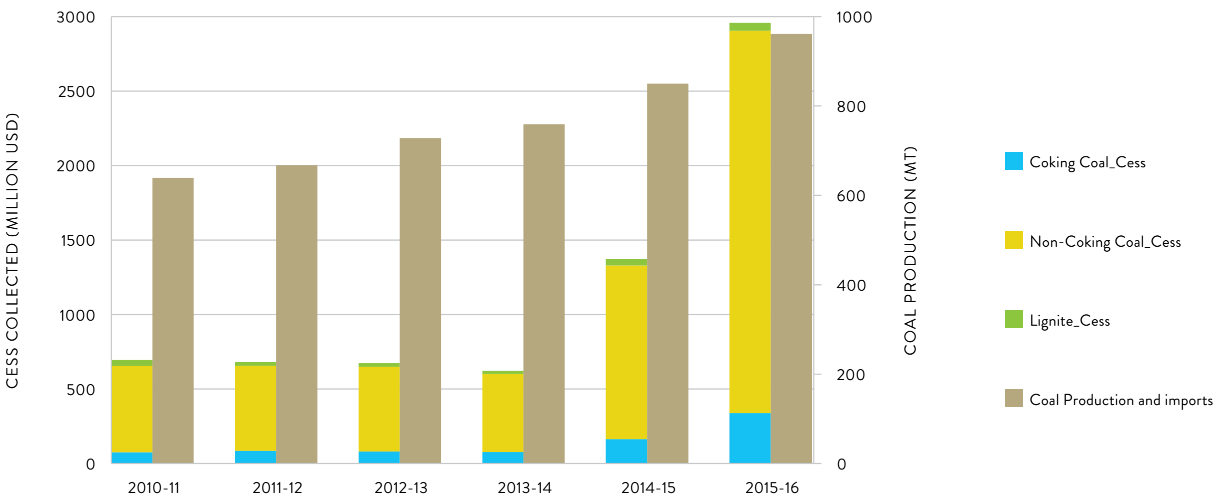
FINANCIAL YEAR	AMOUNT OF CLEAN ENERGY CESS LEVIED/ BILLED ON SALES
2011-12	INR 25.8 billion (USD 386 million)
2012-13	INR 30.5 billion (USD 456 million)
2013-14	INR 35.3 billion(USD 527 million)
2014-15	INR 68.6 billion (Provisional)* (USD 1025 million)

** Source: reply to a parliament question in Lok Sabha (Qn. No. 4314) on 18 December 2014*

1 USD = 67 INR (March 2016)

The amount of coal cess collected in 2015-16 will be approximately USD 2,959 million, since 961 Mt of coal was consumed and the rate was INR 200 (USD 2.99) per tonne. The revenues collected from coal cess have increased sharply (Figure 26) due to the increase in both the rate of cess and the production of coal.

FIGURE 26: Coal grade wise cess collected and coal production & imports



11.2 WHY THE POLICY WAS INTRODUCED AND IMPLEMENTED

The Clean Energy Cess was introduced to promote and finance clean environmental activities, and fund its related research activities. It has also resulted in an implicit price on carbon and, therefore, helps in creating a more level playing field for environmentally cleaner technologies.

11.3 WHAT WAS DONE

Under the Tenth Schedule to the section 83 of the Finance Act, 2010, the Government of India started levying a Clean Energy Cess at the rate of INR 50 (USD 0.75) per tonne of coal (DoR, 2010). This cess is levied on coal, lignite and peat. The funds collected were used under the National Clean Energy Funds (NCEF). In the Union Budget of 2014-15, the scope was also expanded to include financing and promoting clean environmental initiatives and funding research in the area of clean environment. In the Union Budget of 2015-16, cess was raised to INR 200 per tonne of coal (USD 2.99), and further raised to INR 400 per tonne of coal (USD 5.97) in the Union Budget of 2016-17 (Arthapedia, 2016).

