Energy and Economic Growth
Applied Research Programme

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Thematic Note: Energy Supply and Efficiency in Urban Areas

Shobhakar Dhakal and Rachita Daga

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EEG will commission rigorous research exploring the links between energy, economic growth and poverty reduction in low-income countries. This evidence will be specifically geared to meet the needs of decision makers and enable the development of large-scale energy systems that support sustainable, inclusive growth in low income countries in South Asia and Sub-Saharan Africa.

This Thematic Note was authored by Shobhakar Dhakal (Asian Institute of Technology) and Rachita Daga (Oxford Policy Management).

Email: eeg@opml.co.uk

Website: www.opml.co.uk/projects/energy-economic-growth

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DELP	Domestic Efficient Lighting Program
EEG	Applied Research Programme on Energy and Economic Growth
ESCO	Energy Service Company
IPCC	Intergovernmental Panel on Climate Change
LED	Light-Emitting Diode
LIC	Low Income Country
MIC	Middle Income Country
PV	Photovoltaic

1 Introduction

This Thematic Note is one of six produced in the first year of the Applied Research Programme on Energy and Economic Growth (EEG). Each summarises a set of EEG State-of-Knowledge Papers that explore current understanding around one aspect of a theme related to large-scale energy infrastructure and economic development. This Thematic Note summarises the State of Knowledge Papers produced under EEG's Theme 3 – Energy Supply and Efficiency in Urban Areas. It highlights the key findings and research gaps that were identified by State of Knowledge Paper authors through their literature review and their engagement with policymakers and industry practitioners at the EEG Policy Workshops and Research & Matchmaking Conference.

Energy plays a vital role in stimulating and sustaining economic growth. It also plays a pivotal role in the daily functioning of urban systems such as in transportation, households, businesses and industries. 54% of global population already live in urban areas and with rising income and economic growth and rural-urban migration, the urban population is projected to increase to 70% by 2050. A majority of future global population is expected to be added in urban areas in developing countries where per capita energy demand is generally higher than the national average (UN, 2014). Global assessments such as IPCC, Global Energy Assessments and others have already identified the importance of urban areas for sustainable energy solutions, on both the supply and demand sides, and highlighted that these will lead to additional opportunities for addressing economic growth, and mitigating pollution and climate change (Grubler et al., 2011; Seto et al., 2014; Rosenzweiz et al., 2015). This implies that the next two decades is a crucial time when energy efficiency can be built into the new wave of urbanization and smart cities. This is also indicative of the large opportunities for improving energy supply and enhancing efficiencies in existing urbanized areas through better spatial planning.

In LICs, the level of energy consumption is still relatively low but this is expected to increase as LICs further urbanize and modernize. The relatively high price of energy and the cost of power outages and irregular energy supply are especially high in urban areas currently. This lowers the economic competitiveness of the industries in the region, hampers overall growth potential and leads to the loss of businesses. Additionally, high energy prices and irregular supply also impairs the basic functioning of socio-economic systems in the cities. A clear understanding of electricity and other energy carriers and how they are constrain economic growth will provide clues for unlocking growth barriers in urban areas for decision makers.

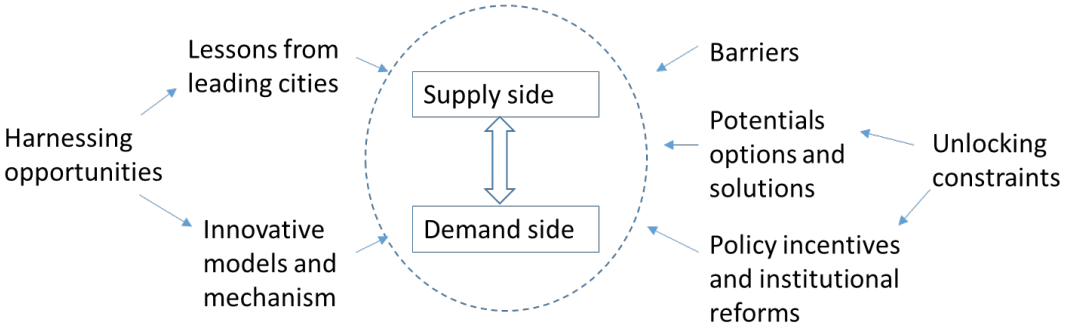
Many cities in LICs, especially in South Asia, are experiencing serious electricity shortages resulting in scheduled and unscheduled power interruptions. In addition to the issues of inadequate and unreliable power supply, these cities are also grappling with the issue of affordability of alternative energy sources to cope with the power outages (e.g.: diesel generators, etc.)(Timilsina et al., 2015). Informal settlements, where energy service provision is either poor or absent often pay a higher price per unit of electricity consumed which has implications for their overall livelihoods and purchasing power (Grubler et al., 2011).

