Energy and Economic Growth
Applied Research Programme

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Thematic Note: Large-scale Renewable Energy Sources

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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.

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List of abbreviations

EEG	Applied Research Programme on Energy and Economic Growth
EU	European Union
IRENA	International Renewable Energy Agency
LIC	Low Income Country
MIC	Middle Income Country
PV	Photovoltaic
RE	Renewable Energy
REEEP	Renewable Energy and Energy Efficiency Partnership
SA	South Asia
SSA	Sub Saharan Africa
US	United States of America
VRE	Variable Renewable Energy

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 4 – Large-scale Renewable Energy Sources. 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.

Grid connected renewables have the potential to make a significant contribution to electricity supply in Sub-Saharan Africa and South Asia at both a national as well as at a regional level. To date, the contribution from grid connected renewables other than hydro has been limited. However, the recent reduction in the cost of wind power technologies and solar PV technologies has created opportunities for more investment in renewable energy, with other renewable energy sources projected to contribute a significant level of renewables generation in the two regions in future. This theme examines the economic and non-economic barriers for the large scale adoption of renewables, how renewable energy might be effectively integrated into electricity grids, and how markets might be designed to accommodate a range of variable and non-variable renewable energy.

Renewable electricity technologies differ from conventional fossil fuel generation in a number of ways. Even at grid scale, wind and solar PV installations are often smaller, modular (e.g. numerous wind turbines make up a wind farm), and operate variably. The location of projects is resource dependent. Renewable energy and non-renewable or conventional energy also differ in terms of the investment profile, with renewable energy plants requiring relatively higher up front capital costs compared with fossil fuel plant but also relatively low operation and maintenance costs, including zero fuel costs (apart from biomass, which is not considered in the following papers). The potential for modular, and incremental investment implies that renewable projects can be scaled up over time, rather than being built in one go as is the case with conventional, fossil fuel based plants.

These differences are not just technical or financial. These difference have wider implications for how the electricity networks the power sources are connected to operate, and in the case of expanding electricity systems, how infrastructure investments might best enable the location of renewable projects. Weather-dependent variations present challenges to system operators who have to keep the system in balance, as well as raising questions about the future viability of investments in fossil fuel plant. Crucially, policy makers and system operators in countries with high levels of variable renewable generation are now beginning to focus on how best to design systems to operate optimally in situations with highly variable renewables output, while also ensuring that system security is maintained, carbon emissions are limited and electricity remains affordable.

In this context, the two State of Knowledge papers focus on current issues with renewables, as well as how systems might develop in the longer term to accommodate renewable technologies with significantly different operating characteristics.

This Thematic Note is based on the following two papers:

1. Woodman, B., Mitchell, C. & Ragwitz, M. (2016) Economic and Non-Economic Barriers and Drivers for the Uptake of Renewables. Energy and Economic Growth Applied Research Programme.

2. Wolak, F. & Strbac, G. (2016) Power Markets and Renewables Deployment in Developing Countries. Energy and Economic Growth Applied Research Programme.

The papers in this theme focus on the following questions:

- What are the main causal factors behind real or perceived (economic and non-economic) barriers and challenges to successful deployment of large scale renewable energy? What measures have been taken to address these and what is the evidence for success?

- What policy mechanisms and planning tools are needed, or are available, to encourage use of renewables, including ‘green growth policies’, such as pricing and regulation to internalise environmental capital costs and why they have had limited application?

- How can the disparate performance of international/regional power pools be explained and what lessons can be drawn out for LICs entering such agreements?

- What are the opportunities to learn from and transfer knowledge from successful pools to poorer performing pools in SSA and SA? Building on the experience of international power pools, what are the opportunities for large scale renewable energy development and how can these be applied in the context of LICs?

- What approach is needed and what are the requirements for building greater familiarity and access to knowledge on large-scale renewable energy development in SSA and SA?

2 Key insights from the State of Knowledge Papers

2.1 Paper 1: Economic and Non-Economic Barriers and Drivers for the Uptake of Renewables

The design of electricity markets is becoming increasingly sophisticated, with a growing understanding of the role of the market in shaping the electricity system through encouraging or discouraging investments. Using examples from power markets in a variety of countries, this paper identifies a number of significant issues which policy makers and system operators should consider while designing electricity systems and incorporating renewable technologies.

Many state owned companies in developing countries find it difficult to raise the capital to invest in new electricity infrastructure, or improvements to existing infrastructure. This can cause delays in electrification as well as serious reliability issues. As a result, many countries are moving towards restructuring the industry to allow for some competition between generators and suppliers, and separate out the monopoly transmission and distribution activities. In this context, the paper identifies key areas which should be considered when seeking to improve system performance. Briefly, these are:

- How electricity is dispatched and the network operated to reflect the location of generation and time of day. Two measures are discussed – Location Marginal Pricing and Multi-Settlement Markets – which can improve system and pricing efficiency, and avoid generators being ‘constrained off’ if there is not adequate network capacity.