11.4 EFFECTS OF THE POLICY/PROGRAMME

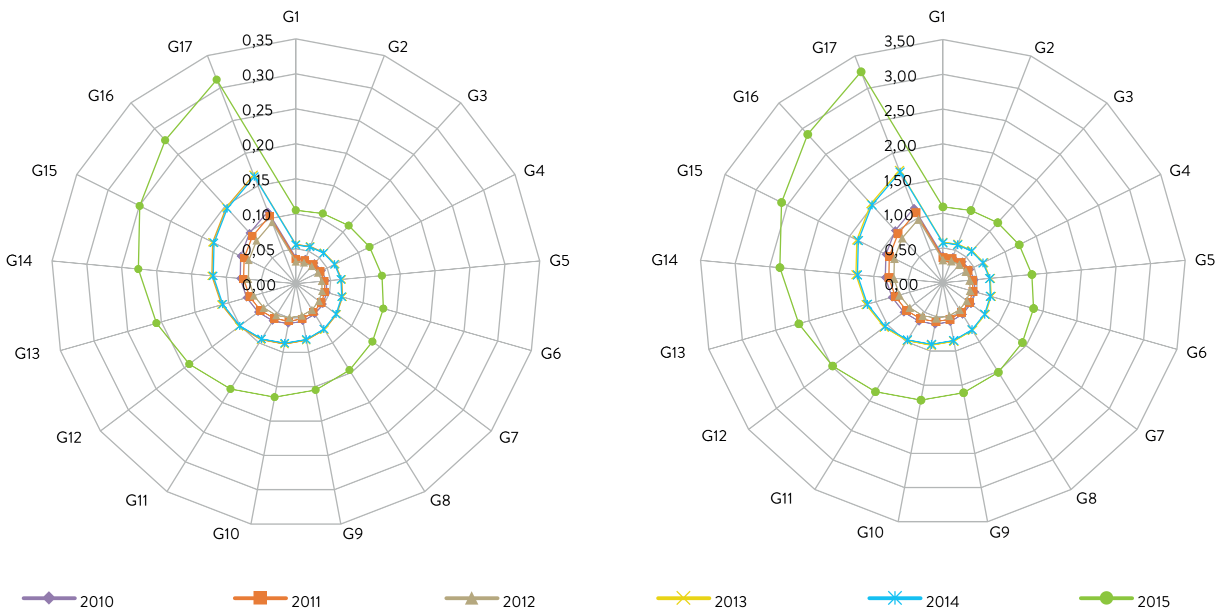
Since coal cess is a fuel tax, an optimum tax level can help control externalities associated with the burning of coal. Theoretically, a fuel tax can reduce demand for coal and thereby reduce energy use and GHG emissions. However, some time would be needed before the impact of these taxes can be evaluated. Therefore, an analysis of the design of this tax is done on the basis of which energy use and GHG emissions are inferred.

The coal cess is applied per tonne of coal from a practical standpoint and not on the basis of energy content. Consequently, tax values are higher per unit of energy for lower grades of coal[1] compared to higher grades. This fact has been further amplified since the tax rates have increased sharply over time. In 2016, the tax per GJ of coal varied from USD 0.32 for lowest grades to USD 0.11 for highest grades of coal (Figure 31). Due to this demand, inferior grades of coal would be affected more than higher grades of coal. Since a large amount of coal available domestically is of an inferior quality, the impact of this tax can be significant on domestic coal demand.

The coal cess is an implicit carbon tax for coal, and is higher for lower grades of coal and lower for higher grades. In 2016, the tax per tCO_2 for coal varied from USD 3.3 for lowest grades to USD 1.1 for highest grades of coal (Figure 27). The carbon tax levels are very low and, therefore, would not lead to a dramatic technology transformation to improve efficiency. Nevertheless, the tax can provide an incentive for coal beneficiation so that the energy content of coal is improved, which can lead to reduced transportation of coal and reduce emissions from freight.

