NEW PERSPECTIVES ON DRIVERS AND TRANSITIONS RELATED TO HOUSEHOLD ENERGY ACCESS IN DEVELOPING COUNTRIES

CASE EXAMPLES FROM INDIA

Ibrahim Hafeezur Rehman

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NIEUWE PERSPECTIEVEN OP DRIVERS AND TRANSITIES MET BETREKKING TOT DE TOEGANG TOT ENERGIE IN HUISHOUDENS IN ONTWIKKELINGSLANDEN

VOORBEELDEN UIT INDIA

(MET EEN SAMENVATTING IN HET NEDERLANDS)

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Ibrahim Hafeezur Rehman
geboren op 5 January 1967 te Chandigarh, India

Promoters

Promoters

Prof Dr Ernst Worrell
Prof Dr Atul Kumar

Promotie commisse Ibrahim Rehman

- Prof. Dr. Joyeeta Gupta, University of Amsterdam
- Prf. Dr. Carolien Kroeze, Wageningen University/Open University
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- Prof. Dr. Rob Raven, Utrecht University
- Prof. Dr. Annelies Zoomers, Utrecht University

Dedication

Dedicated to my father Late Mr Azizur Rahman and uncle Late Mr Obaidur Rahman

Contents

CHAPTER 1

Introduction

This dissertation brings forth new perspectives on the issue of facilitating basic access to energy for the deprived population. The perspectives are largely focused on Asia in general and India in particular. The introductory essay provides a background to the research, it collates, compares the appended papers, and the concluding chapter puts the results into a broadly assessed new perspective.

The launch of "Sustainable Energy for All" by the United Nations Secretary General has brought into sharper focus the agenda of energy access for the poor. Globally, 1.3 million people lack access to electricity and nearly twice that number are dependent on inefficient energy sources for cooking (IEA, 2011). Majority of the energy poor are located in Africa and Asia where the political processes and economic factors play a critical role in determining access.

In order to move forward, it is desirable to have a clear understanding of what constitutes modern energy. While use of kerosene-based archaic lighting devices (lamps and lanterns) and direct burring of biomass in inefficient cookstoves for cooking depict the traditional energy usage transition to grid/off-grid electricity and use of LPG for cooking purposes represent modern energy usage. Therefore, use of polluting fuels and inefficient appliances/devices relates to traditional energy usage and cleaner fuels and efficient appliances are the targeted goal of universal energy access.

The literature on energy access in publications by agencies such as International Energy Agency, World Bank, World Energy Council, USAID, UNEP, UNESCAP (OECD/IEA, 2003; ADB, 2009, World Bank, 2010; WEC, 2007a, 2007b; UNEP 2003, AGECC, 2010; UN-ESCAP, 2011; etc.) has largely focused on issues such as rate of electrification, policy, technical, social and economic challenges of access (Gangopadhyay et al, 2005; Lin and Jiang, 2011; Li and Dorian, 1995; Hossain, 2006). Over the years, the studies have also delved into issues related to transition and the possible way forward (Sauter and Watson, 2008; Kemp, Schot and Hoogma, 1994; Wickramasinghe, 2011; Bhattacharya, 2006; Ailawadi, and Bhattacharyya, 2006; Bhattacharyya, 2005). Some studies have very effectively brought out challenges on the technical, social, and economic side separately as well as collectively (Balachandra, 2012; Bhide and Monroy, 2011).

In developing countries, energy is often the driver for sustainable development, owing to its critical linkage to agriculture, water, health, education, and even biodiversity. However, the studies have primarily focused on access to technologies and fuels and there is limited focus on energy service provisioning which is a key to sustainable energy access. The aspect of service provisioning is critical wherein energy is only a means of facilitating better access to different basic amenities such as health, education, and livelihood enhancement (ESMAP, 2000; Srivastava and Rehman, 2006). This necessitates that energy provisioning is analyzed in the context of wider linkages to sustainable development including, concerns related to health and environment. Hence, technology and fuel specific delivery which has been the driver of energy access facilitation and focus of researchers needs to be collated and assessed with end use and service-based provisioning options wherein the linkages of energy to areas such as health, education, and potable water supply are also assessed and analyzed (Rehman et al, 2011).

The environmental and health concerns related to lack of energy access have also received significant attention recently and studies (Wilkinson et al., 2009; Balakrishnan, et al., 2014; Smith et al, 2014a; Smith et al, 2014b), have clearly brought out the negative consequences on health and environment (Ramanathan et al., 2008; WHO, 2002). The focus on sustainability and environment demands that the energy access initiatives recognize and address the health and environmental impacts of use of traditional biomass and fossil fuels such as kerosene. However, pollutants such as Black Carbon (BC) which are related to direct burning of biomass and kerosene have been largely confined to laboratory studies with little empirical evidence from the field (Rehman et al, 2011). Therefore, the emerging findings on the role of short lived climate pollutants (SLCPs) particularly Black Carbon which is an essential ingredient of traditional energy use also needs focus to place the environmental and health concerns related to energy access in a comprehensive perspective (Venkataraman et al, 2005).

The energy transition literature has been confined primarily to assessments based on the classical energy ladder only to find that the ladder was more like a steep slope and it was not only possible to be on several steps at the same time (stacking) but even to leap frog to the top missing several steps in the process (Rehman et al, 2011, 2012; Pachauri and Jiang, 2008). From a transition perspective, existing regimes sustain and perpetuate traditional energy usage. Therefore, it is important to analyze new initiatives in relation to challenges and destabilization that interventions bring to existing regimes (Rehman et al, 2011, 2012; Kar et al, 2012).

Based on the literature review, the key questions that this thesis addresses are as follows:

- What are the new and emerging perspectives on energy access?
- How can these perspectives be collated to derive lessons for accelerating universal access to modern energy?

The collation and integration of perspectives becomes important as studies often focus on specific areas, usually leading to a "silos" approach to analyzing the energy access situation. While different studies and programme have put benchmarks related mainly to quantity, there is increasing understanding that the access is a dynamic process determined by needs that evolve over a period of time. Thus, moving away from the classical energy ladder the transitions are now viewed in a broad three step process that starts with basic access, moves to intermediate to include livelihood needs, and then finally to modern energy usage (AGECC, 2010). This means that there are overlapping factors that determine transitions and it becomes imperative to view energy access from a much broader perspective so as to include multiple cross-sectoral linkages and diverse stakeholders. The sub-questions that emerge are as follows:

- What is the political economy and the underlying governance concerns, including linkages with sustainable development, that determine energy access interventions?
- Focusing separately on environmental concerns, what are the critical linkages of biomass burning and Black Carbon?
- Cooking energy and lighting being the most basic determinants of access, what are the new perspective on energy transitions?
- Based on the collation of different perspectives, what are the modalities for going forward on universal energy access?

The studies (Chapter 2–7 based on already published work in reputed international journals such as *Atmospheric Chemistry and Physics*; *Energy Policy*; *Sustainability Science*, *Environmental Science and Policy*, etc.) discussed here recognize and highlight that, besides technical and social concerns, political economy and cross sectoral linkages of energy are the key determinants for effective energy transitions. Additionally, the environmental concerns also need to go beyond to encompass new knowledge particularly on the linkages of energy access with health and climate pollutants such as Black Carbon. Therefore, compilation provides a comprehensive and cross cutting view of political economy of energy access, linkages of energy to sustainable development, linkages of SLCPs with energy use, and new perspective on energy transitions when viewed through the lens of strategic niche management. Based on the compilation of the published work, the dissertation also provides a pathway for accelerating and upscaling access to energy.

In Asia, almost 80% of electricity-deprived and 86% of biomass-dependent populations are located in the "Big 5" countries—Bangladesh, China, India, Indonesia, and Pakistan (Rehman et al, 2012). Chapter 3 focuses on the broad contours of the political economy of energy access in these countries. The political economy is assessed through an examination of three sustainability objectives—accessibility of physical infrastructure; energy service delivery; and conformance to social goals. The key areas of concern include emphasis on supply-driven grid electricity; vested power dynamics favouring affluent and urban areas; unreliability of energy service provision; and misdirected and misappropriated subsidies. These issues are responsible for limiting accelerated achievement of universal energy access in the "Big 5" countries and need to be addressed through innovative approaches. The chapter analyzing the political economy of energy access emphasizes the need for firm commitments, policy convergence, and the implementation of 'pro-poor' equitable energy policies through a broad-based energy framework of bench-marked, technology-neutral energy provisioning that ensures reliability and equity. It highlights the need for reorienting of the subsidy regime and incorporating energy service delivery indicators in monitoring and reporting mechanisms.

The political economy of energy access has a bearing on the sustainable development agenda. Chapter 4 taking the example of India, with a population of over 1,000 million of which 400 million are electricity deprived and over 600 million do not have access to modern cooking, discusses the critical linkages that energy provisioning has with other sustainable development parameters such as agriculture, water, health, and even biodiversity. India has set itself a target, going beyond the Millennium Development Goals (MDGs) of energizing all households. In view of the differentiated responsibilities of the various ministries to the Government of India, the strategy for reaching this target may not address itself to the larger development goals. The study brings forth issues of inter and intra agency coordination among energy provisioning bodies and lack of an inter-sectoral approach to addressing energy access.

Moving from cross sectoral energy needs to basic household energy provisioning, the focus is on traditional burning of biomass or use of inefficient technologies for domestic applications like lighting is common, triggering concerns related to fuel or technology switching. Chapters 5 and 6 focus on use of kerosene for lighting and use of biomass in traditional and highly inefficient cookstoves. In India with over 30% households yet to be electrified, the households are dependent on meeting their lighting energy needs through archaic kerosene burning lamps and over 60% of households are dependent on use of biomass in cookstoves. Both the uses contribute significantly to indoor air pollution which is a major health hazard, especially for women and children. The study on kerosene taking the example of a The Energy and Resources Institute (TERI) case study in the state of Rajasthan, analyzes the issues of access and availability of kerosene to rural masses, especially the poor. A majority of the rural population in India continues to rely on kerosene for domestic lighting. Measures to promote inter-fuel substitution in domestic lighting by promoting rural electrification have met with partial success. Electrified households in rural areas also use kerosene as a back-up fuel because of erratic and poor electricity supply. Kerosene is subsidized and an extensive network has been put in place for its distribution. Both these measures are meant to facilitate access and affordability by the poor. However, this is not the case at the grass roots level. Further, use of traditional lighting devices have also had an adverse effect on the quality of life of the people since these devices are inefficient, emit smoke, and give poor quality light. In this, the poorest of the poor, who have limited choices and options are the worst affected. It highlights the existing problems with the kerosene distribution system and examines subsidy-based, supply driven approach to distribution in terms of facilitating access to the poor. It, accordingly, puts forward specific policy measures for improving access to kerosene and its more efficient use as a lighting fuel in rural India. The second part (Chapter 6) on the subject focuses on the cookstoves and the linkages with health and environment particularly the Short Lived Climate Pollutant—Black Carbon. For the first time, under Project Surya, we use field measurements taken simultaneously inside rural households, ambient air, and vehicular emissions from highways in a rural area in the Indo-Gangetic Plains region of India to establish the role of both solid biomass-based cooking in traditional stoves and diesel vehicles in contributing to high BC and organic carbon (OC), and solar absorption. The major finding of this study is that BC concentrations during cooking hours, both indoors and outdoors, have anomalously large twice-daily peak concentrations reaching 60 μgm−3 (median 15-min average value) for indoor and 30 μgm−3 (median 15-min average value) for outdoor during the early morning (05:00am to 08:00am) and early evening (17:00pm to 19:00pm) hours coinciding with the morning and evening cooking hours. The BC concentrations during the non-cooking hours were also large, in the range of 2 to 30 μgm−3. The peak indoor BC concentrations reached as high as 1000 μgm−3. The large diurnal peaks seen in this study lead to the conclusion that satellite-based aerosol studies that rely on once daily daytime measurements may severely underestimate the BC loading of the atmosphere. The concentration of OC was a factor of 5 larger than BC and furthermore, optical data show that absorbing brown carbon was a major component of the OC. The imprint of the cooking hour peaks were seen in the outdoor BC both in the village as well as in the highway. The results have significant implications for climate and epidemiological studies.

Close to three billion people globally and over 800 million in India are dependent on direct combustion of unprocessed solid biomass fuels in inefficient traditional mud stoves. Current cooking practices, besides causing serious health problems, are also being linked to emissions of climate change and pollution agents such as black carbon and ozone precursors. In India several initiatives have been taken up to tackle the problem but the present trajectory of limited technical and social change in cooking energy use is nonetheless persistent in rural areas. The use of inefficient devices and polluting fuels demands transition to more efficient and cleaner forms of energy for rural households. Chapters 6 and 7 discuss energy transitions using the strategic niche management framework. The studies bring into focus the opportunities to promote cleaner energy options through development of value chains delivering improved energy efficiency and access in developing countries. In order to develop and scale up alternative cooking technology options, it analyzes using the principles of strategic niche management. Chapter 6, while highlighting reasons for stability of the current cooking regime, also points to such triggers that can destabilize the regime. The focus is also on assessing the influence of protection in the form of subsidies on the process of transition. User preferences relating to social and technical aspects have been analyzed, pointing to forced draft cook stoves as the preferred option, notwithstanding cost reductions to address affordability concerns. The assessment indicates that while it is critically important to understand and address the preferences of users and to improve the technology, scaling up will depend on stove cost reduction through further research. Creativity in effective financing schemes and support structures put in place by fostering public–private partnerships are also required.

In most developing countries, at the household level, traditional burning of biomass or use of inefficient technologies for domestic applications like lighting is common, triggering concerns related to fuel or technology switching. Chapter 6 focuses on opportunities to promote cleaner energy options through development of value chains delivering improved energy efficiency and access in developing countries. It discusses the example of *Uttam Urja*, a field project involving the dissemination of photovoltaic lighting technologies in rural areas of India. The chapter focuses on the challenges of introducing radical innovations into the residential energy sector in developing countries. The *Uttam Urja* project is conceptualized as an ‘experiment’ and is analyzed using the Strategic Niche Management Framework. The chapter emphasizes that to effect socio-technical transitions to clean energy options, it is desirable to focus on technology customization and innovative financing to cater to the needs and concerns of end users.

While there have been exceptional cases like China, Vietnam, and Brazil, where the public sector-led grid expansions achieved incredible gains and almost completely eradicated the energy access gap as far as electricity was concerned, the general trend over the years, in most developing countries, has demonstrated that both public and private led approaches have been unsuccessful in independently yielding the desired acceleration and continuity to deliver universal energy access. This is primarily due to the fact that despite the inherent benefits revealed in both public and private sector led initiatives, typical systemic inefficiencies and inadequate capacities in both approaches prevent them from fully addressing the principal objective of facilitating energy access for the poor in the long term. Also, even if required investments were adequately capitalized, with the current population growth rate continually outpacing the rate of interventions, the number of people who remained energy poor 15 years hence, would still be the same. Thus, not only is there a need for providing energy access to the existing population mass, but an equal need to do it fast enough to truly reduce the number of energy poor across the globe.

An alternative approach therefore needs to be explored that juxtaposes the social welfare objectives of public sector led initiatives with the enterprise development and growth objectives of the private sector, to support the creation of an enabling ecosystem and a viable value chain that successfully and effectively delivers energy solutions to the last mile. Such a pro-poor hybrid model will essentially address the inefficiencies and inadequacies of both public and private approaches and capitalize on their strengths through a complementary mix of social and commercial goals. The model facilitates collaborations at the corporate, institutional, and individual levels to drive individual parts of a unified energy provisioning system, making it adaptable, dynamic, flexible, and maneuverable within structures, relationships, and entities. Policy level support and accompanying regulatory frameworks are critical for clear role definitions, proper planning, and execution.

The final Chapter 8 collates the key learnings derived from different perspectives on energy access to bring forth a framework strategy for accelerating access to energy in rural areas. It emphasizes the need for orienting energy access to service delivery thereby taking the focus beyond technology or fuels towards targets and subsidy driven government programmes. It proposes a framework and approach wherein social concerns related to energy access can be integrated with commercial approaches to have a hybrid model for accelerating access to energy. The approach recognizes that while balancing the social and poverty issues, it is equally important to develop a sustainable model that creates a local service delivery value chain, recognizing the cross sectoral aspects of energy access.

CHAPTER 2

Understanding the political economy and key drivers of energy access in addressing national energy access priorities and policies[1]

Abstract

Globally, 1.5 billion people lack access to electricity and nearly 3 billion lack access to modern cooking energy options. Of the world's "energy poor", 95% are in Asia and Sub-Saharan Africa. Within Asia, almost 80% of electricity-deprived and 86% of biomass-dependent populations are in the "Big 5" countries: Bangladesh, China, India, Indonesia and Pakistan. Therefore, we have discussed here the broad contours of the political economy of energy access in these countries. The political economy is assessed through a discussion on three sustainability objectives: accessibility of physical infrastructure; energy service delivery; and conformance to social goals. The key areas of concern that have been dealt with include: emphasis on supply-driven grid electricity; vested power dynamics favouring affluent and urban areas; unreliability of energy service provision; misdirected and misappropriated subsidies. The said issues are responsible for limiting accelerated achievement of universal energy access in the "Big 5" countries and need to be addressed through innovative approaches. The paper emphasizes the need for firm commitments, policy convergence and successful implementation of 'pro-poor' equitable energy policies through a broad-based energy framework of bench-marked, technology-neutral energy provisioning that ensures reliability and equity. It highlights the need for reorientation of the subsidy regime and incorporation of energy service delivery indicators in monitoring and reporting mechanisms.

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[1] This chapter is reproduced from Rehman, I. H., Kar, A., Banerjee, M., Kumar, P., Shardul, M., Mohanty, J., Hossain, I., 2012. Understanding the political economy and key drivers of energy access in addressing national energy access priorities and policies. Energy Policy 47 (2012) 27-37.

2.1 Introduction

The well-documented linkage of modern energy access to development and environment makes it a central element of the debate on sustainable development. Globally, 1.5 billion people do not have access to electricity and nearly 3 billion people do not have access to modern cooking options[2] (AGECC, 2010). These low levels of access and the trade-offs between environmental and development imperatives demand firm political commitments and actions for meeting energy needs, particularly from countries that have the highest share of the energy poor[3]. Therefore, understanding the political economy and drivers of energy access in these countries becomes critical to achieving the goal of universal energy access.

Among the world's "energy poor," nearly 95% are localised in Asia and Sub-Saharan Africa. In developing Asia alone, there are close to 700 million people without access to electricity and about 2 billion dependent on inefficient burning of biomass for meeting cooking energy needs. Within developing Asia, five countries, namely Bangladesh, China, India, Indonesia, and Pakistan, hereafter referred to as the "Big 5", constitute nearly 80% and 86% of the global population lacking electricity access and modern cooking energy access, respectively (Figure 2.1; Figure 2.2) (IEA

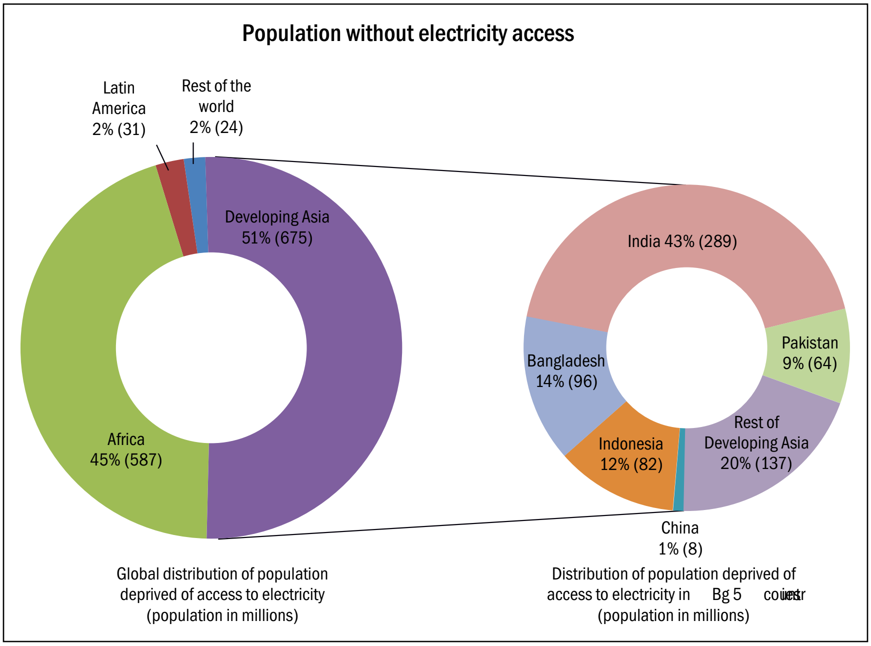

Figure 2.1 Population without electricity (global and Big 5)
Source: IEA 2011

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[2] For the paper, modern cooking fuel include electricity, LPG, biogas

[3] For the paper, it is defined as population without electricity access and/or without access to modern cooking technologies

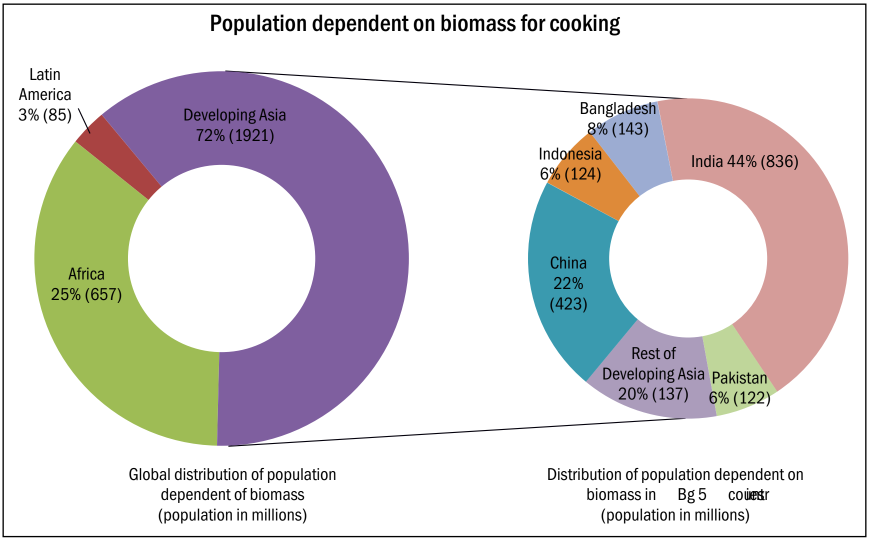

Figure 2.2 Population dependent on biomass for cooking (global and Big 5)
Source: IEA 2011

2011). It is obvious that the key drivers and political economy of energy access in the "Big 5" countries would determine the success or failure of the goal of achieving universal energy access in Asia. Therefore, while it is acknowledged that more than 50% of the population in countries such as Cambodia, DPR (North) Korea, East Timor, Myanmar, Afghanistan and Nepal can be categorized as energy poor, this paper focuses on energy access issues in the "Big 5" countries.

The paper aims to assess the political and economic factors that guide the pursuit of specific carriers or fuels in order to facilitate energy access in the "Big 5". Political economic theory highlights the role of politics as an enabler or inhibitor of structural changes, including broadening energy access (Moe, 2010). Hence, the paper analyses the key drivers of household energy access in the context of the political economy of these nations. Within and across the chosen fuels or carriers, we have analysed the approach and mix of options that have been pursued. Three sustainability objectives for energy provision are discussed: access to physical infrastructure, energy service delivery in terms of supply quantity and reliability, and conformance to social goals, particularly equitable energy access across the urban-rural divide (WEC, 2007). This paper aims to provide inputs to policy makers to make informed choices with regard to energy access by providing analytical and policy-derived perspectives on a set of key political and economic drivers of energy access.

2.2 Skewed pursuit of specific carrier or fuels

The social and economic objectives of decreasing energy disparity among populations and stimulating economic development serve as an impetus for the creation of national-level policies and programmes on energy access (World Bank 2010a). Historically, electricity has for long been regarded as one of the primary inputs for economic growth and development; hence, the national initiatives on facilitating energy access are primarily aimed at provisioning of centralized grid electricity for the poor (Mathur and Mathur, 2005). This prioritization of energy provision has relegated the modern energy need for cooking to a lower level of political consideration. This is reflected by the fact that the global population dependent on traditional cooking fuel (biomass) is double that deprived of access to electricity. The thrust on electricity access is also corroborated by the fact that almost half of developing countries have set targets for access to electricity, while very few have set targets in relation to access to modern cooking fuels or improved cookstoves (UNDP and WHO, 2009).

Recent International Energy Agency (IEA, 2011) data for energy access indicates that 18% of the combined "Big 5" population do not have access to electricity while 54% of population do not have access to modern cooking options (IEA, 2011). Yet, while most of the "Big 5" countries have set targets for the provision of electrification (Table 2.1), the same intent and focus was not demonstrated for modern cooking energy access initiatives in the "Big 5". As long-term strategic vision of a nation often provides key insight about its political economy, such bias towards electrification indicates that modern cooking access does not hold the same priority or importance as a development challenge facing these nations. Consequently, with the exception of China, over 50% of the respective population of the "Big 5" are dependent on burning biomass in traditional, polluting stoves (Figure 2.3).

Table 2.1 Electrification targets in the "Big 5"

Country	Electrification Target	Target Year
China	Expected Universal Electrification[4]	2015
India	Electricity to all rural households[5] Power for all[6]	2009, 2012
Pakistan	Electrify all villages[7]	2010
Bangladesh	Electricity for all[8]	2020
Indonesia	Electricity access for 95% of population[9]	2025
Source: (IEA 2011)		

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[4] Source: International Energy Agency, 2011. World Energy Outlook. Paris, France

[5] Ministry of Power, 2006. Gazette of India, Rural Electrification Policy.(http://powermin.nic.in/whats_new/pdf/RE%20Policy.pdf) , (last accessed on March 2012)

[6] Official website of Ministry of Power, Government of India, .(http://powermin.nic.in/indian_electricity_scenario/power_for_all_target.htm) (last accessed on March 2012)

[7] Ministry of Finance, Government of Pakistan.(http://www.finance.gov.pk/poverty/PRSP-II.PDF). (last accessed on March 2012)

[8] Source: International Energy Agency, 2011. World Energy Outlook. Paris, France

[9] Source: International Energy Agency, 2011. World Energy Outlook. Paris, France

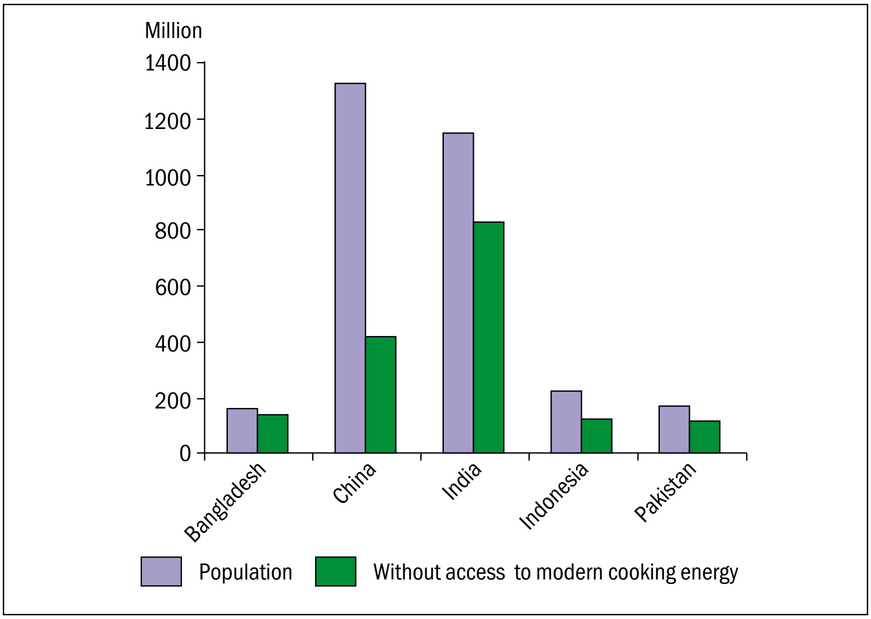

Figure 2.3 Status of Modern Cooking Energy Access in "Big 5" in 2008
Source: (IEA, 2010 for China; IEA 2011 for rest of "Big 5")

In the "Big 5" countries, the primary vehicle for meeting cooking energy needs have been the subsidisation of improved biomass cookstove programmes and of cooking fuels, such as Liquefied Petroleum Gas (LPG). Subsidy-driven efforts have been difficult to sustain and upscale, as evidenced by a review of improved stove programmes and the penetration of LPG in these countries. For example, China introduced more than 180 million improved stoves in early 1980s and mid-1990s through the National Improved Stove Program (Zhang and Smith, 2007). However, by the latter half of the 1990s, improved stoves had become a minor part of the government's integrated energy programs (Sinton et al., 2004). Similarly, in Bangladesh, the government disseminated approximately 300,000 improved cookstoves through the Bangladesh Council for Scientific and Industrial Research (BCSIR)-led program between the years 1998 and 2001. However, sustainable commercialisation failed primarily due to an overemphasis on targets and subsidy orientation without enough attention to proper monitoring mechanisms (World Bank, 2010 b). Further, as noted in a study by ESMAP (2009), rural households with low income and limited cash in hand are not in a position to afford the high cost of LPG connections and cylinders. In addition, LPG transport and storage costs (unlike kerosene's narrower range of prices) make it a prohibitively expensive proposition for rural areas in Bangladesh (ESMAP, 2009). Similarly, in India, while there has been considerable thrust on rural electrification, which included a target of power for all by 2012 (Ministry of Power 2005), the National Programme for Improved Cookstoves was withdrawn in 2002 (Box 1).

BOX 1: Inadequate focus on meeting modern cooking energy needs in India

In India, as of 31st December 2011, under the flagship electrification programme, Rajiv Gandhi Gram Vidyutikaran Yojana (RGGVY), during the Eleventh Five Year Plan period (2007-2012), 343 projects have been sanctioned for implementation at a cost of 3.3 billion USD for electrification of 49,912 villages and release of connections to 16.4 million BPL households (GoI 2012). On the other hand, there was no specific allocation for pursuing dissemination of improved biomass cookstoves[10], limited allocation for biogas, and limited thrust on reaching and making LPG affordable for rural poor. With the withdrawal of the central government subsidy, lack of state government initiatives and inability of the earlier programme to establish a market for stoves, cooking energy needs were left to be addressed through subsidised provision of LPG and continues to be urban-centric with limited reach in rural areas. As a consequence, in the last decade, dependence on modern cooking technology has not significantly changed in rural India when compared to dependence on electricity. Percentage of households using subsidised LPG and kerosene (which though intended for cooking is actually used for lighting) increased from 8% in 1999-2000 to 13% in 2008-09. In the same period, dependence on electricity as a main source of lighting increased from 48% to 66% in rural India (NSSO, 2011).

2.3 Inequity in access

Centralised grid-based electricity provision and implementation of cookstove programmes, coupled with LPG subsidies in some countries have not been able to fully address the inequities in energy access. The inequity is most evident in the form of a rural-urban divide, which is prevalent in all countries comprising the "Big 5", perhaps with the exception of electricity access in China. Electricity access among the "Big 5" provides a clear illustration of the inequity of access between urban and rural energy provision, as illustrated in the graph below (Figure 2.4).

For instance, in Indonesia the electricity access situation at the national level is at par with India; however, its urban-rural access inequity is the highest among the "Big 5" (Figure 2.4). Thus, Indonesia has the largest gap between urban (94%) and rural (32%) electricity access among the "Big 5" countries (Figure 2.3; IEA, 2012). Because energy deficits are more prevalent in rural areas, the national capacity to address rural energy needs has surfaced as a differentiating factor among the "Big 5" and is a key driver for universal energy access.

When analysed further, the rural-urban inequity is significantly greater for modern cooking than for electricity provision. For example, analysis of the recent National Sample Survey (2011) in India indicates a rural-urban electricity access gap of 28 percentage points (94% and 66% of urban and rural households use electricity as a primary source for lighting, respectively); the rural-urban divide increases to 68 percentage points (71% and 13% of urban and rural households respectively use commercial fossil fuel-based cooking options[11] as the primary cooking energy source) when modern cooking access is considered (NSSO 2011; TEDDY 2011) (Figure 2.5).

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[10] The subsidy on the National Programme for Improved Cookstoves (NPIC) was withdrawn in 2002

[11] While LPG is the benchmark commercial fossil fuel based cooking option, we have also included kerosene stoves and biogas to arrive at the percentage.

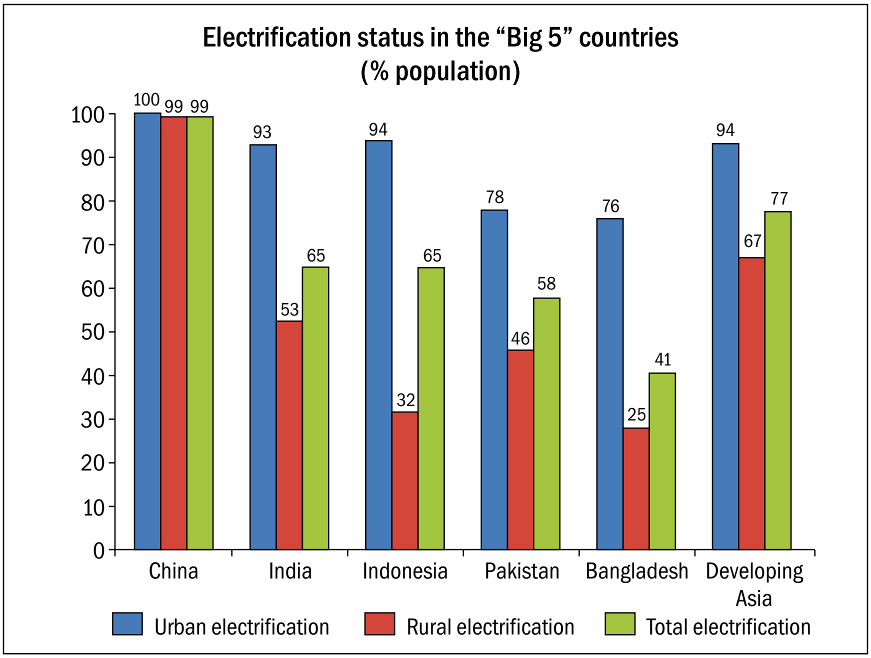

Figure 2.4 Status of Rural and Urban Electrification Levels in Big 5 in 2008
Source: Website of International Energy Agency (accessed on March 2012)

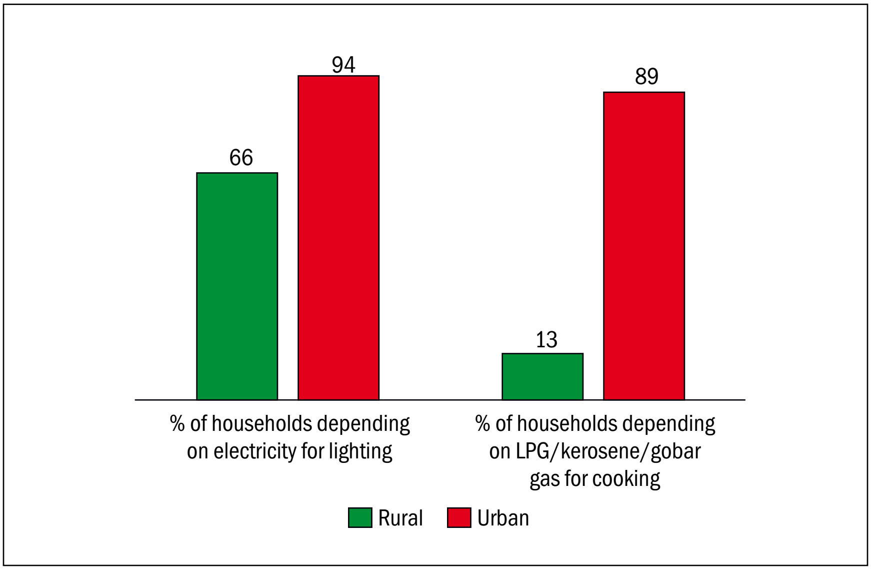

Figure 2.5 Rural Urban Energy Access Inequity in India
Source: (TEDDY, 2011)

2.4 Skewed supply and vested interest driven approach

The inequity in physical access is in turn a manifestation of governance of energy access, which is supply-centric (Oda and Tsujita, 2011). With centralised planning and implementation at the core, the parameters of access often ignore the demand impetus (Hiremath et al., 2009; Srivastava and Rehman, 2006). In such a scenario, the supply of energy takes on a complicated role, as it is governed primarily by coverage pertaining to infrastructure expansion or centralised incentives for facilitating access, failing to properly account for actual delivery or end use. Political expediency is reflected in the form of merely extending the infrastructure and providing hope to deprived sections of the population through grid-extension and fuel subsidies. Communities fed on a diet of energy access being synonymous with grid-based electrification and subsidized commercial fuels aspire to have grid connectivity and kerosene/ LPG, which have consequently emerged as the primary metric for energy access.

A critical component of centralised governance of energy access is the installation and management of infrastructure for the distribution of energy. Physical infrastructure includes the transmission and distribution lines for grid-based electricity and the market chains for the provision of commercial fuels, such as kerosene and LPG. Transmission and distribution systems for electricity provision often get constrained by the institutional inability to manage the supply systems, particularly in rural areas. For instance, the expansion of India's power generation capabilities, exhibiting a growth rate of 6.3% in the year 2007/08, was accompanied by an increase of at least 25% in transmission and distribution losses for more than half of the states (CEA, 2011). The poor efficiencies of the distribution systems adversely impact the key elements of the cost-affordability-quality-viability nexus. Thus, compounding the existing power generation deficit, the differential between actual consumption and anticipated supply, due to theft or free provision through government schemes, causes frequent power cuts and poor quality supply. Furthermore, losses continue to contribute to the weakening financial health of State Electricity Boards, which have already experienced an increase in deficits from $0.9 billion to $5.8 billion during the last few decades (Kemmler, 2007). This adversity turns into a vicious cycle, wherein the challenges of scattered populations, low loads and low paying capacities, coupled with unsustainably subsidised tariffs, discourages private investment and complicates the logistics of revenue collection (Kemmler, 2007; GNESD, 2007). These factors make rural electrification a burdensome initiative, fostering the general tendency to cater to electrification of non-remote villages that are relatively easy to connect and manage (Oda and Tsujita, 2011). Similarly, there is limited incentive to establish market chains for supply of commercial fuels to populations with low paying capacities and low densities due to uncertainty regarding recovery of capital costs (Pohekar et al, 2005).

Notwithstanding inadequacies of public sector based centralised supply, access is primarily reduced or restricted to connectivity to centralised grid or subsidized fuels.

As access is also linked to freedom of choice (Pachauri 2011), the uni-dimensional approach decreases the voice including the negotiating powers of rural populations regarding energy access options (Moe, 2010; Oda and Tsujita, 2011). Thus access continues to be a supply driven effort often propagated by vested interests, which combine with the political system to foster large-scale centralised investments and subsidies. The result is a vicious cycle of allocation of public resources for extending physical infrastructure of centralised grid lines or providing incentives for subsidized fuels.