The energy technology and consumption patterns in cities in LICs are not efficient and the scale of energy efficiency-gaps are largely unquantified (Allcott and Greenstone, 2012; Gillingham and Palmer 2014; Gerarden et al. 2015). However, end use technologies are improving and costs of more efficient technologies such as LEDs, building insulation materials, and clean transportation, amongst others, are declining. In recent years, new business models (such as ESCOs) are coming up, and government stakeholders are becoming more aware of the different financial modalities for improving energy efficiency. Additionally, there is greater recognition of the fact that enhanced energy efficiency could not only reduce pressure on constrained energy supply in cities, but also lead to cost savings for the end-user.

The main drivers for renewable energy sources such as Solar Thermal, Solar PV and others come largely from alleviating the supply and reliability constraints rather than desire for provisioning sustainable energy. Tradition alternate energy provisions, such as diesel or other fossil-based supplementary electricity, on the other hand, also affect energy independency, air pollution and climate change. The provision of clean, reliable and affordable energy, is of great interest to policymakers.

One of the key questions which will assist in understanding why sustainability of energy provision is why are electricity supply challenges and energy efficiency gaps still persistent, even though there are options to resolve these issues. Most of the research on this question has focused on high or middle income countries. This research indicates barriers such as lack of sufficient technical knowledge, capacity and awareness, economic barriers, institutional barriers, socio-cultural barriers and misallocation of incentives, amongst others. However, further research focusing on LICs is essential to understand the constraints and barriers specific to these countries. Unlocking these constraints requires tapping new opportunities in rapidly changing scenario in cities in LICs. As the solutions should be specific to the place and the context, lessons could be drawn from other sectors that have successfully implemented reforms in the last few years. In addition to the lessons learnt, resolution of supply side issues could also build on innovative market mechanisms, proven social and financial models, awareness building, and the right set of incentives, policies and institutional reforms to better assist the transition to a sustainable urban energy system. These proposed solutions are described in the figure given below.

Figure 1 : Key Solution Space for Urban Energy Needs



Therefore, to summarise, our research seeks to understand (a) the specific ways in which energy infrastructure can promote or constrain productivity in urban areas (b) the sustainable electricity supply provisions and the extent of energy efficiency gaps and options (c) the economic justification for policy intervention, and the risks of failure, and (d) opportunities for developing solutions and unlocking barriers for leap-frogging to clean and energy efficient settlements with high economic productivity. It is crucial that we understand and evaluate the opportunity for creating enabling environment. We will examine the regulatory, institutional, governance, incentives and co-ordination arrangements and bring lessons from good cases to provide better insights.

This Thematic Note is based on the following papers:

1. Fowlie, M., & Phadke, A. (2016). Energy Efficiency in the Developing World. Energy and Economic Growth Applied Research Programme.

2. Gertler, P.J., Kenneth, L., & Mobarak, M. (2016). Electricity Reliability and Economic Development in Cities: A Microeconomic Perspective. Energy and Economic Growth Applied Research Programme.

3. Smith, H. (2016). Urban Governance, Urban Development, Land Use and Energy Access. Energy and Economic Growth Applied Research Programme.