1 *According to Coal Ministry Guidelines, coal would be categorised into 17 grades for G1 to G17 based on calorific value http://pib.nic.in/newsite/PrintRelease.aspx?relid=108242.*

FIGURE 27: Cess for different grades of coal (a) Cess per unit of energy (USD/GJ) (b) Cess per tCO_2 emissions (USD/tCO_2)



11.5 CHALLENGES EXPERIENCED

The policy has been implemented without any major challenge on the collection side, although it has been argued by its opponents that it would make electricity more expensive since India depends heavily on coal for electricity generation. The cess was intended for allocation to projects related to cleaner energy, however, the utilisation of collected funds has not happened strictly as envisaged.

11.6 REPLICABILITY AND SCALING UP POTENTIAL

The policy started at a low rate, and the rates have since been enhanced twice. Moreover, the policy has been taken forward by the new government, which came to power in 2014. A broader acceptance of the policy would require political support for implementation, among other things. It may be easier to implement such a policy in other countries using coal, since coal is coming under increased pressure internationally due to climate change and more ambitious visions for mitigation of CO_2 emissions.

REFERENCES

Aggarwal, P., Jain, S. (2014), Energy demand and CO_2 emissions from urban on-road transport in Delhi: current and future projections under various policy measures, Journal of Cleaner Production, <http://dx.doi.org/10.1016/j.jclepro.2014.12.012>

Almeida, A.T., Fonseca, P., Bertoldi, P. (2003). Energy-efficient motor systems in the industrial and in the services sectors in the European Union: characterisation, potentials, barriers and policies. Energy 28(7), 673–690.

Antika (1989). A Publication on Improved Chuiha Vol. 2 New Delhi: Improved Chulha Division, Department of Non-Conventional Energy Sources.

Arthapedia (2016). Clean Energy Cess - Carbon Tax of India. Arthapedia, portal is managed by government economists of India <http://www.arthapedia.in/index.php?title=Clean_Energy_Cess_-_Carbon_Tax_of_India> (accessed on March 8, 2016)

BEE (2016). Guidelines for Permittee-Standards and Labelling program of BEE. Version 1. Bureau of Energy Efficiency, Ministry of Power, Government of India. <https://www.beestarlabel.com/Content/Files/Scheme%20of%20energy%20efficiency%20labelling.pdf> (accessed on 23 May 2016)

BEE (2016a). BEE PAT Cycle II Notification for Sector Table as the energy consumption norms and standards, The Gazette of India, Government of India, New Delhi. <https://beeindia.gov.in/sites/default/files/PAT2%20Target_0.pdf> (Accessed on 19 May 2016)

BEE (2016b). BEE PAT Cycle II Notification, the Gazette of India, Government of India, New Delhi. <https://beeindia.gov.in/sites/default/files/Gazette%20Notification%20373%28E%29_0.pdf> (Accessed on 19 May 2016)

Bhogle, S. and Anand, V. (1985). Development of an Improved Two-Pan Wood Stove. Proceedings of ASTRA seminar. Bangalore: Indian Institute of Science.

Bloomberg (2015). Tata Completes 2-Megawatt Rooftop Solar Plant in India. Retrieved from Bloomberg <http://www.bloomberg.com/news/articles/2014-07-31/tata-completes-2-megawatt-rooftop-solar-plant-in-india>

BUR (2016). India First Biennial Update Report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change. Government of India.

CAPITALINE (2015). Two and Three Wheelers: Players try to capitalise on easing interest cost & festive demand, Capitaline database, A paid database at the Indian Institute of Management, Ahmedabad (Accessed on 25th November 2015)

CEA (2014). Review of Performance of Thermal Power Stations 2013-14. Central Electricity Authority, Government of India, New Delhi.

CPCB (2000). Environmental Standards, Central Pollution Control Board, New Delhi <http://cpcb.nic.in/Industry-Specific-Standards/Emission/MotorVehicles.pdf> (Accessed on 25th November 2015)

Das, A., Parikh, J., (2004). Transport scenarios in two metropolitan cities in India: Delhi and Mumbai. Energy Conversion and Management 45, 2603-2625

Dhar, S., & Shukla, P. R. (2015). Low carbon scenarios for transport in India: Co-benefits analysis. Energy Policy, 81, 186-198.