2.5 Limited focus on ensuring energy availability and use

As mentioned earlier, the supply-centric provision is not sensitive to the actual use of energy. On one side, access is critical, as it indicates whether the infrastructure and supply chain mechanisms exist for a willing household to use modern energy options. For instance, if a village does not have the basic electricity distribution infrastructure, even the most eager and affluent households cannot access grid electricity. On the other side, going beyond access, availability and reliability of energy manifests in the form of dependence and consumption, indicating whether a willing household having access to modern energy options is able to utilize it as the dominant energy source. For example, if an electrified household (that is willing to use electricity and hence took an electricity connection) primarily depends on kerosene for lighting, it raises affordability and/or supply concerns. Similarly, modern cooking energy access should not focus on mere dissemination of options, such as LPG, as studies have indicated that merely having an LPG connection does not guarantee usage or dependence on the same. For instance, in a classical example of fuel stacking, many Indian households with LPG connections still depend on firewood as their primary cooking fuel, generally due to affordability issues; LPG is then used sparingly for quick cooking (Joon et al, 2009). The practice is prevalent in Bangladesh as well, where LPG is used as a supplementary fuel to biomass (Hossain and Tamin, 2006). Despite the above mentioned evidence, the primary focus of energy access is on mere infrastructure expansion as opposed to ensuring quality, reliable and affordable supply and enhancing dependence and use of modern energy. Further, the misguided focus has reduced the notion of access to mere physical numbers. This is evident from the fact that, globally, over 1 billion people, while having physical access to electricity infrastructure, receive only sporadic and poor quality electricity supply (AGECC, 2010).

The approach of infrastructure expansion that often discounts the real needs is also the main driver of policies and programmes in majority of "Big 5" countries (Moe, 2010; Buscher, 2009). For example, programs on rural electrification in India focused mainly on providing connectivity (physical infrastructure) to the grid and largely ignored the issue of reliable electricity supply (Balachandra, 2011). As per Greenpeace (2011), the RGGVY represents 94.5% of the Government of India's total budgetary allocation for rural electrification, and the latest Economic Survey of India (GoI, 2012) reports a sanction of USD[12] 3.3 billion for implementation of 343 projects during the eleventh plan period. Despite the hefty budget, approximately 53% of households in RGGVY-electrified villages[13] still lack an electricity connection while the electrified households receive a poor quality, interrupted power supply. This is a classic example where the energy needs of both the non-serviced and under-serviced populations remain unfulfilled, and are sometimes enshrouded in blanket policies and national-level statistics (TERI, 2010; Oda and Tsujita 2011). As a consequence, even for electrified areas due to poor quality of supply and long outages, the annual residential power consumption in rural India is reported to be only 96kWh/person (IEA, 2011), lower than the 120kWh/person consumption level proposed by Sanchez (2010). Despite the existing constraints, the centralised infrastructure expansion and provision of subsidised fuels continues to drive energy access. Resultantly, other possibilities, such as renewable energy based mini-grids or off-grid systems for electrification, and biogas, improved cooking energy technologies, are often ignored or relegated to a lower national priority.

Many developing countries, including the "Big 5", do not follow a proper mix of centralised, local renewable energy based micro-grids and renewable energy based stand-alone systems for meeting electricity needs, or putting in equal political and economic emphasis on provision of improved cookstoves, biogas, etc. to meet cooking needs. Likewise, with little or no emphasis on promoting renewable energy based micro-grids in Indonesia, most off-grid (isolated) regions are forced to depend on diesel-based micro-grids (UNDP and Government of Indonesia, 2006). Diesel-based generation consumes high-priced diesel oil, increasing the cost of production far above affordability levels and making any such commercial venture economically unsustainable. The supply of electricity to remote areas is therefore emerging as a potential constraint on Indonesia's long-term growth and development ambitions. Therefore, mere physical infrastructure expansion, without simultaneously ensuring quality, reliability and affordability, cannot provide meaningful and effective access to modern energy.

2.6 Misdirected and misappropriated subsidies

Two key factors governing demand for energy centres are affordability and willingness of the end user to pay for electricity and commercial fuels. The affordability of the poor is shaped in part by economic policy, namely subsidies, and through economic development, or the transition of the poor to higher income brackets (D'sa and Murthy, 2004, Pohekar et al, 2005). Further, willingness to pay for energy among the poor is governed by awareness regarding advantages of using alternative energy options and the overall value addition such options provide. For instance, the awareness of

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[12] INR 2644 million as on October 2011, Foreign Exchange Conversion assumed 1USD= 46 INR

[13] 80% of India's villages are currently covered under RGGVY (RGGVY, 2011)

health benefits (reduced indoor air pollution) can play an important role in taking forward initiatives such as improved cookstoves (Shrimali et al, 2011). The cost associated with the perceived advantages of alternative energy options has to be comparable to existing energy expenditure, or the consumer's motivation level has to be very high to transcend the affordability barrier to adoption. For instance, use of fuels, such as LPG and kerosene, in spite of high level of subsidies, can continue to be perceived as expensive when compared to non-monetised direct burning of biomass in traditional mud stoves (Ailawadi and Bhattacharyya, 2006; Bhide and Monroy, 2011). The complexities of the economics and politics of energy access for the poor are often governed by subsidy regimes that are perpetuated primarily in the name of the poor, but largely usurped by the rich and the powerful (Jain, 2006; Rao, 2002). There is strict adherence to subsidy regimes that are difficult to modify or do away with due to the role of vested interests. The vested interests of the rich and powerful become an integral part of political considerations and pose challenges to any structural changes and further translate into more subsidy-dependent policies (MoE, 2010). Therefore, the primary driver is not the need of the end users but the political and related vested interests that drive energy access subsidies (Jain, 2006). As a result, there is strict adherence to subsidy regimes that are difficult to modify or do away with due to the role of vested interests. The subsidies not only alter the economics of energy provision but also shape the social landscape and power dynamics that feeds back in to the political system; thereby creating a cycle of provision of subsidies that do not yield intended benefits (Jain, 2006). Consequently, of the $409 billion spent globally on subsidising fossil fuel in 2010, only $35 billion, or 8%, of the total reached the bottom 20% (IEA, 2011).

Subsidy programmes in the "Big 5" countries in Asia have led to loss and inefficiencies, which can deprive electricity utilities of funds and, therefore, impair their ability to extend and improve services. For instance, the biggest beneficiaries of the electricity subsidies in Pakistan are the richest 20 per cent of population in both March 2008 and March 2011 (Trimble et. al, 2011). Despite the revised tariff structure in 2011, it is estimated that at least 90% of electricity consumers in residential areas receive a net subsidy; this implies that less than 10 per cent of consumers pay more than the cost recovery level (Trimble et al., 2011). A study in China has found that 22% population of the lowest economic strata shared 10.1% of the electricity subsidy, while the economically affluent sections comprising 9% of the population, for whom the subsidy is not required, received 18.6% of the subsidy allocated for the domestic sector (Lin and Jiang, 2011). The study indicates that the poor performance of electricity subsidies is largely a deviation from its policy intention; hence, addressing social issues by alternative measures, such as direct welfare payments or investments in social services was recommended from the study (Lin and Jiang, 2011). In India, current electricity tariffs recover on average only 85% of the full costs of supplying customers throughout the country (UN-ESCAP, 2011). A past study indicated that rural households pay only about half the cost and farmers pay up only 10 % (World Bank, 2003). Above-cost prices for industrial and commercial customers are insufficient to offset these subsidies. Another study indicated that, subsidization of sales for farmers totals roughly around $6 billion per annum; relative to government spending on health and rural development, farmer sale's subsidies are double (UNEP, 2008). In such a scenario, the poor who are supposed to benefit from the subsidies can actually end up worse off. Again, in case of LPG distribution in India, an estimated 76% of this subsidy is allocated in urban areas, which contain only one quarter of the population. Of this urban subsidy, over half is enjoyed by approximately one quarter of households. This means that almost 40% of the LPG subsidy benefits a mere 7% of the population (UNEP, 2008). Further, recent data on Public Distribution System (PDS) in India shows that over 460,000 private licensed retailers sell subsidized grains and kerosene in over 6 lakh villages of the country. Although, kerosene is sold through PDS, it is leaked to black markets through well-established channels in the distribution chain where it is sold to households at higher prices, or as an adulterant to automotive fuels (Rao, 2012). The government sought to justify these subsidies on social grounds, but it clearly failed to achieve its social goal. Higher-income groups actually appropriate most of the benefits, since the subsidy is applied to the price of electricity within a given consumer-category, independent of individual level of income. The subsidies on kerosene and LPG can also have broader implications on the oil and gas sector as a whole. Under-recoveries by power companies lead to the diversion of valuable resources that alternatively could contribute to investments in oil exploration or enhancing production and delivery mechanisms by improving technology and infrastructure. This can be understood by analysing the subsidy structure in India, where government subsidy stands at $0.49/ cylinder of LPG (of 14.2 kg) and $0.02/ litre of kerosene since 2004-05 (PPAC, 2011). This flat-rate subsidy scheme has been extended by successive governments and is currently valid through March 2014. In the last fiscal year (2010-11), the government provided a subsidy of approximately $430 million and $200 million for LPG and kerosene respectively (www.indiastat.com[14]). In 2004-2011, while direct government subsidies on these fuels did not change significantly, there was an increase of 86% in the price differential due to rise in prices in global oil markets. Thus, public sector[15] oil companies are forced to bear the price differential[16] over and above the flat government subsidy. As a result, under recoveries to oil companies in 2010-11 were approximately $5.92/ kg of LPG and $0.90/ litre of kerosene that amounted to 92% and 95% of the price differential respectively. The total revenue loss (estimate based on import parity price) for the companies was $9.67 billion in 2010-11 (PPAC, 2011).

It would be fair to summarise that subsidies often fail on several accounts (Gangopadhyay et al., 2005). In the current form, it has actually worsened the energy

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[14] Last accessed on August 2011

[15] Regulated price regime has discouraged entry of private players and nationalized oil firms are in marketing business for kerosene and LPG

[16] The difference between the import parity price and the end user [regulated] price

poverty of rural poor, for which subsidy benefits were intended, thus reducing their "chance" to access modern energy technologies at an affordable cost. The potential pitfalls of misguided subsidies are exemplified in the case of India. First, subsidies can be misdirected and misused, as seen in India, where subsidized kerosene intended for cooking is being inefficiently used for lighting (NSSO, 2011). Second, subsidies can also be misappropriated and diverted for adulteration, as evidenced in India, where subsidised kerosene is used for adulterating diesel (Rehman *et al.,* 2005). Third, subsidies may be sub-optimally utilised if the intended service is not made available, as is the case in the RGGVY programme in India where qualifying Below-Poverty-Line (BPL) households receive free electricity connections, but the electricity supply itself is infrequent. Under these conditions, the poor would benefit more by a decentralised source that ensures at least some minimum hours of supply when energy is most needed. Fourth, subsidies are often poorly targeted and often end up being consumed more by the relatively affluent, often in urban areas. Additionally, the subsidies on fossil fuels in countries heavily dependent on imports can lead to under recoveries of public sector oil companies, thereby restricting growth and expansion of oil and gas sector. Therefore, there is an urgent need to change the existing approach towards energy subsidies and make it targeted and service linked.

To summarize, the skewed political and economic emphasis on centralised grid electricity; vested power dynamics favouring affluent and urban areas; unreliability of energy service provision; and misdirected and misappropriated subsidies are responsible for limiting accelerated achievement of universal energy access in the "Big 5" countries. Thus, to take energy access forward, out-of-the-box and innovative approaches are needed that address the aforementioned concerns.

2.7 Way Forward

The approach to providing energy access needs a paradigm shift which: considers the diverse contexts across and within countries; brings modern cooking energy needs at par with provision of electricity; sets firm, phased targets with adequate resource provision; provides for equity of physical infrastructure access and ensures reliability of service; brings together public and private entities; and reorients the subsidy regimes to ensure viability and sustainability of energy services. Further, financial innovation and new metrics for measuring delivery of energy services are also needed to lessen the burden on the government and ensure effective delivery of energy services.

2.7.1 Addressing cooking energy needs and setting firm targets

Realistic and quantified targets can act as a powerful tool to help policymakers focus their efforts and improve the delivery and efficiency of their policies (Christiaensen, et al., 2002). Modern cooking energy provisioning needs to find the same thrust and priority as is given to electricity access services. As mentioned earlier, "Big 5" countries have declared goals related to provision of physical infrastructure for electricity access (Table 2.1);

however, they are yet to set targets for modern cooking access. Consequently, even the countries that have made great strides in providing access to electricity are way behind in achieving access to modern cooking. This is seen in the case of China, where the government has provided electricity access to 99% of rural populations, but one-third of its population still lacks access to modern cooking energy. The setting of targets for provisioning modern cooking energy needs to be matched with resource allocation for achieving the said targets. For instance, India has launched the New Biomass Cookstove Initiative (NBCI) in late 2010, which is yet to have specific targets and resources allocated.

Even in case of electricity, where specific targets are set, there is an urgent need for firm political commitments. The firmness of targets is essential, as shifting of goal posts is evident in some countries. India targeted "electricity for all households" by 2009 and "Power for All" by 2012 with no energy or peaking shortages (Ministry of Power, 2005 and Ministry of Power, 2006). Since the targets formulated in 2005 have not been met, the government may simply come out with new targets (and accompanying slogans).

It would be useful to split the targets on an annual basis and set up tracking mechanisms for review, as well as implement additional measures where there is a likelihood of slippage. Therefore, the target setting also needs to be realistic and set against a baseline. Further an incremental and phased approach to achieving targets should be adopted. For instance, China is expected to achieve Universal Electrification by 2015 (IEA, 2011) and is on way to achieving its goal, having reached to a level of 99% access. Conversely, India, which had declared "electricity for all households" by 2009 in the year 2006, has accomplished 66% coverage (TEDDY, 2011) and is far from achieving its target. In absolute numbers, China and India have to cover 8 million and 290 million people, respectively. While China is in a relatively comfortable position to reach universal electricity access within the declared time horizon, India would require a more realistic, firm and phased approach to target setting. Also, from a political economy perspective, for democracies, setting long-term goals without an incremental or phased approach coupled with strict monitoring may not have much value in the long term horizon, as it is open to a change of governments with the potential to shift national agendas and priorities.

Further, setting up of firm targets and matching financial commitments should be followed up with enabling regulations and policies. For instance, the Chinese government, in addition to allocating requisite financial resources, also introduced The Energy Conservation Law in 1998 and Renewable Energy Law in 2006 to create a legal system for realization of rural electrification and energy efficiency targets (Zhang et al., 2009).

2.7.2 Right mix of centralised and decentralised approaches

A more detailed analysis of China's approach towards its successful rural electrification programme provides insight on how a combination of centralized, de-centralized and off-grid electricity supply was successful in providing 500 million people in rural areas with electricity access since 1990 (IEA, 2011). In addition to laying emphasis on expansion of centralised grid electricity, the Chinese government implemented two schemes: the Brightness Programme and the County Hydropower Construction for National Rural Electrification. These schemes were intended to cater to underserved regions using small hydropower, wind, and solar power generation. The process was supported by promoting preference to domestic manufacturing of stand-alone technologies through nationwide public tenders (Niez, 2010). The supply side efforts were matched by initiatives for creation of local opportunities for rural inhabitants through the setting up of electricity-based rural enterprises and other mechanisms that led to an enhancement of purchasing power. This in turn led to an increase in the energy demand of rural households (Peng and Pan, 2006). In some other areas, the establishment of local grids at the village or community level was followed by an upgrading of the system to link them to the regional or national network (Bhattacharyya and Ohiare, 2011). At a macro level the process for decentralisation in China was further aided by enhancing the share of renewable energy in the total energy mix. An allocation of $266 billion package has been made by the government to utilize 15% of its primary energy from renewable energy sources by 2020 (Thavasi & Ramakrishna, 2009). China has also announced to increase plant-based ethanol (biodiesel) production from 1.02 to 10 million tonnes and wind power capacity from 1.26 to 30 million kW by 2020 (Thavasi & Ramakrishna, 2009). In contrast, Indonesia uses a non-cost reflective, subsidized electricity tariff of the centralized grid-connected load as reference to purchase renewable energy, which has made small and renewable Power Purchase Agreements (PPA) “non-bankable”, indicating an uneven playing field between centralized grid and de-centralized or off-grid options (USAID 2008).

Hence, the approach to reducing energy inequity needs to move beyond a one-dimensional focus on centralised options to have the right mix of centralised and decentralised approaches. The approach is particularly desirable for rural and remote locations where grid extension may not be viable or beneficial due to substantial demand and supply gaps. In areas with low scattered habitations (like islands in Indonesia and north eastern states of India), extending gridlines can significantly exceed national cost/ tariff benchmarks of grid extension. For example, in Indonesia, rural electrification is not financially attractive to “Perusahaan Listrik Negara” (PLN, the Indonesian government-owned corporation which monopolises electricity distribution in Indonesia), because Indonesia’s off-grid areas are sparsely populated, have very low load factor, and are dominated by low-end household consumers who are charged a heavily subsidized tariff (USAID, 2008). Despite the obvious constraints in a majority of “Big 5” countries, options other than grid extension have been considered costlier, and hence, major energy allocation is marked for grid-based power.

The approach of singular focus requires correction wherein centralised grid, micro-grid and off-gird options need to be recognised and promoted on a level playing field. This is particularly important for countries that are not in a position to make major investments in infrastructure creation for centralised grids. For example, in

India, as on 31 December 2011 of the Eleventh Plan period, USD 3.3 billion has been allocated for electrification of 49,912 villages and release of connections to 16.4 million BPL households (GoI, 2012). Understandably, investments to this extent may not be feasible in the short term for countries such as Bangladesh. In such a scenario, the best should not be the enemy of the good, and the transition has to follow a more graded approach where there is scope to focus on alternatives that can provide benefits in terms of physical coverage while ensuring dependence and consumption. Thus, government allocation and programmes should not have a cap for decentralized energy solution options.

A wider menu of options and choices within a broadly defined framework can help accelerate the process of energy access compared to the existing approach of focussing on policies and programmes directed at providing specific fuels and technologies. The goal of universal access and quality electricity to all can be better achieved through more broad based policy and programme framework that take into consideration the recent increase in efficiencies and lowering of capital costs of several renewable energy options. Thus, allocation of resources can factor in economic viability of the energy options based on cost of supply and the ability to make energy available to the end users. Hence, if a renewable energy source can guarantee minimum hours of supply that exceed the centralised grid capacity, the end user should have the flexibility to make an informed choice on the basis of a cost-benefit analysis. Similarly, although LPG-fuelled cooking is significantly less polluting and more energy efficient than traditional biomass usage, the population should not be forced to choose only between traditional and LPG cooking options. To achieve universal energy access under such situation, parallel policies for promotion of efficient cooking energy options, such as biogas and improved cookstoves, need to be promoted on an equal footing. The main driver should not just be a specific technology or fuel, but rather a standard or benchmark of service that energy provision is expected to provide.

2.7.3 Promoting private participation and local involvement

The mix of different approaches and the need for investments that may not be feasible for public utilities would also require involvement of stakeholders like local governments, communities and entrepreneurs to plan and manage the energy systems. The process of involvement of private sector and local stakeholders would also help in improving management of the infrastructure and energy delivery process. Thus, transitioning from the existing regime of uni-dimensional centralised grid extension needs to be fostered by government support, technological flexibility and the involvement of the private sector and communities in electrification schemes.

The process of involving the private sector may require reforms, the drivers of which can be both internal and external factors. For instance, in India the internal mismanagement by power utilities, coupled with the inability of the government to cater to the power demand, led to opening of the electricity to private players in

1991. Thus, the private sector was brought in to improve the financial position of State Electricity Boards that had been adversely affected by the electricity subsidies and operational inefficiencies (Shukla and Thampy, 2011). Similarly, in the East Asian countries, initial reforms were largely an outcome of the rise in electricity demand and inability of the government to meet the same, leading to the entry of independent power producers (IPPs) (Wamukonya, 2003). In China and the Asia Pacific countries, reforms were a consequence of a lack of capital to boost domestic power supply (Li and Dorian, 1995; Cope, 2000). The external sources of funding, including the World Bank and ADB, were responsible for pushing the Government of Bangladesh towards Power Sector Reform in 1994 (Wamukonya, 2003). Overall, the reforms in the "Big 5" countries, such as Bangladesh and India, have been relatively strong and largely justifiable, allow more choices, reduce prices and provide improved services as opposed to the dissatisfaction amongst consumers associated with government-owned electricity utilities corruption (Wamukonya, 2003).

The advent of new technologies (off-grid electricity) also offers opportunities for bringing in new players and to contribute to competition for improving services. Over the years, decreasing per MW costs of decentralized renewable energy technologies and development of high-voltage transmission lines facilitate long distance electricity transportation. Additionally, technological advancement has helped to attract private sector and help reform and rationalize and regulate the power sector (Pineau and Hamalainen, 1999). The process has contributed to offering technological opportunities for electrifying majority of the un-electrified households in the remote areas.

The involvement of local governments, communities and entrepreneurs is also desirable to accelerate universal energy access in an effective manner. One of the key factors for China's success in reaching 99% coverage was a bottom-up and phased approach for electrification. The approach involved the formation of a Rural Electrification Leading Group, led by the county governor, and established in every county to make key decisions in the construction, fund raising and other key elements of the rural electrification effort (Peng and Pan, 2006). Similarly, India's rural electrification program (RGGVY) has popularized a franchise model to manage local distribution to enhance service delivery and curb energy leakage (TERI, 2010). In some areas, such as Sualkuchi, Assam franchises have resulted in a dramatic reduction of commercial and technical losses, including a 60% to 19% adjustment, and an increase in revenue collection by 214%. However, it should be noted that the viability of the franchise model is contingent on the quality of the franchisee, and has had mixed success (ADB, 2009). In China, local engagement is also developed at a smaller scale, where farmers are hired part-time to monitor energy meters (Niez 2010). Similarly, at a micro-level, TERI has piloted a business model that provides lighting through low-powered LEDs installed in rural households or business centres. The pilot estimates installation cost in the range of USD 80 per Watt peak. The capacities of the micro-grid range between 60 Wp and 1200 Wp. The tariff is approximately USD 3 per month for fixed hours of supply, which is in accordance to average household expenditure on kerosene for lighting by rural households (Jaisinghani, 2011). Furthermore, the micro-grid is owned and operated by a rural energy entrepreneur at the local level. Thus, these examples clearly suggest that any new approach to facilitating energy access would necessitate joint ownership between local communities, entrepreneurs, and private sector and government institutions.

2.7.4 Reorienting and redirecting subsidies

A multi-dimensional approach to universal access to energy would not only require a mix of options and multiple stake- holders, but also requires supporting financial instruments such as subsidies and investments. Generally, provision of a subsidy to certain sections is influenced by political reasons or/and to meet the development goals. Generally, provision of subsidy to a certain section is influenced by political reasons to meet development goals. Politics often affects the continuance, distribution, geographic expansion and eventual termination of subsidies in developing countries. Appropriate design of subsidies is vital to make them more productive. Hence, while continuing with energy access subsidies, it may be desirable to reorient subsidy regimes by making them end-use-based (as opposed to product- based) and then making directly available to consumers. Under such a situation, users benefit from the flexibility to choose among competing means for meeting energy needs.

The first step in rationalising subsidies can be to make it product or technology neutral. The decision to choose the option and, to an extent, the usage of the subsidy amount can be in the hands of the consumer rather than the supplier, ensuring efficient usage both in terms of utility and targeting, as well as curbing pilferage or diversion. Thus, an energy subsidy can be used partly for meeting cooking energy needs and partly for use of electricity, depending on the priority and the choice of the consumer. Here it is important to assess the product or the option that is subsidized and its benefits in terms of conforming to some minimum standard of the energy service provided. The earlier point on subsidizing kerosene in India, which is used for poor quality lighting, is a case in point. Once an option with a basic minimum standard is decided, the quantum of subsidy can be decided in a manner so that it is equitably available and used amongst the targeted section. Further, all subsidies should also incorporate the unit cost of actual delivery so as to bring in an element of transparency in terms of creating a level playing field.

The delivery process of subsidies also requires a major shift with a focus on ensuring better targeting and management of pilferage. One such option could be to deliver subsidies through smart cards (Planning Commission, 2008). Smart cards are com- puter chip based 'intelligent cards' on which specific information can be loaded and monitored through a remote system. These cards are in use in several parts of the world for providing a number of basic services. Such card systems can be used in developing countries with the requisite IT infrastructure (like India) for provision of micro-credit and payment of bills to utilities. The subsidy provision through smart cards can then be made directly to the consumer. For instance, in the Indian case of kerosene, the subsidy flows from the top (supplier), to the retailer and finally to the consumer. It is at middle level of value chain that diversion and pilferage occurs. Once kerosene is made avail- able to the middle level (dealer and retailer) at the full market price, the channel for diversion would be plugged. The consumer can then get kerosene using his card, on which the subsidy amount is already loaded and gets transferred to retailer and dealer once actual delivery has taken place. In the future, cards can be made technology or product neutral so that consumers have the choice to go for the best option that is available or required. The use of smart cards also highlights the potential of information technology in improving delivery systems and facilitating access to basic services. Of course, use of smart cards cannot be a universal solution for all countries as it would require investments in building data bases and related infrastructure which may not be immediately feasible for countries such as Bangladesh.

Overall, the efforts at redirecting of subsidies need to ensure that the delivery process does not involve large value chains, as seen in the case of the kerosene subsidy delivery in India. The emphasis has to be on innovation and transparency, and the countries would have to focus on ensuring that subsidies are properly and transparently accounted in terms of their actual dispensation and use. Moreover, it needs to be recognised that subsidies are just one instrument among several other financial options that are required for achieving universal energy access.

2.7.5 Investments and access to finance

Given the high capital costs of energy infrastructure investments and the need to provide subsidies at various levels, universal energy access cannot be financed by national governments alone in developing countries (AGECC, 2011). For example, the macroeconomic crisis (late 1990s) in Indonesia damaged the financial health of the government owned PLN, due to devaluation of the national currency. PPA (power purchase agreement) of PLN with power supply companies were in USD, resulting in almost 75% reduction in value of the ultimate funding currency (PwC, 2011), thereby severely constraining its ability to finance rural electrification. Going beyond dependence on public resources, energy access initiatives need to connect to private sector financial institutions to facilitate financing of energy provision and as well as its access. For instance, in China, during 1994–2000, more than 1700 rural hydropower stations were built, with a total installed capacity of 1.06 million kW. The total cost for the new stations were 1.33 billion USD, out of which, 0.97 billion USD was invested by the private enterprises (Zhiwu, 2006). Therefore, as mentioned earlier, it is imperative that the private sector is involved to bring additional resources for facilitating access. For this purpose, governments need to provide measures for risk sharing and hedging of investments by private parties.

Given the limited involvement of financial institutions, work- shops and training programs can facilitate building institutional understanding of the real costs and benefits of rural energy development. Moreover, micro-finance programs are needed that focus on finance to support rural energy entrepreneurs and for consumers to purchase energy delivery systems and appliances. Specifically, capacity building initiatives can focus on development of methodologies for evaluation and mitigation of risks related to financing for energy related entrepreneurship. In India, SELCO, an Indian solar energy enterprise, partners with third- party lenders to provide micro-credit loans on a household basis for solar energy applications (GEF and UNEP, 2007). These financial innovations can be customized based on country context and capacity. For example, in Honduras and the Dominican Republic, where the presence of a third-party credit provider is limited; micro-lending (rental) is used by the US-based company Soluz to enable access to unsubsidized energy service through PV technology (Rogers et al., 2006). Carbon finance is another route that can provide much needed support for addressing afford- ability issues for the poor. It is desirable that programmes for developing carbon finance methodologies, particularly for provision of modern and clean cooking energy options, are promoted and supported by the national governments. Countries such China and India can provide leadership in developing such methodologies as well as mobilising the international community to provide resources that can take forward carbon finance based initiatives for facilitating energy access.

2.7.6 New metrics of measurement and monitoring

The aforementioned approach to addressing energy access would also require a much needed shift in measuring and monitoring energy access. In line with the emphasis on actual delivery of affordable and reliable energy, the energy access goals should include minimum service delivery benchmarks that need to be complemented with measures for monitoring of such bench- marks. For example, National Electricity Policy in India has a declared minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012; however, there is no system that monitors and reports on its adherence. Hence, the process and system of reporting and monitoring energy access needs to be reoriented to move away from just focussing on physical coverage and connection, toward capturing the actual availability, reliability and consumption of electricity and modern cooking fuels at household level. Thus, time bound targets for energy access programmes should include parameters like percentage of dependent households, actual availability of energy and consumption. Monitoring in this regard can lead to a more objective evaluation of energy access programmes. Hence a key issue related to monitoring is collection and collation of new data sets that incorporate demand-side indicators (Pachauri and Spreng, 2011; Nussbaumer et al., 2011). Currently, such country-level data points in developing countries of Asia are often scarcely available, updated or even collated for policy decisions.

2.8 Conclusion

The realization of international objectives, such as the United Nations vision of "Energy for All" by 2030, for a majority of the countries will critically depend upon a concerted focus on policy convergence and the successful implementation of pro-poor policy through a broad-based energy framework, including reorientation of subsidy regime. Additionally, the provision of technology and fuel neutral energy access, with benchmarks focusing on reliability/quality of energy services and equity, is necessary to achieve the ambitious objective of sustainable energy for all. As mentioned earlier, the key factor in facilitating energy access has to be an element of flexibility within a broadly defined frame- work. The need is to move away from reporting merely on targets in the form of physical coverage, and to focus on outcome- oriented energy provision that takes into consideration demand- side parameters such as availability, reliability and consumption. This requires an enabling environment by developing and mobilising a level playing field related to a suite of technology choices, financial mechanisms, business models, and institutional and human capacities.

CHAPTER 3

Energy for sustainable development in india: linkages and strategic direction[1]

Abstract

In recent times the two major international endorsements of the elements of sustainable development in recent times, the Millennium Development Goals (MDGs) and the World Summit on Sustainable Development (WSSD), have recognized universal access to energy as an important goal. In India, with a population of over a 1000 million people, it is estimated that a mere 43.5% of the households have access to electricity. The choices that the country makes towards energising the remaining population would have a significant impact on other parameters such as agriculture, water, health and even biodiversity. India has set itself a target, going beyond the MDGs, of energizing all households by the year 2012. In the differentiated responsibilities that various ministries to the Government of India have the strategy for reaching this target may not address itself to the larger development goals.

Acknowledgements

Part of the analysis in the paper is based on the data collected under the TERI project "Strategies for electrification of villages inaccessible to the grid in the state of Jharkhand" for UNDP.

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[1] This chapter is reproduced from Srivastava, L., Rehman, I. H., 2006. Energy for sustainable development in India: Linkages and strategic direction. Energy Policy 34 (8), 643–654.

3.1 Introduction

The recognition of energy as a key input for economic development is evident from the fact that the two major international endorsements of the elements of sustainable development (SD) in recent times, the Millennium Development Goals (MDGs) and the World Summit on Sustainable Development (WSSD) have recognized universal access to energy as an important goal. The rationale for this lies in the fact that there is huge discrepancy in energy consumption levels between the developed and developing countries (Figure 3.1) exemplified by the fact that more than two billion people in the world (largely in Latin America, Asia and Africa) have no access to modern energy supplies.

Owing to the critical link between energy and several economic activities this has a negative bearing not only on their livelihood but also on several other drivers of sustainable development including water, agriculture and health. The relationship between energy and development is best illustrated by the fact that the population living below poverty line in developing countries reduces as we move from a stage of low level of electrification to higher levels (Figure 3.2).

With a rural population of over 741 million people and the UNDP HDR reporting human poverty value of 31.4% for 2004, India ranks 48th among 95 developing countries on poverty levels. In this context, inequitable access to clean energy sources in the country is a major impediment to sustainable development. This is amply borne out by the fact that misery of close to 30% of the rural masses who do not have access to potable drinking water over 40% who lack access to proper

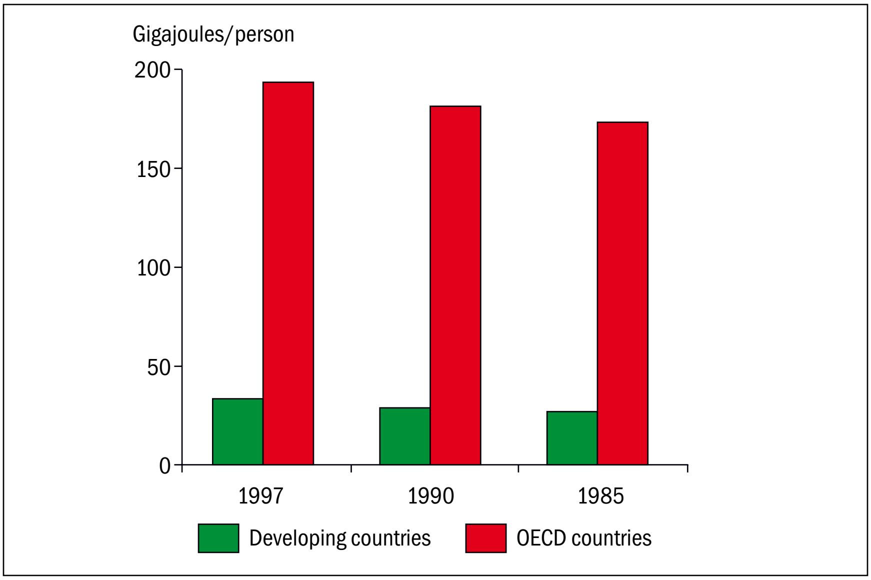

Figure 3.1 Energy use in developed and developing countries
Source: Data from OECD/IEA 2000

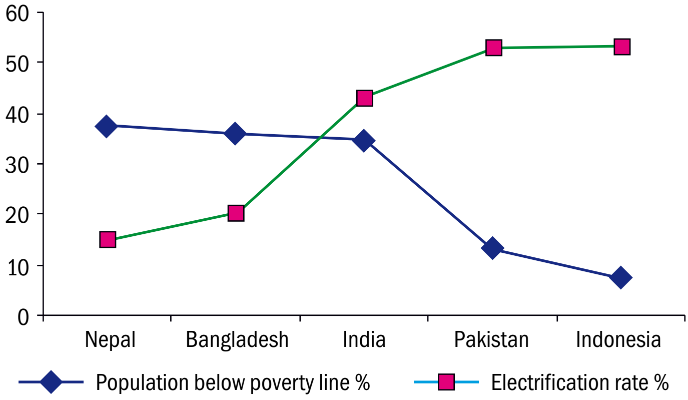

Figure 3.2 Electrification vis a vis population below poverty line

health facilities can be addressed to a large extent through the provision of clean and efficient energy (Census 2001, Government of India, 2001a). Moreover, agriculture and micro-enterprises sector that together employs more than 30% of the population can become more productive and efficient through provision of clean and sustainable energy options. Hence in order to address the needs of sustainable development it is necessary to examine the constraints related to rural energy and find appropriate solutions that have a bearing across all other sectors of rural development.

3.3 Issues and problems related to clean energy access in Rural India

The issues and problems plaguing the rural energy sector in the country include lack of a policy framework, division of the sector across multiple agencies, over emphasis on grid, misdirected subsidy regimes and lack of research and development (R&D) initiatives. The following sections briefly analyse each of the above-mentioned problems.

3.4 Lack of a policy framework

Probably the most overarching factor contributing to the poor development of the rural areas is the lack of a rural energy policy. Rural energy is considered to be a small part of the energy sector and hence the planning process does not allocate enough space to it (Rehman and Bhandari 2002). Consequently, rural energy provision has been basically driven by target oriented and subsidy driven national programmes that have either been technology centric (National Programme on Biogas Development, National Programme on Improved *Chulhas*) or end use based (Kutir Jyoti – the programme for provision of a single light point in each home) without having any interlinkages (Malhotra *et al.*, 2000). Moreover, the programme-based approach has led to a scenario wherein the emphasis has only been on meeting physical targets with little or no attention being given to either the effectiveness of these programmes or the issues that require a coordinated approach to development. Hence, in spite of the existence of these programmes for nearly two decades, their impact on the rural energy scenario, and on the development scenario in general, has been limited as is evident from the low penetration level of modern fuels in rural areas (Malhotra et al., 2000) (Figure 3.3).

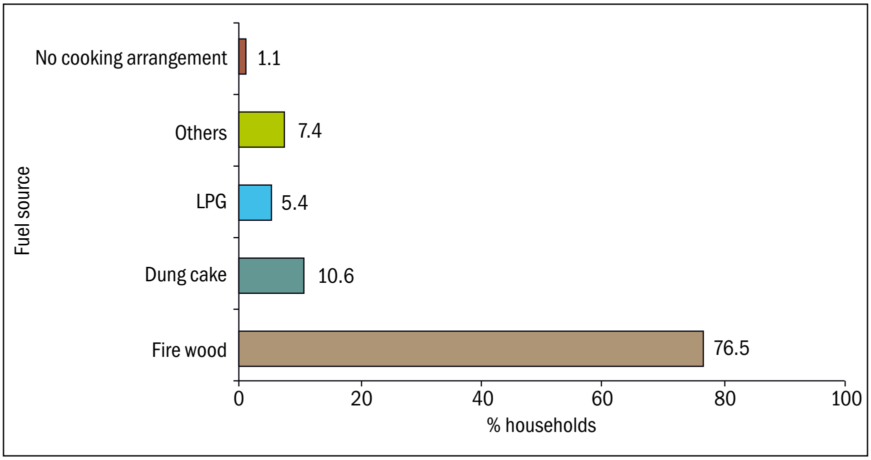

Figure 3.3 Energy use in rural households
Source: NSSO 2001

3.5 Multiple agency management

A UNDP- report on energy for sustainable development (UNDP, 2000) indicates that in developing countries often there is a lack of clarity on specific roles and responsibilities of various departments /institutions/ministries/ agencies involved in disseminating energy services in the rural areas leading to functional overlaps and increasing the pressure on the already scarce resources. In this context the energy sector in India is today administered at the apex level by five ministries (including the Department of Atomic Energy). Therefore, though the planning for the energy sector is done by a single agency, the Planning Commission of India, the implementation of the plan is split across different ministries thereby limiting the scope of adopting an integrated approach (Box 1).

Moreover, even the plan approach resembles more an aggregation of the plans of individual sub-sectors, rather than an integrated view of the sector as a whole (Box 2,TERI 2002).

3.6 Lack of access to clean technologies and fuels

At the rural level there is a continued problem of lack of choices to cleaner fuels and technologies. This is borne out from the fact that the penetration level of commercial

Box 1 Lack of inter agency co-ordination

Consider the case of kerosene and electricity. As part of a complex arrangement the Ministry of Petroleum and Natural Gas through the Oil Companies supplies kerosene to the Department of Food and Civil Supplies that in turn distributes it to rural consumers through the PDS (public distribution system). On the other hand electricity distribution is under the purview of Ministry of Power (MoP) (2003). Thus, while the subsidy on kerosene was to promote its use as a cooking fuel to substitute for the use of firewood, in practice most of the kerosene consumption in rural areas is primarily for lighting purposes. Not recognizing this reality, its dissemination at the rural household level, instead of being linked to electrification, is dependent on Liquefied Petroleum Gas (LPG) connections. A household with a double bottle LPG connection cannot take kerosene from the PDS (public distribution system). However, little effort has been made by the respective ministries to sort out the problem.