- Effective market and regulatory mechanisms to ensure the adequacy of both generation and transmission in the long term. These include the provision of forward contracts to enhance investor certainty, or the development of a capacity market to provide generators with payments to reward their availability.

- Regulatory oversight and mechanisms to avoid market power in systems with a wholesale market.

- The inclusion of the demand side as a resource in the market as a way of reducing the need for some capacity, and as a way of mitigating the impact of variable renewable power.

The paper also highlights some measures which could be implemented in power pools to support the cost-effective deployment. These include the development of markets for greater flexibility and provision of other ancillary services to more clearly reflect the variable nature of renewables generation and also to provide investment signals for demand side actions and storage. It also recommends that markets should be ‘system wide’ – in other words, incorporating both transmission and distribution connected generation as well as storage and demand side measures. Overall this would allow the holistic assessment of both centralised and decentralised generation as well as reducing infrastructure investment costs by reducing infrastructure redundancy.

2.2 Paper 2: Power Markets and Renewables Deployment in Developing Countries

Many countries in Sub-Saharan Africa and South Asia have renewable electricity targets and support mechanisms to encourage their deployment. These targets and policies are intended to increase access to electricity and improve energy security as well as by a desire to provide low carbon electricity. However, the rates of non-hydro renewables deployment to date are low in many cases.

The key drivers and barriers to renewables deployment are reasonably well understood, although much of the work has focused to date on renewables deployment in developed countries, particularly the EU and US. The key drivers include the strategic contributions that renewables can make to increasing security and access, reducing pollution and contributing to economic development through employment and training in the context of an industrial strategy. These are complemented by recent falls in the costs of some technologies – onshore wind and solar PV – which make them increasingly viable investment alternatives to conventional technologies.

While the relative importance of the different factors may differ between developed and developing countries, and between individual countries, at a high level they seem essentially the same, and are summarised in Figure 1.

Figure 1: Conceptual Framework for the diffusion of RE from Investors' perspective

1) Economic and political framework	2) Electricity market structure & regulation	3) Grid infrastructure & grid regulation	4) Administrative procedures for RE-projects
• Existence & reliability of RE strategy and support scheme • Relative remuneration level • Access to finance • Revenue risk	• Fair & independent regulation of the electricity sectors • Existence of functioning & non-discriminatory short-term markets • Availability of reliable long-term contracts (PPA)	• Cost of RE-grid access • Lead time for RE grid access • Predictability & transparency of grid connection procedure • Treatment of RE dispatch (curtailment) • Transparent & foreseeable grid development	• Cost of administrative procedure • Duration of administrative procedure • Complexity of administrative procedure

Source: Boie et al. (2015)

Within this general framework, some key issues for developing countries are:

- The availability and cost of financing for renewables projects, whether they are proposed by donor institutions or independent power producers, and the impact that this has on the bankability of the project. This arises for a range of factors, including uncertainty about longevity of government policy and issues relating to the financial viability of the off-taker of the power.

- The uncertain financial situation may be exacerbated in some instances if there is not a clear and established regulatory framework for both the buying and selling of power, and grid operation

- The transparency and licencing and connection procedures, and the time it takes to agree these arrangements

- In addition, there are broader socio-political issues including difficulties in collecting payments for electricity bills, macroeconomic instability and uncertainty over private property rights
- A lack of institutional capability, such as a lack of familiarity with renewables in education and policy making fora.

All of these issues influence the costs of proposed projects – the higher the perceived risk, the higher the costs of obtaining finance and the more difficult (and less attractive it is) it is to develop a renewable energy project. As a general statement, compared to developed countries, developing countries are characterised by higher perceived levels of investment risk across the board. This is particularly true for new, renewable technologies.

Clearly, the level of public or private ownership of utilities and power networks is a key factor in deciding the relative importance of different factors set out in Figure 1, and the degree to which independent power producers are able to enter the market. However, many countries in SSA and SA are increasingly allowing independent power producers to enter the system as a way of addressing some of the financial problems faced by state-owned utilities, but in many cases participation is limited. These issues are discussed in more detail in the Eberhard paper (Theme 2).

In addition, subsidies to fossil fuels are widespread in Sub Saharan Africa and South Asia, as in most other countries in the world. Suppressing the prices of fossil fuels makes it difficult for renewables to seem a competitive option, particularly if they are competing against each other at grid level. Conversely, apart from South Africa where a carbon tax is being proposed, there is little or no discussion of measures to cost the externalities of fossil fuel generation.

What is clear from a review of the literature on renewables deployment in developing countries is that a range of social, political, economic and technical factors combine to create broad, systemic barriers to renewables. Depending on the country, its resource and the state of its market, the severity of those factors vary. However, understanding what the barriers might be is central to understanding what measures might mitigate them (e.g. through policy mechanisms such as auctions or feed in tariffs) or to remove them (for example removing subsidies for fossil fuels or simplifying connection procedures for renewables projects), hence, creating an 'enabling environment' for renewables deployment. Actions to address the barriers to renewables will also have to be systemic, rather than focusing on the 'end product' of these factors, as systemic barriers add to the risk associated with investing in renewables and the resulting cost and availability of financing.

