Energy and Economic Growth Applied Research Programme

EEG-ERP Joint Research Partnership Seminar – Workshop Report

April, 2017

Acknowledgements

The Applied Research Programme on Energy for Economic Growth (EEG) is led by Oxford Policy Management in partnership with the Center for Effective Global Action and the Energy Institute @ Haas at the University of California, Berkeley. The programme is funded by the UK Government, through UK Aid.

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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This programme is funded by UK Aid from the UK Government.

Table of contents

List of abbreviations

Amp	Ampere
EDF	Électricité de France
EEG	Applied Research Programme on Energy and Economic Growth
ERP	UK Energy Research Partnership
GDP	Gross Domestic Product
ICT	Information and Communication Technology

1 Introduction

On 9th March, 2017, EEG and the UK Energy Research Partnership (ERP) jointly held a research partnership seminar with industry experts form the private sector. This main purpose of the seminar was to provide a private sector perspective on some of the key themes and cross-cutting topics under EEG, and seek views from the industry experts on the EEG programme. The programme was attended by participants the Carbon Trust, Oxford Energy associates, M-Kopa, EDF, ERP, Private infrastructure development group, UC Berkeley, Columbia University, ABB and Atkins Trust. This event focussed on three themes and one cross-cutting themes. These are as follows:

- Cross-cutting theme 3: Data-Leveraging Smart System Technologies in National Energy Data Systems
- Theme 6: Innovative design for large scale energy infrastructure.
- Theme 3: Electricity supply, energy efficiency and sustainable development
- Theme 4: Constraints in the use of large scale renewable energy sources

This workshop report summarises the main discussion points at the seminar, and outlines a series of next steps.

2 Key themes in the seminar

2.1 Data: Leveraging Smart System Technologies in National Energy Data Systems

Catherine Wolfram discussed the limitations of existing data and models about energy use in the developing world. Key points discussed with attendees were:

- Macro-economic models have consistently under-estimated energy demand growth in developing countries, and forecasts have had to be raised repeatedly
- Extension of main power grids into rural areas does not necessarily lead to connections for customers.
- Initial data suggests that the immediate socio-economic benefits of investments in rural main power grids are small; one contributing factor could be regressive tariff structures.
- Electrification of workplaces can be a more effective driver of socio-economic benefits, posing questions for policies of prioritising electrification of homes in favour of workplaces.

Macro-economic models using GDP-energy correlations have consistently under-estimated growth in energy demand, and forecasts have had to be raised repeatedly. Attendees noted that forecasting is more accurate for developed energy systems because: 1) they are undertaken by utilities using a bottom-up approach and detailed knowledge of their networks and customers; and 2) they have historical data to underpin forecasts.

Extension of main power grids into rural areas does not necessarily lead to connections for customers. There has been a general assumption that an area is either on-grid or off-grid, but studies show a widespread “under-grid” phenomena whereby homes and businesses are near enough to power grids to be connected easily, and yet remain unconnected. This is an economic issue, because many households cannot afford the connection, and attendees noted that loans are effective at overcoming the upfront cost hurdle (and have the added benefit of building up their households’ credit ratings).

Initial data suggests that the immediate socio-economic benefits of investments in rural main power grids are small; one contributing factor could be regressive tariff structures. A study undertaken 1.5 years after homes were connected to main power grids did not show significant improvements in key development metrics; it will be necessary to repeat the study in a few years’ time to understand whether improvements simply take time to appear, but some factors are already understood. At a simple level, connection to a main power gird does not necessarily lead to energy-related steps that can improve development metrics. Amongst households that can afford a connection, in some areas the average demand per home is falling as more households are connected that either do not have many appliances or cannot afford the power to use them much. Lack of appliances (e.g. fridges that contribute to health metrics) can be because households cannot afford them, or because poor power system reliability (e.g. very long outages) diminishes their merit, or because there can be a preference for others appliances (e.g. TVs). Limited use of appliances can be due to inappropriate charging methods (e.g. payment after use can lead to debt, whereas pre-payment does not), and regressive tariff structures. Tariff reform is needed, e.g. if monthly standing charges are too large then poorer customers have money left for only a little power (and at a very high overall unit price factoring in the standing charge).