(Source: TERI 2005)

Box 2 Lack of intra agency co-ordination

The biogas programme and the improved Chulha (cookstoves) are both directed at meeting the cooking requirements in rural areas but each programme has its own targets and these are pursued independent of each other. Thus even in the same ministry the programme specific resources are not judiciously employed for improving access to energy sources.

fuels like LPG in the rural areas is just over 5% (Figure 3.3) while in the urban areas over 40% households use LPG for cooking purposes. Similarly, the access to electricity in urban households is about 90% while in the rural areas it is well below 50% (NSSO: 2001). There are two reasons for this limited access to cleaner fuels : one the policies have been largely urban centric and have not given the issue of rural energy its due; and two there is lack of appropriate credit mechanisms for energy access at the rural level which has limited the options to consumers with a low purchasing power.

3.7 Over emphasis on grid

Apart from the experiments with the biogas development and the improved cook-stove programmes, energy provision in the rural areas has become synonymous with extension of the centralized grid to the villages. Hence, if the grid reaches the village, its energy needs were understood to have been met irrespective of whether any actual consumers exist or not. This approach has two inherent flaws. One, electricity provision solves only a limited problem and does not address the cooking and heating needs for which the rural populace continue to depend on inefficient biomass based sources of energy (Rehman and Bhandari, 2002). Two, even the grid extension does not guarantee access to electricity, which is amply borne out by the fact that though 86.76% villages have been electrified (Planning commission, Government of India, 2001b) only 43.5% of rural households have access to electricity. Consequently, 70–80 million rural households still depend on kerosene lamps for meeting their lighting requirements.[2]

An important aspect in terms of grid based rural electrification is its overall viability for the hamlet settlements in the villages. Uncertainty of power, load shedding and rostering schedule on an extensive scale dampen the demand for power in

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[2] According to the draft Tenth Five-Year Plan for 2002-07 of the Planning Commission, Government of India.

rural areas. On the other hand, the costs of setting up transmission and distribution capacities are high and are accompanied by significantly higher losses. Also, while close clusters characterize the rural settlements in the plains, those in the hilly, forest and desert regions are highly dispersed. Given such sparse nature of demand, it becomes economically infeasible to provide power transmission lines to a few houses with a load that is a fraction of a kilowatt. Therefore, the centralised grid based rural electrification program has been expensive, and due to social considerations, has become a huge financial burden on electric utilities (Rehman and Bhandari, 2002).

3.8 Lack of an inter-sectoral approach

Often, the problem-solving approach in India's planning efforts has been sectorial. A classic example is the treatment of water and energy problems in isolation. Highly subsidized power supply policies for agriculture have had an adverse effect on the health of the electricity utilities and have led to an overexploitation of water. This, coupled with poor and unreliable power supplies, has resulted in farmers withdrawing as much water as possible during the limited time that power is available using oversized and inefficient pump sets. The power supply and consequent lack of water for irrigation purposes perpetuate the poverty cycle (Padmanabhan 2001).

Similarly, the implications of access to clean energy sources on the health of rural population is not adequately acknowledged and internalised in the cost-benefit analysis of rural energy projects. While Box 3 highlights some of the health costs of using poor quality solid fuels; however, the evidence on the relationship between access to electricity and the provision of health services (diagnostic and hospital) is largely undocumented.

Box 3 Environment and health

With its large poor, urban, and rural populations still using solid fuels in traditional devices, the problem of indoor air pollution is likely to persist in India. As per the 1991 census data, 81% of all households in India relied on unprocessed solid fuels. Such fuels are substantially more polluting than liquid and gaseous fuels. Measured levels of health damaging pollutants from biomass stoves are over 10 times higher than the standards. This leads to serious health implications such as acute respiratory infection, chronic obstructive lung disease, adverse pregnancy outcomes, and eye irritation. Children and women are the most affected sections of the population, as their levels of exposure are high. Estimates of annual premature mortality due to indoor pollution in India (given below) indicate that the disease burden due indoor air pollution is of an order of magnitude higher than that of outdoor air pollution, and this places indoor air pollution as a major risk factor in the country.

Premature mortality ('0000) due to		
Outdoor exposure		Indoor exposure Source
50–300	850–3300	Smith (1994)
84	590	WHO (1997)
200	2000	Pachauri and Sridharan (1998)
Source: TERI 2002b		

3.9 Subsidy regime

The subsidies on some of the key energy sources that impacted the subsistence need of the poor were to be the main mechanisms for provision of equitable access to energy. Thus, electricity for pumping water for agriculture and for kerosene for rural lighting on a subsidized basis were provided to the rural masses. Both the subsidies have had disastrous consequences (Box 4). The total amount of subsidy on electricity for agriculture in 1999-2000 was approximately 5.5 billion dollars while estimates indicate that only 10%-12% of the cost of power supply for irrigation purposes is recovered (TERI, 1998). While the agriculture subsidy has led to the bankruptcy of electricity boards the kerosene subsidy has led to its large-scale diversion for adulteration with diesel (Planning Commission, Government of India, 2001b).

As per the Census of India 2001 there are 83.12 million rural households in the country using kerosene as a primary source of lighting. An analysis of traditional kerosene lighting devices in India by TERI has estimated weekly kerosene consumption at 0.4351 liters/week (Pal et al., 2004). Assuming a linear analysis of one such kerosene lamp per household the annual subsidy on Kerosene for lighting alone works out to nearly 384.5 million dollars for 2004-05 (Table 3.1). Comparing this to the overall kerosene subsidy of 2.9 billion US dollars for 2004-05 it is evident that only a small portion of the kerosene subsidy is used for rural lighting which can be put to better use as has been indicated in Table 3.1.

On the other hand, TERI's experience with alternate lighting options such as solar photovoltaic (SPV) lanterns at around 28 US dollars per system has demonstrated sustainable and workable solutions to switch rural populations to an efficient and modern energy systems. Hence, at current levels of subsidy (20 cents a litre) for kerosene nearly 14 million households can be provided such solar power home lighting systems per year. Extrapolating the lessons from dissemination of solar

Box 4 Power subsidies: loss of developmental opportunities

In Andhra Pradesh, power subsidies to the farm sector amount to 2% of the gross domestic product and 12% of the total fiscal outlay -- comparable to the state's expenditure for education and more than double its expenditure for health. Similar figures for Uttar Pradesh indicate that accumulated power sector subsidies of 3.7 billion dollars represent a lost opportunity to build 340 000 primary health centres or lay 250 000 kilometers of tarred roads or build 1.13 million primary schools (Padmanabhan, 2001).

Even within the energy sector kerosene subsidy could have been better utilised if it had been used for disseminating solar lanterns rather than promoting use of kerosene in archaic polluting devices and facilitating its diversion for mixing in diesel.

Table 3.1 Kerosene subsidy for rural lighting

Total number of rural households using kerosene for lighting (million)	Kerosene consumption (l/ week)	Annual kerosene consumption – 52 weeks (1/week)	Subsidy on kerosene for 2004 (cents)	Total subsidy for 2004 (million USD)
83.12	0.435	1880.2	20.45	384.5

lighting devices in Rajsthan and Uttaranchal, a 50% contribution from individual beneficiaries for SPV systems would allow for disbursement of nearly 28 million such systems per year covering nearly 100% of the un-electrified rural households in a 3 year time frame (TERI, 2005). Since the households will save approximately USD 3 and battery life for the system varies from 2 to 3 years the savings can be used by the households to replace battery (USD 7-9) (Table 3.2).

Owing to the price distortions that they produce, it is inevitable that most of the subsidies benefit higher income strata and commercial establishments rather than disadvantaged households. If we consider the analysis of a TERI-SDC study that indicates that only 30% of the total kerosene disseminated in the rural areas goes to the poor, then it is the affluent who are benefiting the most from the subsidy (TERI 2002a). Figure 3.4 illustrates the dependency of different expenditure classes of the rural population on various fuel types. It is apparent that the higher expenditure (income) classes benefit more from subsidised cleaner fuels.

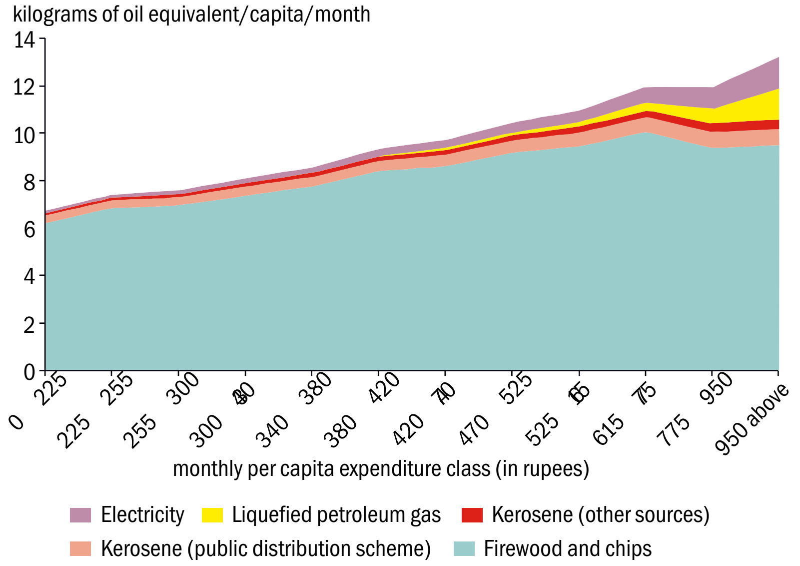

Figure 3.4 Dependency of the different expenditure classes of the rural population on various fuel types
Source: NSSO (2001)

Table 3.2 Possible utilisation of kerosene subsidy for disseminating solar lanterns

Total no. of households (million)	Total subsidy for 2004 (million USD)	Cost of one solar lighting system (USD)	Number of households that can be covered in a year (million)	Number of households that can be covered in a year with 50% contribution of beneficiaries (million)
83.12	384.5	28.2	14.2	28

India is facing difficulty in phasing-out subsidies even after they have outlived their utility. Electricity prices in the early stages of the Green Revolution were heavily subsidized by the government to encourage irrigation. However, the use of high yielding variety (HYV) seeds enhanced productivity and hence, the income, and it was no longer justifiable to subsidize electricity. However, the farmer lobby in the county has been successful in keeping the subsidies in place and also has persuaded politicians (in few states in India) to provide farmers electricity for free. Consequently the state electricity boards - which are the primary public electricity companies in India - have been severely decapitalized and cannot finance the necessary investments to maintain reliability and extend service to the poor who still lack access (ESMAP, 2000).

Moreover, in both the national and global contexts subsidies have also kept renewable energy technologies out of the mainstream energy planning by making them appear unattractive vis-à-vis the more subsidized and conventional options, and have hampered the process of commercialization of alternative energy options. For instance, the world energy assessment report states that "total sale of the energy services worldwide in 2001 was 2 trillion dollars; a small share of this amount could make an enormous difference in terms of sustainable development if efforts are directed towards cleaner energy forms." In the present scenario subsidies at the global level for conventional energy are of the order of 250 billion dollars per year, while the sales of renewable are around 20 billion dollars per year (UNDP, 2000).

Even in the case of renewable energy options, the resources could have been better utilized if instead of providing upfront subsidy the planning process had focused on encouraging R & D, commercialization, and the setting up of a marketing and service network. For instance, a TERI project focussing on the dissemination of SPV-based lighting systems in rural areas of Rajasthan and Uttaranchal revealed that in the case of solar-based lighting products subsidies are declared without analysing the related components (charge controllers, batteries, etc.) and the barriers that the poor face in accessing the same. This results in a situation where the poor may access the service/product but not a related component that is essential for the functioning of the service/product.

3.10 Lack of research and development

Policy makers and implementers have failed to recognize the important role that R & D can play in improving access to clean technologies. This reflected by the fact that research and development in the form of short term low budget projects that fail to incorporate specific outputs or future relevance in the energy agenda. The issues that can be comprehensively tackled include initiation of efforts at improving the efficiency, introduction of effective measures related cost, and utilization of local resources, etc., (Box 5).

In the entire planning mechanism there is no emphasis on the need for designing as per community needs and this is reflected in the absence of a mechanism that can

Box 5 Ignoring basics

Archaic kerosene devices are used in rural areas for lighting purposes. They have problems of high kerosene consumption, emittance of smoke, and poor luminosity. Similarly, kerosene-based cooking stoves are also highly inefficient. However, the planning process, while focusing on the subsidization of the distribution of the fuel by spending billion of rupees, completely ignores the need for improving technologies using the fuel. Hence, there has not been any concerted effort at Research and Development (R&D) for the devices and only the Indian Oil Corporation has made marginal efforts at improving device efficiency. The efficiency, marketing, and even the availability of these devices are very limited. Hence, the subsidy for kerosene could have been more productively employed for promoting and undertaking R&D for improving the efficiency of devices and protecting the consumers from the harmful ill effects on health.

Source TERI (2002a)

take and incorporate feedback for assessing R & D requirements from the community in the planning process.

More than hardcore Research and Development (R&D), the planning and implementation processes of the different energy programmes have also not focused on the efforts in terms of providing a broad menu of options and configurations.

3.11 The way forward

In India today, rural energization is manifesting itself primarily in the form of ' Rajiv Gandhi Grameen Vidyutikaran Yojana' (Rajiv Gandhi Village Electrification Scheme) that was launched in 2005 with aim of providing electricity to all rural households in 5 years. The scheme focuses on setting up a Rural Electricity Distribution Backbone (REDB) through provision of at least one 33/11KV (or 66/11 KV) substation of adequate capacity in each Block; provision of a distribution transformer in each habitation; decentralised distribution generation and supply system in villages where grid connectivity is not feasible or cost effective; no discrimination in hours of supply between urban and rural areas and sustainability of electricity supply through franchisees (MoP, 2005).

3.12 Comprehensive rural energy policy framework

- The need of the hour is to come out of the national programme mode and develop a comprehensive policy framework that
- gives due recognition to cross-sectoral energy needs,
- facilitates the provision of multi-sector based energy products and services rather than single end-use directed technologies,
- facilitates rural credit for accessing clean energy sources and technologies, and
- redirects subsidies to facilitate commercialization and entrepreneurship-based energy provision.
- The said framework should be jointly developed with the active participation of not only the line ministries but also the ministries related to agriculture, health, water resources, rural development, etc.

3.13 Balancing demand and supply

The energy planning process till now has followed a supply-driven approach making little allowances for demand patterns. There is a specific need to factor in cross-sectoral requirements and modify supplies as per the existing demand. It is equally important that efforts are made to rationalize energy demand by focusing on initiatives pertaining to demand-side management. This is particularly true for pumping water where energy intensity can be optimized by putting in place measures related to the promotion of appropriate cropping patterns (Padmanabhan, 2001).

Energy as an input for goods and services is a prerequisite for economic development that requires various forms of energy around which the economic system revolves. Comparative studies show that there is a strong positive correlation between per capita income and energy consumption (UNDP 2000). Hence, with the ensuing changes in the economy and the increase in per capita incomes the energy demands will also change, and rural energy planning process must be programmed to adapt to these changes. This would also require changes in the institutional and delivery mechanisms, both of which have been based on the supply-driven approach. The need for a demand-driven approach is best exemplified by the problems related to managing power for irrigation purposes wherein electricity is supplied without assessing the ground-water status and the specific needs of the farmers. No effort is made to introduce the farmers to less water-intensive crops, techniques of managing the power supply, or efficient irrigation technologies (pump sets) (TERI, 1998).

3.14 Coverage of villages through centralized grid

In the Tenth Plan there has been a three-fold increase in the outlay for electrification coupled with specific measures for facilitating rural electrification. One of the key issues in terms of covering the rural areas is the need for extension of the grid to over 62 000 unelectrified non-remote villages (Planning Commission, Government of India 2001b). This would require assessment of the cost of laying the distribution and transmission lines. In order to judiciously utilize the resources earmarked for electrification of villages, they would have to be categorized according to the length of the distribution system required. This would facilitate a better understanding of the economics of the process and would assist in assessing the viability of extending the centralized gird for each of the categories.

However, the issue cannot be resolved by merely extending the grid as the supply of electricity through the existing centralized grid is plagued with problems related to both quantity and quality. The downtime in a number of cases varies from 10 - 16 h per day. Moreover, the poor quality of supply, especially for the three-phase systems, results in motor burnouts and other damage to electrical equipment. Thus, extension of the grid without proper augmentation of generation capacities would place additional burden on the already fragile supply system. Moreover, the poor quality of supply would make it difficult to earn revenue from the customers, because the per capita usage will continue to remain low and the beneficiaries would be reluctant to pay for services that are either not provided or do not fulfil their basic requirements. Hence, the extension of grid to these villages has to be coupled with an augmentation of supply, improvement of infrastructure at the sub-station level, and specific measures related to voltage stabilisation. Thus, the extension of grid to these villages has to be coupled with an augmentation of supply, improvement of infrastructure at the sub-station level, and specific measures related to voltage stabilization. These points need to be incorporated in the objectives of the government programmes and adequate resources enough provided to take care of them.

3.15 Electrification of villages through decentralized/ distributed generation options

An important and critical element in resolving the rural electrification 'juggernaut' will be the electrification of over 20 000 villages which are remote and inaccessible to the grid (Planning Commission, Government of India, 2001b). The coverage of these villages through the centralized grid is ruled out primarily because the costs involved in terms of extending the transmission network itself would be at least 1.5 times higher than the already high costs of extending the network to non-remote villages. In such a scenario, the options for electrifying both the remote villages and some that could be classified as 'non-remote' would be centred around decentralized/distributed generation facilities comprising largely renewable energy technologies and diesel-based generation units.

Traditionally, in India, the approach to renewable energy has focused mainly on small-scale dissemination of household systems and not on village electrification, though mini grids based on photovoltaics and gasifiers have been set up. While the household-centred renewable projects have facilitated the rural communities in meeting their basic household consumptive needs, they have been completely inadequate in catering to productive activities. On the other hand, mini grids are able to cater to both the productive and consumptive needs, but have to be designed to meet the long-term needs of the community in a sustainable and comprehensive manner.

Based on the fact that, on an average, there are approximately 300 households per village in India (Census, 2001) with 5 - 6 hamlets (habitations) per village, it can be inferred that the basic unit of habitation would be a cluster of 50 households. A TERI study conducted in 30 villages in the state of Jharkhand revealed that the basic minimal load required for meeting the various community needs of a village with 50 households is approximately 6.3 kW (Kilowatt) (TERI 2003, Figure 3.5). In case of remote habitations this can be easily met through renewable energy options and an analysis of the data obtained for the 40 villages in Jharkhand and Uttaranchal indicated that the levellized annual cost was the least in the case of micro-hydro. However, the approach in terms of electrification has to be technology neutral as the choice of technology is related to the availability of local resources.

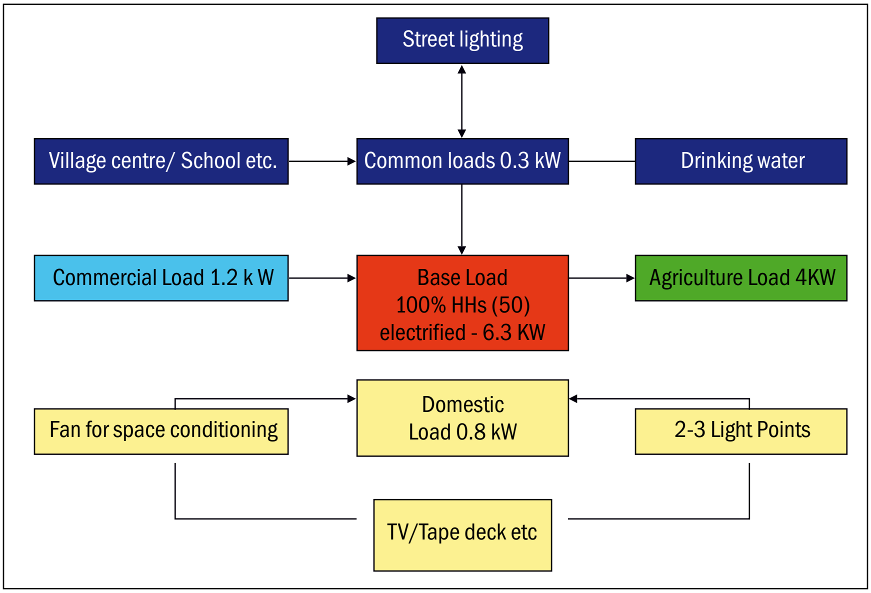

Figure 3.5 Base load profiles for a habitation of 50 households

The progression from the mini grid stage has to be to a stage where such mini-grids, at some time in the future, can be connected to a local grid or centralized grid. However, the effort to energise all villages and households by the year 2012 will lead to the setting up of a large number of mini grids that must form part of a long term strategic integration plan.

The new Electricity Act 2003 deregulated the generation and distribution of electricity in the rural areas with a view to attract private participation and/or rural entrepreneurship. Historically, a large number of factors - such as level of product maturity and user-friendly features, low volumes, high initial costs, and the distortions in pricing in the energy sector – constrained the choice of renewable energy options in particular. In the move towards deregulation and private participation it is also important to bear in mind that simply transferring public monopoly into a private monopoly is not a panacea for alleviating energy poverty, improving energy efficiency, or price distortions. In the current rural energy service delivery context Private Public Partnership (PPP) can help in meeting financing challenges of rural electrification. Partnerships are instrumental to facilitate dialogue, engage stakeholders for achievement of a common goal, sharing of knowledge, expertise and capacities and empower local communities in development of their resources.[3] Drawing lessons from some of the existing partnerships for initiating local development activities the key issue to be borne in mind include:

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[3] http://www.un.org/esa/coordination/ecosoc/hl2003/RT6%20summary.pdf accessed on February 16, 2005.

- clarity in allocation of roles and responsibilities at each level,
- encourage participation at various levels and have a decentralized approach and
- develop a public private partnership model or framework that does not significantly distort efficiency in the energy sector; but does take into consideration societal goals of expanding access to energy services by poor and rural populations.

Improvements in technology and proper scaling combined with adequate marketing infrastructure could enhance the attractiveness of renewable energy technologies significantly. In this context based on the resource availability in different areas of the country three technologies namely micro-hydro, biomass based gasifiers and solar photo-voltaics offer a viable alternative. The choice of specific technology option would depend on local resources, skills and specific needs of the community.

The lessons from different projects that have been implemented in the past indicate that in order to sustainably and efficiently establish and operate mini grids the process of selection of entrepreneurs or agency be clearly and professionally defined. As in the case of large electricity projects, the electrification (or even more broadly – energisation) of rural areas should be packaged as projects and put out to bid with clearly laid down qualifying (including service) criteria and selection procedures. Recognising the characteristics of rural electricity demand with its low and dispersed loads leading to the need for subsidies, the government could draw upon successful international experiences such as the "bidding for subsidies" approach adopted in Chile to ensure efficiency in deployment of subsidies.

The other option could be to focus on the development of build, operate, transfer projects which may require selecting local institutions or NGOs or local panchayats (*village bodies)* who, after requisite capacity building, can take over the operation and maintenance of such projects on a no profit no loss basis. The first option would ensure efficiency and commercialisation, while the second one could be more effective in ensuring that the benefits of electrification are more equitably distributed or shared. The approach could well be to follow a combination of both the options depending on the availability of willing entrepreneurs or civil society organizations. Since the government of India has set the target of 2007 for electrification of remote villages it is imperative that some of these options are quickly tested in the field and different 'institutional models' worked out for replications.

3.16 Energisation of all households

Traditionally household electrification has not been an issue and the old definition of rural electrification was confined to erection of an electric pole in the village. Consequently, while more than 86% of the villages have been electrified the coverage of households is only 43.5 (Census 2001, Government of India, 2001a). Given the mandate of energizing all the households by 2012 considerable innovation will be required in this direction. Hence, the third scenario could look at comprehensive needs of the rural communities. Electricity may not explicitly be on top of the priority list of rural communities but as it facilitates better access to basic amenities like water, health, education and connectivity with outside world through radio/ tape-recorder/TV, it is very often the starting point of development.

In order to link energy provision with sustainable development, the provision of lighting for the households must be is coupled with provision for meeting thermal and mechanical energy needs. According to World Energy Investment Outlook (OECD/IEA, 2003) the strategy for promoting sustainable development in rural areas of developing countries must include provision of the following;

- clean liquid or gaseous fuels for cooking and electricity for lighting and other basic needs,
- liquid fuels and fuels to mechanise agriculture and, and
- electricity sufficiently low in cost to attract industrial activity to rural areas.

Hence, while rural electrification schemes would primarily focus on supply of electricity, the strategy wherever necessary may include distributed generation technologies for providing single and multiple forms of energy. The options in this scenario would focus on provision of electricity for household level needs as well as other end uses. Additionally this scenario will also cover all energy needs related to thermal applications. This scenario is closely linked to the concept of sustainable development wherein energy needs related to housing, common infrastructure, economic activities, agriculture, micro enterprise will be covered.

In this context it is imperative to understand the village consumption patterns and then device localized plans for catering to the same. For instance, a TERI study conducted for developing a strategy for electrification of remote villages indicated that with an increase in the number of households in the village there was a progressive increase in the demand for load (Figure 3.6). This is obvious but what is significant are the variations and trends in the required load with respect to different activities. A detailed analysis of the data compiled from 32 villages as part of a TERI study for developing a strategy for electrification of remote villages in the state of Jharkhand indicated that across villages there are large variations in the agriculture load requirement (Figure 3.7).

These variations do not follow the trend of overall increase in load with the increase in number of households, as agriculture loads are dependent on local land holdings and crop patterns. However, the data indicate that the average agriculture load per household ranges from 0.075 kW to 0.185 kW per household. Hence, 0.075 kW can be taken as a base norm for electrification of villages and households for catering to agriculture loads. Moreover, the data also revealed that addition of agriculture load requirements to the other loads at the village level led to a seven-fold increase in the total required load (TERI, 2003).

Similarly, the data indicated that the commercial loads at the village level led to two fold increase over the total common (village schools, street light etc,) and, domestic lighting load requirement (Figure 3.7). Hence, the strategies for electrification of

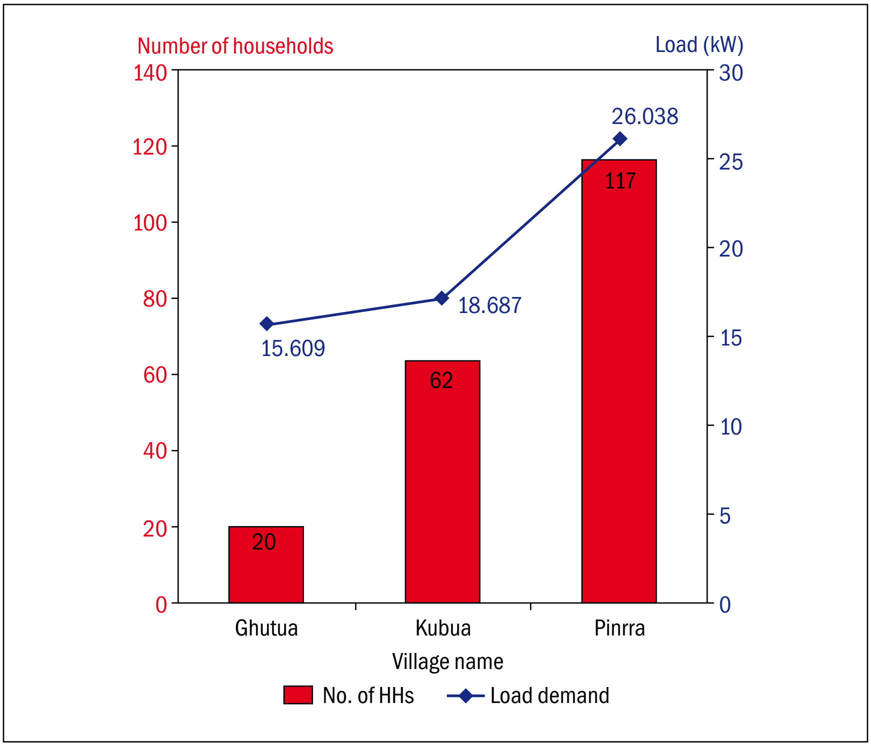

Figure 3.6 Increase in electricity loads with increase in number of HHs
Source: TERI 2003

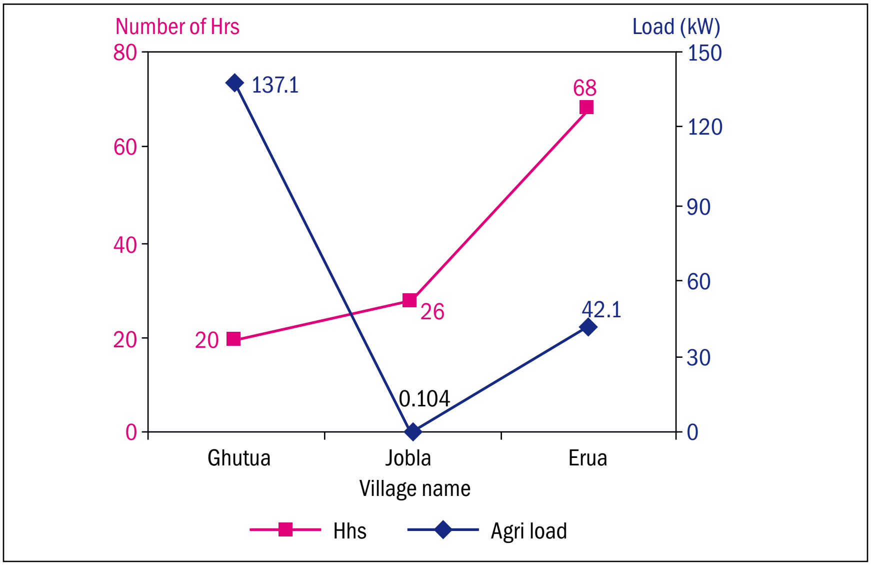

Figure 3.7 Variation in agriculture load with increase in number of households
Source: TERI 2003

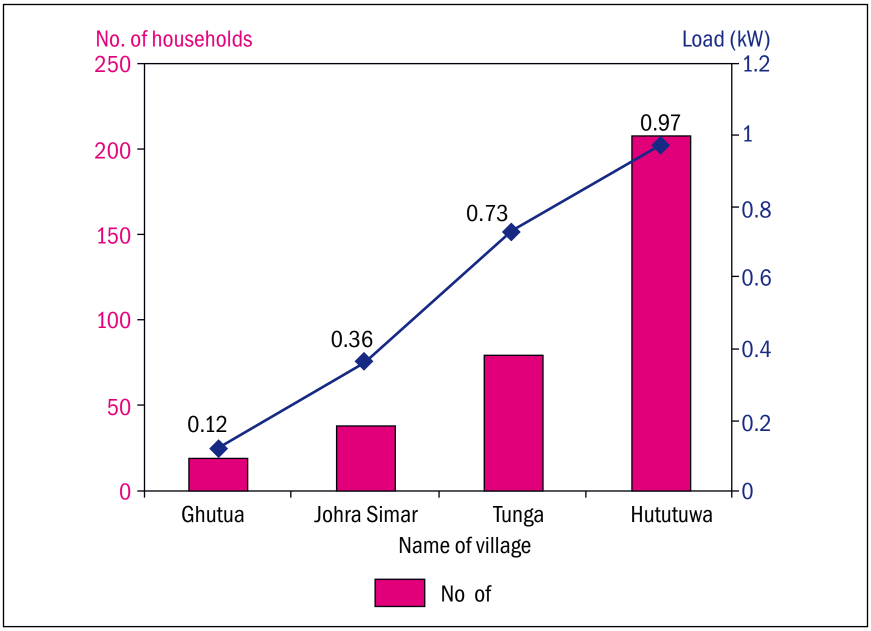

Figure 3.8 Variation in commercial load with increase in no of households

households have to factor in different needs of the households that go much beyond simply lighting for the households (TERI 2003).

3.17 Conclusion

In order to solve the energy problems of rural India it is necessary to look beyond rural electrification and focus on an integrated approach to meeting comprehensive energy needs. This would mean focussing on both consumptive and productive needs of the community through efforts that are interrelated both in planning and execution. A desirable energy programme need to focus on a service centred rather than product or technology centred approach wherein the costing is done on a life cycle cost instead of capital investment. Moreover, it is also necessary to redirect subsidies to encourage energy efficiency, entrepreneurship and demand side management. India has a unique opportunity to design and implement its ambitious rural energisation programme for meeting the needs of sustainable development while creating entrepreneurship opportunities at the local level. While the target it has set itself is steep, the biggest mistake would be to try and achieve this any which way possible as that would undoubtedly lead to sub-optimal, unsustainable solutions.

CHAPTER 4

Availability of kerosene to rural households: a case study from India[1]

Abstract

A majority of the rural population in India continues to rely on kerosene for domestic lighting. Measures to promote inter-fuel substitution in domestic lighting by promoting rural electrification have met with partial success. Electrified households in rural areas also use kerosene as a back up fuel because of erratic and poor electricity supply. Kerosene is subsidized, and an extensive network has been put in place for its distribution. Both these measures are meant to facilitate access and affordability by the poor. However, this is not the case at the grass-roots level. Further, use of traditional lighting devices has also had an adverse effect on the quality of life of the people for these devices are inefficient, emit smoke, and give poor quality light. In this the poorest of the poor, who have limited choices and options are worst affected.

This paper, taking the example of a TERI (the Energy and Resources Institute) case study in the state of Rajasthan, analyses the issues of access and availability of kerosene to rural masses, especially the poor. It highlights the existing problems with the kerosene distribution system and examines the subsidy-based, supply driven approach to distribution in terms of facilitating access to the poor. It, accordingly, puts forward specific policy measures for improving access to kerosene and its more efficient use as a lighting fuel in rural India.

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[1] This chapter is reproduced from Rehman, I. H., Malhotra, P., Pal, R. C., Singh, P. B., 2005. Availability of kerosene for rural households: a case study from India. Energy Policy 33 (17), 2165-2174.

4.1 Introduction

About 72% of the population of India lives in rural areas (Census of India, 2001. www.censusindia.net, accessed on 5/10/03). Only 42-44% of households use electricity for lighting; despite the fact that over 87% of the inhabited villages have been declared electrified as of 31st March 2003 (Source, Ministry of Power, Government of India. 2003. http://powermin.nic.in, accessed on 15/12/03). Further, of the MPCE (monthly per capita expenditure) for non-food items in rural areas, half is spent on fuel and light and the rest on clothing and footwear (MOSPI, 2001). The achievement of village electrification is, however, to be viewed along with the earlier definition, which declares a village 'deemed to be electrified if electricity is used in the inhabited locality within the revenue boundary of the village for any purpose, whatsoever' (MoP, 2003). At present, there are 80 000 villages in India that need to be electrified, of which 18 000 are so remote and geographically inaccessible that grid extension is not economically viable (Census of India, 1991). The other aspect of rural household lighting in India is that even in the electrified households, people continue to depend on other energy sources, chiefly kerosene, for lighting. According to an estimate, about 65% of the households in electrified villages do not receive benefits of electricity even now. This is both on account of the inability of households to afford electricity connections as well as low demand on account of poor reliability and quality of the existing supply. The net result is that at least 70–80 million rural households still depend on kerosene lamps for meeting a basic need such as lighting (MNES, 2001). On the other hand, the monthly per capita consumption of kerosene in rural areas is the lowest among all fuels (0.611 litres), only after LPG (NSSO, 2001).

Kerosene based lighting devices used widely in rural areas include kerosene wick lamps, hurricane lanterns, kerosene petromax, and non-pressure mantle lamps. Other flame based lighting devices include candles and LPG (liquefied petroleum gas) petromax. These devices (especially wick lamps, commonly known as diyas) are made at home (a used glass bottle or tin is used as the base and a scrap of cloth, dipped in kerosene, as the wick) or by local manufacturers. Hence, no quality standards are maintained. These devices have low luminous efficiency and high SFC (specific fuel consumption). Both electrified and un electrified households depend on kerosene-based lighting devices. In a study of the usage of kerosene-based lighting devices in the rural areas of Uttar Pradesh (TERI 1999), 85% of the electrified households surveyed, were using homemade wick lamps for more than four hours a day on average, and the remaining were found to be using hurricane lanterns. Another interesting pattern of usage was that a majority of electrified households used bulbs for lighting in their living rooms and outer verandahs, but continued to use kerosene-based lighting devices in the kitchen and for other miscellaneous activities. An inherent gender bias, therefore, exists.

This continued reliance on kerosene for rural lighting has adverse impacts on the wellbeing of the people on account of low luminosity and emission of smoke. Perhaps an even more overarching problem is that issues that relate to poor access to kerosene are still plaguing people living in rural areas of the country, especially the poor.

4.2 The Case study

The case study was carried out by the Energy & Resources Institute (TERI), New Delhi in the year 2002 under the project titled 'Policy research on promotion of cleaner technologies and fuels among low capacity end users' supported by the Swiss Agency for Development and Cooperation (SDC), New Delhi. The aim of the case study was to examine the access and availability of kerosene amongst the rural population in selected districts of Rajasthan. The fieldwork for the study was carried out in districts Barmer, Jalore, and Udaipur. The districts were so selected as to represent both desert and non-desert regions of the state, which also reflect different degrees of development particularly in terms of infrastructure such as connectivity and electrification status. For example, district Barmer represents the desert region of Rajasthan with low levels of infrastructure development. Jalore, on the other hand, has a high density of industries using kerosene. Udaipur is richly forested non-desert region of the state, however, the connectivity in rural areas is poor. Further, Udaipur district has a predominant tribal population that represents the poorest of the poor section of the society in rural Rajasthan. Within these districts, a cluster of villages were selected (based on stakeholder discussions) for primary data collection.

The objectives of the case study were 1) study of the national and state level policies on kerosene allocation, pricing and distribution, 2) assessment of the actual availability of kerosene to various socio-economic segments of the rural population, 3) study of the constraints faced in using kerosene as fuel for both cooking and lighting, especially by the rural poor, and 4) give policy level recommendations to improve the availability of kerosene in rural areas as well as enhance access to the fuel. Data collection was done through household surveys and using PRA methods such as focussed group discussions (FGDs), key person interviews (KPIs), resource and social mapping, matrix scoring, time line, etc.

4.3 Kerosene allocation and distribution: a policy perspective

4.3.1Policy for allocation of superior kerosene oil (SKO)

SKO in India is an allocated product. Allocation has been made to states/ UTs (union territories) on a historical basis. There was a lot of disparity in the process of allocation of kerosene to different states/UTs till 1998/99 when the Government of India provided a one-time growth of 8.58% at the national level (source. http://www.petroleum.nic.in, accessed on 15/10/03). The distribution has been based on the principle of higher growth rate of allocation to the states, having lower per capita availability and vice versa (source. http://www.petroleum.nic.in, accessed on 23/01/01).