3 Priority Research Questions

We believe that future research on renewables deployment in developing electricity systems should focus as much on broad systemic issues as on individual policies or regulations. In other words, research should consider how best to encourage renewables deployment at a system level to ensure that as systems develop, they are able to accommodate variable and small scale generation, and avoid some of the current network and operational issues being experienced in developed systems with high levels of variable renewables. This approach would incorporate a longer term, strategic consideration of network and market issues which impact on renewables deployment and operation.

As renewables become more widely deployed and economies of scale and learning effects are experienced, it is likely that technology costs will continue to fall and they will become more competitive options. This is already being witnessed with onshore wind and solar PV. The key question then is how to maximise the impact of these effects by developing stable revenue conditions to minimise financing costs and by ensuring that the system overall is optimised to accommodate increasing levels of renewable generation. In effect, this means extending the idea of an enabling environment from a technology-focused approach to something which is more systemic.

Electricity systems with high shares of VRE technologies like wind and PV tend to deviate from the traditional structure consisting of central generation units combined with unidirectional transmission and distribution of electricity and supply following demand. Instead these systems are characterised by bi-directional flow patterns on both transmission and distribution networks, and variable output, which needs to be balanced across the system. This requires increased flexibility on both the demand and supply sides, and more active system management. In places with high renewables deployment, it can also require grid strengthening (Cochran 2014, IEA 2005, IEA 2008, IEA 2014, IEA 2016).

Both papers have identified the need for future research on renewables deployment and market design to include a more holistic, 'system-wide' approach. Renewable generation technologies can differ from conventional generation both in terms of investment profile and operation – in other words, they are often characterised by smaller scale, high upfront costs and, in the case of wind and solar, variable output. Power markets and network operation are often currently designed to reflect and reward the characteristics of conventional generation with relatively low upfront costs, constant, output dispatches, and large size generating units. Researching potential suitable models for how to design and regulate electricity markets, and the operation of both transmission and distribution networks can help enable more renewables deployment by ensuring that renewable projects have access to the grid and are not disproportionately penalised for their variable output, thereby reducing investment risk in the new technologies.

In addition, as renewables are becoming more widespread in a number of countries, policy makers and regulators are recognising the need to incorporate different elements into electricity markets. These include demand management techniques, which may reduce the need for additional capacity to mitigate the impact of variable generation, and storage technologies to mitigate the impact of variable generation.

In this context, we recommend the following areas for future research, with the aim of developing frameworks that reflect the needs of a future, more sustainable system, rather than reflecting the characteristics of current conventional generation. The proposed questions are intended to build on the original questions in the Terms of Reference by incorporating future systems development explicitly, as well as enhancing the understanding of the current policy and regulatory situation in developing countries in SSA and SA. Ideally, the issues would be examined through a series of case studies in relevant countries, and incorporate the views and experiences of policy makers as well as other system stakeholders, particularly investors and system operators. The results should be disseminated through regional conferences and workshops as well as using online resources.

1. Innovative governance

   New approaches to policy making and governance could have a positive impact on the viability and investment risk for renewables projects, and also enable the emergence of new business and operational models. This research would draw on and disseminate examples of innovative policy making, regulatory approaches. This could include the design of renewable electricity support mechanisms (such as auctions or feed in tariffs), network and market operational rules, for example the incorporation of the demand side in electricity markets. It should also consider new ways of financing renewable technologies and the licensing and permitting the development of new projects, drawing on and developing best practice around the world.

   Essentially this is research which would analyse ‘what works and why’ in a specific country context and against specified criteria (essentially cost effectiveness and efficiency in delivering greater renewables capacity and generation) and seek to enable those successes to be generalised across SSA and SA. The main activities include identifying case studies at country level, evaluating performance and disseminating findings through existing or new networks such as IRENA or REEEP. While much of the early stages of the research could be desk based, face to face discussions with policy makers or regulators could improve the effectiveness of the analysis and subsequent dissemination. For this reason, this project should include attendance at specific high profile regional workshops or conferences.

2. Empirical analysis of drivers and barriers for an uptake of large scale renewable energies in SSA and SA

   Research on this would consider the impact of barriers and drivers for renewables, as well as the current and alternative policies and framework conditions on market development based on techno-economic modelling of energy systems. The modelling would produce a quantitative analysis which could be used to put forward suggestions for designing effective and economically efficient policies and regulations for an uptake of grid connected renewable energies. Building on existing expertise at the Fraunhofer Institute, the modelling would employ the Green-X system model (or similar) to examine optimal promotion strategies for renewables.

3. Understanding the value of system flexibility

   Research on this would seek to quantify the value of grid connected renewable technologies and their relationship to flexible measures in national and regional systems. Value here is understood to be both the economic value of the generation, but should also include the value of delivering broader social goals such as accessibility.

4. New actors and business models

   Research in this area would evaluate possible business and ownership models, such as expanded community ownership, which may be suitable to investors in renewable projects. It would also consider innovative financing models that have been adopted in specific instances, which may be replicable more widely.