Electrification of workplaces can be a more effective driver of socio-economic benefits, posing questions for policies of prioritising electrification of homes in favour of workplaces. The latter accounts for >50% of power demand in most countries, they make the more direct contribution to economic growth, and they can have more ability to overcome challenges noted above for the uptake and use of electrical appliances.

2.2 Innovative designs for energy infrastructure

Vijay Modi presented examples of stand-alone "mini-grids" for villages in developing countries. Key points discussed with attendees were:

- Costs of infrastructure (on any scale, whether main grid or mini-grid) depends largely on the geographical distribution of customers and their distance from the energy infrastructure.
- Demand for electricity can be hard to forecast, with large variations between different households and different communities.
- Energy demand reflects demographic trends, migrations trends and government's policies, but does not necessarily reflect local energy resources.
- Electrification appears to have a relatively stronger affect on economic growth through providing regular electric supply to workplaces than to homes.

Costs of infrastructure (on any scale, whether main grid or mini-grid) depends largely on the geographical distribution of customers and their distance from the energy infrastructure. However, one consistent factor for solar-based power systems, whether mini-grids or single-building grids, is the cost of the battery. The largest cost of solar based power systems in the battery. Mini-grid systems for villages are not necessarily cheaper than single-building systems (economies of scale in producing mini grids can be cancelled out by meters and longer circuits required by single cuilding systems), but have the advantage of diversity i.e. varying the load sharing, capacity of the solar supply, and storage. Limited grid capacity increases the value of energy management, rather than just energy production, as customers have to consult with their grid provider before connecting new equipment, much more so than customers on developed energy systems. In addition to this, systems have to cope safely with excessive demand e.g. mini-grids with multiple fridges can use software to safely disconnect loads and to stagger reconnection. On the supply side, integration of renewables onto main grids could be benefit from adopting appropriate technical standards used in developed power systems.

Demand for electricity can be hard to forecast, with large variations between different households and different communities. For example, small solar-powered grids in sixteen villages (eight each in poor areas of Mali and Uganda) saw demand grow more than expected in ten cases and less than expected in six, with no further information on the driving factors. Individual demand is strongly influenced the ability of the individuals' to pay. As noted in section 2.1 on Data, ability to pay for electricity not only refers to unit rates but also includes upfront charges like grid connections, appliance purchases and standing charges. These upfront costs are high, and often pose a barrier for households to connect to the grid. These barriers can be reduced by allowing the households to pay for the upfront costs in instalments. Other barriers include payment systems, and there is great benefit in offering zero-cost, unified payments interfaces. Attendees also noted the benefits of the blockchain system, where everyone holds their own ledger. Similarly, billing and payment methods also pose challenges for utilities, as in some cases, issues like poor metering inhibits the ability of the utilities' to manage technical and commercial losses, and theft.

Energy demand reflects demographic trends, migrations trends and government's policies, but does not necessarily reflect local energy resources. Demand for electricity for heating and cooling purposes in developing countries has increased, and is further amplified by the rural-urban migration. However, the infrastructure in these countries poorly equipped to deal with energy demands efficiently. For instance, buildings are inefficient users of electricity, due to reasons lke incorrect application of fabric energy efficiency, and incorrectly sized heating and cooling systems.

In this context, the attendees noted that the UK can assist in capacity building for regulation, as a world leader in standards and guidance for buildings systems.

Energy demand is reflective of policies, as government's policies to combat poor quality may necessitate a shift to using natural gas for cooking and transportation. However, in some areas like the African rift valley, natural gas is not available for consumption, even though the region is major producer of natural gas for export. More generally, abundant renewables are hugely under-utilised in many developing countries.