The papers in this theme focus on the following questions:

- Are electricity supply problems a major constraint to the productivity and growth of cities? Are there special nth –best market and governance solutions which can work (like separate mini-municipal power authorities or companies)? Are there barriers to supply to specific groups, if so what mechanisms are best utilised to overcome these?

- What have been the historical experiences in successful cities/ in LIC-MIC transition counties? Is there a menu or mix of options for cities with constrained supplies? How can this energy provision be delivered to the poorest and disadvantaged?

- What method is best used to ensure energy efficiency in an urban context, both point of generation, distribution and end use? Which sectors are best targeted for efficiency gains (excluding transport) building stock, end user etc.? Where are the trade-offs? Which sector is best for delivering benefits to the urban poor and disadvantaged?

- What are the main barriers to achieve access and efficiency in urban areas, pricing regulation, consumer behaviour, access to goods etc.? Subsidies generally act as a significant disincentive for energy efficiency investments and limit the scope and profitability of energy services companies.

- What effective measure/successful examples have there been to address these issues which can be replicated in the developing world.

- Is there an Energy Efficiency Gap in developing countries? Some research suggests that the size of the gap is overestimated for failing to account for all costs and neglecting particular types of economic behaviour. Is this the same for the urban context and in developing countries?

- Does a rebound affect happen in the context of the urban poor, and does it contribute to economic growth?

- What are the legal, institutional and co-ordination arrangements needed to scale up Energy Efficiency in developing countries, and ensure Energy access in urban context, and at what level (national regional, municipalities)? What are the barriers including from a political economy perspective?

2 Key insights from the State of Knowledge Papers

2.1 Paper 1: Energy Efficiency in the Developing World

Given the projected two-fold increase in the energy requirements in developing countries by 2050, investments in demand side energy efficient technologies can help in mitigating many of the energy related challenges including the social and economic impacts of high energy costs. This paper focuses on the demand side, energy efficient investments in developing countries, providing a framework to assess the costs and benefits of investing in energy efficiency improvements, the market failures and barriers to such investments, the externalities that influence the level of these investments and the factors that should influence the design and implementation of relevant policies in low income settings. The paper also provides a case study of the adoption of LED bulbs in India as an example of government programmes increasing the adoption of energy efficient technologies.

The paper uses social welfare maximization as an organising principle to analyse investments in energy efficient technologies. There are three related concepts of efficiency there are included in this framework: energy efficiency (level of energy services provided per energy input), private economic efficiency (maximising net private benefits given income, costs and preferences), and social economic efficiency (overall social welfare). Given this framework, investments in energy efficient appliances would result in lower energy costs for the household for a given level of consumption, increasing the income available to the household to spend on other consumption. Second, improvements in the energy efficiency of appliances would result in an induced increase in the level of lighting services consumed. From the private perspective, the decision to invest in such technologies would be determined the investments costs, and whether these costs were lesser than the improvement in the consumer's welfare, which in turn is directly related to their willingness to pay. The willingness of the consumer to pay for such technologies is directly proportional to the price of energy, overall household income, and the 'efficiency' gap between the different choices.

However, in spite of the benefits highlighted in the model, there are market failures and barriers that restrict investments in energy efficient technologies. These include information asymmetries between consumers and manufacturers (as the consumers cannot test the manufacturers' claims about energy efficiency till they have purchased the products, they will tend to discount these claims), capital market failures (consumers might be discouraged to invest in energy efficient technologies due to high upfront costs), imperfect competition (imperfectly competitive markets for energy efficient technologies may limit the efficiency of the technologies), myopic purchasing behaviour of the consumers, and additional transaction costs such as time taken to choose the appliance/technology that increases the overall costs of the technology adoption for the consumer. In addition to this, externalities like environmental externalities and inefficient energy prices due to subsidies given by the government, amongst others, also constrain private investment in energy efficient technologies.

Given this broad framework, policies should be designed to target the specific market failure and/or externalities that are restricting the investments in producing and adopting energy efficient technologies. The policy choice should also consider the equity, i.e., the distribution aspects of designing and implementing these policies, as well as the institutional capacity and constraints that may affect the implementation of these policies.