The annual PCA (per capita allocation) for states ranges between 10–24 kg. While allocating kerosene for the year 1999/2000, the maximum annual PCA has been frozen at 24 kg (MoPNG, 2000). Monthly allocation is now being done on a uniform basis, except for the state of Jammu and Kashmir (TERI, 2001).

At the level of the state, allocation changes district-wise and month-wise. It may be noted that allocation is linked to consumption, and that consumption is invariably higher in agriculturally prosperous regions, especially during the period of irrigation. For example, Jaisalmer district, which has limited agriculture, has the lowest overall allocation annually (450 – 600 kl) in the state of Rajasthan and has the maximum allocation for the months of June to September (Unpublished data, Department of Food and Civil Supplies, Jaisalmer, Government of Rajasthan, 2001). Accordingly, for the agriculturally prosperous eastern districts of the state, allocation is much higher. In district Ganganagar in eastern Rajasthan, the allocation of kerosene for 2001 was 1764 kl, which had increased from 1350 kl in 1998.

4.3.2 Policy for distribution of SKO

In India, there are two mechanisms that are followed for kerosene distribution. These are as follows:

Public distribution system (PDS)

Kerosene is distributed primarily through an elaborate institutional arrangement comprising state and district level officials, wholesalers, and retailers (owners of fair price shops).

At the national level, the Ministry of Petroleum and Natural Gas (MoPNG) fixes the quota for each state. The allocation varies from state to state and is based on historical patterns rather than on demand or on consideration of relative poverty levels (source. http://lnweb18.worldbank.org, accessed on 7/11/03). At the state level, the Department of Food and Civil Supplies (DFCS) does the district-level and retailer-wise allocation on the basis of the advice received from the Oil Co-ordination Committee (OCC). The Department also decides on the quota per ration card. At the District level, the District Supply Office regulates the supply. There is a District Supply Officer (DSO) at the district level, an Enforcement Officer (EO) at the Sub Divisional level, and an Enforcement Inspector (EI) at the tehsil[2] level. The specific allocation for wholesalers and retailers is decided by the DSO. The responsibility of the enforcement officer and the inspectors is to ensure that the dealers and retailers do not flout rules and guidelines. These officers also report to the executive authority, the District Magistrate at the district level, the Sub-Divisional Magistrate at the sub- division level, and the Tehsildar[3] at the tehsil level.

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[2] Tehsil is a sub unit of the district

[3] Tehsildar is the official in charge of revenue collection at the sub unit (tehsil) level

The oil companies make the kerosene available at their depots from where the wholesaler lifts the quota, under the direction of the Food and Civil Supplies Authority. The wholesaler delivers kerosene to retailers as per the allocation set by the DFCS. Figure 4.1 gives a schematic representation of the distribution of SKO under the public distribution system in India.

4.3.3 Parallel marketing of kerosene

Participation of private (domestic and international) capital was felt imperative by the early nineties for developing infrastructure necessary for meeting the growing

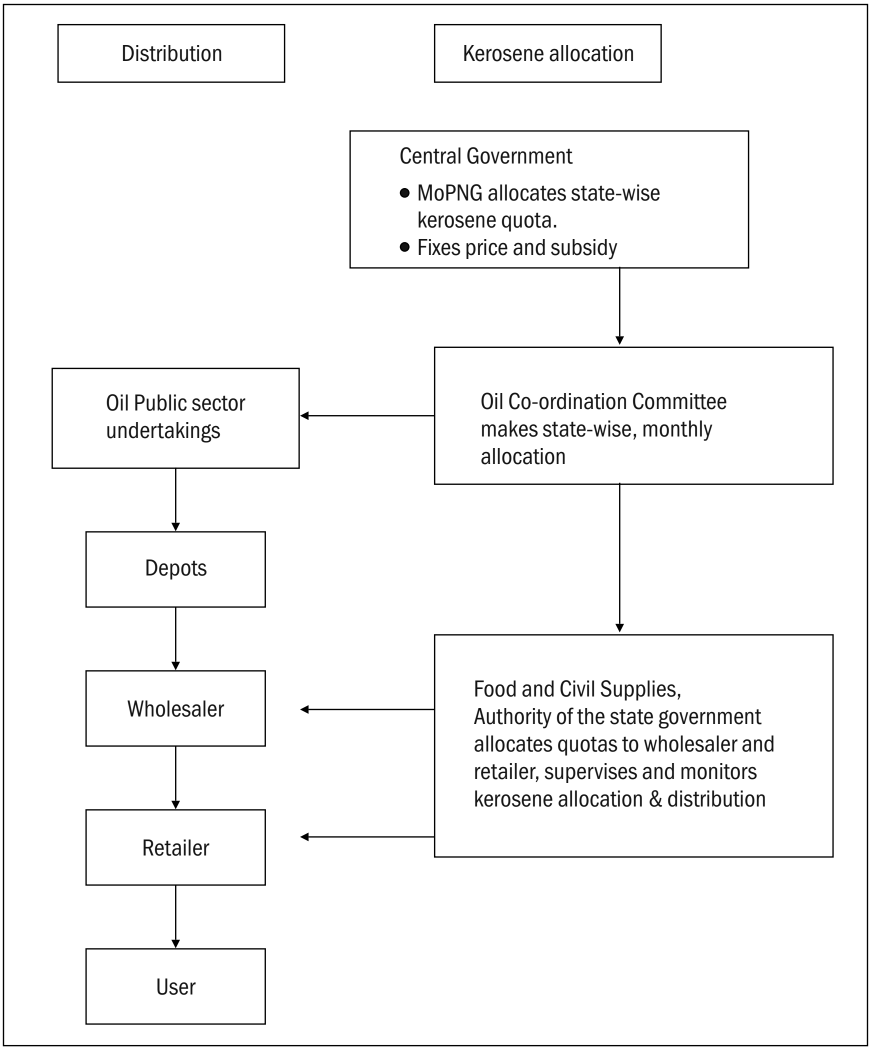

Figure. 4.1 Stakeholders involved in allocation and distribution of kerosene in rural India

demand of petroleum products in the country. The administered pricing mechanism (APM), divorced from economic realities, was considered far from attractive by private capital. In 1993, the Government of India announced the introduction of parallel marketing of SKO and LPG to bridge the wide gap between the supply and demand of these products. Under the scheme, private parties were allowed to import and market LPG and kerosene at market-determined prices. Over the years, parallel marketers developed facilities for imports and tanks for storage and set up their own distribution and marketing networks. A blue dye is added to the kerosene supplied by the PDS to differentiate it from that supplied by parallel marketers.

4.4 Kerosene pricing

The APM, till lately, governed the supply of petroleum products in the country. It was instituted in 1977 largely in response to the oil price shock of 1973. The APM essentially guaranteed oil companies a 12% post-tax return on their net worth under a cost-plus pricing regime. The system ensured.

- insulation of domestic markets from volatility in international markets,
- continuous availability of petroleum products across the country at stable prices, and
- fulfilment of the socio-economic objective of the government to subsidize access to commercial energy

There were, however, serious unintended effects. Oil pricing was divorced from underlying economic realities. The prices of politically sensitive products did not reflect the economic costs of these products. Subsidies and cross-subsidies resulted in a wide distortion of consumer prices, and led to wasteful use of energy. The APM provided little incentive for improving productivity or efficiency, as return on capital employed was guaranteed. Competition was stifled, with marketing companies acting as mere distribution companies.

The APM was dismantled in April 2002. For domestic fuels such as LPG and kerosene, this meant a steady increase in prices. However, the subsidies are still continuing (Figure 4.2).

At the micro level, there are several other factors that may determine the price of kerosene. Distance is an important one. For example, in the desert district Jaisalmer of Rajasthan, the minimum rate of kerosene is USD 0.18 per litre while the maximum is USD 0.19 per litre in the border villages located about 150 km from Jaisalmer city. With increase in kerosene rates, the wholesale and retailer commission rates also increases (TERI, 2001).

4.5 Demand and supply

Over the years, a decline in the consumption of kerosene has been reported as against a corresponding increase in the rate of rural electrification. A similar trend is proposed for the future. While in 1988/89, 69.20% of rural households were using kerosene as

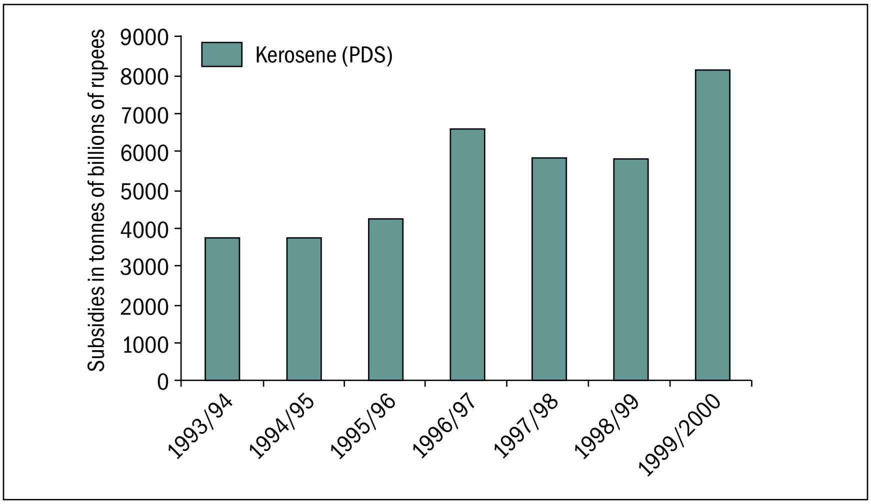

Figure 4.2 Subsidy on kerosene under the PDS
Source: http:/www.petroleum.nic.in, accessed on 23.01.01

their primary source of energy for lighting, this reduced to 62.4% in 1993/94. On the other hand, an increase of 10% was reported in the number of rural households using electricity as their primary source of energy for lighting (NSSO, 1990, 1997). Similarly, it has been projected that the demand for kerosene for cooking and lighting would reduce from 8.22 MT (million tonnes) in 2001/02 to 6.69 MT in 2006/07 to 5.57 MT in 2011/12 (GoI 1998).

At the micro level, there exists considerable variation in the pattern of demand and supply of kerosene. The main reasons for this variation are differences in climatic conditions, lifestyles and the economy. Such variation was found in the desert and non-desert regions of the state of Rajasthan (TERI 2002). Demand for kerosene in Sri Ganganagar district (non desert) is very high. On the other hand, in rural areas of Jaisalmer district (desert), the demand is so low that a certain proportion of the quota has to be surrendered almost every year. The demand for kerosene in the desert region (especially villages near the border with Pakistan) is generally low because (TERI 2002):

- villagers do not use kerosene for cooking, largely due to the undesirable smell kerosene lends to the cooked food and the preference for food cooked on mud stove;
- there is no industry and agriculture is limited; and
- means of transportation are limited, therefore pilferage is virtually non- existent.
- Accordingly, Jaisalmer district has the lowest kerosene allocation in the state of only 450 kl per month (for the month of June) on an average (TERI 2001).

4.6 Kerosene consumption patterns—macro and micro perspectives

Perhaps the two most significant facts that are not taken into account in policy -making and planning for kerosene allocation and distribution are that kerosene in the rural domestic sector in India is used primarily for household lighting (this is highlighted by the fact that rural households using LPG are given less kerosene) and that there is no complete substitution to, or of, kerosene in either cooking or lighting.

At the macro level, very little information is available on kerosene use in rural areas. Whatever information is available exists in the form of case studies, on the basis of which several projections have been made on kerosene use for lighting in rural areas. In 1978/79, 95% of the rural households in the country were using kerosene for lighting (NCAER 1985). In 1993/94, this reduced to 62% (NSSO 1997). The total kerosene consumption in India during 2000/01 was estimated at around 11.5 MT out of which about 60% was for rural areas (MoPNG 2000). Further, the uptake of kerosene has increased over the years, particularly PDS kerosene (Figure 4.3). This is further substantiated by the fact that only 1.2% rural households use kerosene for cooking (GoI 1995) highlighting that the primary use of kerosene in rural areas is for lighting.

Micro level analysis (TERI 2002), however, provides us with factors determining such consumption patterns. Across all socio-economic categories in rural areas of select districts in Rajasthan, the usage of kerosene was primarily for lighting (80%). Even

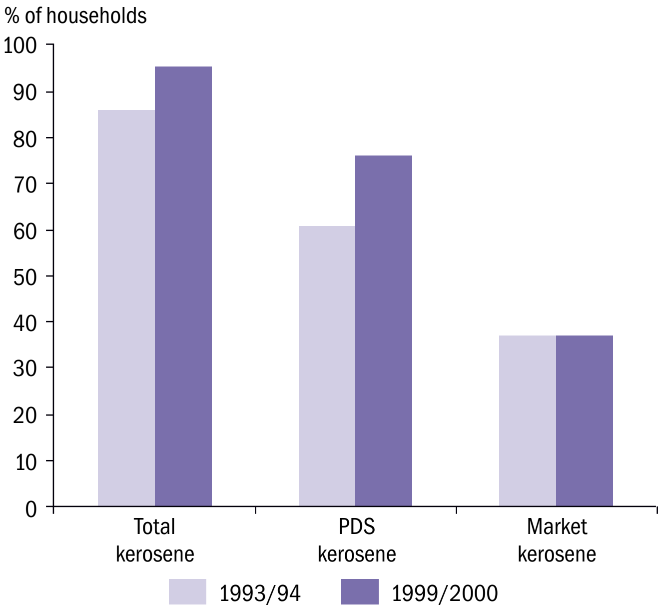

Figure 4.3 Uptake of kerosene (percentage of all rural households)
Source: World Bank, 2003

among households reporting usage of kerosene for cooking, use was restricted only to igniting the mud stove.

Further, there were sets of perceptions guiding this usage, which in turn, was influenced by the lifestyles of people that are culturally determined. The staple food cooked (millet/bajra rotis and a dish made of wheat called bati) requires baking and not direct heat; so, people prefer to use their traditional mud stoves. Likewise, the villagers do not find kerosene stoves suitable for cooking cattle feed, primarily because cattle feed is required to be cooked in huge quantities. The smell that cooking with kerosene gives to the cooked food was also highlighted as undesirable by most households (TERI 2002).

The other grass-roost reality that is often not considered in planning for the electrification of rural households is that even those households that are electrified continue to use kerosene for lighting (Ravindranath and Hall,1995; TERI 1995). Hence, the transition to use of electricity for lighting is only partial. Micro-level analysis (TERI 2002) showed that only higher-income categories could afford electric lighting. Further, kerosene consumption did not reduce proportionately (Figure 4.4). The reasons for this were mainly, high ownership of kerosene-based lighting devices (nos), and high usage (no. of hours per day) of kerosene devices.

However, in most cases, kerosene consumption did reduce in electrified villages. For example, in case of Barmer district (desert ecology) two villages with a higher electrification status, namely Bishala and Sura, had lower overall consumption levels of kerosene. Village Trisingda, which is un electrified, and with 80% tribal (Bhil)

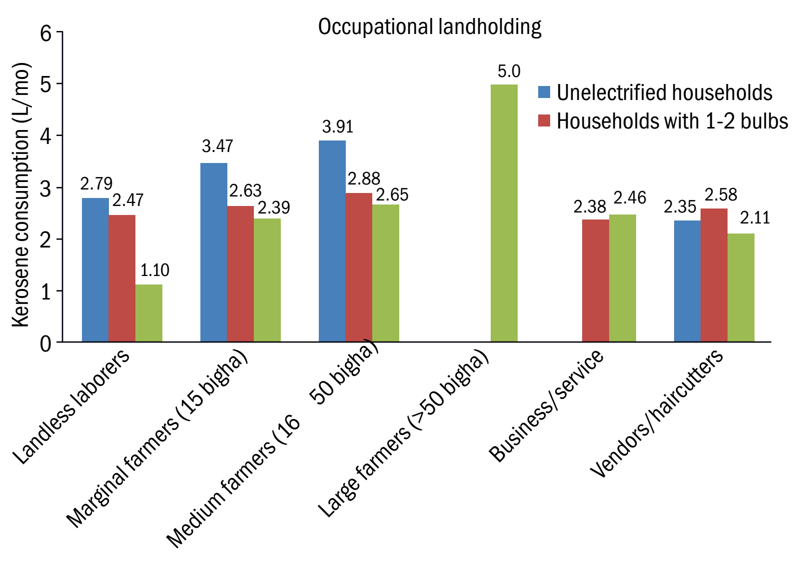

Figure 4.4. Kerosene consumption for different occupations and levels of electric lighting

population, had an almost peak average consumption of 5 litres per month. In this regard, the allocation of kerosene should be governed more by the electrification status of the household rather than by ownership of LPG. The current policy is not sensitive to this important factor.

In this context, it may also be noted that the PDS was set up largely to cater to the poor. However, as there is no differential allocation according to class or even the electrification status, it is the affluent and the electrified households that consume the highest quantities of kerosene. The data analysis for Jalore district in Rajasthan state revealed that the Choudharies and the Rajputs, who constitute the upper and hence the affluent castes, consume the most kerosene for lighting. On the other hand, the Bhils, who are tribals and are at the lower end of the socio-economic spectrum, consume the least.

It is important to mention here that though Choudharies are categorized as other backward caste (OBC), they constitute an affluent group in terms of asset ownership, including land and livestock.

Similarly, the scheduled castes and tribes, who form the lowest rung of the social ladder (below poverty line-BPL families) for whom the PDS has primarily been established, are the lowest recipients of the subsidy. When the village level analysis was carried out across socio economic categories, average kerosene consumption again favoured the economically strong segment of the community (Figure 4.5).

4.7 Issues in kerosene access and availability in rural India

There are several issues that emerge from both the macro and microanalysis of kerosene use in rural India. These are particularly relevant at the policy level and are

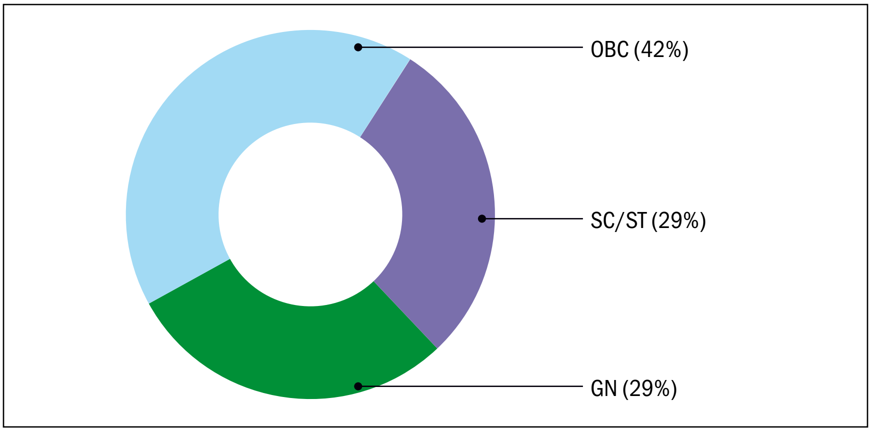

Figure 4.5. Share of kerosene consumption across different social classes

pertinent since they hit the poor the hardest. These issues are discussed under two broad heads (1) kerosene distribution, (2) kerosene pricing. These in turn relate to how kerosene is allocated both at the national and state levels, which has already been discussed.

4.7.1Problems associated with distribution of kerosene

Despite the fact that kerosene is largely the poor man's lighting fuel and that the PDS objective is mainly to facilitate access of the poorest of the poor to it, the distribution process is beset with problems related to lack of transparency in the distribution system and diversion to more profitable uses. The factors responsible for this situation are as follows.

4.7.2 Location of PDS outlet

The locations of PDS outlets are not geared to serving the poor. Normally, there is a single PDS outlet in a Gram Sabha that comprises six to seven villages. The outlet is usually located in the main hamlet where economically better off families reside. The poor typically inhabit outlying small settlements and do not have easy access to the PDS outlet.

4.7. 3Lack of transparency in distribution

The distribution of kerosene itself leaves a lot to be desired. The poor are often unaware of their quotas and the days on which the kerosene supply reaches the PDS shop (Box 1).

The retailers' vested interest in hiding information is that he is, therefore, able to divert the quota that is not lifted by the consumers. The lack of transparency in quota allocation at the state level aids the dealer. The declared norm allows distribution of five litres of kerosene per card per month but the actual allocation fluctuates monthly.

4.7.4 Linking kerosene quota to LPG connection

As mentioned in the previous sections, kerosene consumption in rural households is largely for illumination. However, its availability has been linked to the supply of LPG, which is used primarily for cooking. Households with a single-cylinder LPG connection are entitled to only half the usual quota of kerosene, while double-barrel connection holders are not allowed to buy kerosene through the PDS (Box 2).

Box 1. Lack of transparency in quota distribution

While most people were aware that the quota for kerosene is five litres per ration card per month, the allotment was less. In certain cases the quota had been reduced, which was not communicated to the people. Hence, while some villagers got 3 litres per card per month other villagers in the vicinity were getting 4 litres per ration card per month.
Source: TERI, 2002.

Box 2. Lopsided view to kerosene allocation

In Rajasthan's densely forested Sawai madhopur district, an odd situation has arisen: some poor households who have been provided free LPG connections must forfeit their entire kerosene quota. This has become a very serious problem for the poor who cannot afford to buy kerosene from the open market.

Source:TERI, 2002.

Since the two fuels are consumed largely for different end uses, the existing norm poses a problem, and might also deter lower income groups from using LPG for cooking.

4.7.5 Arbitrary adjustment of quota

The TERI case study (TERI 2002) found the kerosene quota for districts to be arbitrarily adjusted. The adjustment is based mainly on macro-level information on quota utilisation. For instance, if the quota is regularly under-utilised then a uniform reduction takes place in the individual quotas. This kind of adjustment causes problems for poorer households (Box 3).

4.7.6 Unattractive business

Kerosene dealers do not find the business of kerosene under the PDS an attractive one. A wholesale kerosene dealer gets a commission of approximately 15 paise per litre as well as a commission for transportation and related expenses normally fixed by the District Supply Officer. The total commission varies from 25 –30 paise, which translates into a monthly income of no more than USD 144.4 for a 250 kl dealership – an inadequate sum that forces dealers to look at ingenious ways of increasing their earnings. Since a litre of diesel is sold at about USD 0.22 more than that of kerosene, a convenient solution is to mix kerosene with diesel and sell it at a higher cost. Petrol pumps have over the years offered a parallel market for the supply of PDS kerosene where the retailer and dealer have fetched higher prices and made substantial profits.

Box 3 Arbitrary adjustment of quota & impacts on the poor

All study districts (TERI 2002) showed a decrease in district level quota allocation over the previous months and years. The rationale for the reduction was that the estimated average consumption of kerosene at the household level over the last few years had been around 4 litres per month only. However, this was because about 20% of cardholders did not lift their quota for various reasons. Hence, in order to prevent pilferage, the district administration decided the allocation limit on the basis of 80% cards only. As a result, within the overall norm of 5 litres per ration card per month for rural areas, actual district level allocation was reduced. Further, while it may be true that overall 20% cardholders are not lifting their quota, the actual situation was found to vary across villages. In some villages, all the cardholders would lift their quota while in others only half were found to be lifting their quota. For instance, in district Jalore, the Rebaris who are at the lowest end of the economic spectrum, and migrate seasonally in search of employment often do not lift their quota. However, the presence of Rebari community is uneven across villages while quota reduction is done uniformly for all villages. In the process, it is the vulnerable and the disadvantaged sections of the community that mainly suffer.

The subsidy on kerosene has only encouraged its diversion for use as an adulterant in diesel.

4.7.7 Subsidies and increased dependence on 'black market': impact on poor

The ineffectiveness of the subsidy and its delivery mechanism is further illustrated by the finding from NSS that even the poorest households buy some market kerosene for lighting, even though the total amount of kerosene they use can be less than the allocated subsidized quota. Thus, given the high level of diversion of subsidised kerosene, subsidies for the fuel are ineffective in promoting equitable access (World Bank 2003). This is further exemplified at the micro level, though here affordability also becomes a constraint for the poorest of the poor (Box 4).

4.7.8 Limited parallel marketing

The quantity of kerosene marketed under the parallel marketing scheme in 2000/01 accounted for just even more pertinent.about 10% of the total kerosene consumption in the country (MoPNG 2001). With the constraints in the PDS, the access issues become

4.8 Kerosene pricing-the issue of subsidy

A large portion of kerosene (3.2 MT) consumed in the country is imported (TEDDY TERI 1996/97) which constitutes a heavy financial burden on the government. It is estimated that the country paid more than USD 733.3 million for kerosene imports during 1995/96 (Maithel and Joshi 1997). This trend is likely to continue in the near future. The deferment of the reduction in subsidies over three years by the central government has resulted in under-recovery of approximately 3 rupees per litre of PDS kerosene amounting to approximately USD 1822.2 million for 2003/04 (including LPG) (source. http://in.news.yahoo.com, accessed on 7/11/03). The cost of the subsidy is to be borne by state-owned oil and gas companies. Further, as much as half of the subsidised kerosene in 1993-94 and 1999-2000 is estimated to have been diverted to the black market or other sectors, most prominently the automotive diesel sector. This

Box 4. Kerosene access and impact on the poor

Raigar women belonging to the weaker caste in village Khilchipur in district Sawai Madhopur, Rajasthan reported that they had to buy kerosene at USD 0.33 per litre from the black market. The same was the case in Bhilon ki Basti (a hamlet of the scheduled tribes, the Bhils). The information regarding when the kerosene quota will be distributed is provided to the villagers only a day in advance or at times a few hours in advance. As a result, the poor (Raigars, Bhils) are unable to arrange for the money and are therefore not in a position to lift their quota. Hence, some poor families are forced to buy small amounts of kerosene from the black market as and when they are able to arrange for the necessary cash.

Source: TERI, 2002.

meant that an estimated USD 889 million of government subsidy in 1999-2000 did not reach the intended beneficiaries (World Bank 2003).

Parallel marketing, on the other hand, has been a success, though a somewhat limited one. Parallel marketers have been competing with public sector oil marketing companies, who have access to LPG and kerosene at subsidized prices. Government subsidy on LPG and kerosene sales by public sector oil marketing companies in 2000/2001 was as high as 140 billion rupees (source. http://in.news.yahoo.com, accessed on 7/11/03). With such a high level of subsidy, the impact of the effort of parallel marketers has been marginal.

4.9 Diversion and pilferage

Studies carried out in the past have revealed that about 25% of the kerosene supplies for the PDS gets diverted to the black market for sale to unauthorized users and for adulteration of other petroleum products like petrol because of price differentials (source. http://petroleum.nic.in, accessed on 15/10/03).

The reasons for pilferage and the extent of pilferage may also vary from one geographical region to the other. For example, in the desert areas of Rajasthan (Jaisalmer district), pilferage is minimum, because:

- distributors are all cooperatives
- major towns are located far off (Jodhpur city is 310 km away while Barmer city is 150 km away)
- there is no major industry in the district
- there are very few diesel pump sets, because the irrigated area is small
- In non-desert districts with a sound agricultural base, pilferage is maximum because:
- distributors are mostly petty shopkeepers
- major towns are located relatively close
- there are industries in many districts
- there are many diesel pump sets for agriculture

4.10 Way forward

With regard to the use of kerosene for lighting, the NSSO data indicate that 62% of rural households used kerosene as a primary source for lighting (NSSO 1997). However, past survey rounds of the NSSO indicate that this proportion has been declining. Extrapolating these trends, it may be estimated that by 2020 only 54% of rural households would use kerosene for lighting. The figure of households using electricity, correspondingly, increases.

Kerosene, however, will continue to be a dominant source for household lighting in rural India. The case study (TERI 2002) brought forward some of the critical issues related to distribution of kerosene through the PDS. Figure 4.6 summarizes the various forces related to consumption of kerosene at the rural household level. The

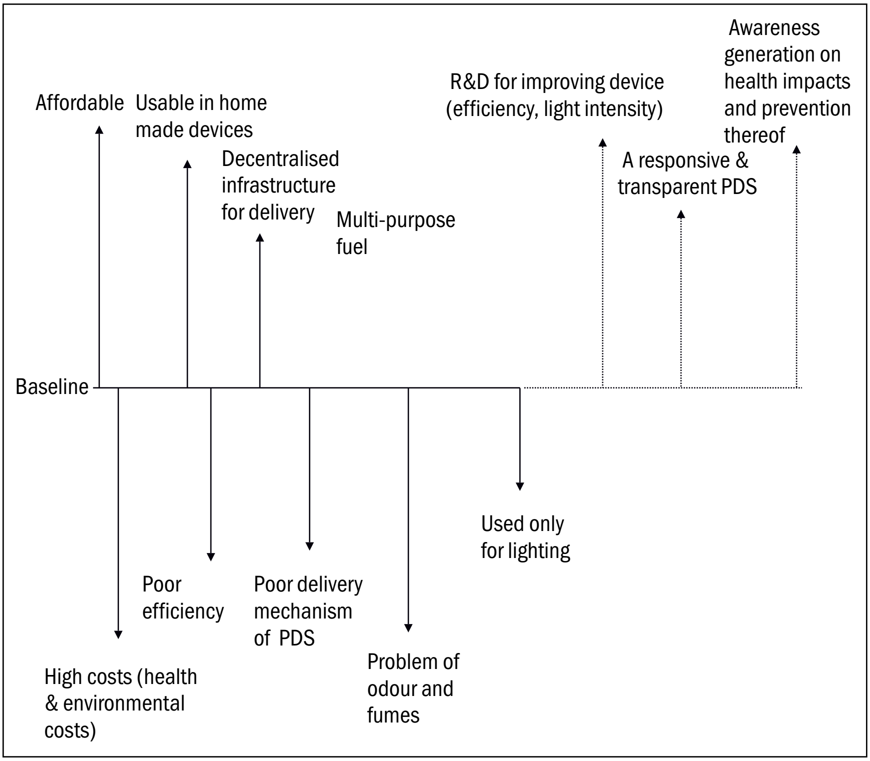

Figure 4.6 Positive and negative forces related to consumption of kerosene in rural households

arrows above the baseline (pointing upwards) show the forces, which facilitate in adoption of the fuels, technology and the downward arrows, show the negative forces, which impede or hinder the adoption or usage of the fuel/technology. The dotted arrows show the possible interventions that can be carried out in order to make the fuel/technology available and affordable. The lengths of the arrows roughly try to demonstrate the intensity of a particular force. The force field analysis reveals that the loopholes in the delivery mechanism, the poor efficiency of the devices, and the problems of odour and fumes are the main factors hindering the widespread use of kerosene. However, some of the so-called negative factors are also one of the main reasons for its popularity as a lighting fuel. For instance, the fact that kerosene can be used in local home made devices has always been a major attraction for the poorest of the poor. Hence, in order to improve access to kerosene, it is necessary to improve the delivery mechanism. This may require redirecting the subsidy, and raising awareness on health-related issues, especially focussing on aspects related to indoor air pollution.

4.11 Redirecting kerosene subsidy

The subsidy for kerosene costs the government USD 1333.3 million per annum (source. http://www.rediff.com/business, accessed on 2/1/2004). On the other hand, oil public sector undertakings such as the IOC (Indian Oil Corporation) had to bear a loss of USD 222.2 million due to non-revision of LPG and kerosene prices only in the first quarter of the fiscal year 2003-04. The under realization on kerosene is approximately 5.4 rupees per litre (source. PTI 2003, http://www.rediff.com/money, accessed on 2/1/2004). Overhauling the existing system to bring about greater efficiency would require drastic changes and might not be possible. Hence, it may be desirable to explore other options. For instance, the subsidy could be used more profitably to promote alternative lighting options such as solar photovoltaic lanterns. A small solar lantern (5 W) costs USD 26.7-28.9. Assuming that this alternative is used and if the subsidy on kerosene distributed through the PDS is diverted for promoting lanterns, close to 100% households can be lighted in 3–4 years. Money saved at the household level can be used for battery replacement and other repairs.

4.12 Improving efficiency of kerosene devices

The poor in rural India depend the most on kerosene lighting devices. These devices are technically `obsolete'. In case of lighting, the problems are related not only to high kerosene consumption, but also to smoke emission and low luminosity. There have not been many concerted R&D efforts for improving the devices. However, whatever limited work has been done shows tremendous potential. In a field test of improved kerosene lighting devices[4] done by TERI covering about five hundred rural households (TERI, 1999); over 60% households gave the feedback that the improved kerosene lighting devices give higher intensity of light compared to local devices. The market survey further indicated people's willingness to buy the improved devices on account of higher light intensity, low levels of smoke and better appearance. However, these improved lighting devices have so far failed to make their way out of the laboratories. Hence, R&D and field trials of improved kerosene lighting devices needs to be given impetus.

4.13 Increasing role of local institutions in monitoring

In order to reduce pilferage and introduce efficiency and transparency in the distribution of kerosene, local institutions need to play a proactive role. An initiative in this regard has come from some state governments wherein the locally based Panchayati Raj Institutions (PRIs) have been made responsible for PDS. Such initiatives need to be given more emphasis.

4.14 Conclusion

Consumers in India have so far been shielded from the volatile international prices of petroleum products. However, as the petroleum sector and pricing in particular

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[4] Developed by Indian Oil Corporation (IOC), Research & Development Centre, Faridabad, India.

becomes deregulated, the poor may find it difficult to cope. However, when this will actually happen only time will tell. The subsidy phase down was originally planned to be completed by the time of sector deregulation in April 2002. This has not happened. Further, the government later decided that the subsidy on domestic LPG and PDS kerosene would be provided on a specified flat rate basis from a consolidated fund, which started from 1 April, 2002. In June 2003, however, the Ministry of Finance, Government of India announced that LPG and kerosene subsidies would be phased out in three years and eliminated by April 2006. If this happens, private players may find it profitable to expand their market share. This may make the system more accountable and transparent and therefore resolve some issues of access and allocation. However, affordability may become a constraint for the poor. Hence, there is a need for policy reflection and selective subsidies targeting the poor may be considered. On the other hand, there is also a need for concrete research efforts towards improving device efficiency and luminosity as well as developing markets for such efficient products.

4.15 Acknowledgments

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CHAPTER 5

Black carbon emissions from biomass and fossil fuels in rural India[1]

Abstract

Black carbon (BC) emissions from biofuel cooking in South Asia and its radiative forcing is a significant source of uncertainty for health and climate impact studies. Quantification of BC emissions in the published literature is either based on laboratory or remote field observations far away from the source. For the first time under Project Surya, we use field measurements taken simultaneously inside rural households, ambient air and vehicular emissions from highways in a rural area in the Indo-Gangetic-Plains region of India to establish the role of both solid biomass based cooking in traditional stoves and diesel vehicles in contributing to high BC and organic carbon (OC), and solar absorption. The major finding of this study is that BC concentrations during cooking hours, both indoors and outdoors, have anomalously large twice-daily peak concentrations reaching 60 µg m-3 (median 15-min average value) for indoor and 30 µg m-3 (median 15-min average value) for outdoor during the early morning (05:00 to 08:00) and early evening (17:00 to 19:00) hours coinciding with the morning and evening cooking hours. The BC during the non-cooking hours were also large, in the range of 2 to 30 µg m-3. The peak indoor BC concentrations reached as high as 1000 µg m-3. The large diurnal peaks seen in this study lead to the conclusion that satellite based aerosol studies that rely on once- daily daytime measurements may severely underestimate the BC loading of the atmosphere. The concentration of OC was a factor of 5 larger than BC and furthermore optical data show that absorbing brown carbon was a major component of the OC. The imprint of the cooking hour peaks were seen in the outdoor BC both in the village as well as in the highway. The results have significant implications for climate and epidemiological studies.

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[1] This chapter is reproduced from Rehman, I. H., Ahmed, T., Praveen, P. S., Kar, A., Ramanathan, V., 2011. Black carbon emissions from biomass and fossil fuels in rural India. Atmospheric Chemistry and Physics 11, 7289–7299.

5.1 Introduction

BC, a fine particulate matter, is a result of incomplete combustion of fossil fuels and biomass fuels. BC though short lived is also the strongest absorber of solar radiation in the atmosphere. It contiributes significantly to global warming after long-lived greenhouse gases (Forster et al., 2007; Ramanathan and Carmichael, 2008; Jacobson, 2010). In addition, in South and East Asia, BC is estimated to contribute to the disruption of the monsoon in South Asia (Ramanathan et al., 2001, 2005; Lau et al., 2008) as well as East Asia (Menon et al., 2002) and heating of the elevated regions of the Himalayan-Tibetan region (Ramanathan et al., 2007; Flanner et al., 2009; Menon et al., 2010) thus potentially having a large impact on the food and water security of the region (see Lawrence and Lelieveld, 2011 for a detailed review). Due to its short life with a residential time of a maximum of two weeks as against CO2 that can stay in the atmosphere for centuries, reducing in BC emissions has been increasingly proposed as one of the mitigation measures for limiting climate warming (Ramanathan and Carmichael, 2008; Grieshop et al., 2009; Kopp and Mauzerall, 2010).

About 3 billion human beings in developing countries, who subsist on a daily income of less than $2 a day (IEA, 2007) rely on solid biomass fuels for cooking and space heating, contributing to about 25% of the global emissions of BC and about 50% of the anthropogenic emissions of BC (Bond et al., 2007). In South Asia, BC emission from residential biofuels (wood, crop residue, dung) cooking is the largest source of atmospheric BC concentrations (Venkataraman et al., 2005). In India alone about 80% of 160 million rural and 58 million urban households use solid biofuels (Venkataraman et al., 2010). Several studies have demonstrated the adverse impact on health from inhalation of fine particulate emissions containing BC from fossil and solid biomass fuels (Pope et al., 1995; Ezzati and Kamen, 2002; Sauvain et al., 2003; Forastiere, 2004; Penn et al., 2005; Rom and Samet, 2006; Schwarze et al., 2006; Dockery and Stone, 2007). It is estimated that globally inhalation of smoke from indoor cooking using biomass fuels leads to 1.6 million deaths annually (WHO, 2002). In addition, the high levels of BC emissions from biomass fuels (Gustafsson et al., 2009; Venkataraman et al., 2005; Bond et al., 2007) can also significantly impact climate forcing from local to global scales (Forster et al., 2007; Ramanathan and Carmichael, 2008).

Indo-Gangetic Plains (IGP) region in South Asia is one of the most densely populated regions in the world and also a major source of BC emissions from cooking with biomass fuels. Large uncertainties exist in BC emission data from this region, which in turn induce large errors in estimating its radiative forcing. To reduce these uncertainties, as well as to document the role of biomass BC on health, regional climate change and Himalayan retreat, field data sets are needed. These data sets will improve the urgently needed ground measurements of BC for validation of climate and epidemiological models and will also help to guide the regulatory bodies to outline BC mitigation policies. Action taken to reduce or mitigate BC emissions from biomass fuels can save millions of lives, especially among women and children, and presents an opportunity to reduce warming on short-time scale (Grieshop et al., 2009). Thus, BC connects poverty and health with rural development and climate mitigation. Towards this goal, Project Surya was conceived as an international research effort and is being implemented in the IGP region in northern India (Ramanathan and Balakrishnan, 2007; Ramanathan et al., 2010).