Electrification appears to have a relatively stronger effect on economic growth through providing regular electric supply to workplaces than to households. Households may take a relatively longer time to fully utilise electric connections than workplaces. For example, in a study of Senegalese villages, households took 4-5 years to fully utilise electric connections, whereas farms took 2 years. Such research can serve as an effective signal for investing in further incremental capacity. Larger one-off investments are generally more cost-effective. However, the limited value of long-term forecasts poses a higher risk that such invetsments may be under-utilised and hence less cost-effective. The impact of electrification on business can be attributed to a number of factors. For example, in fams, solar-powered electrical water pumps have weather-limited operating hours, but are cheaper than the alternatives and also transfer responsibility for management and maintenance to a service provider. Studies have investigated the impact of electrification and grid capacity on job creation.

2.3 Electricity supply and energy efficiency measures to support sustainable urbanisation

Catherine Wolfram discussed the different types of power system, their (un)reliability and their impacts upon households and businesses and hence their ability to inhibit development. Key points discussed with attendees were:

- Power outages ("on/off" reliability) deter customers from investing in appliances that would have socio-economic benefits, and/or they require customers to invest additional funds in back-up generation.
- Quality of power (e.g. power spikes) causes damage to appliances, and hence deters customers from purchasing appliances that would bring benefits, and in particular deter purchases of (more expensive) energy efficient appliances.
- The impact of power outages and poor power quality can be so significant that a greater overall benefit could be achieved by improving reliability for existing customers than by extending grids to new customers.

Power outages ("on/off" reliability) deter customers from investing in appliances that would have socio-economic benefits, and/or they require customers to invest additional funds in back-up generation. Developing countries experience short power outages as do all power systems, but some areas also face outages lasting weeks or even months in severe cases. There is often no compensation for outages; indeed, even in developed power sectors it is complicated to determine the "value of lost load", which depends very much upon the type of customer (e.g. industrial, service, household, etc.) and the use of the power (e.g. precision manufacturing, date-specific festivities, etc.). Customers can respond by reducing their expectations and not purchasing appliances (e.g. fridge) and hence not enjoying the benefits (e.g. fresh food or vaccines). In particular, businesses are less likely to invest in equipment that would allow for greater efficiency or other improvements. Alternatively, for customers (particularly businesses) that have become dependent upon electricity, can respond to the threat of outages by purchasing back-up generation, which adds to their costs. The usual choice is diesel genetators which has negative environmental impacts, and such investments will not be sufficient to ensure business continuity unless related businesses are have similar resilience (e.g. internet service providers, caterers, etc.).

There is limited monitoring of power outages in many areas of developing countries and the speed of remedial works. However, examples show that the processes are often cumbersome (e.g. manual fault reporting by customers and slow allocation of tasks to engineers), face practical challenges (e.g. engineers travelling through busy traffic), and can be biased in favour of wealthier customers (e.g. around the US Embassy in Nairobi). Communications technologies are being used to help address challenges in these processes, e.g. the GridWatch system gathers charging and motion data from mobile phones and notifies the utility company if multiple phones in an area have stopped charging and remained stationary (indicating a power outage).

Quality of power (e.g. power spikes) causes damage to appliances, and hence deters customers from purchasing appliances that would bring benefits, and in particular deter purchases of (more expensive) energy efficient appliances. Customers in developing countries do not necessarily have legal protections in the event their appliances are damaged by poor power quality. The risk of appliances being damaged deters customers from investing extra upfront costs in energy efficient appliances, even though they have lower running costs, adding to points made in the previous sections. Monitoring of power quality is often limited, and communications technologies are being used to help, e.g. in the Witenergy system, specially equipped power plugs monitor power quality and transfer that data to a mobile phone that is being charged through the plug, and the mobile phone then transmits the data to a central system.

The impacts of outages and poor power quality can be so significant that a greater overall benefit could be achieved by improving reliability for existing customers than by extending grids to new customers. Issues caused by unreliable power systems particularly in urban areas, in conjunction with the apparently limited (or at least slow) impact of rural electrification and the shifts from rural to urban living, can suggest that the emphasis should be on improving urban power reliability. However, it is possibly unrealistic for developing power systems to aim for the levels of reliability seen in developed power systems, particularly as renewables penetrations increase; high marginal costs of the "last 1%" of reliability might mean that customers are content with "99% reliability" and accept the 1% as a feature rather than a problem.