DoR (2010). Notification No. 01 /2010-Clean Energy Cess. Department of Revenue, Ministry of Finance, Government of India.

DtE (1993). Two-stroke or four-stroke?. Down to Earth Magazine. <http://www.downtoearth.org.in/news/twostroke-or-four-stroke-30590> (Accessed on 25th November 2015)

EAI (2015). Tata Power Solar commissions the largest rooftop solar plant in South India. Energy Alternatives India <http://www.eai.in/360/news/pages/13058>

Edwards, M., Hulme, D. (1992). Scaling up NGO impact on development: learning from experience. Development in Practice 2(2), 77–91.

EESL (2015). EESL Tooklit for Agricultural Demand Side Management (AgDSM) Projects. Energy Efficiency Services Limited, Noida. <http://www.eeslindia.org/writereaddata/EESL%20Toolkit%20for%20AgDSM%20Projects.pdf>

EMC (2010). Investment Grade Energy Audit in Government Buildings in Kerala. Energy Management Centre-Kerala Department of Power, Government of Kerala. <http://www.keralaenergy.gov.in/pdf/Summary%20Report%20-%20Investment%20Grade%20Energy%20Audit%20Conducted%20in%2022%20Kerala%20Government%20Buildings.pdf>

Garg A., Maheshwari J., Mahapatra D. and Kumar S. (2011). Economic and environmental implications of demand-side management options. Energy Policy, 39, 3076-3085.

Garg A., Shukla P.R., Maheshwari J. and Upadhyay J (2014). An assessment of household electricity load curves and corresponding CO_2 marginal abatement cost curves for Gujarat state, India. Energy Policy, 66, 568–584.

GBPN (2014). Residential Buildings in India: Energy Use Projections And Savings Potentials. Global Buildings Performance Network (GBPN). <http://www.gbpn.org/sites/default/files/08.%20INDIA%20Baseline_TR_low.pdf>

George, R. (1988). Research and Development studies. In Antika Vol. 1. New Delhi: Improved Chulha Division, Department of Non-Conventional Energy Sources.

GoD (2015). Mass Rapid Transit System, Department of Transport, Government of Delhi. <http://delhigovt.nic.in/newdelhi/dept/transport/tr7.asp>

GoTN. (2015). Chief Minister Solar Powered Green House Scheme (CMSPGHS). Retrieved from Government of Tamil Nadu. <http://www.tnrd.gov.in/schemes/st_cmspghs.php>

GTZ (2009). Two- and Three Wheelers" module 4c, Sustainable Transport: A Source book for policy makers in developing cities. Division 44, Water, Energy and Transport. Sustainable Urban Transport Project. GTZ Transport Policy Advisory Committee, on behalf of Federal Ministry for Economic Corporation and Development. <http://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB4_Vehicles-and-Fuels/GIZ_SUTP_SB4c_Two-%20and%20Three-Wheelers_EN.pdf> (Accessed on 25th November 2015)

Gusain, P.P.S. (1990). Renewable Energy in India. New Delhi: Har-Anand Publications.

Hanbar R.D. and Karve Priyadarshini (2002). National Programme on Improved Chulha (NPIC) of the Government of India: an overview, Energy for Sustainable Development, Volume VI, No. 2.

Hulscher, W. S. (1998). Improved Cook Stove Programs: Some Lessons From Asia. Available at <http://www.fao.org/docrep/006/AD590E/ad590e00.pdf>

ICCT (2007). Air Emissions Issues Related to Two and Three-Wheeled Motor Vehicles: An Initial Assessment of Current Conditions and Options for Control. Prepared for the International Council on Clean Transportation by Dan Meszler, Meszler Engineering Services <http://www.theicct.org/sites/default/files/publications/twothree_wheelers_2007.pdf>

IITD (2010). New Initiative for Development and Deployment of Improved Cookstoves: Recommended Action Plan, Final Report, Prepared by: Indian Institute of Technology Delhi and The Energy and Resources Institute, New Delhi For Ministry of New and Renewable Energy, Government of India.