Project Surya is a scientific intervention field experiment. Unlike earlier studies which reported BC concentrations in emission plume close to wood-burning cook stoves (Roden at al., 2006, 2009) or BC concentration from wood in laboratory conditions (Gonçalves et al., 2010), the aim of Project Surya is to simultaneously measure both indoor and outdoor BC concentration in rural village; first from traditional mud-based biomass burning cook stoves, and then after replacing them with more energy efficient cooking technologies, so as to document the impact of BC mitigation on health and climate.

The first (or pilot) phase of Surya was started in October of 2009 in a rural village located in the IGP region. The real-time simultaneous measurements of BC were recorded from mud stoves both indoor and outdoor and also at highway (~3 kilometers away) for baseline data collection. In the second (or demonstration) phase, the mud stoves were replaced with improved cook stoves and measurements were again recorded. This is the second in a series of 4 papers on the pilot phase study. The first paper (Ramanathan et al., 2011) deals with a cell-phone based BC monitoring system for large scale (e.g. 100-300 households) measurements. This is the second in this series documenting the village scale measurements with traditional mud stoves. The third paper (Praveen et al., 2011) explores the link between the local scales and regional scale radiative properties and forcing of BC. The last paper (Kar et al., 2011), reports on how replacement of the mud stoves with highly efficient cook stoves impact indoor BC concentrations, as well as compares various new cook-stove technologies on BC emissions.

5.2 Experimental setup

5.2.1 Sampling location

Project Surya site is located in and around rural village (26°N, 81°E) in the IGP region in northern India. Figure 5.1 shows the MODIS TERRA monthly mean aerosol optical depth (AOD) over India for November 2009 along with the location of our sampling site. Clearly high AOD values can easily be seen over the IGP region. The Surya village (hereafter denoted as SVI_1) has around 485 households in seven close by hamlets that burn biomass fuel for their daily domestic needs of heating and cooking. For sampling we selected the largest hamlet that has around 200 households compared to other hamlets. The nearest traffic road is the Uttar Pradesh State Highway-15 (SH-15) located around 2 km to the south of the SVI_1 village. The nearest town center is located around 3 km southeast of the SVI_1 village, and where both SH-15 and National Highway-56 (NH-56) intersect.

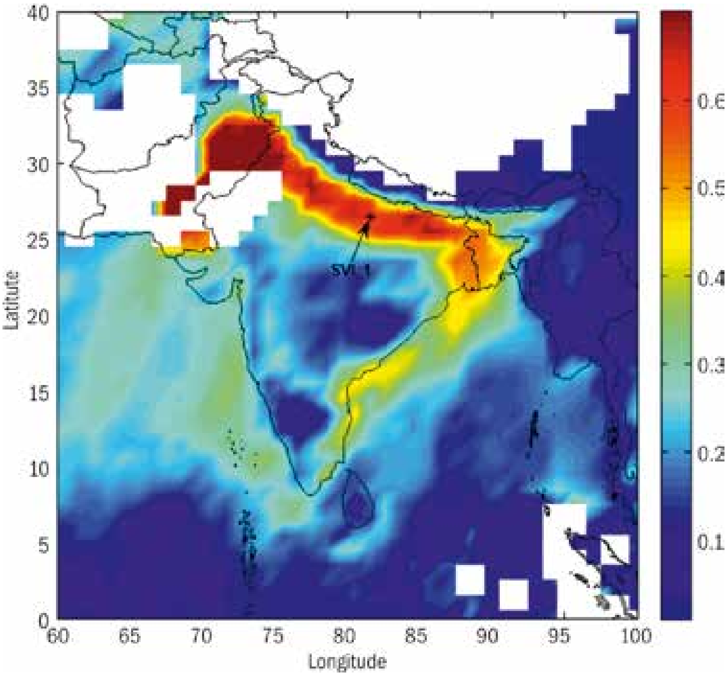

Figure 5.1 MODIS TERRA monthly mean aerosol optical depth (AOD) over India for November 2009. Also shown is our sampling site Surya village (SVI_1) located in the IGP region.

5.2.2 Indoor sampling

Concentrations of BC and elemental carbon (EC) were measured in the kitchen microenvironment close to mud cook stoves in the selected households. Indoor BC sampling was conducted in two periods, first between 27 September to 29 November 2009 in randomly selected 35 households, and again during 1-9 September 2010 in 18 of 35 households selected during the first period. Real-time BC concentration in indoor air was measured using a microAeth Model AE-51 (Magee Scientific, Berkeley, CA). AE-51 is a portable battery operated instrument, based on widely used Aethalometer technology (Hansen et al., 1984), and designed specifically to monitor personal exposure of BC. AE-51 draws ambient air on quartz filter based strip which then measures BC using single 880 nm LED. The length of the inlet tubing in AE-51 was 0.15 m and the instrument was placed such that it represents breathing position of cook stove emission, i.e. 1 m away and 0.6 m above the ground. The flow rate of AE-51 was set at 50 mL/min with measurement frequency of 1 min. Due to very high BC loading in cook stove emission plume; the filter strip of AE-51 was changed periodically to prevent attenuation saturation level from exceeding 120. From field test it was found that the AE-51 saturation level was reached in 30 min operating at 50 mL/min during cooking hours.

In addition to AE-51 BC measurement, we also collected 24 h indoor BC samples using our new cell-phone based BC monitoring system (BC_CBM) operating simultaneously with AE-51. The details of the BC_CBM system are described in Ramanathan et al. (2011), which is the first in series of 4 papers of this pilot phase study. Briefly, Miniaturized Aerosol filter Sampler (MAS) in BC_CBM system draws air at flow rate of 0.57 L/min and deposit particulate matter on 25 mm quartz filter (Pall Life Sciences). Some of these filters collected were analyzed for EC and organic carbon (OC) concentrations using thermal-optical EC/OC analyzer (Sunset Laboratory Inc., Forest Grove, OR) employing NIOSH TOT protocol (Schauer et al., 2003). For quality assurance, 25 mm quartz field blanks filters were also collected periodically using MAS during the sampling campaign and analyzed for EC/OC fraction using the same thermal-optical technique for blank filter correction.

The term EC or BC is defined operationally in the literature and refers to the same light absorbing component (i.e. dark-colored "soot') in carbonaceous aerosols. Destructive analytical techniques (such as thermal-optical method) that utilize the thermal resistance, oxidative resistant and chemical inert nature of higholy polymerized graphitic-like fraction of sot termed it as EC. Whereas non-destructive analytical techniques (such as optical method) that utilize the light absorbing characteristic of soot termed it as BC. The definition of BC includes EC as well as all components in the soot that absorbs light such as some OC fractions (known as brown carbon) that show strong absorption in near-UV region of solar spectrum. The readers are referred to Andreae and Gelenscser (2006) for detail discusssion on the definition of EC and BC. In this study the term EC will be used for measurement of soot by thermal-optical method (NIOSH TOT) and BC will be used for measurement of soot by optical method (AE-51) at 880-nm.

5.2.3 Outdoor sampling

Real-time outdoor BC concentrations were continuously measured from November 2009 using Aethalometer Model AE42 at two locations in the SVI_1 village; one at the center of the SVI_1 village, and in a less dense area on the northeast corner of the SVI_1 village. In addition, BC concentration was also measured at a highway traffic junction of SH-15 and NH-56 (3 km southeast of SVI_1 village) between 19 and 27 November 2009. Highway measurements were restricted to eight days to compare with the BC data from the SVI_1 village center. Details of outdoor measurements, data quality and analysis were given in the third paper of this series (Praveen et al., 2011). In this paper, the outdoor BC data from SVI_1 village center is compared with the indoor cook stove BC data only for the period of indoor sampling campaign.Households selected for indoor sampling were located within 100 m of SVI_1 village center.

5.3 Results

5.3.1 The Large Scale Context of the Observations

It has been demonstrated clearly (e.g., Ramana et al., 2004; Di Girolamo et al., 2004; Ramanathan and Ramana, 2005; see Lawrence and Lelieveld, 2010 for a review of the South Asian pollution problem) that the entire IGP region is subject to dense layer of atmospheric brown clouds (ABCs; consisting of BC, OC, sulfates and other aerosols) whose concentration varies with the season, reaching peak values during the dry season (November to March).

Beginning in April, dust becomes a major constituent and by July, the wet season (summer monsoon) begins and lasts until September. The monsoon rains are effective in removing the aerosols. This does not however imply that the aerosol pollution is negligible during the wet season, because aerosol emission at the surface (e.g., through cooking and transportation) continues throughout the year, and it does not rain every day during the monsoon season. As a result, in between rainy days, the aerosol concentration builds up. For example, dust concentrations reach peak values during the monsoon season (Zhu et al., 2007) because dust transport into India reaches a peak during the wet season.

The primary data discussed in this study were collected during the dry season (November of 2009). The monthly mean satellite AOD shown in Figure 5.1 for November 2009 clearly reveals near homogeneous layer of high AODs (>0.4) in the entire IGP region extending from Pakistan on the western side of IGP into Nepal and Bangladesh on the eastern side. Over 600 million people inhabit the IGP, with biomass cooking a major source for BC. Fossil fuel combustion (by the transport sector, and local tractor emissions during agriculture activities, brick kilns and industry) is the second major source of BC. The experimental site at SVI_1 village is typical of the IGP region and the data collected in the SVI_1 site should be representative of the IGP. We are not implying that the SVI_1 data is identical to data over other regions of the IGP, but that, what we are observing at SVI_1 is part of the larger scale regional problem dealing with biomass cooking and fossil fuel combustion. This point is further illustrated in Figure 5.2, where we compare the extinction coefficient, Ke, measured at SVI_1 with the column AOD measured by AERONET at a neighboring city, Kanpur (26.30°N, 80.31°E). Ke is the sum of absorption by BC and scattering by all aerosols including BC. The similarity between the monthly variation in Ke (a surface measurement) and the AOD (a column measurement) supports our claim that measurements at SVI_1 are part of the larger scale widespread ABCs. This issue is analyzed and described in greater detail in the third paper of this series (Praveen et al., 2011).

5.4 Link between Indoor and Outdoor BC Concentrations

The 15-min median indoor (SVI_1 village kitchen) and ambient (outdoor at the SVI_1 village center) BC diurnal variation is shown in Figure 5.3 (a) for November 2009 (the

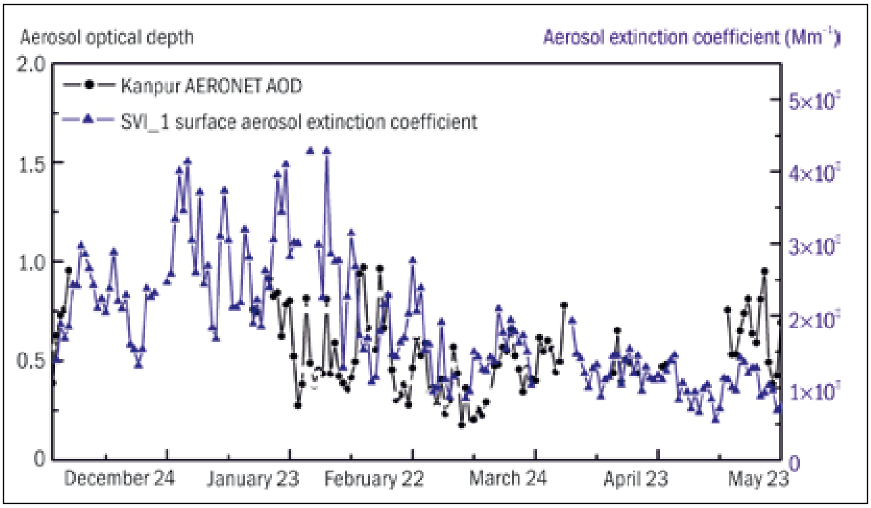

Figure 5.2 Comparison of surface aerosol extinction coefficient at Surya village (SVI_1) with the column AOD measured by AERONET at neighboring urban center, Kanpur.

dry season). The major qualitative features of the results in Figure 5.3 (b) are listed below:

The most striking feature of the data in Figure 5.3 (a) is the twice daily maximum in the BC concentrations. Focusing on the indoor first, peak values of about 60 μg m-3 are reached between 05:00 and 08:00 in the morning and between 17:00 and 19:00 in the evening, closely matching the morning and evening cooking hours in the village. During the cooking hours, the outdoor BC values closely follow the diurnal peaks seen in the indoor values. We can understand this behavior by noting that the outdoor values are influenced by ventilation of cooking smoke from all of the homes of the entire SVI_1 village (and likely neighboring villages).

The slow exponential decay of the BC after the cooking hours is significantly different between the day light hours and the night values. The day time minima (<10 μg m-3) are much lower than the night time minima (>10 μg m-3) both indoors and outdoors. The most likely explanation is the fact that the boundary layer is deeper during mid-day than the night time values (when inversion sets in) - and as a result emission at the surface is ventilated to the free troposphere more efficiently during the day time. The role of the transportation (fossil fuel BC emission from trucks and other vehicles playing the highway several kms away) is discussed in the next section.

It is also interesting to note that the non-cooking period BC indoors during the day time is larger than the outdoor BC, whereas it is smaller than the outdoor values from midnight to the beginning of cooking hour in the morning. This suggests to us that indoor cooking BC drives outdoor concentrations during the daytime until the cooking hours in the evenings, whereas, the outdoor BC (likely due to BC emissions from trucks and other vehicles) becomes more important during the night time hours.

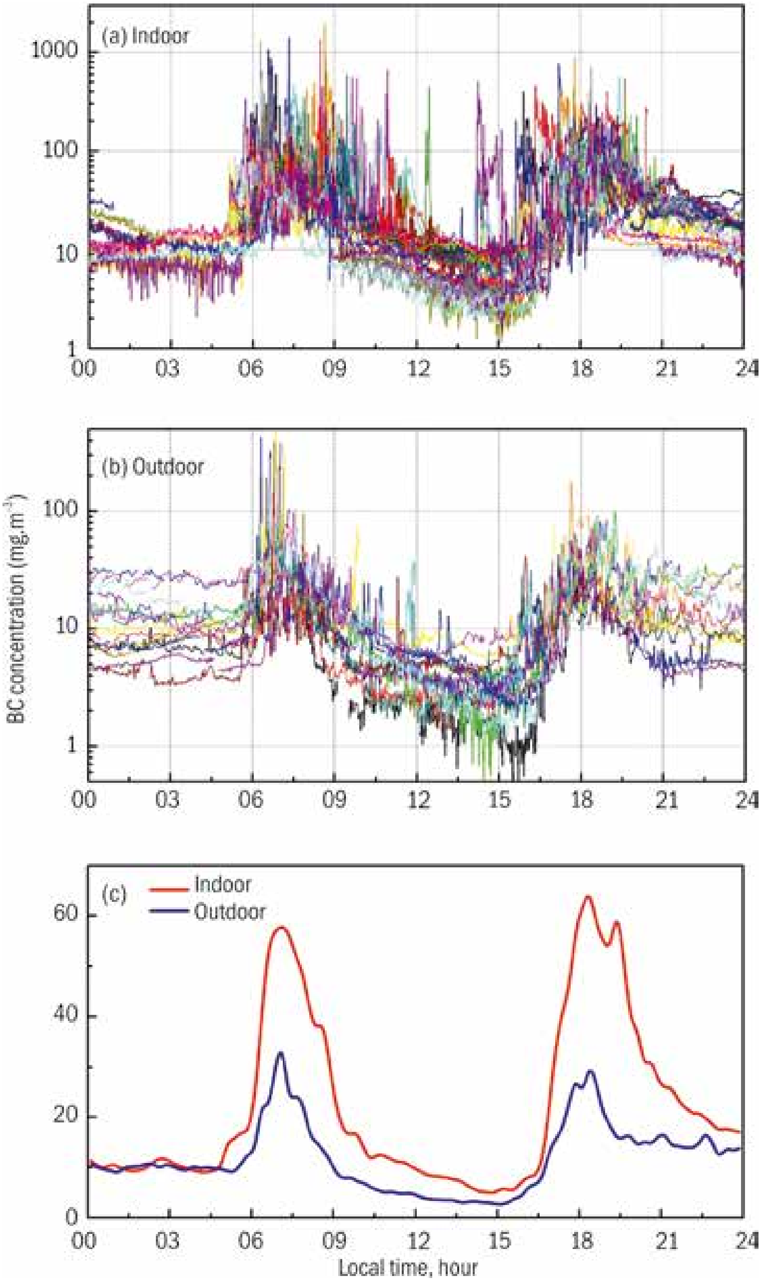

Figure 5.3 Daily diurnal variation of BC concentration for the period 6-26 November 2009 in (a) indoor kitchen of 26 households in Surya village (SVI_1) and (b) at outdoor (ambient) SVI_1 village center (c) Comparison of 15-min median variation of BC concentration in indoor and outdoor for the same period at SVI_1 village.

Focusing on the quantitative values, Figure 5.3 (a) shows the indoor diurnal variation of BC concentration in 26 households. Out of 35 households sampled initially for indoor BC measurement, the data from 9 households were not included due to instrument malfunctioning or lack of battery power during the sampling period because of which diurnal variation for these households could not be recorded. During morning cooking hours (05:00 to 08:00) BC concentration varied from ~3 to 1970 μg m-3 with a mean value of 54±73 μg m-3. Similarly, during evening cooking hours (17:00 to 19:00) BC concentration varied from ~3 to 1070 μg m-3 with a mean value of 62±61 μg m-3. It is important to note that the mean values of BC concentration during cooking hours are derived from the data collected in 26 households where measurements were not recorded simultaneously, and therefore these values are representive of the mean exposure of SVI_1 households rather than any specific household. The large variation in the BC concentration observed during cooking hours could be attributed to the fact that that not all households cook at the same time; some households start cooking early around 05:00 while other start at a little later time. Similar reasoning also explains occasionally sharp peaks in BC concentration (> 100 μg m-3) during the morning and evening cooking hours.

Incense burning for rituals and religious practices are common in Indian households, and could be a possible source of interference in our measurement (Jetter et al., 2002). However we did not observe any incense burning during our study period and therefore no correction was needed.

Figure 5.3 (a) shows the daily diurnal variation of ambient BC concentration at SVI_1 village center. The data was recorded simultaneously with the indoor measurements. During morning cooking hour's outdoor BC concentration varied from 3 to 390 μg m-3 with a mean value of 24±39 μg m-3. Similarly, during evening cooking hour outdoor BC concentration varied from 3 to 180 μg m-3 with a mean value of 26±18 μg m-3. The ambient BC diurnal variation had similar trend to indoor BC mass concentrations with the peaks following closely the morning and evening cooking cycle suggesting strong influence of indoor cooking on outdoor BC concentration. Table 5.1 summarizes the mean BC concentration for indoor (kitchen) and outdoor (ambient) in Surya village (SVI_1) for November 2009.

5.5 Verification of the Cooking Link to BC

We used the twice daily maximum in indoor and outdoor BC to conclude that cooking was the major source for the observed diurnal variations. There was a unique opportunity to verify this conclusion, during the Ramadan religious festival (11 August to 12 September 2010) observed only by the Muslim religious community, when cooking patterns compared to other months are quite different. As the SVI_1 village population has dominant Muslim community, most of the household were observing fasting. Majority of the houses cooked the major morning meal before sunrise (03:00 to 05:00) instead of the usual 05:00 to 08:00 with in-between milk simmering during

06:00 to 07:00. The evening cooking was done before sunset (15:00 to 18.00), instead of the 17:00 to 20:00. The BC indoor measurements shown in Figure 5.4 clearly reveal the altered cooking pattern, with the major peaks during 03:00 to 05:00 (compared with the 05:00 to 08:00 in Figure 5.3 for normal cooking pattern) and during 15:00 to 17:00 in the late afternoon hours, with a secondary peak during the milk simmering hours of 06:00 to 07:00. Ambient altered BC (shown as solid red line in Figure 5.4), while it reveals the new peak during 03:00 to 05:00, is not similar to the ambient normal BC diurnal pattern shown in Figure 5.3. We have to note that the large difference in transport between the dry season (when large scale transport is weak) data shown in Figure 5.3 and the monsoon season (when large scale transport effects are dominant) data shown in Figure 5.4 is one contributing factor. In summary, the Ramadan data for indoor BC supports the conclusion drawn from Figure 5.3 that, diurnal loads and peaks in indoor and ambient BC mass concentration are primarily governed by the morning and evening cooking and can mainly attributed to burning solid biomass in inefficient biomass stoves, the dominant mode of cooking in SVI_1 village.

The ambient BC concentrations measured in SVI_1 village also compare well with the earlier studies involving field measurements of BC in IGP region. Beegum et al. (2009) reported mean BC mass concentrations of 27 μg m-3 and 19 μg m-3 for January and February 2006, respectively, during field observation in Delhi. Similarly, Tripathi et al. (2005) reported ambient BC mass concentration for the month of December ranging from 6 to 20 μg m-3 over Kanpur city.

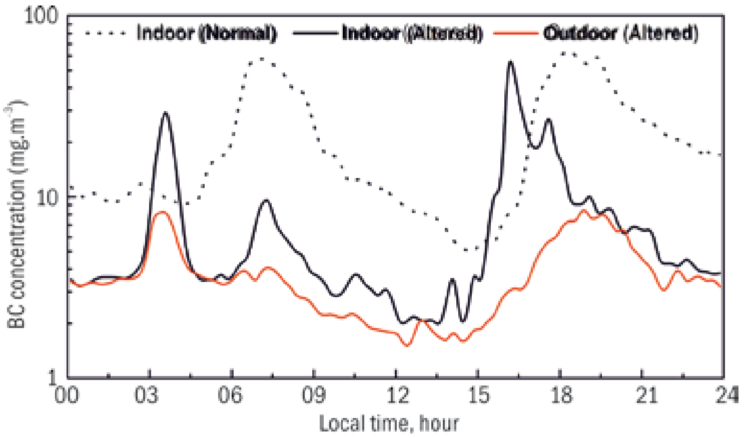

Figure 5.4 15-min median variation of BC concentration during altered cooking pattern during 1-9 September 2010 period for indoor (black solid line) and outdoor (red solid line) at Surya village (SVI_1). For comparison the 15-min median variation of BC concentration during normal cooking pattern for indoor (dotted black line) is also shown.

5.6 Relative Importance of Biomass and Fossil-Fuel Combustion

The SVI_1 village was adjacent to a major national highway (NH-56) about 3 km southwest of SVI_1. We recorded BC measurements from 19-27 November 2009 at a traffic junction intersected by the highway. Traffic was dominated by diesel driven transport trucks and passenger buses. Figure 4 compares mean of 8-days of available data for highway with the SVI_1 village center data for November 2009. It also compares the two data sets for the 2 days (21-22 November) when simultaneous data were available for both the sites. We first note that the diurnal pattern of the difference between highway and SVI_1 for 21-22 November is similar to that for the longer period. This gives us confidence to interpret the longer-period averages in Figure 5.5. The following key features are of importance for the present purposes:

The diurnal patterns are similar between the two sites, with the highway site peaks lagging behind the SVI_1 (village site) BC by about half hour. One possible explanation for the lag is that the sources for the peaks are the biomass cooking in neighboring villages. But, the amplitude of the variations is much smaller in the highway site. Again, this suggests the villages as the main source for the strong diurnal variations.

The BC concentrations at the highway location during the non-cooking hours is a factor of 3 to 5 larger than the SVI_1 village center BC. The BC concentrations ranged from 20 to 50 µg m-3 on the highway crossing whereas BC ranged from 3 to 15 µg m-3 in the SVI_1 village. The significantly larger concentration in the highway site is suggestive of the importance of fossil fuel combustion source for the IGP region. Again, similar to the SVI_1 village observations, the day time minimum in the highway

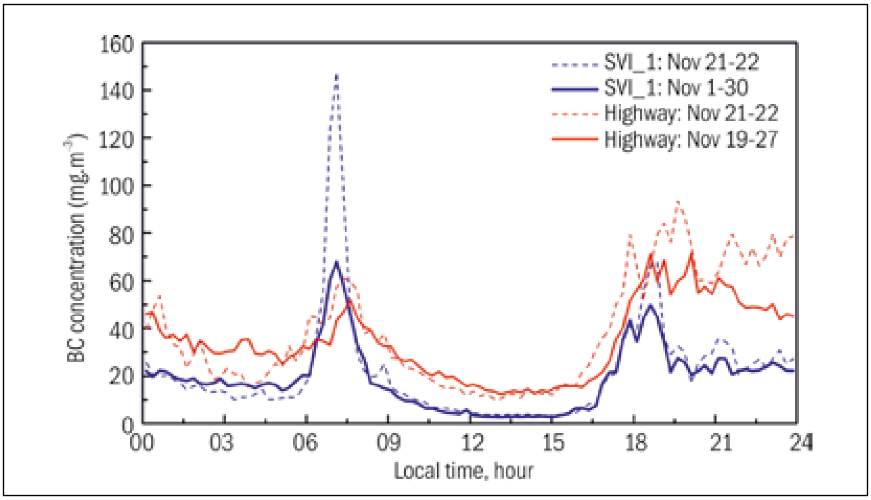

Figure 5.5 Comparison of diurnal variation of BC concentration at Surya village (SVI_1) center with highway measurement (locates around 3 km to the southeast of SVI_1).

BC is much lower than the night time minimum. There are two factors that are contributing to this difference in the minimum BC. First is the diurnal variation in the boundary layer thickness. The second possible factor is the larger night-time traffic in trucks carrying cargo. We don't have sufficient traffic data to quantify the latter factor.

We next use two independent measurement techniques to examine the relative importance of biomass cooking and fossil fuel combustion in the observed indoor and outdoor BC in the village site.

5.6.1 Optical Technique

Figure 5.6 compares the normalized light absorption (measured by the Aethalometer) as a function of wavelength for ambient aerosols from our two sites (SVI_1 and highway) with the previously published results from Kirchstetter et al. (2004). As shown by Kirchstetter et al. (2004) wavelength dependence of absorption is another way to understand the relative importance of biomass and fossil fuel contribution to BC. Thus far, we focused on BC. But this is not the only light absorbing aerosol produced by biomass or fossil fuel combustion. These combustion processes also produce organic aerosols, some of which strongly absorb in the near-UV re-gion of the solar spectrum, and they are referred to as Brown Carbon (BrC) (Andreae and Gelencser, 2006). The BrC absorption increases with decreasing wavelength as approximately λ^{-2} from near infrared t oUV region (Kirchstetter et al., 2004) and can go as high as approximately λ^{-7} in presence of humic-like substance in biomass aerosols (Hoffer et al., 2005; Chakrabarty et al., 2010). Whereas BC absorption increases as approximately λ^{-1} from near infrared to UV region. The Kirchstetter curves were obtained in a laboratory in California. Biomass burning produces significantly more (factor of 3 to 6 more) organic aerosols (and hence BrC) than fossil fuel combustion and as a result the spectral dependence of the absorption coefficient is much steeper than that of fossil fuel BC and OC (see the two Kirchstetter et al curves in Figure 4.6). Figure 4.6 shows that for both locations absorption dependence on wavelength is in between biomass and fossil fuel curves. As expected, the SVI_1 village curve is slightly closer to the Kirchstetter biomass curve, whereas the highway curve is slightly closer to the fossil fuel curve. The data shown in Figure 5.6 is yet another indication that both biomass cooking and fossil fuel contributes to the observed BC in both the SVI_1 village and the highway site.

5.7 Filter based mass analyses

During February-June 2010, 24 h samples were collected using BC_CBM system alternately in indoor (one selected house) and outdoor (at village center). Out of these, 30 samples from indoor and 27 samples from outdoor were analyzed for EC and OC (consisting of BrC and other organics). The sum of EC and OC is referred to as total carbon (TC). For quality control, 6 field blank (randomly selected) samples were also analyzed for EC and OC. No EC was detected in the field blanks; therefore

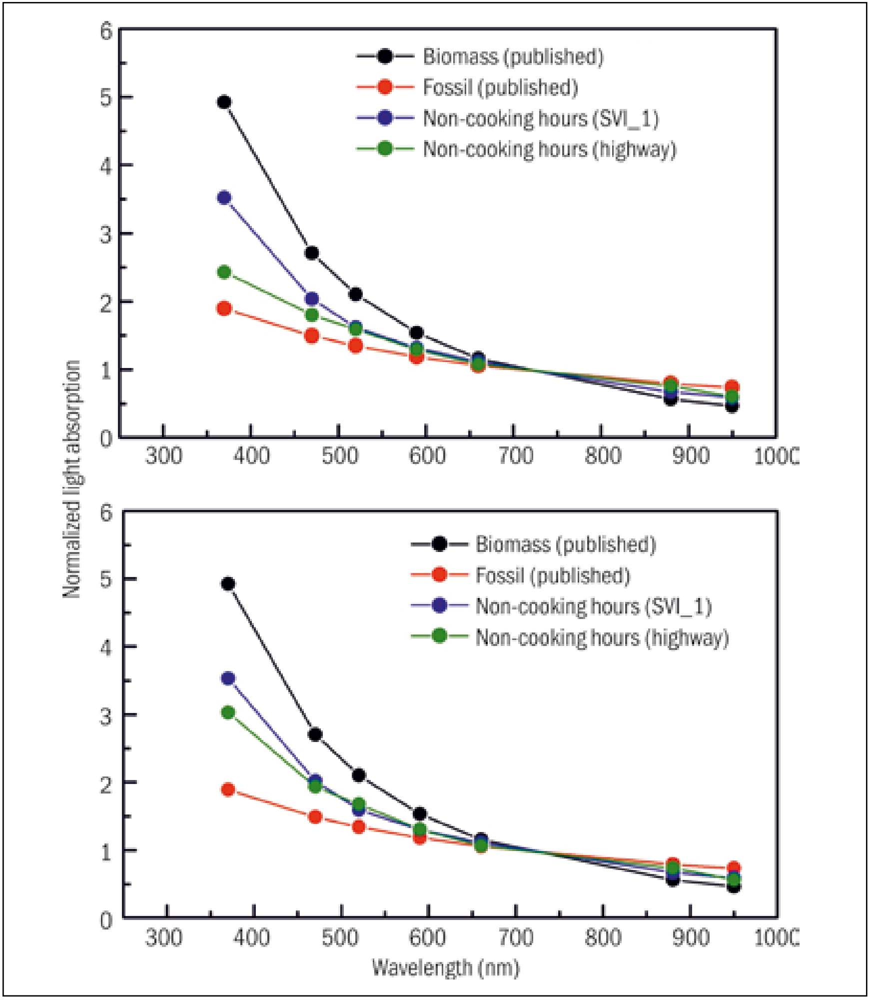

Figure 5.6 Comparison of normalized light absorption in aerosol samples collected during cooking and non-cooking hours at Surya village (SVI_1) center and highway, with the previous published (Kirchstetter et al., 2004) study

no blank correction was needed. Figure 5.7 shows the OC/EC ratio as a function of EC concentration in indoor and outdoor samples. The OC/EC ratio in indoor samples varied from 2.9 to 8.4 (mean value of 5.3±1.6) after excluding two data points with ratio above 10; the corresponding EC concentration varied from 14 to 200 μg m-3 Similarly, the OC/EC ratio in outdoor samples varied from 2.8 to 8.7 (mean value of 4.9±1.5) in close agreement with the indoor OC/EC ratio; the corresponding EC concentration varied from 6.3 to 25 μg m-3. It is interesting to note that even though the OC/EC ratio in indoor samples is from one household, the similar ratio is found in the outdoor samples where concentrations are influenced by around 200 households, strongly suggesting that the outdoor OC/EC ratio are dominated by biomass fuel burning in indoor cook stoves. The OC/EC ratio is characteristic of the type of fuel burned (higher for biomass fuel and lower for fossil fuel) and can be helpful in differentiating between combustion aerosol sources (Novakov et al., 2000). Typically mean OC/EC ratios for fossil fuel dominated aerosol in urban cities (range from about 1 to 3, whereas in regions dominated by biomass burning, the OC/EC ratio are about 8 (range from about 4 to 13) (Novakov et al., 2000). In our study the observed ratio of OC/EC ratio for both outdoor (ambient) and indoor (kitchen) represents aerosol from typical biomass sources. Roden at al. (2006, 2009) reported OC/EC ratio between 0.5 and 13 (mean value of 2.3) during field measurements from traditional Honduran wood-fired cookstove. The authors argued that the large amount of EC emitted during cook stove combustion may not be able to distinguish between fossil and biofuel combustion aerosol when cooking with biofuel is dominant. Schmidl et al. (2008) reported OC/EC ratio between 2.7-3.3 for hardwood and 2.6-5.7 for softwood typical burned in Austria and mid-European Alpine region for space heating during winter in domestic tiled stove. Gonçalves et al. (2010) reported OC/EC ratio from burning test in chimney-type woodstove on four common types of wood (3 hardwoods and 1 softwood) prevalent in Portuguese. The authors found lower OC/EC in softwood (ratio of 0.9) compared to hardwood (ratio ranged between 1 and 4.4). The OC/EC ratio found in our study agrees very well with the ratio found in earlier studies. However, some of the differences are attributed to the type of fuel burned and cook stove design. We also compared the OC/BC ratio observed in this study with the gridded biomass burning BC and OC emission data (Lamarque et al., 2010) used in current climate models for the grid (26-27° N, 81-82° E). This grid includes our sampling location SVI_1. For the year 2005, the monthly gridded biomass burning OC/BC ratios in Lamarque et al. (2011) ranged from 5 to 10, which is in close agreement with the ratio observed in this study.

5.8 Implications

5.8.1 Air Quality and Health

The WHO recommended level for 24 hour PM exposure is 25 μg m-3. The daily BC concentration from mud stoves alone exceeded this level by factor of ~5. Furthermore the concentration of OC was found to be factor of ~5 higher than BC both indoor and outdoor. Thus the concentration of TC alone exceeded WHO recommended level by a factor of ~25. Inhalation of such high concentration of PM can significantly impact the health of females (and young children) who spend most of their cooking time sitting next to mud cook stove.

5.9 Climate Implications

The large regional and global climate effects of the South Asian ABCs were highlighted with data collected over the North Indian Ocean. The near-surface BC concentrations over the North Indian ocean were typically of the order of 0.5 to 1 µg m−3. This should be contrasted with the concen-trations of 10 to >100 µg m−3 found in this study for the IGP. Furthermore, as shown in Fig. 2, the pollution per-sists throughout the year. The column AOD are in the range of 0.5 to 1.5 compared with peak AOD values of 0.3 over the North Indian Ocean (Ramanathan et al., 2007). Lastly, our data shows the single scattering albedo of the aerosols in the village are typically around 0.8 to 0.9, indicating highly absorbing aerosols (explained elsewhere in Praveen et al., 2011). Thus the atmospheric solar heating over the IGP by the biomass BC should be factor of 2 to 5 larger than that over the North Indian Ocean (see also Satheesh et al. (2002) for values over the Bay of Bengal). Such large solar heating by BC over the IGP, should have significant impacts on the monsoon system on meso-scales as well as regional scales. As discussed elsewhere (Ramanathan et al., 2007; Lau et al., 2008), the heating of the air by BC, would be transported to the elevated regions of the Himalayas, where it can amplify the greenhouse warming. The atmospheric heating by BC, will be accompanied by large dimming at the surface, which can reduce crop productivity due to less sunlight for photo-synthesis (Auffhammer et al., 2006) and perturb surface energy budget and the hydrological cycle.

Another important finding of climate relevance is the large increase in solar absorption in the visible wavelengths by the BrC, as shown in Figure 5.7.This absorption will amplify the BC solar heating. The results obtained in this field study demonstrate the importance of biomass cooking related BC to regional climate.

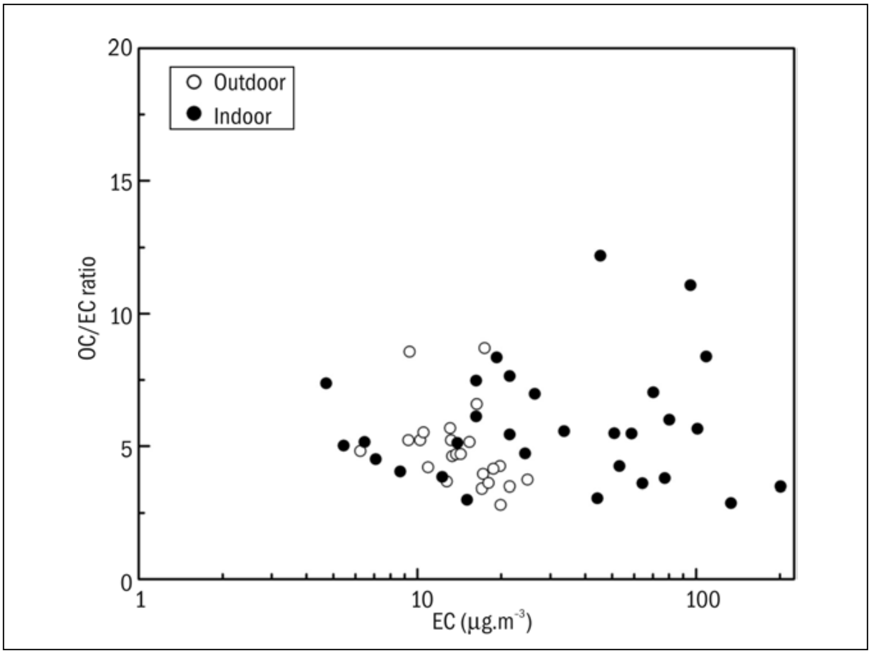

Figure 5.7 Comparison between OC/EC ratio vs. EC concentration for indoor (SVI_1 village kitchen) and outdoor (SVI_1 village center) samples.

Lastly, most satellite observations of aerosols are collected during the day light hours (typically during 09:00 to 04:00); whereas our data shows the BC and OC reach peak concentrations during early morning (before 08:00) or late afternoon (after 17:00). It is likely satellite data of aerosols may have a large bias over regions where cooking dominates BC sources.

5.10 Conclusions

The fundamental insight gained from this field study is that cooking with solid biomass fuels is a major source of ambient BC over the IGP region. The second major finding is that peak values of BC are reached during early morning hours (05:00 to 08:00 hours) and early evening hours (17:00 to 19:00), and the peak values of about 100 µg m-3 are a factor of 10 to 30 larger than the day time values. Indoor BC values during the peak hours are much larger than outdoor values. The OC concentrations are a factor of 5 larger than the BC concentrations. However, the OC had significant absorbing BrC, as revealed by the spectral absorption in wavelengths ranging from 350 nm to 600 nm. Even in the rural area sampled in this study, fossil fuel combustion from the transportation sector had a significant influence in the background BC concentrations during the non-cooking hours.

The results have significant implications to health impact studies as well as climate impact studies. On the epidemiological side, studies that rely on mean day time values will underestimate the cooking-hour exposure by factors ranging from 5 to 20. Likewise, climate impact studies that rely on satellite data or the ground based AERONET network will severely underestimate the effects of BC and other aerosols, since satellites and AERONET rely on day time data. With respect to regional climate impacts, the observed BC concentrations, the column AOD and the solar absorption efficiency of the aerosols are significantly larger than the values reported over the North Indian Ocean. This implies that the atmospheric solar heating as well as the surface dimming over the IGP region due to BC, OC and other particles from cook stove emissions should be larger by factors ranging from 2 or more. Clearly, our understanding of BC effects on monsoon and Himalayan glaciers needs to undergo a major revision with new modeling studies.