Monitoring and reporting systems that use mobile phone data (e.g. location) touch of questions of privacy (e.g. similar to debates about smart meters in the UK). As with other apps, there is self-selection by customers that are content to share their data. These groups might be large enough to provide sufficient data; but if more monitoring customers were needed, it would be interesting to see whether utility companies value such data enough to be willing to pay for it, and also interesting to see how customers responded to the offer of payment for downloading an app.

2.4 Integrating large-scale renewable energy sources

Frank Wolak presented options for structuring power markets, discussing their relative merits for incorporating and managing renewable generation. Key points discussed with attendees were:

- Developing countries can decide to encourage investment to improve reliability and/or capacity of their power systems.
- Power markets do not have to be complicated.
- Power markets can foster investment in renewable or non-renewable power sources, and can have features that help to manage different generation mixes.
- Regulations and market rules do exist in some developing countries but tend to lack the features needed to make best use of resources, including renewables.
- African cross-border power pools have existed for several years, but are not used as much as might be expected.

Developing countries can decide to encourage investment to improve reliability and/or capacity of their power systems. All power sectors can follow a similar path initially, with initial public investment in state-owned companies to build up the core of the sector; but now developing countries that want greater reliability and/or higher capacity can seek to encourage private investment by agreeing to restructure their power sectors to allow competition. This can be done either by divesting some generation assets, if the sector is large enough; or if the sector is so small that divested assets would be too small to be viable, then this can be done by rules to limit the incumbent's market power to protect new generation assets. For generators to have confidence that they can recoup their upfront investments, there has to be a free market (without manipulation) to allow price discovery. This can be distorted by political interference including pressure on state-owned generators to push prices artificially low to gain popularity. This tends to mainly benefit wealthier citizens and energy customers, whilst being of no benefit to the poorest citizens without electricity. And the tactic makes it harder to convince citizens and customers of the need for increased bills to pay for private investment in reliability and capacity.

Power markets do not have to be complicated. Simple markets can be sufficient, whereas attempts by some developed power sectors to design "perfect" markets risk "making the perfect the enemy of the good". Lowest Cost Market is a simple market model that does all that is required; it is used very effectively in Latin America, and is a good model for developing power sectors. The basic requirements for an effective market are rules that are transparent and fair (to customers, new generators, and incumbents) including fair access to regulated monopoly networks.

Power markets can foster investment in renewable or non-renewable power sources, and can have features that help to manage different generation mixes. Electricity is a unique product and hence requires a unique market, placing constraints compared how we might think the market should operate. Locational issues can prevent a market from simply stacking up the cheapest generators to meet demand, and instead markets need rules to account for constraints, but these offer opportunities for gaming by participants to profit by distorting prices. Locational marginal pricing is applied in many markets around the world (most of which are based on non-renewables), almost always with uniform price for demand customers and locational prices for generators; the system operator knows marginal costs of all generators, and uses a map of the network to determine which generators should "trade places" in the market in order to account for constraints. Multi-settlement Locational marginal pricing markets are well-suited to renewables, partly because they account for resource adequacy: renewables bid to provide a certain volume on a day-ahead market and are paid for that volume regardless of out-turn, but they have to buy any shortfall from a thermal generator, and the resulting net incomes reflect the value of the thermal generator's reliability.

Regulations and market rules do exist in some developing countries but tend to lack the features needed to make best use of resources, including renewables. For example, Kenya has basic market regulations and a system architect, but the outcomes are distorted by external impacts (e.g. political decisions), and they would need to be developed further in order to incentivise optimal deployment and use of renewables (solar power balanced by dispatchable geothermal power). The Danish power market would be an interesting case study for the potential future of developing power sectors, with its high penetration of renewables; but it differs in its gas back-up generation and its interconnection to Europe (including Norwegian hydroelectric storage).