The case study of India's DELP provides an example of using government policy and networks to provide accessible energy efficient appliances to consumers. Under this programme, the large scale procurement of energy efficient LED bulbs by the government helped to reduce prices of LED

bulbs by over 80%, and these cost savings were passed on to the consumers through lower prices. In addition to this, consumers who were unable to afford the upfront costs of LED bulbs were given the option of on-bill financing. Finally, by leveraging the distribution networks of the government, the programme also reduced transaction costs on both the demand as well as the supply side.

2.2 Paper 2: Electricity Reliability and Economic Development in Cities

Recent studies on electrification in developing countries focus on increasing access to electricity. However, in addition to access, reliability of electricity supply is also a major issue in developing countries, indicating that even after the access gap has been bridged, potential gains from electrification maybe limited due to power outages. This paper reviews the evidence on the causes of electricity outages in urban areas, focusing on the supply, demand and political economy factors, and the impact of electricity outages on the economy, households and firms. Given this framework of causes and consequences, the paper provides a case study of power outages in Dhaka, and finally proposes future areas for research.

The paper highlights that reliability of electricity supply is a key concern in both rural as well as urban areas. However, it may be relatively more important in urban areas because of two key reasons. Firstly, access to electricity supply is much higher in urban areas as the marginal costs of connecting additional users to grid is lower, and there are more possibilities for illegal connections and theft. Economic activity in urban areas is concentrated in the manufacturing and services vis-à-vis agriculture, and hence the economic cost of outages will be higher in urban areas. Thus, the paper focuses on the causes and consequences of electricity outages in urban areas.

The paper finds that the causes of electricity outages may either be because of supply side factors, demand side factors or the political economy. The supply side factors that can lead to electricity outages are insufficient electricity generation, network fragility and scheduled maintenance. Insufficient electricity generation is a persistent issue, and even if the installed capacity base is large, utilization rates maybe low due to poor utility performance. Insufficient generation and network fragility can be addressed through greater investments in the infrastructure, whereas the impact of scheduled maintenance can be minimized through advance notice.

The demand side factors that can contribute to electricity outages are transitory factors that lead to demand spikes (e.g.: harsh weather conditions), or longer term trends like unanticipated increase in demand. It is more difficult to identify solutions to these causes. The Dhaka case study substantiates this, finding that demand shocks during the summer leading to outages. Potential solutions to such demand side factors may include better use of data for more accurate demand forecasting, better supply infrastructure and flexible prices to curb demand. Political economy factor like electricity subsidies, political priorities and corruption may also lead to electricity outages. Subsidies result in a non-paying, low-quality equilibrium, and discourage investment in infrastructure.

In the context of the impact of electricity outages, there is very little research that is done on the impact on the economy, households and firms, and more research is needed to understand the economic costs of unreliable supply. On the macroeconomic side, evidence indicates that electricity has a substantial effect on the economic growth, although it is difficult to determine causality. In terms of household level impacts, reliable electricity supply has a positive impact on women's employment and empowerment, as it allows for the adoption of labour saving technologies for household chores, reducing the burden of domestic responsibilities on women. However, more research is required in this area to understand the impact of unreliable power supply on households. For firms, unreliable power supply may affect firm's investment decisions, as they may decide to invest in alternative power sources like generators, the firm's production decisions regarding what

they produce in house and what they outsource, and the use of production technologies. If the unreliable power supply continues in the long term, the impact on industries may be more significant as it may influence the firm's long run choices and growth, and pose barrier to entry.

The paper also highlights a number of different options that can be implemented in order to mitigate the electricity outages. These include options like facilitating access to self-generation, with large firms that resell electricity to smaller firms, using prices to curb demand in the peak seasons, and using load shedding to ration power.

2.3 Paper 3: Urban Governance, Urban Development, Land Use and Energy Access

Irregular electricity supply, illegal connections and theft have resulted in domestic hazards like fires, and damage to electrical appliances. This is closely linked to weak urban governance and uncontrolled urban development. This paper reviews the evidence on the evolution of governance in urban areas in LICs and MICs, highlighting the experience of successful cities, the institutional arrangements that supported their performance, and the role of local government actors like municipalities in energy access and efficiency.