Therefore, the climate forcing of BC when viewed with the already studied impacts on health of fine particulate matter emissions from biofuels necessitates the need for concerted effort to focus on finding clean energy solutions for rural household in conjunction with the measures to reduce emissions from fossil fuels particularly diesel driven vehicles. Considering the long-term actions required for mitigation of CO2 and related pollutants the most effective strategy that would yield dividends both for environment and health in a short time span is to focus on short-lived carbonaceous pollutants such as BC. The strategy would be particularly relevant for developing countries where the reduction in short lived pollutants by introduction of efficient technologies for burning biomass for cooking is a development imperative. Given the fact that a large number of people using biomass based cook stove usually live below the poverty line it is also desirable to evolve methodologies that systematically capture the reduction in BC emissions and make it feasible for rural households to get financial benefits from the existing carbon economy. The process would facilitate and incentivise the adoption of improved cooking devices in rural areas. Further the findings from this work clearly establish the need to focus on scientifically assessing the transport of black carbon emitted from biomass burning and diesel exhaust to glaciers and its potential warming impact that may lead to accelerated melting.

Acknowledgements

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CHAPTER 6

Distribution of improved cookstoves: analysis of field experiments using strategic niche management theory[1]

Abstract

Close to three billion people globally and over 800 million in India are dependent on direct combustion of unprocessed solid biomass fuels in inefficient traditional mud stoves. Current cooking practices, besides causing serious health problems, are also being linked to emissions of climate change and pollution agents such as black carbon and ozone precursors. In India several initiatives have been taken up to tackle the problem but the present trajectory of limited technical and social change in cooking energy use is nonetheless persistent in rural areas. In order to develop and scale up alternative cooking technology options, we have analyzed, using the principles of strategic niche management, two projects implemented by The Energy and Resources Institute (TERI) in nine villages in India. The assessment, while highlighting reasons for stability of the current cooking regime, also points to triggers that can destabilize the regime. The focus is also on assessing the influence of protection in the form of subsidies on the process of transition. User preferences relating to social and technical aspects have been analyzed, pointing to forced draft cook stoves as the preferred option notwithstanding cost reductions to address affordability concerns. The assessment indicates that while it is critically important to understand and address the preferences of users and to improve the technology, scaling up will depend on stove cost reduction through further research. Creativity in effective financing schemes

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[1] This chapter is reproduced from Rehman, I. H., Kar, A., Arora, A., Pal, R., Singh, L.,Tiwari, J., and Singh, V. 2012. Distribution of improved cookstoves: analysis of field experiments using strategic niche management theory. Sustainability Science.

and support structures put in place by fostering public–private partnerships are also needed.

6.1 Introduction

More than 2.7 billion people, primarily living in rural areas of Asia, Africa and South America, are dependent on direct combustion of unprocessed solid fuels such as wood, dung and agricultural residues in inefficient traditional mud stoves for meeting their cooking and space heating energy needs (IEA 2011). For instance, in India, close to 13 million rural households (855 million people) use solid unprocessed bio-fuels such as wood, agricultural waste, and dried cattle manure in traditional mud stoves for cooking purpose (NSS 2011; IEA 2011). Solid biomass-based fuel burning in mud stoves is characterized by incomplete combustion, resulting in emission of pollutants such as particulate matter, carbon monoxide, nitrogen and sulfur oxides and other toxic compounds including poly-aromatic hydrocarbons, which occur inside, mostly poorly ventilated kitchens in rural areas (Kim et al. 2011; Desai et al. 2004).The negative health effects of such cooking practices are well documented and half a million premature deaths and nearly 500 million cases of illness are estimated to occur annually as a result of exposure to smoke emissions from biomass use by households in India (UNDP/ESMAP 2003).Recent literature also links current cooking practices with emission of climate change agents such as black carbon BC), and ozone precursors, making it an environmental hazard (Rehman et al. 2011).In India, several initiatives have been taken up in recent years to tackle the unsustainable practice of direct combustion of solid biofuels in traditional stoves (Venkataraman et al. 2010). Yet, the present trajectory of limited technical and social change in the rural cooking energy situation is nonetheless persistent and is likely to continue in the same direction (IEA 2002). Government initiatives to introduce clean cooking alternatives like liquefied petroleum gas (LPG) have had limited success as penetration in rural India is limited to only economically affluent rural households (Nautiyal and Kaechele 2008; Pachauri and Jiang 2008). In spite of subsidized prices in India, high up-front costs associated with the equipment needed to use LPG (stoves and cylinders), low population density, poor road infrastructure, and lack of supply security and low economies of scale in rural areas pose challenges to commercial viability of LPG distribution networks at current prices, hindering its wider adoption among rural households (Pachauri and Jiang 2008; UNDP/ESMAP 2003). Another clean cooking technology, biogas, is capital intensive, with no tangible monetary savings on invested capital if biogas is used for cooking only in households with access to non-monetized fuel (Quadir et al. 1995). Large-scale dissemination of biogas is also restricted by household level ownership of cattle, as a minimum of four to five cattle are required per household to maintain a family size biogas plant irrespective of availability of sufficient land and water (D’sa and Murthy 2004; Quadir et al. 1995).The above discussion indicates that cooking technology switching in rural households in the developing world in general, and

India in particular, has emerged as one of the key concerns related to transitions to a more sustainable energy sector (Rehman et al. 2010). However, in the absence of accepted benchmarks for biomass-based cooking energy provision, the term “improved cookstove” has become a catch-all phrase that encompasses a range of different cooking technologies that may enhance either heat transfer efficiency or combustion efficiency or both with varying degrees of performance and cost (Kar et al. 2012). The existing scenario necessitates creation of‘ ‘spaces” where interested players like stove developers and grassroots implementers can develop, customize and disseminate improved cooking technologies. Such experimentation with technology and dissemination models is required as the first step towards sustainable transition in the rural energy sector. The Energy and Resources Institute (TERI), a not-for profit research institute based in New Delhi, has undertaken two “societal experiments” that provide insight into consumer psyche and assess/improve upon cooking technologies. We have used the strategic niche management (SNM) framework to examine these experiments. Transition scholars view SNM as an important tool with which to “understand and manage” innovations (like clean cooking technologies) and “facilitate their diffusion” (Witkampet al. 2011). The socio-economic, cultural and technological characteristics of the current rural cooking energy regime are reported in this paper. We have also assessed and highlighted the primary reasons for stability of the socio-technical regime (usage of mud stove), which are characterized by deep and embedded links between technologies, habits, cultural norms and practices, together with high level of inertia (Rehman et al. 2010; Kemp et al.1998; Berkhout et al. 2010). We have also described the ‘technological niche’ created under these two experiments where technology innovations are protected from existing regime pressures. The analysis of experiments using the SNM framework led to identification of various drivers that may enable a regime shift from traditional mud stoves to less smoke-emitting and more energy-efficient improved cooking technologies.

6.2 SNM experiments

The two experiments were carried out by TERI in nine villages in the state of Uttar Pradesh in India. The first experiment focused on development, customization and dissemination of environment friendly sustainable technologies, which included improved biomass cookstoves, in eight villages. Supported by the Department of Science and Technology (DST), Government of India, this experiment(hereafter referred to as DST) provided a platform for usertrials for improved cookstoves. In order to introduce instability into the current regime, the experiment focused on two aspects. First, optimization of cookstove technology was approached by taking into consideration the socio-technical needs of the local population, e.g., vessel dimensions and family size. Second, a sales and service set up through local entrepreneurship was set up. In the process of arriving at a new design, a total of eight improved stove models were tested first in the laboratory and then some selected models were trial tested at the rural household level to determine the efficacy of the technology to identify the needs of households (TERI 2010).

Laboratory testing was carried out as per internationally accepted protocols, namely Water Boiling Test version 3.0, and Controlled Cooking Test version 2.0. For user trials, in each of the eight project villages, ten households willing to cooperate and provide help for conducting various experiments were selected. However, efforts were made to short list willing households, which were selected in such a way so as to represent different types of cooking fuel usage (e.g., fuels like biomass energy fuels, coal, charcoal, kerosene, LPG, biogas, etc.), economic status, housing characteristics (such as location of kitchen/stove-indoor/outdoor), and ventilation conditions in the house. These households were provided with the short-listed models on a rotational basis (on a weekly basis), viz. each of the selected household would have access to all the short-listed models of improved cook stoves. The rationale behind the concept of rotation of devices was to enable a household to compare various devices to reduce bias and judge user acceptance from a common platform.

Under the project, awareness generation camps were organized, which resulted in both awareness and interest (manifested in queries received in our site offices about the cook stove) from villages in the vicinity of the experimental sites. A business value chain was developed where local entrepreneurs linked up with stove manufacturing companies to cater to interested potential consumers. In the vicinity of the experimental sites in a rural market area, a retail outlet dealing with improved stoves, solar lanterns, and other renewable energy/energy efficient products was opened to provide interested consumers with the opportunity to see the product first hand, purchase it and get the stove serviced locally, when necessary.

The second experiment, Project Surya (hereafter referred to as Surya), with support from United Nations Environmental Programme (UNEP) and Scripps Institute of Oceanography, University of California, San Diego (UCSD) introduced improved biomass cookstoves in almost all households in one village. Based on the results of the user trial in the DST experiment and field trials to measure BC concentration levels in rural kitchens, the best IC model. was used for dissemination. The experiment had a mandate to lower the baseline level of indoor air pollution with special focus on BC at the indoor (household) and ambient (village) level. The experiment further focused on assessing user preferences and attitudes related to cookstoves with the objective of bringing about a transition in the existing cooking energy regime. A baseline survey in Surya was designed strategically for assessment of social, cultural, technological and economic characteristics of the present regime. The survey was carried out in four project villages/hamlets comprising of 487 households. Of these, 404 households participated in the survey, and 83 households had either migrated to cities for the duration of the survey or were not willing to participate in the survey. The survey captured the opinion of both the primary decision maker of the house (generally, the eldest working male member) and the primary cook of the house (generally, the female member). The survey had three distinct sections. The first section dealt with the socio-economic indicators of the household, such as family size, occupation, assets and monetary income, The second section dealt with the primary decision maker's perspective on his/her willingness to purchase a new stove, maximum possible investment, and benefits he/she would look for in such a stove. The third section sought information from the primary cook about the cooking pattern-schedule, fuel sourcing and usage, reason for continued usage of mud stove and benefits she/he would seek from a new stove. The surveys were carried out prior to distribution of stoves to assess their expectation about a new technology. As the households are already locked into the existing regime, it was deemed appropriate, from the lens of transition, to understand the factors that could motivate them to switch to an alternative technology. The strategy served two crucial purposes. First it gave an insight into the reasons for current regime dominance due to which there may not be a "felt need" for alternatives. Second, the survey helped to understand the relative advantages desired by stove users in any new technology, which can be interpreted as a latent need. This second insight is critical to nurturing innovation in stable regimes, contributing to initiation of the process of regime change (Raven 2005).

Viewing these interventions through the lens of SNM, the two transition experiments represented small initiatives in which the earliest stages of a process of socio-technical learning took place. The experiments brought together new networks of actors such as research institutions, policy makers and development agencies with knowledge, capabilities and resources, cooperating in a process of learning related to user acceptance of existing cooking technologies as well as development and application of new cooking technologies in the selected environment.

6.3 Existing regime: biomass as the main fuel source

In the project area the average family size comprises six members. Cooking in the project villages is invariably the responsibility of women, and they typically spend about 4 h a day on cooking. There are typically two major cooking sessions in a day—one in the morning and another in the evening. However, each cooking session on an average lasts for about 1.5–2.5 h daily. The staple diet in the households consists of rice, vegetables, pulses and chapatti—kneaded and baked wheat bread (TERI 2010). Traditionally, locally procured biomass such as firewood, crop residues and dried (cattle) dung cakes are used as fuel in traditional cooking devices locally known as chulha, made of clay, with one or two burners that require quarterly maintenance. While majority of households used firewood as main cooking fuel, some households used cattle dung cake as primary fuel. For the households that use firewood, the average wood consumption is around 6 kg per day per household. A majority of families in the villages do not purchase fuel wood, but collect it from the roadside or their own fields. With regard to other fuels, crop residue is used in the households generally for igniting the chulha. However, in the post-harvest season, the share of crop residue in the fuel mix is higher compared to the annual average. About 1 %

of households have LPG but its usage is infrequent and serves the purpose of quick cooking, for example preparation of tea for a guest. A single cylinder containing 14.2 kg LPG usually lasts for more than 3 months (TERI 2010).

The above-mentioned data clearly indicates that biomass in general, and fuelwood in particular, are the main sources of fuel in the project area. The widespread use of biomass clearly indicates a level of stability of the current cooking regime that is centered on solid biomass being burnt directly in traditional mud stoves, making it important to ascertain the reasons for continuity of existing practices.

6.3.1 Regime stability

There are no direct monetary costs attached to the production and maintenance of traditional stoves in rural societies across developing nations (Kar et al. 2012). Field observations have indicated that women in rural households have the skillset (passed on over generations) to build a mud stove from locally available mud and bricks within a few hours and they can use it after sun drying for 2–7 days (depending on weather). Once cracks appear on the stove body after 6–10 months of usage, the stove is repaired with a layer of clay on the crack or destroyed, and a new one quickly built.

Survey data indicates that the strength of the current regime derives from the existing favorable economics of using traditional stoves. This is borne out by the fact that a majority (84 %) of respondents reported zero or negligible capital investment as the primary reason for their continued use of traditional mud stoves (Figure 6.1). Further, for 77 % of households, linkage of mud stoves with local tradition/ customs was the second most important reason for continued usage of mud stove, while 73 % of respondents reported that their habituation to mud stoves would count as the third most important reason for their dependence on such stoves; 51 % of respondents stated that the fourth most important reason for continued usage of mud stoves is because they are user friendly. On the other hand, 38 % of respondents stated that 4th most important reason for preferring traditional mud stoves is because they do not need any technical expertise to operate or service.In contrast to many transitions where the cost economics advantage of alternative technologies has emerged as driver of regime change (Raven 2005), in the case of improved cookstoves cost emerges as the biggest barrier as no commercial technology alternative can surpass the negligible investment that is required for the traditional stoves. It is indeed exceptional for innovation to occur considering the alternative option for the consumer entails zero monetary cost.2 Similarly, social beliefs, including user convenience and compliance with existing cultural practices, also emerged as important regime stability factors, which validates the theory of regime stability (Geels 2004).

6.3.2 Barriers to regime change

The alternative cooking technologies are either mature (LPG) or other improved cookstove models at a elatively less advanced stage of development. When questioned

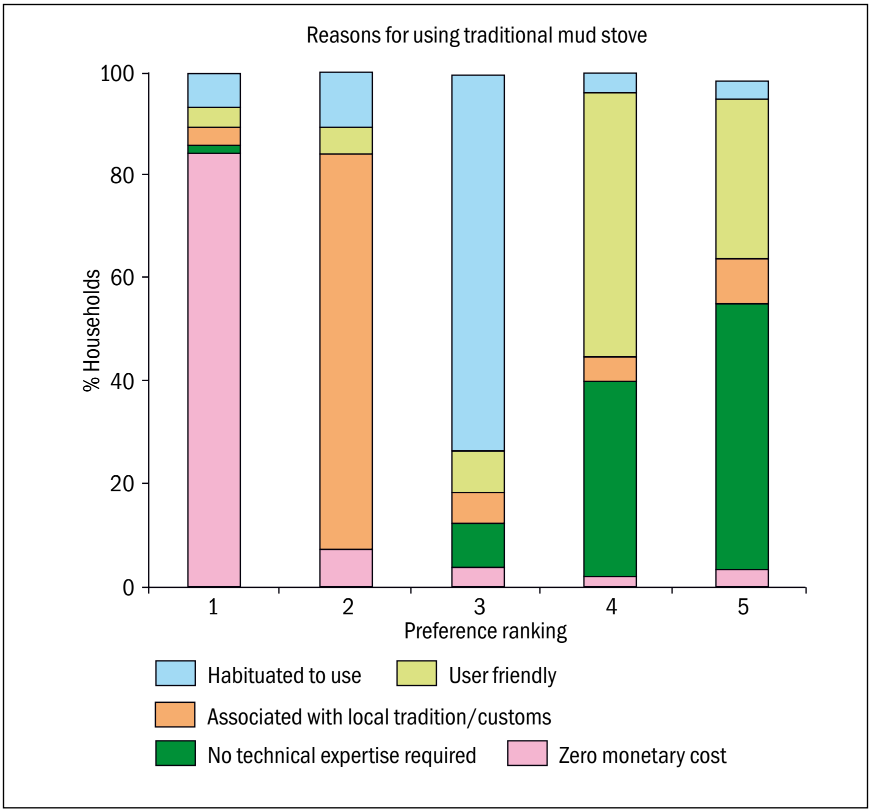


Figure 6.1 Regime stability factors: current technology usage triggers

about the reasons for not switching to alternative technologies 88 % of households expressed satisfaction with the traditional cookstoves and due to the absence of “felt” need, over 63 % of households were reluctant to try alternate technologies (Figure 6.2). Lack of availability as well as knowledge about availability of alternatives also emerged as dominant factors contributing to existing regime stability which in turn led to anxiety about the unknown or perceived uncertainty about alternate technologies

6.3.3 Triggers for potential regime instability

Instability in a regime is not a precondition to transition; even stable regimes change over time (Raven 2005). It is important to identify if the users (critical component of actor network) of a regime are sufficiently ‘open’, ‘stable’ or ‘adaptive’ to accept innovations, and then to identify triggers of regime change to expedite and increase the resource efficiency of the process (Raven 2005; Kemp et al.1998). Triggers of regime change were identified by an assessment of desired features in alternative technologies that can provide a competitive advantage over existing technology regimes and assessment of alternate technologies in the context of user

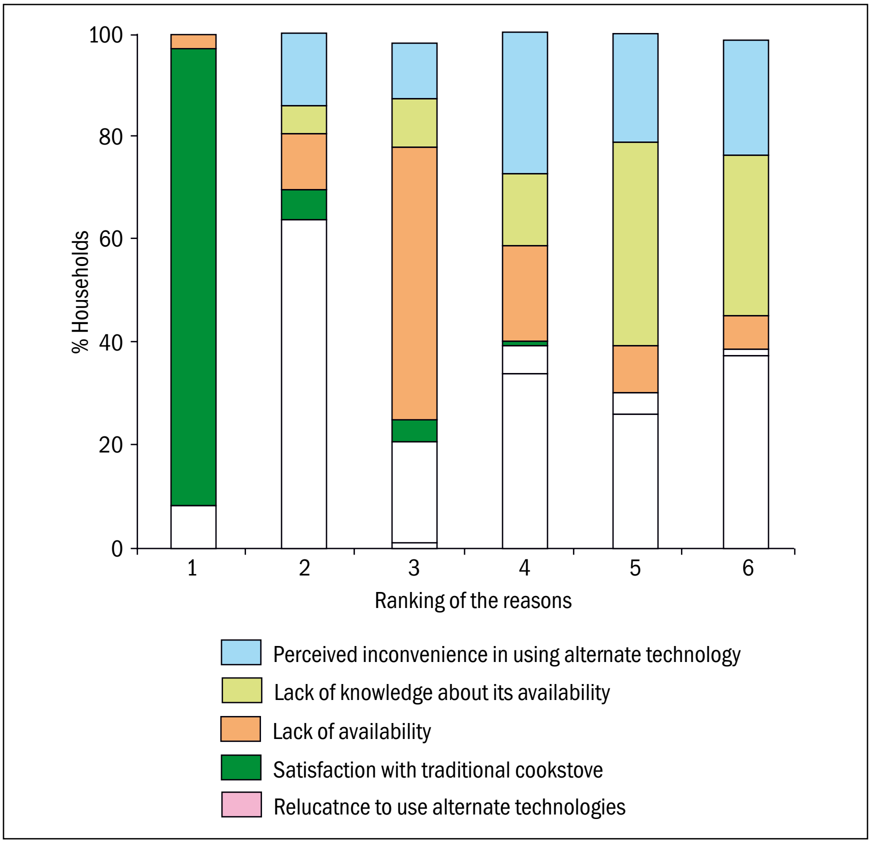


Figure 6.2 Regime stability factors: alternative technology barriers

expectations. The survey revealed that 74 % of households ranked affordability as the most important factor that would attract them to a new technology (Figure 6.3). This indicates that there is openness to regime change but economic factors are the primary drivers when households are making a decision about adoption of an alternative technology to replace the existing "free" technology. 60 % of households ranked reduction in time taken for cooking as the second most important motivator for switching to alternate cooking technologies, while 50 % of respondents cited convenience of use as the third most important factor for acquiring an alternative technology (Figure 6.3). This indicates that users may prefer an "affordable" alternative technology, which results in significant saving of time and effort. The majority of households ranked efficiency and cleaner cooking as less important factors, indicating that households lack awareness or give lower priority to the negative effects of the current technology regime (Figure 6.3).

The survey clearly corroborates earlier findings that a complex web of social, economic, cultural, technical, organizational and individual factors determine the

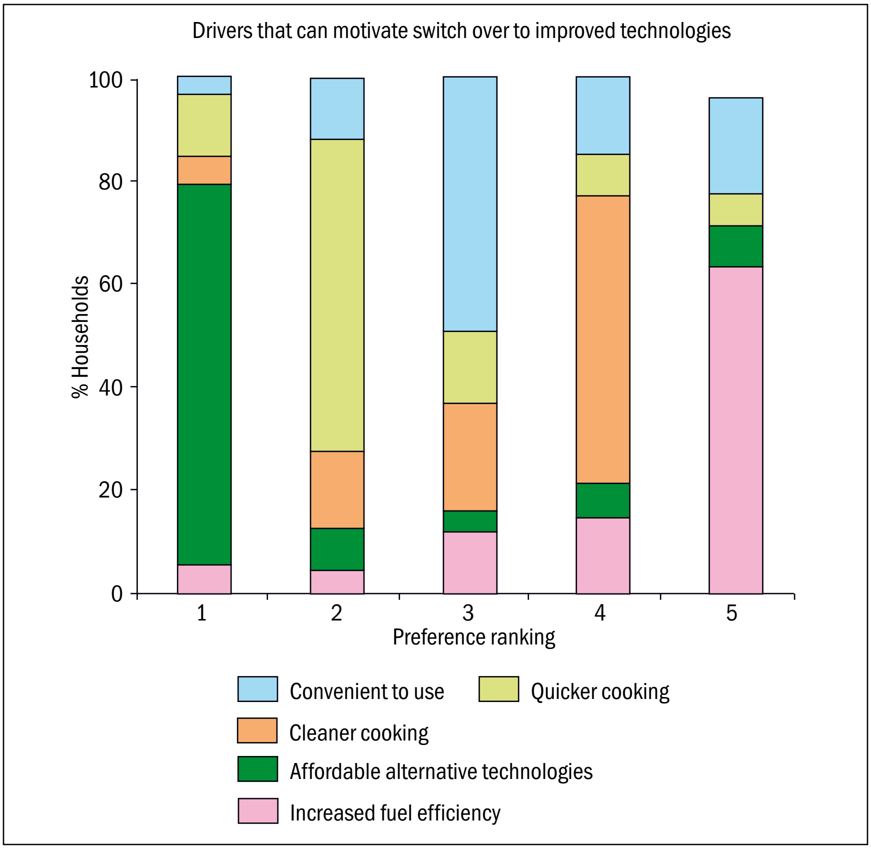


Figure 6.3 Desired attributes in alternatives of traditional cookstoves

adoption of new technologies [such as improved cookstoves] (Segal 1994). Hence, technical efficiency parameters (thermal efficiency and combustion efficiency are indicators for fuel savings and emissions, respectively), though important, are rarely the exclusive factor determining whether or not an improved cookstove is widely adopted. For instance, apart from affordability, the technology must meet a variety of cultural requirements, such as ease of cooking.

6.3.4 Introducing instability into the current regime

The introduction of instability in the regime required a marked improvement in the technology so as to offer substantive benefits to the end users. From a technical point of view, the cookstoves can be segregated into two broad categories based on airflow sources, one that naturally enhances the convection flow called "natural draft stoves" and the other in which the air is forced through a fan in to the combustion chamber and hence called "forced draft stoves" (Kar et al. 2012). Thus, a portion of the survey focused on the comparison between natural draft and forced draft stoves disseminated for pilot testing that helped in recording and understanding community preferences with regard to different stove options. On the technical aspects, 86 % households felt that natural draft stoves are able to burn multiple fuels, while 67 % stated the same about forced draft stoves (Figure 6.4); 83 % of households stated that forced draft stoves were able to reduce smoke while only 59 % stated that natural draft stoves reduced smoke. A total of 73 % of respondents also indicated that time taken for cooking was reduced (in comparison to traditional mud stove) for forced draft stoves, while only 52 % of households stated the same about natural draft stoves (Figure 6.4). On the non-technical side, aspects such as the ease of operation, aesthetics, quality of cooked food and burning safety concerns, it was the forced draft stoves that found favor with most households (Figure 6.4). Hence, it was evident that destabilization in the current cooking regime could best be introduced by the forced draft cookstove technology.

The desire of households to have a technology that, besides reducing costs, was also convenient, required much less time and produced considerably reduced smoke is addressed by a new stove designed as part of this experiment. The stove has been patented and is currently in the process of being commercialized. It helped considerably in destabilizing the current regime. While the earlier commercially available forced draft stove was in the range of US $70–$90, the new stove is priced around US $45, which is comparable to some commercial natural draft stove models.

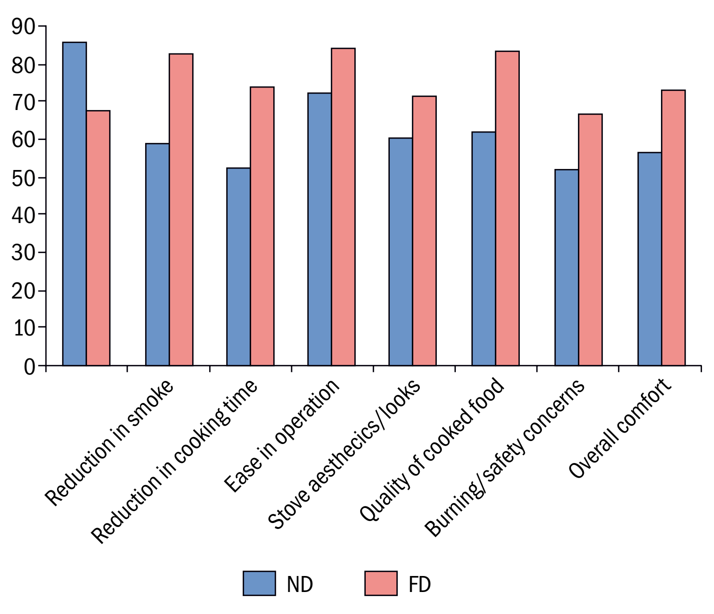


Figure 6.4 Feedback from users on the benefits of imporved stoves

6.3.5 Role played by protection

Protection is the main dimension that draws the boundary between niches and regimes, and the different players must strike a continuous balance in exercising and ending protection in an experiment. In the Surya and DST experiments, different levels of protection were in place. While in Surya initially the cookstoves were disseminated for free, in DST the cookstoves were initially subsidized. We attempted to understand the interplay of stabilization and protection in the context of improved cooking technologies (Figure 6.5) using the framework developed by Raven (2005). The horizontal axis represents the level of stabilization as it represents the stability in rules at the niche level and to what extent this level provides a structure to local practices in experiments. The vertical axis represents the level of protection from rules in the regime. The dissemination of cookstoves at zero capital cost under the Surya experiment (upper left-hand corner grid) represents high level of protection (greater subsidy) and low stabilization (less consumer stake as they did not invest in the product). It is an example of a technological niche that happens in the early phase of introduction of technologies where the focus is on field trials ("real life context") of the innovation and learning about its desirability (Raven 2005). On the other hand, the baseline (existing regime) scenario of non-monetized mud stove usage by almost 100 % households (lower right hand grid) is characterized by high stabilization in the long term that requires zero or minimum protection. The initial phase of the DST project when subsidized cookstoves were made available (upper right hand corner) represents a high level of protection along with higher level of stabilization. The lower left hand corner grid represents the later phase of the DST project when entrepreneurship and creation of a local value chain had been introduced, leading to sales of stoves at market price. Here, protection is no longer needed, or needed only in a limited form while there is more certainty about technological design, functionality and models. It represents the early phase of a market niche.

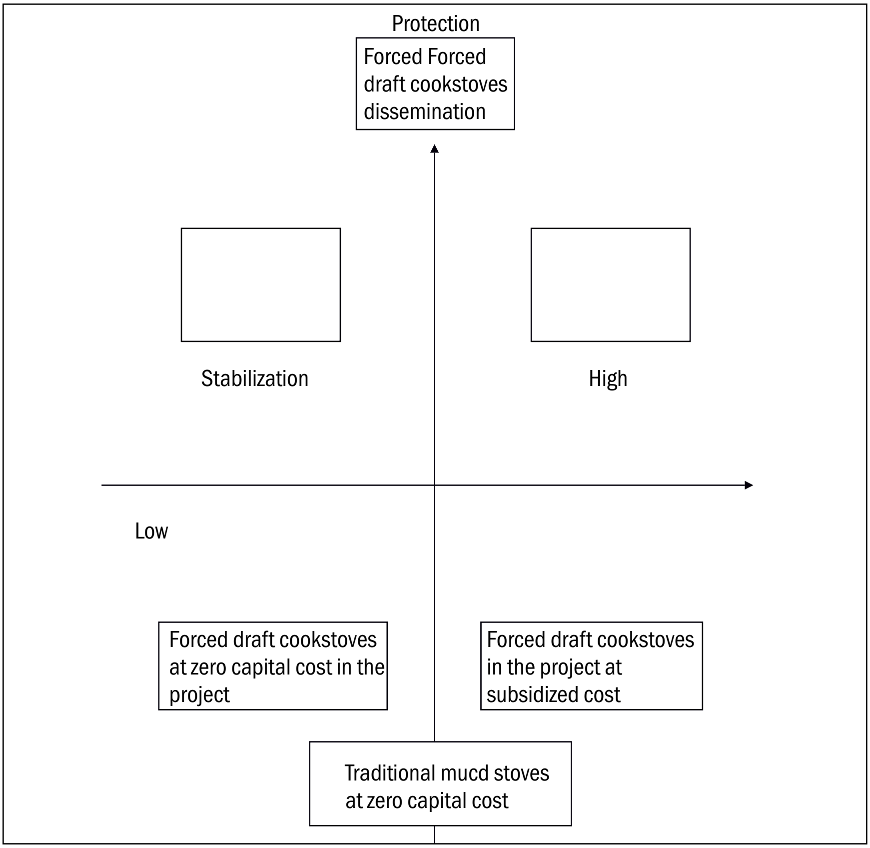
6.4 Expected future trajectory of transition experiments

Four patterns of niche formation may emerge from the cycle of experimentation, and not all niches lead to the transformation of the dominant regime. In a number of cases the experiment leads, at best, to the formation of a technology or a market niche and stagnates beyond it (Weber et al. 1999; Hoogma et al. 2002). To understand this better it would be useful to look at the various patterns of niche formation. The first pattern involves technological niche proliferation. The experiments carried out by TERI should be further replicated (after modifications to suit local conditions) in various parts of India and in other developing countries. Such initiatives can provide more robust localized evidence and technologies, thereby creating multiple technological niches. A second pattern is characterized by conversion of technological niches in to one or more market3 niches, i.e., when the technology becomes economically sustainable but has still not dislodged the dominant regime. The cook stove technology solutions has a long way to go in terms of technology innovation and dissemination model development in these multiple technological niches to be able to progress to a market niche. In the third pattern, several stages of technological and market niches makes the innovation a dominant technology, and thus transform the regime. This is not possible in foreseeable future without significant activities linked to the first two patterns. In the fourth pattern technological or market niche extinction, the novel technology fails to attract further support and becomes (again) a research and development option. This has happened in past cases of improved stove initiatives because innovations failed to deliver on what potential consumers wanted at a specified price.

The technology niche created in the two transition experiments discussed above would be contingent upon the adoption of the disseminated cookstoves by the households, and success achieved in the technological niche in turn would depend on its ability to attack the stability of the existing dominant socio-technical regime (traditional biomass cooking practice in rural areas). While the Surya experiment is still in the process of creating a technological niche, the DST experiment has moved to the stage of technological niche proliferation through the setting up of entrepreneurial ventures. Both experiments are yet to arrive at the stage of regime transformation or market niche creation. The challenge that the two TERI experiments have highlighted is the need to further reduce the cost of the forced draft stoves from the existing level of $45 (brought down under the project from $80) while adding to the improvement of features. The process is being taken forward in the DST experiment by development of a forced draft stove and inverter that can operate both the stove and a light point using solar or grid electricity. As the additional cost is only $10, dovetailing the lighting option makes the stove more attractive and relatively higher 'value for money' for the community.

6.5 Conclusions

Scaling up experiments over wider geographic boundaries requires the formation of a technology niche; however, this in itself would not be sufficient for a regime shift. The technology niche formed eventually has to transform into a market niche, which would have to scale up to wider geographical areas for a regime transformation to happen. Improved biomass cookstoves are expensive compared to the traditional mud stove (without the subsidies), require a significant change in user habits (like fuel processing) for some stove models like TLUD gasifier stoves (Mukunda et al. 2011), and, at the initial level, may not hold much value in the minds of potential users. For a successful transition to a cooking energy regime led by improved cookstoves, these obstacles would have to be addressed, in addition to dealing with long-term challenges of developing cost-effective supply chains to remote rural areas. For example, policy level changes like tax incentives for large.


Protection
Forced Forced draft cookstoves dissemination
Stabilization
High
Low
Forced draft cookstoves at zero capital cost in the project
Forced draft cookstoves in the project at subsidized cost
Traditional mucd stoves at zero capital cost

CHAPTER 7

Rural energy transitions in developing countries: a case of the "*Uttam Urja*" initiative in India[1]

Abstract

In most developing countries, at the household level, traditional burning of biomass or use of inefficient technologies for domestic applications like lighting is common, triggering concerns related to fuel or technology switching. The paper focuses on opportunities to promote cleaner energy options through development of value chains delivering improved energy efficiency and access in developing countries. We discussed the example of *Uttam Urja*, a field project involving the dissemination of photovoltaic lighting technologies in rural areas of India. We focus on the challenges of introducing radical innovations into the residential energy sector in developing countries. For the purpose of this paper the *Uttam Urja* project is conceptualized as an 'experiment' and analysed using the Strategic Niche Management (SNM) framework. The paper emphasizes that to effect socio-technical transitions to clean energy options on the ground, it is desirable to focus on technology customization and innovative financing to cater to the needs and concerns of end users.

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[1] This chapter is reproduced from Rehman, I. H., Kar, A., Raven R., Singh, D., Tiwari, J., Jha, R., Sinha, P. K., Mirza A., 2010. Rural energy transitions in developing countries: a case of the Uttam Urja initiative in India. Environmental Science and Policy(13): 301-311.p

7.1 Introduction

Sustainable development is increasingly gaining momentum. There is recognition of the need to reconcile development goals, even in developing countries, with the environmental limits of the planet (NRC, 1999). Transitions towards sustainability demand an approach based on environmentally benign alternatives for development in general, while also improving the quality of life (Holdren 2007). Energy is a driver of global economy and a key input for raising living standards in developing world (Szuromi, et al 2007). As an agrarian industrial transition involves a two to four fold increase in the demand for energy (Schanl et al., 2009), rapid industrialization and improvement in living conditions in agriculture based developing countries will be a major contributor to world energy demand over coming decades. In addition to the depletion of fossil fuels (Kriengsak, et al, 2009), increasing demand for energy in developing countries is constrained by high and rising costs. For instance, in 2008-2009 India's energy import bill was over INR 4000 billion (USD 88 Billion), some 8.4% of its Gross National Product (MoPNG2009). The development of energy also needs to take account of climate change, which is primarily linked to use of fossil fuels (Ross and Piketh 2006). Therefore, alternatives to fossil fuels and significantly more efficient technologies for energy production and consumption are being promoted, particularly in sectors where energy consumption is high in developing countries (Benson and Orr, 2008).

In most developing countries it is often the residential sector that accounts for most primary energy consumption due to traditional burning of biomass and the use of inefficient technologies (Horst and Hovorka 2008; TERI 2009). Thus one of the key concerns related to transitions to more sustainable energy technologies has been fuel or technology switching in household. The classical energy ladder that focussed on achieving transitions from biomass to fossil fuels involved fuel switching. However, in the context of sustainable development, the transition from biomass to fossil fuels does not qualify as progression, due to the associated CO2 emissions. For instance, in a number of developing countries, kerosene is often used in inefficient technologies, such as wick lamps for lighting producing particulate emissions (Schare and Smith, 1995) that have an adverse impact both on human health and environment. Therefore, an alternative to the concept of transition through the classical energy ladder is leapfrogging[2] which either bypasses or effects a transition directly to cleaner fuels or technology options.

7.2 Leapfrogging to cleaner technology options

About 42% of India's 160 million rural households use kerosene as a primary source of energy for lighting (NSSO, 2008). Fuel consumption of various kerosene-based lighting

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[2] Leapfrogging refers to the deployment of a new technology in an application area where "at least the previous version of that technology" has never been deployed (Sauter and Watson, 2008)

devises used widely in rural areas in India, including kerosene wick lamps, hurricane lanterns, kerosene petromax lamps, and non-pressure mantle lamps, varies widely (Rehman et al., 2005). A study by Mills (2003) suggests that variance in consumption can be 6-53 l/year depending on the devise assuming average 3.5 h of operation/day. A study by The Energy and Resources Institute-TERI (2007) indicates that, on average, 36 l of kerosene is consumed annually per domestic lighting device. Making standard assumptions about CO2 emissions (Power and Murphy, 2009) and considering usage of only one kerosene device/household, kerosene usage in rural households in India is estimated to emit some 6.5 million tonnes of CO2 annually. To put this into perspective, total emissions of the Indian economy in 2003-2004 are estimated to be 1.2 billion tonnes (Parikh et al., 2009).

A shift to electricity use based on the current Indian electric power system will produce little improvement. Hypothetically, if all rural households replace kerosene-based lighting devices with a 60 W incandescent lamp, and again making standard assumptions about emissions (Mills, 2003), the related electricity consumption would still contribute to 5.7 million tonnes of CO2, a decrease of about 13% over kerosene usage. However, leapfrogging to renewable energy options, such as solar lantern with an equivalent light output would result in zero emissions at the aggregate level. This approach would also reduce climate change mitigation costs, while development objectives are met, avoiding the fossil-fuel energy route of the industrialized economies (Zerriffi and Wilson, 2010).