INCCA (2010). India: Greenhouse Gas Emissions 2007. Indian Network for Climate Change Assessment. Ministry of Environment and Forests. Government of India.

Indiastat (2016). Total Number of Registered Motor Vehicles (Transport and Non-Transport) in Metropolitan Cities of India. Indiastat – A paid database at Indian Institute of Management, Ahmedabad.

Iyer N.V., (2012). A Technical Assessment of Emissions and Fuel Consumption Reduction Potential from Two and Three Wheelers in India. Prepared for: the International Council on Clean Transportation. Washington, DC.

Jadhav P. and Rao, A.B. (2014). Sustainable Energy Solutions for Grassroots Development. SQ Journal, Vol. IV No.1 January-March 2014, Bombay Chamber of Commerce and Industry. <http://www.bombaychamber.com/admin/uploaded/SQ%20Vol%20IV%20No%201%20January-March%202014.pdf>

Jose A. (2011). Energy Efficiency Standards and Labelling in India: Current Situation and Challenges. The Institute of Energy Economics, Japan. <http://eneken.ieej.or.jp/data/3694.pdf> (accessed on 23 May 2016)

Kishore V.V.N., Ramana P.V. (2002). Improved cook stoves in rural India: how improved are they? a critique of the perceived benefits from the National Programme on Improved Chulhas (NPIC). Energy, 2, 47–63.

Kokaz K., Harshadeep, N.R., Rogers P. and Srinivasn S. (2000). A Simulation Analysis of Transportation Policies on Health and Environment in Delhi, India. Harvard – John A Paulson, School of Engineering and Applied Sciences. <http://www.seas.harvard.edu/TransportAsia/Presentations/cupum-Harvard-Delhi.pdf>

Kumar, R. Lokras, S.S. Jagadish, K.S. (1990). Development. Analysis and Dissemination of a 3 Pan Cook Stove. Bangalore.-Karnataka State Council for Science and Technology.

Maiti, K.N. and Gupta, A.K. (May, 1993). New Generation Efficient Chulhas. Invention Intelligence. 28 (5)118.

Masera, O., Edwards, R., Armenda′ riz Arnez, C., Berrueta, V., Johnson, M., Rojas Bracho, L., Riojas-Rodrı′guez, H., Smith, K. R., (2007). Impact of Patsari improved cook stoves on indoor air quality in Michoaca n, Mexico. Energy for Sustainable Development 11(2), 45–56.

MNRE (2014). Implementation of Unnat Chulha Abhiyan (UCA) Programme during the year 2013-2014 and balance period of the 12th Plan. Retrieved from <http://mnre.gov.in/file-manager/dec-biomass-cookstoves/programme-biomass-cookstoves_unnat_chulha_abhiyan-2013-2014.pdf>

MNRE (2015). A short term course on Biogas Production, Purification and Power Generation. National Biogas and Manure Management Programme. Ministry of New and Renewable Energy. <http://web.iitd.ac.in/~vkvijay/National%20Biogas%20and%20Manure%20Management%20%20Programme_Mr.%20G.%20L.%20Meena,%20MNRE.pdf>

MNRE (2016). Biogas Technology Development Division, Ministry of New and Renewable Energy, Government of India. <http://mnre.gov.in/schemes/decentralized-systems/schems-2/>

MoPNG (1995, 2000, 2005). Basic Petroleum Statistics. Ministry of Petroleum and Natural Gas, Government of India.

Nasery, V. (2011). Biogas for Rural Communities. TD390 Supervised learning: Study report, Under the guidance of Prof. A. B. Rao, Centre for Technology Alternatives for Rural Areas, Indian Institute of Technology Bombay. <https://www.cse.iitb.ac.in/~sohoni/pastTDSL/BiogasOptions.pdf>

Neilson (2013). All India Study on Sectoral Demand of Diesel & Petrol. Petroleum Planning and Analysis Cell, Ministry of Petroleum and Natural Gas, Government of India.