The paper notes that urban areas in LICs and MICs may have relatively better access to electricity, but reliability and quality of supply is still a persistent issue. In LICs and MICs, the expansion of urban areas is often characterised by informal means which are not compliant with the regulatory standards for land ownership, planning and building. Due to the nature of these informal settlements, they are often cut-off from the provision of utilities, and have to instead rely on means such as illegal connections, power sharing arrangements and theft. Formal provision in these areas come in much later, as a consequence of lobbying or government initiatives. Power distribution companies are reluctant to operate in these areas, given the frequent occurrences of illegal connections, thefts, and non-payment, amongst others. For example, in Rio de Janeiro, electricity supply is divided into different geographic areas, and supply of electricity to these areas is variable, with the quality of supply received in informal settlements being akin to that received in rural areas.

The concepts of government and governance and its role in LICs and MICs has also evolved over time, the government moving the role of a provider, to that of an enabler, and other stakeholders such as local governmental institutions and private sector, amongst others, assuming responsibilities for provision. In the context of electricity generation and provision, the local actors responsible for generating and providing electricity usually do not have adequate experience and competence in doing so. In addition to this, the agenda of the local actors is usually not reflective of the government's priorities. On the other hand, the local actors are limited by the national framework. Thus, this transformation of the government taking the role of an enabler has resulted in a complex operating environment for the local actors responsible for electricity provision, having both positive and negative effects on the provision of electricity to the urban poor in LICs and MICs.

The paper also highlights different models to improve supply of electricity to the urban poor. For example, in Peru, it was not just privatisation that resulted in an improvement in the quality of services, but also that it was accompanied by a package of interventions like political frameworks to improve access to electricity and technical innovations in network engineering. Other models for improving access to electricity for the urban poor include prepaid systems, as well as holistic interventions that attempt to address the needs of the poor in different sector simultaneously. For example, in Rio de Janeiro, a pilot scheme that proved to be very successful focused on getting people to recycle solid waste in exchange for a discount on their electricity bills.

3 Priority Research Questions

3.1 Questions emerging from Policy Dialogue in Tanzania and Nepal

The Policy Dialogue in Tanzania raised key questions relevant to this theme:

- How can we promote productive uses of electricity?
- How do unreliable electricity systems affect urban productivity? What are the main barriers and solutions in cities to improving reliability?
- How does a country's political economy and governance structures shape energy policy? Where are the entry points for research in the policymaking process? What factors influence policymakers?
- How to can urban-scale renewables be effectively implemented into urban electricity systems?
- How can EEG add value by supporting improved data collection and analysis?

The Policy Dialogue in Nepal raised the following additional issues relevant to this topic:

- What factors enable urban electricity access to have an impact on productivity? At what level of reliability and/or demand and/or consumption does economic activity kick in?
- What is the nature of coping strategies to address electricity-reliability in urban areas and their implications?
- Who is impacted by tariffs in urban setting, and what is the nature of this impact?
- What factors condition – and could help to build – the political will to implement technical solutions to reliability and efficiency?
- How can acute data gaps be bridged to promote well-informed and evidence-based decisions making?

3.2 Priority Research Questions

On the basis of the issues identified in the policy engagement events and the two State of Knowledge Papers, the following research questions are proposed:

1. What is scale of social costs of electricity not-supplied (or reliability) in cities? What are various options (alternate models, including renewable energy), barriers and opportunities to improve energy access and reliability in cities in South Asia and Sub-Saharan Africa?
2. What is the scale of energy-efficiency gaps in cities? What are the options to improve energy efficiency, holistically in cities and in various urban sectors? What are the legal, institutional and co-ordination arrangements needed to scale up energy efficiency?

3. How can governments play a role in improving urban electricity access/reliability and energy efficiency? What are alternate governance models and their likely effectiveness?