This paper takes the example of *Uttam Urja*, a project involving dissemination of renewable energy technologies in rural areas of India. We are concerned with the analysis of the key challenges of achieving a transition to renewable energy sources in the residential sector in developing countries. The main renewable energy technology discussed here is photo-voltaic lighting technology. The *Uttam Urja* project is conceptualized as a 'sustainability experiment' (Berkhout et al., 2010) and analysed using the Strategic Niche Management framework (Kemp et al., 2001; Raven, 2005; Schot and Geels, 2008). This means we (a) analyse the main characteristics of the prevailing regime with a specific focus on the problems related to kerosene lighting; (b) investigate how and which expectations were articulated, emphasizing the role of marketing and branding in this process; (c) analyse the underlying actor-networks supporting the experiment, and specifically the role of dealer and supplier networks; (d) show how learning processes affected the outcome of the project, and in particular focus on the role of training and after sales services, as well as 'learning from the market'; and (e) elaborate how the experiment was 'protected' through innovative financing arrangements (section 3.4). The paper argues for energy transitions that promote leapfrogging to cleaner energy options through promoting and incentivizing development of market value chains for delivery, as opposed to direct end-user subsidies. We further emphasize the importance of a focus on technology customization and innovative financing, so as to fully incorporate the needs and concerns of end users.

7.3 Characteristics and problems of kerosene lighting

Energy consumed for household applications account for about one-quarter of total energy consumed in the world (TERI, 2009). Residential (or household) energy usage primarily comprises lighting, cooking, and space conditioning. There has been 50% increase in the world's average per-capita residential energy consumption from 0.2 toe in 1990 to 0.3 toe in 2006, representing an increase of about 300 MTOE in residential energy consumption in absolute terms for India and China. The linkage between household energy poverty of a country and human development is demonstrated in the trend line Figure 7.1. The trend line clearly indicates a relationship between higher levels of per capita residential energy consumption for countries that fare better in HDI-Human Development Index developed by UNDP (2008).

Improved energy access is fundamental for development in countries with lower values of HDI (GNESD, 2007). Countries with lower values of HDI and lower per capita energy consumption are also dependent on traditional burning of biomass and on related inefficient technologies, such as kerosene wick lamps and traditional cook stoves. To achieve development in a sustainable manner, countries with low HDI should attempt to follow a trajectory for meeting energy demand that is relatively less dependent on both direct biomass burning and on fossil fuels. The point can be better understood by taking the example of energy consumption in rural households in India, where nearly 68 million households primarily depend on kerosene fuelled wick lamps and lanterns (Chaurey and Kandpal, 2009). Further, erratic and poor electricity supply (Rehman et al., 2005) forces a majority of 90 million rural households in India who have access to grid electricity (NSSO, 2008) to continue to partially rely on kerosene for meeting their lighting energy needs.

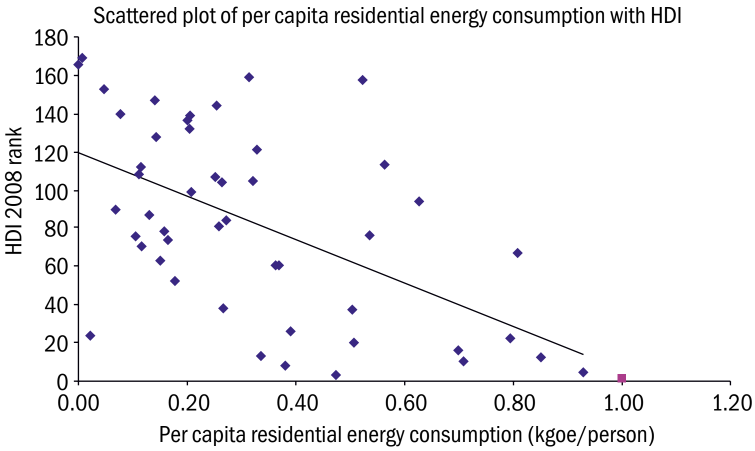

Figure 7.1 Relationship between PCREC and HDI ranking of countries

The inequity of energy services for the rural poor can be demonstrated by the fact that the total annual light output (about 12,000 lumen-hours) from a simple kerosene wick lamp is equivalent to that produced by a 100-watt incandescent bulb in just 10 hours (Mills, 2005). Hence, compared to the recommended standards (see Table 7.1) for lighting for various household tasks, the low quality lighting of kerosene based wicks adversely effects quality of life, as people can suffer eye strain and fatigue, resulting in poor performance (Van Bommel et al., 2002).

Further, the cost per useful lighting energy services ($ per lx h of light, including capital and operating costs) is almost six times greater for a kerosene wick compared to a basic solar lantern model with no optics technology (see table 7.2). Kerosene wick lamps, if used daily for 4 h over a period of 1 year, emit over 100 kg of carbon dioxide into the atmosphere (Mills, 2005). Thus kerosene lamps contribute to global warming. Suspended particulates in the smoke cause indoor air pollution with consequential negative health impacts (Smith et al., 2004) and these lamps pose fire and burn hazards (Mills, 2005).

Accidents due to spillage of kerosene from wick lamps and accidental drinking of kerosene have also been reported (Chaurey and Kandpal, 2009). To confound the issue, part of the kerosene supplies intended for distribution through the subsidized public distribution system in India is illegally diverted to the black market for mixing with diesel stocks (Pachauri and Jiang 2008).

Table 7.1 Illumination requirements for standard tasks as recommended by "Illuminating Engineering Society of North America (IESNA)"

Activity	Recommended Illumination (lux)
General Lighting for conversation, relaxation and entertainment	32.3
Lighting for casual reading, kitchen	323
Kerosene wicks	1-6
CFL Lamp 15 W	More than 100

Source: Compiled by authors from Davis (2009) and Mills (2003)
[a] Lux is calculated horizontally 1m from light source (kerosene wick/CFL lamp).

Table 7.2 Cost per useful lighting energy services ($/lux hour of light, including capital and operating costs) and emissions.

Technology	Cost per useful lighting service ($/1000 lux hours)
Kerosene Wick	5.81
Solar LED 1 W no optics (NiMH battery)	0.90
15 W Compact Fluorescent lamp (grid connected)	0.04
Solar LED 1 W with focusing lens (NiMH battery)	0.01

Source: Mills, 2005

On the other hand besides the need to move away from fossil fuel dependence (Benson and Orr, 2008), the standard alternative of centralized grid based rural electrification programs produces a new dependence on fossil fuels, and is economically infeasible for many dispersed settlements in desert and hill areas (Srivastava and Rehman, 2006). Even in the villages already electrified, power shortages cause frequent power cuts and load-shedding (Ravindranath and Balachandra, 2009). Therefore, about two fifths of India's 160 million rural households (NSSO, 2008) represent a potential for energy development and a business opportunity for distributed and small scale energy production (NSSO 2007). Novel, but readily available cleaner lighting options, such as solar lanterns, exist to meet this new market demand.

As social acceptance and adoption of any technology is critical, because changes in technology are deeply embedded in societies, including in norms, values, and culture (Angel and Rock, 2009), it is necessary to examine the social acceptability of highly novel technologies. A number of ancillary benefits have been identified. Solar lighting allows children to study at night without straining their eyes, aiding better school performance with all its attendant benefits (Ahammed and Taufiq, 2008). Light also provides greater opportunity for home working at night. Moreover, a solar lantern instils a sense of security because the bright lights of solar lantern keeps animals at bay (TERI, 2007) and improved health due to avoided particulates from kerosene (Web, 2003). These factors make solar lantern technology desirable from a socio-economic perspective in a rural household. As improved lighting solutions lead to improved security, literacy, and income-producing activities in the home (Floor and Masse, 2001), solar lanterns have proven attractive for many rural households. Further, rural consumers are often willing to pay high prices relative to their income for reliable quality energy services (Barnes and Halpern, 2000). Past experience suggests that existing lighting options such as solar photovoltaic (SPV) lanterns have been effective in switching rural populations to efficient and modern energy systems (Srivastava and Rehman, 2006). A survey carried out in the project area of Uttam Urja suggested an untapped potential market for solar lanterns (TERI, 2007).

7.4 *Uttam Urja*: a sustainability experiment with an alternative business model for sustainable lighting

TERI India with help of India Canada Environment Facility (ICEF), later the Renewable Energy and Energy Efficiency Partnership (REEEP) executed a project named 'Uttam Urja' (meaning 'better Energy'— in Hindi) that was an experiment to create a market for Renewable Energy Technology (RET) services in rural India and to build up a supply chain to fulfil market demand. The project was executed in five districts of Rajasthan and four districts of Uttaranchal in the first phase (June 1999 -May 2004 under ICEF funding) and 11 districts in Rajasthan in the second phase (October 2004 to August 2006 under REEEP) in the second phase. A group of local entrepreneurs, identified and trained by TERI, was at the heart of Uttam Urja to deliver locally assembled and customized products to the door steps of customers and earn profits good enough to sustain their interest in this business. Lessons learnt from this project to facilitate switching from kerosene lighting devices to solar photovoltaic based devices can contribute to the body of knowledge on technological leapfrogging.

The novelty of Uttam Urja experiment was not so much the technologies used but rather the business model that was applied. The traditional dissemination approach of overcoming the affordability barrier for rural energy technologies is based on centralized government programmes that are target-oriented, and subsidy driven (Srivastava and Rehman, 2006). This approach had limited success due to a number of reasons, including lack of awareness about renewable technologies, limited outlets for procurement, and insufficient adaptation of technology to local needs (Chaurey and Kandpal, 2009). Some of the main constraints related to wide scale adoption of renewable energy technologies are as follows:

Several field assessment studies have highlighted accessibility, reliability and maintenance issues with subsidized rural energy products, such as photovoltaic lanterns and improved biomass stoves (TERI 2000).

Government subsidy on RETs is based on annual budgetary provision, thereby limiting the total amount of subsidies and number of potential beneficiaries (TERI 2000, 2007).

Subsidies are provided on fixed product models in a centralized decision making process, so that the products often do not cater to varied requirements of end users and stifle innovation (TERI 2000, 2007).

Programmes and subsidy schemes are often target oriented with low scope for learning, monitoring and evaluation wherein low quality products also get promoted (TERI 2000, 2007).

The Uttam Urja project attempted to overcome the above mentioned barriers through a business model that promoted delivery and management of energy services through development of a local entrepreneurial chain. Some of the main features of the experiment related to articulating expectations (awareness generation, brand building), social network development (value chain development), learning (product development and customization) and protection (financial innovations) are discussed below.

7.5 Articulating expectations through awareness generation and brand creation

The Uttam Urja project had to compete for the consumers' preferences against similar government subsidized products often available at lower market prices. Hence, it was important to not only provide high quality, need based product and service facility to the potential end-users, but also to articulate the expectation of a customized quality product with assured, reliable and prompt after sales service to the potential customers. The project used several mechanisms such as simple slogans explaining

RETs and their usage, promotion through wall paintings, banners, newspaper articles, outlets and service station signage, customer handbooks, maintenance manuals, and product brochures. These efforts were supplemented by demonstrating various RETs in schools, government offices, marketplaces, service centers, and civic meetings, door-to-door promotions and in mass events – such as haats (weekly/fortnightly markets), melas (fairs), and festivals. To convince customers in a price sensitive market to buy the more expensive product, its advantages needed to be projected through long-term sustained branding, associating it with notions of quality, reliability, and customer satisfaction. A brand titled Uttam Urja with 'The sun and an illuminated house' was designed as (see figure 7.2) along with the marketing tagline of 'Ek rishta vishwas ka' ('A relationship based on trust'). Branding was unheard of in the remote rural solar photovoltaic market where the players are more concerned with short-term benefits (TERI, 2007). Different types of innovative promotional campaigns led to recognition of brand 'Uttam Urja' and its basket of products.

The project concentrated on selling a product line, rather than selling single products. Following this, two strategies for branding were considered: whether to establish one brand for each product, or one brand for the entire product line (known as the 'umbrella brand'[3] concept). The Umbrella brand concept was found to have advantages: the brand logo has greater visibility; it improved cost advantages for advertisements as awareness about entire portfolio; and people do not get confused by a multiplicity of brands. Sales improved remarkably with the articulation of 'Uttam

Figure 7.2 Uttam Urja

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[3] An Umbrella brand gathers together different products that normally possess a common technology or common characteristics for addressing specific needs.

Urja' as a brand (See Table 7.3). It should also be noted that after the usage of the logo in advertisements, dealer response was huge, with products crossing into seven adjoining districts.

The increase in sales clearly demonstrates that branding can play an important role in articulating product expectations to potential users, if appropriate products are made available through a structured and accountable system based on an identifiable brand. Uttam Urja also demonstrated that for the brand to become properly established it needs to have a robust market value chain and service back up.

7.6 Actor networks supporting the experiment

Social network building in this experiment targeted the development of a dealer and after sales service provision network known as Energy Service Networks (ESNs). Figure 7.3 depicts the value chain of Uttam Urja, which indicates various stakeholders of ESN network. Uttam Urja opted for non-exclusive dealership, as this does not strain the dealer network while also allowing the initiative to establish its base. Thus technology

Table 7.3 Sales before and after branding (in million INR)

	Before Branding	After Branding
Bikaner	0.46	3.61
Rishikesh	0.59	2.43

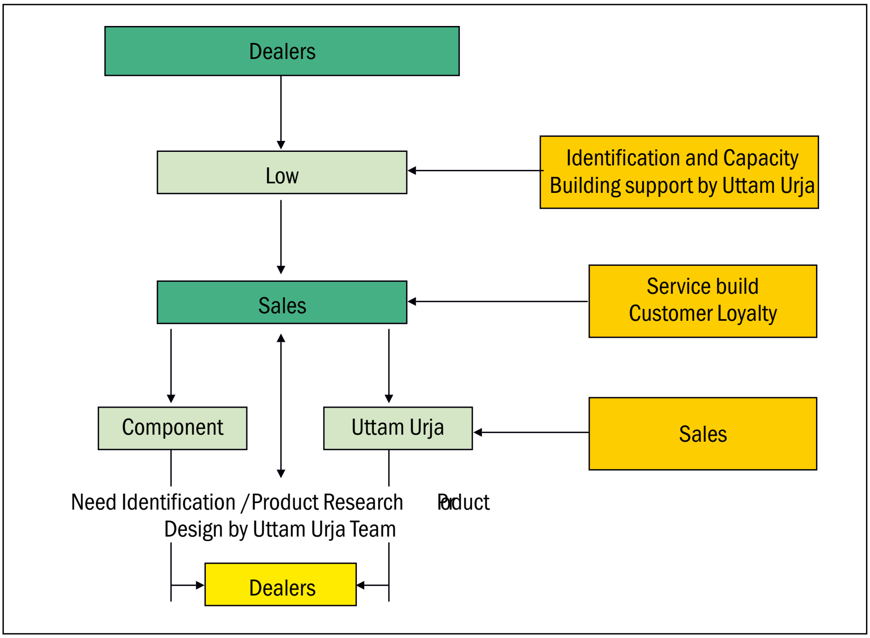

Figure 7.3 Value chain of Uttam Urja

delivery centres were developed "piggy-backing" on existing entrepreneurs. The identified entrepreneurs were already selling electronic products such as radio transistors catering to a cluster of villages. These centres were managed by dealers who worked as permanent channels to deliver the stock to the customers in the villages. In addition, the dealers also had arrangements with smaller outfits at village level to improve product accessibility. Such arrangement reduced cost of setting up a new market chain by leveraging existing infrastructure and entrepreneurial networks (Figure 7.3).

Further, under Uttam Urja, a network of suppliers and vendors that supplied products and components to an assembling centre was developed. Suppliers received a brief on required technical specifications from an Uttam Urja technical team and assembled products based on those specifications. Hence, through an outsourcing business model, there was no need to invest in capital-intensive component production infrastructure. This process helped to bring down the cost of the systems by almost 45% and also improved the quality (TERI, 2007). In addition, Uttam Urja had more than one supplier for most of the components, which helped it to increase its bargaining power and reduce dependence on given vendors. Efforts were made to procure quality components locally and undertake assembly by involving local entrepreneurs. Proximity to supply network had helped the project to reduce its overheads and hence, the cost of the systems. While laying emphasis on quality, local procurement of components was also encouraged for some components to reduce delivery lead-time, which resulted in two added benefits. First, it led to quicker supply of fresh orders and second, the dealers were able to provide more efficient after sales service resulting in repeat orders.

Uttam Urja appointed 24 dealers in the Bikaner region and 22 dealers in Rishikesh region. The dealers maintained inventory of Uttam Urja systems and played a very important role in the Uttam Urja's sales network by adopting a direct selling approach. In the absence of state subsidies, developing a lively dealer network was one of the most important aspects of the experiments. The dealer network also helped the project to deliver on its after sales service promises as the dealer infrastructure was closer to the users (Figure 7.3). The project equipped dealers and their staff with technical information, training and know how to improve their service capabilities.

7.7 Learning through after sales services and learning from the market

Learning had two dimensions in the Uttam Urja experiment. First, high product quality and reliable after sales service was the primary basis for competition with subsidized products. Accordingly, a stringent quality monitoring system of procured components and assembled products was developed and implemented. Hence, in spite of local procurement, reliable product and after sales service was ensured. The Solar Energy Centre of the Ministry of New and Renewable Energy (Government of India) issued quality certification for Uttam Urja products. Extensive capacity building exercises were undertaken to equip Uttam Urja dealers and retailers with technical skills for after sales service. Sixty-five training workshops were conducted for these dealers and retailers to enable them to provide after sale service to the customers at block and village level, leading to the formation of a team of 60 technicians. Training manuals were also developed which were used as ready reference for after sale service. A three-day response time to attend to after sales problems was developed and was rigorously implemented for resolving complaints about Uttam Urja products.

Second, learning from the market played a critical role. Uttam Urja initiated the project with a conventional product portfolio in solar energy based solutions. Over time, as the project team developed a better understanding of the market, new products were developed to meet specific requirements and to create a niche in this traditionally subsidy driven market. Prior to initiation of Uttam Urja, customers in the project area were offered just one model: a 37 Wp2 solar lighting system, supplied through the government channels. It was recognized that learning from the market and subsequent product customization (incorporating needs and concerns of end users) was a key element determining adoption of new technologies (AREED, 2001). The project partners such as dealers, retailers, local partner NGOs, and technicians initially identified the specific requirements of local communities. The potential customer base was segmented based on income level, best symbolized by the size of land holding. Three categories of the households based on their income level were developed and products were classified for these market segments, based on their utility and price. Though there was unavoidable overlap due to similarity of some product features, such classification helped in better understanding the "need and concerns" of different user segments. Based on specific customer feedback, twelve new products, including light emitting diodes (LED) based lighting devices, several versions of lanterns, solar torches, solar Charkha (spinning wheel for yarn which runs with solar power), and solar mixer were developed (Table 7.4).

Access to finance affected the purchase of domestic lighting systems (DLS), even at the subsidized cost to the rural poor. This resulted in the middle- and higher- income groups purchasing DLS rather than the intended target group of lower income groups. In response to this problem, solar panels and lanterns were developed which were more affordable by lower- and middle-income groups.

7.8 Protected spaces through innovative financing schemes

Another success factor in the Uttam Urja experiment was a cleverly designed protected space through innovative financing schemes. In agrarian societies income generation is typically biannual, as it is related to crop harvests. The lack of regular income affects the affordability of new technology options that require high initial investments. Thus purchase of any system on credit needs to be linked to the

Table 7.4 Products offered under the Brand name Uttam Urja

Subsidized systems by Government	Products offered by the company
DLS standard (37Wp)	DLS standard (35Wp)
DLS (18 W)	DLS large (50 Wp)
DLS (74 W)	DLS-small (30 Wp)
Solar Lantern	DLS (15 Wp)
Solar water heater	LED solar torch
Solar cooker	2.5Wp panel
	5 Wp panel
	10 Wp panel
	Kissan torch
	3Wp solar lantern
	5Wp solar lantern
	10 Wp solar lantern
	Solar hot water system
	Emergency torch 1 and 2
	Solar Madhani

pattern of income from harvests; which in turn depend on the monsoons that are unpredictable. Hence small and marginal farmers, and low-income groups find it especially difficult to get loans.

Under the Uttam Urja project, financing options were considered for solar photovoltaic systems involving cooperation with NGOs, dealers and banks. It was observed that NGOs and dealers did not want to take risks involved in financing. High interest rates and the bad reputation of moneylenders excluded the possibility of their involvement, thus leaving banks as the only alternative. Most banks in the region were contacted to get them involved. Subsequently, the financing of solar systems was made possible through a framework evolved for the provision of soft loans by state-owned and cooperative banks. The process of loan processing involved short-listing of applicants based on their past repayment history. Applicants had to submit a 'no-due certificate'. The systems were also ensured to safeguard banks' interest, in case of theft or other risks. To reduce transaction costs, group financing systems (groups of more than five beneficiaries) were also explored and implemented, wherever possible. The Uttam Urja team assisted in crosschecking the credit history of applicants, and providing reminders to debtors. The customer had to pay 25% of the total system price as a down payment, and the rest was payable in 5 equal instalments with an annual interest of 11.5% on the loan amount. Seventy five per cent of the interest amount was paid by Uttam Urja as a subsidy.

Another means to finance the systems was through a Kissan credit card. In this government scheme, national banks issued a card that allocated credit to farmers in proportion to the land they mortgaged. The interest rate is the same as the bank rate, but Uttam Urja made available a rebate on interest for farmers, by means of deposits at the bank for a period of five years.

One objective of Uttam Urja project was to demonstrate the cost-effectiveness of starting businesses with Renewable Energy Technologies, and as an illustration of the financial feasibility of similar projects is possible. Also, the socio-economic impacts are important, as they will bring financial advantages on a long-term basis. As shown in Table 7.5, profits on products earned in 2002-03 in Bikaner, were 87% on panels and 13% on lanterns. The mark-up of the dealers was around 7%–8%. As subsidized DLS was priced at 30% less than the assembling cost of Uttam Urja DLS, no margin was kept during sales of Uttam Urja DLS.

7.9 Conclusions

This paper discussed a novel sustainability experiment focusing on a novel business model for photovoltaic lighting in rural India. The case was studied using the Strategic Niche Management. In particular we have discussed the main environmental and health problems in one of the prevailing lighting regime (the kerosene lamp), the articulation of expectations through marketing and branding methods, the development of a strong supportive dealer and supplier network, the organization of a learning process through training workshops and explicit efforts to learn from the

Table 7.5 Sales and profits of dealers in Bikaner for financial year 2002/03

Product description	Unit Procurement and Assembling Cost (INR)	Unit Sales price (INR)	Profit/unit (INR)	Units sold	Total Profit per product type (INR)
2.5 Wp Solar Torch	425	625	200	720	144000
5 Wp Solar system	865	1150	285	75	21375
10 Wp Solar charger for battery charger	1640	2200	560	75	42000
Luminaire (CFL with fitting box)	300	400	100	35	3500
Lilly-Solar lantern 3 Wp	1100	1500	400	30	12000
Sampurna 8Wp	2300	3000	700	21	14700
UDLS (B)	12500	12500	0	82	0
UDLS (M)	9500	9500	0	9	0
UDLS (S)	7500	7500	0	183	0
Total				1239	237575

Note: B (Big), M (Medium), S (Small), UDLS ('*Uttam Urja*' DLS, assembled locally) market, and the design of financing mechanisms offering protection, through soft loans and credit card systems. The main conclusion is that the SNM framework allowed us to identify critical success factors in the Uttam Urja experiment.

This case also highlights several elements that have received little attention in previous SNM studies. In particular, the role of branding and marketing is new. This case shows how sustained branding and marketing can play important roles in generating sales and, consequently, the success of an experiment in terms of business revenues and the creation of self-supporting enterprises. Another issue that this case sheds light on is the design of protected spaces – a concept so central to the SNM framework. While many SNM studies (implicitly) have focused on public funding as the main protective measure, this case shows how an experiment survives in a market where public funding has been consciously avoided. Rather, protection is sought through innovative funding schemes from banks, targeting upper-end market segments with subsequent product diversification to lower-end markets.

The project also demonstrated that rural consumers, neglected by mainstream manufacturers, are a potential and profitable market. Targeting the rural population is commercially viable for RET manufacturers since rural markets for RETs can be created if high quality products customized to their needs and reliable after sales service is assured. This market segment has been neglected by mainstream manufacturers, as it was perceived as a subsidy-driven consumer base. The dealers in Uttam Urja were able to secure profits to sustain their interest in this business 3 years after completion of the project.

The following several other elements were important to the success of the experiment.

- Development of a local level business network as Energy Service Networks (ESNs), comprising local entrepreneurs, retailers, dealers, manufacturers, vendors, trained technicians and NGOs providing capacity-building of technicians in technical and business management skills.
- Establishment of delivery channels at village/block level improved accessibility of products to the rural consumers and a driver of purchase of a new product type. The Village level dealer network and infrastructure aided delivery of better after sales service.
- The products on sale were designed to meet needs of the local population as customisation of products leads to greater acceptability. For example, a Madhani (churning machine) is widely used across villages in the project area to get home made butter from curd. Uttam Urja designed Solar Madhani (a solar powered home made instrument), which reduced the hand driven churning (by women) to mechanical churning, thereby reducing labour and time.
- A portfolio of products of different capacities and prices was necessary to ensure a broad market. Lower income groups could not afford a 37 Wp solar DLS costing Rs. 18,000, hence Uttam Urja manufactured 15Wp solar DSL costing Rs.5,500 which found wide acceptance.

Offering affordable quality products is imperative to sustain the niche market of renewable energy technologies. Good after sales service resulted in repeat purchase and word of mouth advertisement by existing satisfied customers. The sustainability of *Uttam Urja* after completion of project is demonstrated in the fact that they are still doing the business without any external technical or financial assistance. One of biggest lessons from this project is that rural market for RETs does exist. Low income communities are willing to spend money if they are provided with quality products customized to their needs. By the end of the project, *Uttam Urja* has developed into a mature business model with high horizontal scaling potential in the context of rural areas across developing nations.

CHAPTER 8

Accelerating Access to Energy Services: Way forward[1]

8.1 Context

The implications of energy poverty are profound, as the lack of reliable energy access leads to decreased life expectancy, increased rates of infant mortality and environmental problems—directly linking with key global challenges of poverty alleviation, climate change, and global, environmental, and food security (UNIDO, 2008) (Barter, 2014). As current energy systems fail to meet the needs of the world's poor, they enormously constrain human and economic development. Despite the global upturn in the efforts towards reducing the energy access gap, nearly 20% of the world's population (1.3 billion) still lives without access to electricity, depending on kerosene as their primary source of lighting; and 40% (2.6 billion) lives without access to modern cooking technologies, relying on traditional biomass alternatives such as wood, charcoal, agricultural waste, and animal dung (International Energy Agency 2013).

Deconstructing this further, of the total energy deprived population in the world, more than 95% reside in sub-Saharan Africa and developing Asia and 84% reside in rural and remote areas – indicating the evident divide in energy access between rural and urban geographies (International Energy Agency, 2014). Much of the money that the world is pumping into shrinking the energy gap comes from foreign aid and other public sources and nearly all of it goes toward improving grid access in urban areas, while excluding rural villages from the energy access value chain (Walsh 2011).

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[1] This chapter is reproduced from Rehman, I. H., Arun, S., Gill, B., Worrel, submitted to Energy for Sustainable Development.

Traditionally inherent, but often adverse energy consumption patterns in rural areas and the absence of affordable, reliable and good quality energy services to offset these patterns, results in limited or negligent improvements in living standards in the long term (A. K. Reddy, 2000).

According to the World Energy Outlook, the total estimated investment required to achieve universal energy access by 2030 is nearly $1 trillion, an average of $50 billion a year from 2011 to 2030 (International Energy Agency, 2013). While this may seem substantial, it actually only amounts to about 3% of the annual global energy investment (Walsh, 2011). Nevertheless, even if this investment is secured and capitalized over the next 15 years, with the current population growth rate continually outpacing the rate of intervention, there will still be 1.4 billion people lacking access to electricity and 2.7 billion relying on traditional biomass for cooking and heating in 2030 (UNIDO 2008) (International Energy Agency, 2013)—bringing us exactly where we are today.

Clearly the existence of centralized grids in most countries over several decades have failed to provide adequate and reliable electricity supply to the deprived, with a few exceptions like China, Vietnam, and Brazil, who have made incredible gains in expanding electricity access in the last 25 years to their populations and have achieved an overall electricity access rate of 100%, 98% and 99%, respectively (Shelby 2014) (Goldthau, 2013). Though off-grid options have received favour in other developing countries and have also been supported by international organizations and donor agencies, there has been limited penetration of decentralized off-grid solar options globally. Similarly, even though a majority of developing countries have launched several initiatives to provide improved cooking options, the scale is nowhere near producing a considerable shift in numbers, leaving the overall count of the deprived population more or less the same.

8.2 Current approaches for filling the energy gap

The primary drivers for pushing energy access in majority of developing countries have been the public sector driven grid expansion and making available subsidized fuels, technologies, and electricity to deprived communities. Huge public sector capital investment and high level of consumer subsidies have been the bedrock of energy provisioning efforts. The fossil fuel subsidy rate in South Asia, most of Latin America and large parts of northern Africa are in the range of 50% to 93% (International Energy Agency, 2013). Consequently, national programmes focussing on infrastructure establishment and target oriented subsidy based dissemination of fuels and technologies have been the key vehicles for expanding access to energy.

In recent years there have been concerns related to efficacy of subsidy-based efforts and the need to move to commercial or market driven energy delivery systems. The need for increasing levels of investments and the imperative of pushing universal energy access through multi-stakeholder partnerships have also demanded an increase in private sector participation. Both the public sector and private sector approaches have been strongly advocated and have contributed to taking forward the energy agenda. In recent years the emphasis is tending to shift towards private sector driven energy provisioning although bulk of basic energy provisioning for rural communities is still being driven by the public sector. We discuss here the imperatives of both the public and private sector approaches to meeting universal energy access targets.

8.2.1 Subsidy-driven energy access

Energy provision initiatives for the poor in developing countries have been largely characterized by subsidies and cross-subsidies extended through elaborate public-sector programmes on lighting and cooking energy (Bhattacharyya, 2005) (Lin and Jiang, 2011) (Barnes and Kumar, 2002). The common justification provided for subsidizing energy for the poor is that market efforts often fail to make modern energy services available or affordable for specific economically disadvantaged social groups (UNEP; IEA, 2002) (Fan, Gulati and Thorat, 2008). Subsidies have the obvious benefit of making energy services cheaper, thus enhancing the inclusion of poor rural households in energy access programmes. Hence, public finance driven establishment of primary infrastructure and strengthening the capacities of stakeholders in the value chain coupled with consumer subsidies have been the main vehicles for serving the subsistence energy markets in rural areas.

The Electricity Act (2003) in India and the resultant rural electrification policy (Rajiv Gandhi Vidyutikaran Yojana) obligated the government to ensure access to electricity in villages through a mix of eased regulation, development of distribution infrastructure, capital subsidies, and cross subsidies on tariff (Singh, 2006). In China, residential power was so highly subsidized that the power tariffs did not even meet the supply costs (Peng and Pan, 2006). Likewise, grid extension programmes in South Africa, Brazil, Kenya, and Tanzania have also subsidized energy access and energy use (Bhattacharyya, 2012). Similarly, off-grid electrification, which is seen to have the potential to supplement or complement grid-connected electricity in rural areas, has also been supported by policies to subsidize and cross-subsidize capital and operational costs (Palit and Chaurey, 2011). Similarly subsidy-driven programmes focussing on dissemination of solar photovoltaic based lighting systems, biogas plants, improved cookstoves, etc., have all contributed not only to raising awareness about the role of renewables but in also expanding their reach to the poor and deprived.

In India, national cookstove programmes have focussed on providing direct and indirect subsidies to various stakeholders in the clean cookstove dissemination chain with the intention of enhancing adoption of clean cookstoves by poor households (MNRE, 2012), (Sinha, 2002). Similarly, the Indian government absorbs almost half the cost of modern fuels like kerosene and LPG through subsidies and price control mechanisms (TERI, 2013).

Even while subsidies have contributed significantly to increasing access to energy services, the burden of energy subsidies on the public exchequer is high, sometimes causing severe economic strain on developing countries (Vagliasindi, 2012) (Ali and Badar, 2010) (Fattouh and El-Katiri, 2013). This prompted policy makers to explore the possibility of greater participation of the private sector in the energy services sector.

8.2.2 Private sector driven energy access

Growing levels of public debts in developing nations due to the continued subsidization of public infrastructure and services, including energy, led to the promotion of private investment in the domestic energy sector (Sovacool, Expanding renewable energy access with pro-poor public private partnerships in the developing world, 2013). Reforms in the power sector, pioneered by Chile and the United Kingdom, have stimulated a shift in policy from state-controlled power generation and distribution to greater role for private players in the sector (Wamukonya, 2003). Since then, deregulation initiatives such as privatization, vertical and horizontal unbundling, and the introduction of performance-based regulatory mechanisms have been tried in developing countries with varying rates of success (Zhang, Parker and Kirkpatrick, 2008) (Nagayama, 2007) (I. N. Kessides, 2012). The emerging emphasis in power projects on improvement in technical and financial performance resulted in the development of a better investment climate and less interference of political establishment (Bhagavan, 1999). Innovative financial mechanisms have played an important role in enhancing penetration of the private sector in energy projects, with international financial institutions like the World Bank playing a pivotal role (World Bank, 1993). The most common measure towards commercialization has involved corporatization of state utilities, with privatization of distribution systems being the least favoured measure (Bacon and Besant-Jones, 2001). The objective was to improve the health and management of utilities and bring efficiencies in generation and distribution. In India, for example, the setting up of electricity regulatory commissions reduced theft and distribution losses, and led to enhancing viability of private sector participation in electricity supply through appropriate tariff determination (Lamb, 2006). Various pioneering models of policy frameworks in countries such as Germany and the United Kingdom have led other countries by example (Frondel, et al., 2010) (Burer and Wustenhagen, 2009). The private sector has also been more forthcoming to invest in grid integrated renewable energy sources (Martinot, Chaurey, et al., 2002). In the off-grid sector also the involvement of private sector to drive energy service delivery is being increasingly promoted in many developing countries. In market-supportive renewable energy policies, the role of the government is generally limited to government-funded research to increase technology 'supply', and tax credits to increase 'demand' for renewable energy technology (Held, Haas and Ragwitz, 2006).

In the clean cookstoves sector, there has been an increased thrust worldwide to shift to 'commercial' modes of cookstove delivery to the poor (Hoffman, et al., 2005). However, examples of purely market driven improved biomass cookstove dissemination without any donor support or role of the civil society is lacking. Electric stoves (e.g. induction stoves) can serve as an example of a completely commercially-driven clean cookstove market.

As mentioned above, the major burden of energy access has over the years been on the governments and related public sector entities, that have contributed to not only establishing the necessary infrastructure but have also taken fuels and technologies to remote places through various national programmes. The private sector has more recently got involved in energy provisioning for the poor, particularly in the area of off-grid electrification and dissemination improved cooking options. While each of the two approaches has made disintegrated efforts towards energy provisioning, neither approach has independently succeeded in ensuring universal access to energy in the long term.

8.2.3 Shortcomings of current approaches

The public sector driven efforts focussing on reaching out to the poor in rural areas and the efforts of the private sector to bring efficiencies into access to energy have not yielded the desired acceleration in investments and energy access. It is evident that inspite of several initiatives by the government and the private sector, the number of deprived people have remained more or less constant.

The public sector led initiatives have contributed to establishing energy production and distribution infrastructure and the private sector has helped in bringing efficiencies to the delivery process. However, the slow progress in closing the gap is indicative of inherent constraints of the two approaches and some major concerns related to each of the two approaches are discussed.

8.2.4 Subsidy-driven paradigm

Despite provisioning of subsidized energy as the dominant paradigm in public sector aided energy access programmes, there is a wealth of literature that point to its failings in achieving its goals. Subsidies tend to get misdirected or misappropriated in the absence of strict monitoring. For instance, a study in rural Zimbabwe observed that subsidies were inefficient, failing to make energy affordable for the poor (Dube, 2003). On the other hand, in some cases, the benefits of subsidies are significantly higher for the non-poor households than the poor households (Kebede, 2006). Gangopadhyay noted that removing subsidies will affect affluent households the most and poor households the least (Gangopadhyay, Ramaswami and Wadhwa, 2005). In essence, the subsidies may worsen the deprivation of poor for whom they are intended, particularly if they are misdirected, misused and misappropriated as is the case in subsidization of kerosene and LPG in India (Rehman et al., 2013). Subsidies may also not be efficiently utilized as is the case under Rajiv Gandhi Rural Electrification Scheme (RGGVY) scheme where free electricity connections are provided to below poverty line households that only receive intermittent power supply (Rehman et al., 2013). In such a scenario a more effective and workable arrangement could have been to provide decentralized power with assured supply at critical hours. Even in the off-grid space the tax holidays and related financial incentives including consumer subsidies have not contributed to upscaling of off-grid technologies.

It has been observed that subsidies economically devalue products for both the sellers and the buyers, sending wrong price signals to the market (Rotenberg, 2005). Energy subsidies can lead to market distortions resulting from infrastructural and institutional deficiencies (Bazilian and Onyeji, 2012), and may have negative impacts on markets when reduced or removed. If subsidies benefit only a selected group of suppliers, the market tends to be monopolistic, disfavouring suppliers who cannot avail of the subsidy (Corden, 1967). Consequently, some private players are inhibited from entering the market due to lack of willingness to pay for the actual cost of the service (Vine, 2005). Attending to recurring maintenance requirements and having the managerial and technical skills to operate energy delivery systems is essential for their long-term sustainability. However, development assistance to the energy sector has been mainly directed towards fixed capital assets, with comparatively small amounts earmarked for maintenance and capacity building (Kozloff and Shobowale, 1994).

Once started, the volume of subsidies grows year after year, unless unchecked by robust governance mechanisms. Problems like electricity leakage due to unmetered supply, theft of power, and rise in consumer size contribute to a progressive increase in subsidies year after year (Bhattacharyya, 2012). Top-down subsidies to grid-connected electricity has also imposed severe restrictions on popularization of rural off-grid electrification, which are mainly operated at the level of the village community by local institutions (Palit and Chaurey, 2011).

With the exception of China's National Improved Stoves Program (NISP), subsidies in the cookstoves sector have seldom resulted in the creation of a thriving market (Smith, et al., 1993). Far too many cookstove projects have simply failed because they were not financially viable for commercial operations in the long-term (after discontinuing subsidies), installed inappropriate technologies, and did not implement business models that could meet the needs for long-term maintenance and mitigating operational problems. Consequently, these cookstoves go into disuse very soon (Barnes and Kumar, 2002). Programmes of the Government of India to promote biogas technology and solar cookers in rural areas through direct subsidies failed due to extremely poor adoption rates in the rural communities (Kishore, Rao and Raman, 1986) (Ahmad, 2001).To cite another example, of the 35 million ICS that were disseminated in India during the NPIC, most of the stoves went into disuse within 1–2 years of installation (Sinha, 2002). Barnes and Kumar argue that while most stove programmes involve subsidies in activities such as marketing, information dissemination and technical support, as in China and Sri Lanka, the Indian experiment failed due to major focus on direct subsidy on the stove cost (Barnes and Kumar, 2002). Such disintegrated support to stove dissemination through government programmes failed to address the needs and concerns of diverse actors of the stove supply chain (Shrimali, et al., 2011).