NIUA (2015). Urban Transportation in Indian Cities, Compendium of Good Practices, National Institute of Urban Affairs, New Delhi *<http://citynet-ap.org/wp-content/uploads/2015/05/GP-IN1-UT.pdf>*

Patel (2016). National Workshop on Agricultural Demand Side Management (AgDSM). Presentation on Indian Pump Industry – 2016. Organised by EESL, New Delhi.

Planning Commission (2002). Evaluation Study on National Project on Biogas Development. Programme Evaluation Organisation, Planning Commission, Government of India *<http://planningcommission.nic.in/reports/peoreport/peoevalu/peo_npbd.pdf>*

Planning Commission (2014). The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth. Planning Commissions, Government of India. *<http://planningcommission.nic.in/reports/genrep/rep_carbon2005.pdf>*

PMI (2015). Revision of cumulative targets under National Solar Mission from 20,000 MW by 2021-22 to 1, 00,000 MW. *<http://pmindia.gov.in/en/news_updates/revision-of-cumulative-targets-under-national-solar-mission-from-20000-mw-by-2021-22-to-100000-mw/>*

RDPRD (2015). Note GO (Ms) No. 64 dated 24.04.2015. Rural Development and Panchayat Raj Department, Government of Tamil Nadu. *<http://cms.tn.gov.in/sites/default/files/go/rural_e_ms_64_2015_2.pdf>*

Reddy and Balachandra (2010) Dynamics of Urban Mobility: A Comparative analysis of megacities of India. WP-2010-023, Indira Gandhi Institute of Development Research, Mumbai

Sadaphal, P. M., Pal, R. C., Joshi, Veena (1993). Improved Chulhas for Fuel Conservation. Uria Bharathi 3(3), p.30.

SDP (2015). Gobar Bank, Surat District Panchayat, Government of Surat *<http://www.suratdp.gujarat.gov.in/surat/english/panchayat-vishe/gobar-bank.htmz>*

SIAM (2001). The Indian Automobile Industry – Statistical Profile 2000-2001. Society of Indian Automobile manufacturers.

SIAM (2006). The Indian Automobile Industry – Statistical Profile 2005-2006. Society of Indian Automobile manufacturers.

SIAM (2011). The Indian Automobile Industry – Statistical Profile 2010-2011. Society of Indian Automobile manufacturers.

Singh (2006). The demand for road-based passenger mobility in India: 1950-2030 and relevance for developing and developed countries; EJTIR, 6, no. 3 (2006), pp. 247-274

Sinha, Bhaskar (2002). The Indian stove programme: An insider's view—the role of society, politics, economics and education. Boiling Point 48: 23–26.

TEDA (2015). CM'S Solar Powered Green House Scheme. Tamil Nadu Energy Development Agency, Government of Tamil Nadu. *<http://teda.in/programes/cms-solar-powered-green-house-scheme/>*

TERI (2006). National Energy Map of India: Technology Vision 2030. ISBN 81-7993-099-8; Office of the Principal Scientific Advisor to the Government of India, The Energy Research Institute, New Delhi.

TERI (2012). Life Cycle Analysis of Transport Modes, Prepared for National Transport Development Policy Committee (NTDPC), The Energy Research Institute, New Delhi.