African cross-border power pools have existed for several years, but are not used as much as might be expected. One possible reason for lack of pool activity could be national security concerns over committing domestic generation capacity to an international customer. Some of these power pools do have the necessary characteristics for integrating renewables, but some of the countries lack the necessary wider institutional infrastructure e.g. competition law and information provision to counter market power. Furthermore, whilst power markets provide signals about the best locations for network upgrades to relieve constraints, some transmission investments are made in sub-optimal locations simply due to political links between particular countries.

3 Next Steps

The EEG-ERP joint research partnership seminar outcomes will feed into EEG's broader task of creating a research agenda for Part 2. To incorporate the workshop outcomes, we will action the following next steps:

- OPM and CEGA will incorporate the feedback and insights provided by the leading industry experts at the ERP event into EEG's ongoing mapping of the current state-of-knowledge.
- Potential research partnerships were identified at the workshop with Atkins and the Private Infrastructure Development Group (PIDG). OPM will follow up on these promising opportunities through bilateral meetings.
- OPM will present again at the ERP's Plenary Meeting on 26 March 2017, introducing the EEG research programme to the wider ERP network and highlighting the potential for EEG-ERP collaboration.

These actions to incorporate the outcomes of the EEG-ERP event will ultimately feed into EEG's Final Research Framework Report, due May 30, which will shape the agenda of EEG for the next four years.

Annex A Seminar Programme

EEG – ERP Joint Seminar: Agenda

Date and time: Thursday 9 March 2017, 0930-1700

Location: 58 Prince's Gate, South Kensington, London SW7 2PG

Agenda

- 09:30 – 10:00: **The Energy and Economic Growth Applied Research Programme**.
    - *Speaker: Dr Marcela Tarazona*
- 10:00 – 11:00: **EEG Cross-cutting Theme – Data: needs and opportunities**
    - *30 minute presentation by Prof Catherine Wolfram*
    - *25 minute Q&A (Chair: Dr Simon Cran-McGreehin)*
    - *5 minute wrap-up (Dr Marcela Tarazona/Dr Ryan Hogarth)*
- 11:00 – 12:00: **EEG Theme 6 – Innovative designs for energy infrastructure**
    - *30 minute presentation by Prof Vijay Modi*
    - *25 minute Q&A (Chair: Dr Simon Cran-McGreehin)*
    - *5 minute wrap-up (Dr Marcela Tarazona/Dr Ryan Hogarth)*
- 12:00 – 14:00 : Lunch break
- 14:00 – 15:00: **EEG Theme 3 – Electricity supply and energy efficiency measures to support sustainable urbanisation**
    - *30 minute presentation by Prof Catherine Wolfram*
    - *25 minute Q&A (Chair: Dr Simon Cran-McGreehin)*
    - *5 minute wrap-up (Dr Marcela Tarazona/Dr Ryan Hogarth)*
- 15:00 – 16:00: **EEG Theme 4 – Integrating large-scale renewable energy sources**
    - *30 minute presentation by Prof Frank Wolak*
    - *25 minute Q&A (Chair: Dr Simon Cran-McGreehin)*
    - *5 minute wrap-up (Dr Marcela Tarazona/Dr Ryan Hogarth)*
- 16:00 – 16:45: **Key questions for the ERP Seminar**
    - *Chair: Dr Simon Cran-McGreehin*
- 16:45 – 17:00: Round-up

Annex B Workshop Participants

Name of participant	Name of organisation
Erika Velazquez	ABB
Samuel Stephens	Atkins
Jon Lane	Carbon Trust
Vijay Modi	Colombia University
Colin Gourley	DfID
Will Blythe	DfID / Oxford Energy Associates
Dan Bentham	EDF
Simon Cran-McGreehin	ERP
Harini Dewage	M-Kopa Solar
Marcela Tarazona	OPM
Ryan Hogarth	OPM
Laura Prieto	OPM
Joe Shamash	Private Infrastructure Development Group
Frank Wolak	Stanford University
Catherine Wolfram	UC Berkeley
AbuBakr Bahaj	University of Southampton