The inherent deficiencies in subsidy-based initiatives and the burden that public sector has to bear to build and sustain the infrastructure apart from bearing the cost of never ending subsidies make the government-led initiatives less favourable to pursue an accelerated approach to providing energy services to the poor. It necessitates investments from other players, particularly the private sector and better management to bring in efficiencies in the delivery process.

8.2.5 Market-led paradigm

The intended benefits of bringing in efficiencies and promoting sustainability through private participation for energy access often gets defeated due to efforts to increase profit margins through tariff enhancement and focussing on areas that provide quick and high returns. Consequently, governments have had to suppress arbitrary increases by strict regulation to keep electricity affordable on the principle that supply of electricity is an essential social service (Haanyika, 2006), limiting further investments by private entities. As commercial or privatized utilities focus on profits, they tend to be less interested in supply of electricity to non-profitable rural areas (I. N. Kessides, 2004). Provision of electricity in rural areas would be most beneficial when there is adequate physical and social infrastructure to make best use of the available power (World Energy Council, 1999). However, in most cases, private players are compelled by governments to engage in rural electrification on political or equity considerations without focussing on basic infrastructure for power generation and distribution, rendering the projects unsustainable in the long run (Haanyika, 2006). Some of the other barriers to rural electrification in developing countries by private companies include limited financing, high cost of distribution, poor demand and over-dependence on public funds for meeting the cost of capital (Ranganathan, 1992). Decentralized and renewable energy projects have long gestation periods with low returns on investments, making investments in such technology viable only for large corporations (Bhattacharya and Kojima, 2012). Large initial investments in infrastructure, manpower, and technology limit the role of small and medium private enterprises, unless there is provision of low-risk finance or financial support.

Private entrepreneurship in rural areas has also emerged as a bottom-up approach to commercialization of energy service provisioning. However, the track record of such enterprises to manage business viably and provide efficient after-sales service has been dismal due to a variety of resource and capacity limitations. Examples of such enterprises from Zimbabwe (Mulugetta, Nhete and Jackson, 2000), South Africa (Karottki and Banks, 2000), Bangladesh (Barua, 2000), and Sri Lanka (Gunaratne, 1994) demonstrate how such enterprises collapse due to lack of external support, low profit margins, poor technical skills, lack of finance and poor infrastructure.

The problems related to the participation of private players in the clean cookstoves market are more complex and localized (Mobarak, et al., 2011). In India, where the cookstove market is still 'nascent' owing to insufficient demand for clean cooking technologies, entering the clean cookstoves market without any support from external agencies is a tall order. Unsure demand for improved biomass cooking technologies, lack of capital and disorganized market infrastructure have made small entrepreneurs wary of entering the ICS market (Gifford, 2010). Disorganized markets and significant information gap has also resulted in sub-standard stoves being disseminated to ill-informed end-users, which has further deteriorated the confidence of rural buyers in improved biomass cooking technology (Venkataraman, et al., 2010).

Hence, the private sector initiatives while overcoming investment and efficiency constraints of the public sector initiatives, lead to their own problems wherein the thrust on profits and returns on investments restrict expansion to communities that need low loads and have low paying capacities.

8.3 Transitioning to hybrid models

As seen from the discussion above, both subsidy-driven and commercial paradigms of improving rural energy access have systemic inefficiencies, capacity inadequacies and divergence in results from the overarching goals of facilitating energy access for the poor. At the same time, each paradigm has inherent benefits which may be lacking in the other. The inadequacy of either paradigm to address energy access challenges demands alternative strategies and approaches. Ideally, such strategies should capitalize on the benefits of both subsidy-driven and commercial approaches, through a provident mix of social welfare and commercial viability goals.

Recent literature has pointed to public–private partnerships for expanding energy access in developing nations (Sovacool, 2013) (Mukherjee, 2005) (Tumiwa and Rambitan, 2009). Loosely defined, public–private partnership (PPP) is a "cooperative institutional arrangement between public and private sector actors" to achieve a common goal, without compromising on personal goals (Hodge and Greve, 2007). In PPP related to infrastructure projects, the public role is generally limited to sponsorship of finance while the private sector is responsible for building and operating the infrastructure (Dewatripont and Legros, 2005). Examples of such partnerships are evidenced by 'build-operate-transfer' and 'build-own-operate-transfer' models of PPP commonly seen in energy and infrastructure projects (ADB, 2007). Hart (2003) states that inefficiencies in PPP projects get exacerbated by conflicts between "quality improvement" motives of the public sponsor and the "cost saving" motives of the private partner, leading to information asymmetry, adverse selection and moral hazards (Hart, 2003). The success of PPP projects largely depends on the private partner's capacity to internalize life-cycle costs and generate returns from investment (Bennett and Iossa, 2004). In classical agency theory, the risk-neutral public partner should ideally transfer minimum risks to the private entity, which is usually not the case (Flyvbjerg, Bruxelius and Rothengatter, 2003). This leads the private partners to adopt least-cost and least-risk pathways, sometimes at the cost of quality and intended positive externalities (Hodge and Greve, 2007). An appraisal of pro-poor public–private partnerships in public infrastructure (Estache, Foster and Wodon, 2002) (Evans and Brocklehurst, 2002) (Foster and Irusta, 2001) (Panggabean, 2006) reveals that such projects require rigorous external regulatory mechanisms to ensure that the private actors develop infrastructure that does not exclude the poor, and meets pre-determined quality benchmarks. Such regulatory mechanisms make the project deterministic due to specific guidelines enforced through contracts and periodic evaluations, which evade market competition and tend to reduce the private entities to "contract agents" (Awortwi, 2004) to get the work done, only to fulfil the essential project guidelines. Even while quality considerations are of paramount importance in delivery of energy services, public–private partnerships may constrain dynamism between social-welfare mandate of public partners and profitability considerations of private actors due to enforcement of strict contracts. Delivering quality energy services to the poor may require trade-offs between public and private actor goals, without distorting the relationship equilibrium.

This necessitates rethinking of the relationships between diverse public and private, and market and non-market actors in energy access programmes. Such relationships should try to synchronize and synergize performance-driven operations of private sector players with the funding support and social-welfare mandates of donor agencies and NGOs. The approaches for 'hybridizing' commercial and social objectives have service quality as its core strength, but with a fair amount of flexibility to innovate in terms of the product, service, or business relationships. Hybrid business models have to align themselves to the specific circumstances (social, economic, geographical, and cultural) of the markets in which they operate. Sánchez and Ricart point out that hybrid business models operating in low-income markets have the quality of flexibility, as the market needs and stakeholder priorities may change in course of the business (Sanchez and Ricart, 2010).

Multiple stakeholders in the rural energy value chain (market and non-market) have specific skills and capacities, the convergence of which can lead to the formation of stable and viable business models for dissemination of energy products and services (Ballesteros, et al., 2012). It is through such synergies that social and commercial goals are achieved simultaneously, with or without compromising either goal. The development of hybrid business models in any subsistence market domain can result in fruitful collaborations stimulating social capital transfer from informal to formal markets, and technology, expanded market access and quality assurance vice versa. Such linkages, from a dynamic perspective, can essentially be viewed as a system of interacting market and non-market agents which try to create and maximize value (Magretta, 2002). Mutual commitment and mutual dependence of stakeholders in the business model is essential for creation of value. Through the interaction of diverse stakeholders in market relationships, firms in business markets organize and share an unbounded structure of interdependent activities, enabling them to achieve greater value than would be the case, if they did not engage in relationship development (Blankenburg-Holm, Eriksson and Johanson, 1999). Hence, the need for dynamic synergies between various stakeholders to achieve the common goal of energy access will have to move beyond contractual arrangements to a 'hybridization' of goals, interests, resources, and capacities.

Private sector participation in hybrid models may be limited to activities that are economically profitable. The activities that are considered economically unviable (such as initial capital costs, cost of research, and cost of awareness generation) may be supported through subsidies from the government, corporate social responsibility funds, donor funding, and charities. The overarching goals of social welfare may be built in the hybrid models through the influence of public sector stakeholders and NGOs. Simultaneously, commercial stakeholders may help create sustainable value chains and work towards reducing system inefficiencies. The ratio of resource and responsibility sharing may vary according to the context, providing for customization of the model according to local needs. Such customized approaches may lead to a number of hybrids that collectively can contribute to scaling up the business.

An example of this approach is the National Improved Stoves Program (NISP) in China (Sinton, et al., 2004) (Smith, et al., 1993). Initially, the programme focussed on large-scale and rapid dissemination of improved biomass cookstoves through a coordinated effort by the ministries of health and rural energy, and the state development planning commission. This phase of the programme focussed on major subsidies to counties, households, and technical institutions. In the second phase (early 1990s), as a substantial number of households were covered by the programme, the entry of private players through targeted support for cookstoves manufacturing proceeded. In the third and final phase of the programme, the government withdrew from the actual dissemination process, leaving it entirely to private companies. In this phase, the government focussed on technology standardization and certification. In this way, the NISP has left a visible legacy of active private cookstove manufacturers, and a growing number of households willing to adopt clean cooking technology.

A lot of the current thinking on hybridization of commercial and socially-driven stakeholders is evidenced by the work of social entrepreneurs. This may be commonly seen through the formation of 'social enterprises', which amalgamate the profit-motive of business enterprises with social welfare goals (Chell, 2007). In practice, however, there may be irreconcilable conflicts between social and commercial goals in social enterprises. Hybrid models, however, can help solve this problem by allowing stakeholders to adhere to their core interests, merging individual interests of various stakeholders to result in a business model that triangulates the triple goals of commercial viability, serving the under-served poor households and meeting quality and performance standards. For example, 'energy enterprises' (EE) (see box) created by The Energy and Resources Institute (TERI) in partnership with the Department for International Development, UK (DfID) are essentially small business units engaged in sale and after-sales service of clean energy products in rural markets. The primary goal of energy entrepreneurs is to maximize revenue through sale of clean energy products. However, relationships with community-based organizations, non-governmental organizations, self-help groups, and micro-finance institutions ensure that poor households do not get excluded from the EE's market reach. Reaching out to rural households involves substantial costs of awareness generation, transaction, and logistics. Financial support from the TERI-DfID project and government subsidies ensures that these costs are covered, to maintain the viability of the EE's business operations. TERI also ensures that the products and services being disseminated through EEs meet quality standards determined on the basis of existing national performance benchmarks of the Bureau of Indian Standards and the Ministry of New and Renewable Energy, Government of India.

8.3.1 Designing pro-poor hybrid models

The hybrid business model essentially seeks to combine different aspects of the social and commercial approaches in order to maximise effectiveness and efficiency through the involvement of several entities owning and operating different parts of the system, while at the same time providing flexibility and manoeuvrability within structures, relationships, and entities.

8.3.2 Economic dynamism

By bringing together social and commercial players, aligning synergies and capitalizing on the benefits of both approaches, the model will enable an ecosystem that allows for overall economic dynamism within the created value chain or market. The model works well through clear role definitions and contextual customization in response to specific regional, cultural and behavioural characteristics of end users. Dynamism and flexibility in the model will be driven through the following three aspects:

Case 1: Energy Enterprises created under TERI-DfID collaboration in India

The Energy and Resources Institute (TERI), with support from the Department for International Development (Government of UK) created a network of 220 district-level entrepreneurs (Energy Enterprises) for sales and after-sales service of clean energy products. The Energy Enterprise is managed by a social entrepreneur with three objectives: (a) sale of clean energy technology, (b) rectification of technology disseminated by TERI, and (c) local business development by generating user demand and by initiating partnerships. TERI provided technical support and intensive trainings on business and technical skills to these entrepreneurs to help them set up a profitable clean energy business in their district. Assistance was also provided to help the entrepreneurs forge linkages with NGOs for information dissemination, banks for finance, and government institutions for funds. TERI also helped the enterprises to establish backward market linkages with product suppliers and forward market linkages with community-based organisations and consumer groups. In successful examples, the energy entrepreneurs have been able to create a stable business network of diverse organizations and stakeholders to reach out to poor rural households, making profits through clean energy business at the same time.

8.4 Flexible investment apportionment between social and commercial players

Commercial players and socially driven entities come together based on shared interests of social welfare and available financial resources for investing in energy access projects. As commercial players in the equation gravitate towards components that lend to higher economic viability and support the establishment of infrastructure and systems that deliver the actual solution, the socially-driven players contribute towards the creation of demand for the solution through support activities like awareness generation and information dissemination.

Even though the underlying objectives of both sets of players may remain constant, there is no barrier or restriction on the economic distribution between the two. What this translates to is, that based on the nature and size of players in the commercial-social mix, the investment contributions remain flexible and change in response to the dynamics of the market and value chain. For instance Lighting a Billion Lives (LaBL) programme of The Energy and Resources Institute that focusses on bringing solar photovoltaic based lighting solutions to energy deprived households was initiated mainly as a grant led initiative wherein 90% capital subsidy was provided to village entrepreneurs to provide fee for service-based lighting solutions. Over the years, the programme brought in multi-stakeholder participation for both the grants portion and the equity component. The programme leveraged government subsidy, corporate social responsibility, citizen contributions to mobilize financial resources in order to meet part of the capital cost that the entrepreneurs were not in a position to share. The participation of large scale manufacturers, local level entrepreneurs, and financial institutions ensured development of a market value chain to deliver technologies and services to the rural households. Over the years, the general trend in the programme shifted from 90:10 grant:equity model to a 60:30:10 grant:equity:debt model. However, the uniqueness of the model was that several grant:equity:debt ratios, depending upon the social economic and geographical context, co-exist with varying levels of participation of multiple stakeholders including government, corporations, civil society organizations on the social side and manufacturer, local entrepreneurs, financial institutions representing the commercial side (Chaurey and Kandpal, 2009) (Chaurey, Krithika, et al., 2012).

8.4.1 Price dynamism

By paying attention to the characteristics of households, their energy needs and applications, as well as the social processes within a community, the endeavour is to constantly bring down the level of inequities in the provision or availability of core service values, taking the focus away from a 'one size fits all' approach which usually pays attention to providing financial incentives to the commercial player, assuming that people are mostly economically motivated and equipped to participate (Breukers, 2013) For instance, in the LaBL programme in India, the initial focus on provision of solar lantern through private charging stations was expanded to promote a number of solar photovoltaic lighting options through an expanding network of technology providers. The initiative led to the availability of a large menu of SPV lighting options from USD 10 to USD 150 catering to varied economic and social needs of deprived communities (Chaurey, Krithika, et al., 2012). Similar effort was made in the TERI-DFID partnership on cookstoves to introduce variety of improved biomass cookstoves that were priced between USD 10 to USD 80.

Through price dynamism, it is possible to have different price points existing in a market for the same level of core value delivered by a technology or service, based on the customer's willingness/ability to pay—in turn making it possible for private players to recover costs that are offset across different end-user paying capacities and at the same time reaching a larger volume of users who were otherwise not a viable market.

In case of lighting and clean cookstoves, pricing needs to be based on specific product variations and customization to suit behavioural, cultural, and other typical usage patterns, while ensuring that the core value of the service delivered remains constant within the acceptable range. For example, a solar light costing USD 10 and another costing USD 15 could service two different market segments at two different price points. While the 'core value' in terms of lumens of light is the same for both products, different purchasing prices are due to lifespan of the battery and durability of the components used.

To support the concept of price dynamism, subsidies and grants can act as enablers. For example, one of the big hurdles in rural electrification is that supply to remote villages with low income may not be initially economically viable, making financial sustainability a very challenging aspect of rural electrification projects and programmes. Lack of organizational structures, high levels of initial capital investments, and lack of ability or willingness to pay by rural customers are some of the issues that make it challenging to develop a sustainable business model for rural electrification. Hence, while subsidies may help in reducing the cost of R&D and increasing the affordability of energy, they could support the market by enhancing the quantity of uptake and adoption (Menanteau, Finon and Lamy, 2003) If subsidies can be designed in such a way that it becomes economically viable to invest in the sector then a rural electrification programme will be able to attract private companies (The ACP-EU Energy Facility, 2012).

8.4.2 Innovation

Mere juxtaposition of social and commercial values may not be enough to cater to complexities that arise out of diversity of social, cultural, and economic factors. Innovation in the hybrid model and technology provision is essential for customization and catering to specific local needs.

Innovation can be a driver to help overcome a number of the barriers and challenges in providing affordable energy services to poor consumers profitably and at scale. The variety of innovations for energy access may rely on a range of collaborations and partnerships to develop, produce, distribute, and maintain products and services (WBCSD, 2012). Delivery of technology to the 'bottom of the pyramid' population requires imagination in designing institutional models that ensure inclusion of even the socially and economically marginalized sections of the society. Similarly, energy access programmes can be strategized in a manner that facilitates business development and social inclusion simultaneously.

8.4.3 Facilitating unique partnerships

Cross-sector partnerships address several market barriers by aligning the interests and competencies of global and local actors along a cross-sector value chain. Such partnerships bring together government agencies including utilities, technology, and energy service providers, local enterprises, financial institutions on a common platform to service end-users that need reliable and cost-efficient energy services (WEF-PWC 2013). Participation of local (village-level) actors in the rural energy supply chain helps in efficient delivery of energy to end-users, making the business model more inclusive. The level of engagement of local/village-level actors with rural households in their vicinity is generally observed to be high which helps in forging stronger relationships between the buyers and sellers, and minimizing conflicts in the business model due to divergent interests of various actors.

Convergence with government development and other energy access programmes—Rural energy programmes converging with other government schemes (e.g., related to health, livelihood, gender, forestry) draw the benefit of better physical and financial resources that government programmes can offer. Some government programmes also have the mandate and institutional set-up to reach out to poor households in rural areas, which local businesses can greatly benefit from. Strong alignment across policy domains is important to accelerate the adoption of cleaner fuels and technologies at scale. This involves ministries dealing with traditionally separate portfolios such as energy, environment, rural development, agriculture, education and health, working in tandem. Such inter-agency coordination would ensure a proper allocation of common costs across different types of services and reduce the extent of subsidies justified to ensure access. In India, such a coordinated approach is being adopted to address climate change concerns, of which renewable energy development is an integral part (Ghosh, 2009). Also inter-agency coordination mechanisms that would mandate inclusion of energy considerations in programme design—which could be institutionalized at the level of international bodies such as UNDP, UNICEF, WHO, UN-Energy, World Bank, etc.

8.4.4 Information Dissemination

Lack of information is a significant non-financial barrier for acceptance of rural energy technologies. For instance, many rural households using traditional stoves may not be aware of the benefits of adopting an improved cookstove. Consequently, this limits their interest in purchasing an improved cookstove (Lewis and Pattanayak, 2012). Access to information and to training is therefore fundamental to ensure long-term programme success. Many stakeholders involved in the off-grid rural electrification project chains do not know how to deal with renewable energies, or may not be used to obtaining and paying for electricity. Hence, education, trainings and information about the benefits of access to energy and of renewables are necessary, prior to any project. Civil society organizations have a critical role to play in generating awareness

Case: Project Surya

The core objective of Project Surya is to mitigate the regional impacts of global warming by immediately and perceptibly reducing atmospheric concentrations of black carbon, methane, and ozone. The Project aims to achieve this by replacing highly polluting cookstoves traditionally employed in rural areas with clean-cooking technologies. To achieve its core objective, the Project has developed an interface between three areas of focus—health, through the mitigation of indoor air pollution; climate, through the reduction of emissions from traditional and inefficient cookstoves; and development, by recognizing women as the directly affected section of the target population.

To address all three aspects, Project Surya worked with multiple stakeholders including technology developers, suppliers, NGO partners and local enterprises to provide sustainable, effective and incentive-based plans to enable households region to switch to cleaner-burning technologies such as solar cookers and other efficient stove technologies. The Project operates by incentivizing rural women directly with micro-funds generated from the carbon market through the continued use of improved stoves and solar lighting, in such a way that the micro-payment model is scalable and sustainable. Project Surya employs innovative sensing technologies to measure the positive climate and health impacts that result from this dramatic reduction in black carbon in unprecedented scale and resolution.

'Integrated Domestic Energy Systems' (IDES) are provided to rural households, which include a forced draft stove and a solar light in a single integrated unit. A combination of heat sensors and cell phone technology is used to monitor the duration of use of the stoves and lights. Cook stove/light users are organized into self-help groups of 5–20 households to obtain loans from a bank for purchase of IDES by its members. Part of the loan is repaid from a common fund created through donations from philanthropic organizations. The project is being implemented in Uttar Pradesh and Odisha by TERI, in association with the University of California at San Diego and Nexleaf Analytics and has 1,600 registered IDES users so far.

Case: Lighting a Billion Lives (LaBL)

The LaBL initiative is a live example of a body that mobilises government, NGO and private sector players to disseminate clean lighting solutions to energy poor communities. The initiative employs a unique financing model to help make access to lighting affordable – mobilizing funds from corporate organisations, funding agencies and the community itself to meet hardware and installation costs. Local planning, awareness generation and training are carried out in coordination with partner NGOs. While TERI does not manufacture lighting systems itself, it provides research support to private technology developers who become part of the program. Community based institutions and local entrepreneurs are created to operate and manage the lighting systems on a daily or monthly fee-for-service model. Through this model, the program has reached out to more than 2,500 villages in India with community lighting solutions like solar charging stations and solar micro-grids. (Palit and Singh 2011) (Chaurey and & Kandpal 2009) among members of the community which are normally marginalized or ignored by conventional communication channels. In the case of pure market actors, the costs of effectively communicating a message about the benefits can be a difficult barrier to overcome.

8.5 Supporting Research & Development (R&D)

Research and development is the driving force behind innovation and monitoring research & development of new technological and commercial solutions to energy challenges are a crucial and inherent part of a hybrid model. This includes specific programmes focussing on developing and tailoring products and services for low-income markets, reassessing priorities enabling rapid dissemination of research outcomes, as well as development of new technologies that have applicability in energy access (WBCSD, 2012). This may also include the development of a mechanism for linking and financing basic R&D to applied R&D, both public and private (UNIDO, 2009). This will not only juxtapose social and commercial objectives, but will also keep a steady view on the scientific side of solution and technology developments. Further, it will enable interventions to widen their impact by considering environmental, social, and development objectives as well. The Project Surya case demonstrates this effort to put together various objectives that could be achieved through the provision of energy services—beyond the social and commercial aspects (Ramanathan, et al., 2012).

8.6 Conclusions and policy recommendations

Well-designed and stable policies are critical to facilitate multi-stakeholder participation in the energy sector and the expansion of access to energy. Policy-makers need to focus on prioritizing energy access in national development planning, improving the investment climate and implementing enabling measures to promote the primary energy access solutions (Brew-Hammond, 2010) (Pachauri, et al., 2011).

Governments need to formulate clear and stable policy and regulatory frameworks that elucidate their political priorities in relation to main grid extension vs. mini-grid electrification (Jamasb, 2002). Given the long term investment perspective needed to develop mini-grid projects, private investors' involvement may be deterred if they are not assured that schemes will not be superseded by connection to the national grid—therefore, policy-makers need to focus on improving the investment climate and implementing enabling measures to promote primary energy access solutions. They also must define tariff structures that balance the financial sustainability of the sector on the one hand and the consumers' well-being and willingness to pay on the other hand. Tariffs should cover the entire running costs and generate revenues to ensure the operation of the system through its lifetime (SE4All Energy Access Committee, 2014).

When policy frameworks are developed, the following key aspects should ideally be covered in order to create a supportive envelop around collaborative social and commercial activities in the energy access sector:

8.6.1 Facilitating demand creation through Viability Gap funding/ subsidies /loans

Energy enterprises will sustain in a market that not only has demand but also the capacity to pay. While the target population may have a need and therefore, an associated demand for clean lighting and cooking solutions, there is an affordability gap that inhibits the market to fully develop and operate in a continued manner (Riley, 2014) (Fankhauser and Tepic, 2005). Bringing in financial support in the form of viability gap funding, subsidies, and loans by tapping into socially-driven government programmes and CSR initiatives, it is possible to reach out to the poor consumer and shift the cost burden to a third party. This will support the overall existence of a market by making the solution affordable to the end-user and creating opportunities for profit making (Sovacool and Saunders, 2014) (Ailawadi and Bhattacharyya, 2006).

8.6.2 Facilitating the development of cross-sectoral synergies to promote clean energy solutions

Energy is a pivotal input for overall social and economic development, having observed linkages with sectors of human development such as health, livelihood, education, and gender. Emphasizing the role of energy in each of these sectors will help in bringing together a multitude of institutions and agencies working on different sectors of human development together. While multiple institutions and agencies can draw benefits from energy access initiatives, their individual mandates may also be met at the same time. An example of such a cross-sectoral synergy is linking clean energy interventions with the Clean Development Mechanism. Decentralized renewable energy solutions have shown the potential of benefitting NGOs and community groups through climate finance (Gitonga, 2003) (Schroeder, 2009) (IPCC, 2011). Domestic solar lighting technology may offer opportunities for voluntary emissions reductions through replacement of kerosene as the primary lighting source in rural households (Chaurey and Kandpal, 2009) (Purohit, 2009). Similarly, carbon savings from improved biomass cookstoves due to reduction in greenhouse gas emissions, black carbon emissions, and fuel wood consumption make household-level clean cooking technology eligible for carbon credits (Johnson, et al., 2009) (Zhang, et al., 2000). Examples of such synergies have provided direct benefits to households for adoption of clean energy technologies (Simon, Bumpus and Mann, 2012) (GACC, 2013) (Asplund, 2008).

8.6.3 Creating market value chains involving local enterprise

Involving enterprise at the village and local level will support the development of a robust energy access value chain by strengthening business relationships, improving market structures. A local enterprise is the best positioned entity to understand the exact nature of end-user demand that is crucial for the development and adaptation of the other elements contributing to the value chain (Porter and Kramer, 2011). Assisting the development of local micro- and small-enterprises also helps overcome constraints of poor market access and low bargaining power. Hence, privatization of the energy value chain should not disregard local micro-enterprises, who are critical for long-term stability of the market ecosystem (Jolly, Raven and Romijn 2012). The principle of 'shared value', which involves creating economic value in a way that also creates value for society by addressing its needs and challenges is one of the most important considerations that need to be taken into account in the entrepreneurial energy delivery model.

8.6.4 Building linkages to develop financial capacities of local enterprises

The energy enterprise and the rural end-user may be considered as the two most important stakeholders in the energy access value chain—such that, their sustained participation within the established ecosystem is imperative for the market to become viable and sustainable (Van Leeuwen and Ruff 2014). To keep both stakeholders in the value chain, it becomes extremely important to facilitate the creation of financial capacities in order to maintain a stable rate of demand and supply. Energy enterprises need different types of finance depending on their stage of development such as start-up capital and supplier credit to purchase energy products, whereas, end-users need finance primarily to purchase energy services to meet their business and household energy needs (Zerriffi, 2011).

8.6.5 Focussing on technology development and customization

Technology customization to suit market needs is essential for developing viable business models. For example, in the area of clean cooking, due to geographic and cultural disparities, it is not possible to have a universal improved cookstove solution that equally addresses and satisfies the need of all end-user categories (Lewis and Pattanayak, 2012). Hence, customization of technology that takes into consideration local user behaviour, affordability, and user preferences is important for designing successful programmes for dissemination of energy products.

8.6.6 Focussing on innovation in dissemination models and technology options

The energy access market is considerably under-developed and therefore, a place with abundant opportunities for innovation in business model design and technology development. The development and introduction of the IDES (Integrated Domestic Energy System) by TERI, which integrates solar lighting and improved cooking technology in a single product, is an example of a successful technology-based innovation that addresses both clean lighting and cooking requirements through one system. Energy technology research, development and transfer do not respond to the energy needs and capacities of the poor (Practical Action, 2009). In such a situation, encouraging innovation in technology and dissemination models with focus on users' needs can contribute to better delivery of energy services to the poor.

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Summary

The studies (Chapter 1–6 based on already published work in reputed international journals such as *Atmospheric Chemistry and Physics; Energy Policy; Sustainability Science*, etc.) that are discussed here recognize and highlight that besides technical and social concerns, political economy and cross sectoral linkages of energy are key determinants for effective energy transitions. Additionally, the environmental concerns also need to go beyond to encompass new knowledge, particularly on the linkages of energy access with health and climate pollutants such as Black Carbon. Therefore, the compilation provides a comprehensive and cross cutting view of political economy of energy access, linkages of energy to sustainable development, linkages of Short-lived Climate Pollutants (SLCPs) with energy use, and new perspective on energy transitions when viewed through the lens of strategic niche management. Based on the compilation of the published work, the dissertation also provides a pathway for accelerating and up-scaling access to energy.

Recognizing the governance and political context of energy provisioning, the dissertation brings forth and analyzes key political and related economic drivers represented by target oriented subsidy driven public sector programmes. It dwells on vested power dynamics favouring supply driven centralized grid electricity and fossil fuel provisioning benefiting largely the urban and the affluent.

A desirable energy programme needs to focus on a service centred rather than product or technology centred approach wherein the costing is done on a life cycle basis instead of capital investment. The work here brings forth the need for energy service provisioning, as opposed to mere access, through a broad-based framework of bench-marked, technology-neutral access to modern energy. It emphasizes the

need for reliability and equity as well as linkages of energy to broader sustainable development goals such as livelihood enhancement, education for all, and quality health services.

The use of kerosene for lighting which epitomizes the inadequacies and inefficiencies of current approach to energy access has been discussed to bringing into focus concerns related to indoor air pollution arising out of use of kerosene in inefficient and archaic lighting devices. The need for addressing health and environmental concerns has also been assessed by focusing on the now recognized role of SLCPs such as Black Carbon. The results have significant implications to health impact studies as well as climate impact studies. On the epidemiological side, studies that rely on mean day time values will underestimate the cooking-hour exposure by factors ranging from 5 to 20.

The work here also brings forth new perspectives that treat transitions in a broader framework of regime change involving different stakeholders. The new perspectives highlight that transitions need to be studied comprehensively using new frameworks such as strategic niche management (SNM). This dissertation brings into focus new elements such as role of branding and marketing in energy service delivery. While many SNM studies (implicitly) have focused on public funding as the main protective measure, the work here shows how an experiment survives in a market where public funding has been consciously avoided. Rather, protection is sought through innovative funding schemes from banks, and other financial institutions.

Well-designed and stable policies are critical to facilitate multi stakeholder participation in the energy sector and the expansion of access to energy. Policy-makers need to focus on prioritizing energy access in national development planning, improving the investment climate, and implementing enabling measures to promote the primary energy access solutions. Governments need to formulate clear and stable policy and regulatory frameworks that elucidate their political priorities in relation to main grid extension vs. mini-grid electrification (Jamasb, 2002). Given the long term investment perspective needed to develop mini grid projects, private investors involvement may be deterred if they are not assured that schemes will not be superseded by connection to the national grid—therefore, policy makers need to focus on improving the investment climate and implementing enabling measures to promote primary energy access solutions. They also must define tariff structures that balance the financial sustainability of the sector on the one hand and the consumers' well-being and willingness to pay, on the other hand. Tariffs should cover the entire running costs and generate revenues to ensure the operation of the system through its lifetime.

Both subsidy driven and commercial paradigms of improving rural energy access have systemic inefficiencies, capacity inadequacies, and divergence in results from the overarching goals of facilitating energy access for the poor. This necessitates rethinking of the relationships between diverse public and private, and market and non-market actors in energy access programmes. The dissertation emphasizes that such relationships should try to synergize performance-driven operations of private sector players with the funding support and social-welfare mandates of donor agencies and NGOs. The approaches for 'hybridizing' commercial and social objectives have service quality as its core strength, but with a fair amount of flexibility to innovate in terms of the product, service or business relationships. In conclusion, the following key elements are essential for accelerating energy access:

- Facilitate demand creation through Viability Gap Funding / subsidies / loans
- Facilitate the development of cross sectoral synergies to promote clean energy solutions
- Create market value chains involving the private sector including local enterprise
- Build linkages to develop financial capacities of local enterprises
- Focus on technology development and customization
- Focus on innovation in dissemination models through hybridized public-private partnerships

Samenvatting

De studies (hoofdstuk 1-6 zijn gebaseerd op reeds gepubliceerd werk in internationale tijdschriften zoals *Atmospheric Chemistry and Physics; Energy Policy; Sustainability Science*) die hier worden besproken erkennen dat naast technische en sociale overwegingen de politieke economie en sectoroverschrijdende verbanden binnen de energiesector de belangrijkste determinanten zijn voor een effectieve energietransitie. Daarnaast moeten binnen milieuoverwegingen ook nieuwe kennis worden mee genomen, zoals met name de verbanden met de toegang tot energiediensten, gezondheid, en klimaatverontreinigende stoffen zoals Black Carbon. Daarom biedt dit proefschrift een uitgebreide en sectoroverschrijdende weergave van de politieke economie van de toegang tot energie, inclusief energie en duurzame ontwikkeling, Short-lived Climate Pollutants (SLCPs) en energieverbruik, een nieuw perspectief op energietransities bekeken door de lens van strategisch niche management. Het proefschrift geeft aanbevelingen voor een traject voor het versnellen en opschaling van toegang tot energiediensten.

Met het erkennen van de bestuurs- en politieke context van energievoorziening analyseert dit proefschrift de belangrijkste politieke en daarmee samenhangende economische drivers (o.a. doelgerichte subsidies binnen publieke programma's. Door dat deze bouwen op een gevestigde machtsdynamiek resulteert dit vaak in een aanbodgestuurd gecentraliseerde electriciteitsnet en fossiele brandstofvoorziening die met name de stedelijke en welvarende bevolking begunstigt.

Een wenselijk energieprogramma moet zich richten op een dienst-gecentreerde benadering, in plaats van product- of technologie-gecentreerde aanpak. Hierbij dient de economische berekening gedaan te worden op basis van de levenscyclus basis in plaats van kapitaalinvesteringen. Het proefschrift onderzoekt de behoefte aan energiedienstverlening, in tegenstelling tot louter de toegang, via een breed kader van gebenchmarkte en technologie-neutrale toegang tot moderne energiediensten. Het benadrukt de noodzaak van betrouwbaarheid en billijkheid, alsmede de verbindingen tussen energie en bredere duurzaamheidsdoelstellingen, zoals verbetering in levensonderhoud, onderwijs voor iedereen, en kwaliteitsgezondheidszorg.

Het gebruik van kerosine voor verlichting, die de tekortkomingen en inefficiënties van de huidige aanpak van de toegang tot energie vertegenwoordigd, is besproken om overwegingen gerelateerd aan binnenluchtverontreiniging in beeld te brengen. De luchtverontreiniging komt voort uit het gebruik van kerosine in inefficiënte en verouderde verlichtingsapparatuur. De noodzaak om gezondheids- en milieuoverwegingenwordt verder onderschreven door de nu erkende rol van SLCPs zoals Black Carbon op klimaat en gezondheid. De resultaten hebben belangrijke implicaties voor de gezondheidsimpactstudies evenals klimaatimpactstudies. Aan de epidemiologische kant onderschatten studies die rekenen met gemiddelde dagwaarden voor de kook-uren, de blootstelling met een factor die varieert van 5 tot 20.

Het proefschrift beschrijft eveneens nieuwe perspectieven voort, die transities in een breder kader van regimeverandering plaatsen met betrekking tot verschillende belanghebbenden. De nieuwe perspectieven benadrukken dat transities uitgebreid moeten worden bestudeerd met behulp van nieuwe raamwerken zoals strategisch niche management (SNM). Dit proefschrift brengt nieuwe elementen in beeld, zoals de rol van de branding en marketing in energie-dienstverlening. Terwijl veel SNM studies (impliciet) hebben geconcentreerd op overheidsfinanciering als de belangrijkste maatregel, laat de huidige studie zien hoe een experiment ontwikkelt in een markt waar overheidsfinanciering bewust is vermeden. In plaats daarvan is bescherming gezocht door innovatieve financieringsregelingen van banken en andere financiële instituten.

Goed ontworpen en stabiel beleid zijn cruciaal om participatie van meerdere belanghebbenden in de energiesector, en de uitbreiding van de toegang tot energie te faciliteren. Beleidsmakers moeten zich richten op prioritering voor toegang tot energiediensten in nationale ontwikkelingsplannen, verbetering van het investeringsklimaat, en het implementeren van ondersteunende maatregelen om primaire energie-toegangsoplossingen te bevorderen. Overheden moeten duidelijk en stabiel beleid en regelgevingskaders formuleren die hun politieke prioriteiten verhelderen met betrekking tot uitbreiding van het hoofdelektriciteitsnet versus mini-grid electriciteitsvoorziening. Gezien het lange termijn investeringsperspectief die nodig is om mini-grid projecten te ontwikkelen, kunnen particuliere investeerders worden afgeschrikt als ze niet er niet van verzekerd zijn dat regelingen niet zullen worden vervangen door regelgeving die juist streeft naar aansluiting op het nationale elektriciteitsnet. Daarom moeten beleidsmakers zich richten op het verbeteren van het investeringsklimaat en het implementeren van ondersteunende maatregelen om energie toegangsoplossingen te bevorderen. Ze moeten ook tariefstructuren definiëren die de financiële duurzaamheid van de sector in evenwicht brengen met het welzijn van consumenten en de bereidheid om te betalen. Tarieven moeten de gehele bedrijfskosten omvatten en inkomsten genereren om de exploitatie van het systeem te waarborgen gedurende de levensduur.

Zowel de subsidie gedreven als commerciële paradigma's voor verbetering van toegang tot energiediensten op het platteland hebben systemische inefficiënties, capaciteits-tekortkomingen, en lijden tot afwijkende resultaten ten opzichte van de overkoepelende doelstellingen voor het faciliteren van toegang tot energiediensten voor de armen. Dit vereist heroverweging van de relaties tussen de diverse publieke en private, en markt- en niet-marktpartijen in energie-toegangs-programma's. Het proefschrift benadrukt dat zulke relaties zouden moeten pogen gebruik te maken van synergie bij prestatiegerichte activiteiten van private actoren met financiële ondersteuning en het sociale welzijnsmandaat van donororganisaties en NGO's. De aanpak voor het 'hybridiseren' van commerciële en sociale doelstellingen streeft naar een hoge kwaliteit van dienstverlening, maar met een behoorlijke mate van flexibiliteit om te innoveren op het gebied van product, dienst of zakelijke relaties. Concluderend zijn de volgende sleutel elementen essentieel voor het versnellen van de toegang tot energiediensten:

- Het faciliteren van het creëren van vraag door middel van subsidies en/of leningen, of financiering van de "onrendabele top";
- Het faciliteren van de ontwikkeling van sector-overschrijdende synergiën om duurzame energie oplossingen te bevorderen;
- Het creëren van marktwaarde binnen de ketens voor de particuliere sector, waaronder lokale ondernemingen;
- Het bouwen van verbindingen om financiële capaciteiten van lokale bedrijven te ontwikkelen
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- Richten op innovatie in de verspreidings-modellen door middel van gehybridiseerde publiek-private partnerschappen.

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