TERI (2013). Compendium of Energy Efficiency and Renewable Energy in Leading Indian Corporates. New Delhi: TERI Press. The Energy and Resources Institute, New Delhi. *<http://cbs.teriin.org/pdf/reports/Energy_Efficiency_Compendium.pdf>*

TERI (2015). Green Growth and Buildings Sector in India. The Energy and Resources Institute, New Delhi. *<http://www.teriin.org/projects/green/pdf/National-Buildings.pdf>*

ToI (2015). Tata Power Solar commissions 'largest rooftop solar plant in south India'. The Times of India *<http://timesofindia.indiatimes.com/business/india-business/Tata-Power-Solar-commissions-largest-rooftop-solar-plant-in-south-India/articleshow/39428137.cms>*

TPS (2015). Tata Power Solar partners with Tamil Nadu Energy Development Agency (TEDA) to light up rural Tamil Nadu. Retrieved from Tata Power Solar. *<http://www.tatapowersolar.com/>*

UNEP (2014). Promoting Low Carbon Transport in India - Case Study of Metro Rails in Indian Cities. UNEP Risø Centre on Energy, Climate and Sustainable Development, Technical University of Denmark.

Uvin, P., Jain, P. S., Brown, L. D. (2000). Scaling up NGO programs in India: strategies and debates. IDR Reports 16(6), 1–28.

Venkataraman C., Sagar A.D., Habib G., Lam N., Smith K.R. (2010). The Indian National Initiative for Advanced Biomass Cookstoves: The benefits of clean combustion, Energy for Sustainable Development 14 (2) 63–72

Vijay, V.K. (2015). Rural Empowerment through Biogas Entrepreneurship. Centre for Rural Development and Technology, Indian Institute of Technology, Delhi. *<http://web.iitd.ac.in/~vkvijay/Entrepreneurship%20Models%20on%20Biogas%20for%20Rural%20Areas.pdf>*

World Bank (2008). Residential Consumption of Electricity In India - Documentation of data and methodology. Background Paper on India: Strategies for Low Carbon Growth. World Bank. *<http://www.moef.nic.in/downloads/public-information/Residentialpowerconsumption.pdf>*

AUTHORS (IN ALPHABETICAL ORDER)

Dr. Subash Dhar is a Senior Economist at the UNEP DTU Partnership. He is a Fellow from Indian Institute of Management, Ahmedabad and specialises in energy, transport and climate change.

Prof. Amit Garg is a Professor at the Indian Institute of Management, Ahmedabad. He specialises in energy, climate change and sustainable development issues.

Mr. Bhushan Kankal is a Research Associate at the Indian Institute of Management, Ahmedabad. He is M. Tech (Environmental Engineering) from Indian Institute of Technology, Roorkee.

Prof. Manmohan Kapshe is a Professor at Maulana Azad National Institute of Technology, Bhopal. He is a Fellow from Indian Institute of Management, Ahmedabad.

Mr. Saurabh Kumar is a Managing Director at Energy Efficiency Services Limited. His main fields of specialisations are energy efficiency and climate change, power sector reforms and restructuring, distribution reforms, rural access, financial and fiscal issues related to energy and other infrastructure, tax policy.

Mr. Pankaj Mohan is a Additional General Manager (Technical) at Energy Efficiency Services Limited. He holds an MBA degree with specialisation in project management.

Prof. Tirthankar Nag is a Professor at International Management Institute, Kolkata. He is a Fellow from Indian Institute of Management, Ahmedabad.

Dr. Jyoti Painuly is a Senior Energy Planner at the UNEP DTU Partnership. He is a Fellow from Indian Institute of Management, Bangalore and specialises in energy efficiency and renewable energy.

Mr. Saket Shukla is a Sr. Engineer at Energy Efficiency Services Ltd. He has done his B. Tech in Electronics and Communication and is currently pursuing a Masters in Business Administration in Power Management.

Energy efficiency improvements will be absolutely critical in achieving the ambitious goals of the Paris Agreement under the UN Framework Convention on Climate Change. The Report on Good Practices and Success Stories on Energy Efficiency in India assesses the main policies and measures behind the country's achievements in energy efficiency so far in different key sectors. The study documents a variety of approaches that have succeeded across sectors in India. Replication of these successes in India has been positive, but can be scaled up further. Moreover, these experiences can be replicated in other developing countries with suitable modifications. This report will therefore be useful for policy-makers, practitioners and researchers in India, as well as other developing countries.

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