Paradigms and poverty in global energy policy: research needs for achieving universal energy access

2016 Environ. Res. Lett. 11 064014

(http://iopscience.iop.org/1748-9326/11/6/064014)

Environmental Research Letters

CrossMark

OPEN ACCESS

RECEIVED
15 February 2016

REVISED
16 May 2016

ACCEPTED FOR PUBLICATION
1 June 2016

PUBLISHED
16 June 2016

LETTER

Paradigms and poverty in global energy policy: research needs for achieving universal energy access

Benjamin K Sovacool[1,4], **Morgan Bazilian**[2] **and Michael Toman**[3]

[1] University of Sussex, United Kingdom, and Aarhus University, Denmark
[2] Royal Institute of Technology, Stockholm, Sweden
[3] World Bank, Washington DC, USA
[4] Author to whom any correspondence should be addressed.

E-mail: BenjaminSo@hih.au.dk

Keywords: energy access, energy research, energy and sustainable development

Abstract

This research letter discusses elements of a long-term interdisciplinary research effort needed to help ensure the maximum social, economic, and environmental benefits of achieving secure universal access to modern energy services. Exclusion of these services affects the lives and livelihoods of billions of people. The research community has an important, but not yet well-defined, role to play.

Introduction

Widespread access to clean, reliable, and affordable energy—what we will call 'sustainable energy'—is critical for achieving inclusive, low-emissions growth and development. Access to sustainable energy can influence human progress from job creation, to economic competitiveness, to empowering women[5] [1]. Widespread access to sustainable energy could lead to new global markets for goods and services [2], alter regional energy trade [3], and help ensure that environmental impacts of economic development are minimized [4]. It is an urgent practical necessity, as well as a matter of basic equity, to address the needs and aspirations of those billions of people still in deep poverty that do not have access to sustainable energy.

Their numbers include 1.1 billion people—one in five globally—who lack electricity to light their homes or conduct business, and many more that have access to poor quality service [5]. Over twice that number—nearly 40% of the world's population—rely on wood, coal, charcoal, or animal waste in part or in whole to cook their food—breathing in toxic smoke that causes lung disease and premature death for millions of people each year, a great many of them women and children [6].

Analysts have generated a number of estimates of the cost of providing universal energy access in developing countries, with a variety of methodologies and assumptions. These estimates range from as little as USD $30 billion per year to as much as USD $130 billion per year[6] [7]. The total quantum of investment, however, is only one part of the story. The design of financial tools and risk instruments, the structure of markets, the creation of enabling environments, and the capacity to spend 'well' and plan for expenditure remain ripe fodder for researchers [8–11].

In addition, forecasts from the International Energy Agency subtly, but clearly, underscore that a large proportion of the poor are not likely to reach the goals of *Sustainable Energy for All* anytime soon in the absence of much more vigorous interventions. In projecting the future in a special section of their 2012 World Energy Outlook, the IEA estimated that almost one billion people would still be without electricity by 2030, and that 2.6 billion people would still be without clean cooking facilities. That same year, to provide a sense of scale, the number of people without clean

[5] Focusing on sub-Saharan Africa's infrastructure, [1] show that the continent's chronic power problems (e.g., inadequate generation, limited electrification, unreliable services, and high costs) significantly affect economic growth and productivity.

[6] For example, the International Energy Agency (IEA) has estimated that the additional investment needed for universalaccess, over and above the investment needed to meet growingdemand and reduce carbon emissions, would be on the orderof $34 billion per year. This seems like a large number, but it isonly 2 percent of global investment on energy infrastructure.

cooking technologies in India would amount to twice the population of the United States. Moreover, targets for providing widespread sustainable energy access must recognize that as development progresses, the demand for energy will be much higher than what has been termed 'poverty management' levels. Individuals will continue to seek much more than a single light bulb [12, 13].

Changing these circumstances will require a significant departure from business-as-usual in the deployment of energy systems at different scales. Such a departure in turn will require focused political will to address issues such as energy sector governance, and the creation of enabling environments for technology development and adoption. The challenge is inherently interdisciplinary, cutting across various technologies and distribution systems, business service delivery models, political economy issues, cultural attitudes, and social behavior. It requires capacity building as well as innovative approaches to regulation, policy, and planning. How we support the transformation to sustainable energy in terms of research, analytics, information dissemination, and knowledge sharing will be critical to success.

This Research Letter sketches a research strategy in support of widespread access to sustainable energy. In it, we outline some of the areas where research can demonstrate and help achieve the social, economic, security, and environmental benefits of sustainable energy access. We begin by briefly conceptualizing disciplinary approaches to energy access before moving to examine the problem of energy poverty and lack of universal access to modern energy services as it has been approached in various disciplines. We then offer six possible areas of research focus, and suggest organizing research around problems rather than disciplines.

Though some recent research in the energy studies and policy fields have begun to explore a few of these themes, some shortcomings remain. One drawback in the current literature is the prevalence of a relatively narrow national or regional focus, with many studies investigating an isolated case or small sample of (national or subnational) case studies, or limiting themselves to a particular region such as Asia [14] or Sub-Saharan Africa [15]. Another problem is focusing only on a particular energy technology (such as cookstoves [16–18], solar home systems [19–21], or microgrids, [22–24]), rather than a complete bundle of systems or, better yet, energy services rather than technologies and fuels. There remains as well a focus on household services rather than the needs of the full economy. In addition, research typically has relied upon relatively narrow disciplinary perspectives [25, 26]. Finally, research has been strongly driven by expert judgments with limited input from other stakeholders, especially users [27]. Comparative, mixed-methods and cross-technology investigations are rare [28, 29].

Disciplinary conceptualizations of energy access

There has been relatively little discussion across disciplinary lines of what gaps in knowledge for sustainable energy most need to be filled by the research community. As table 1 indicates, a number of academic disciplines are working on sustainable energy access, but with a plethora of distinct issues and concerns that often remain siloed.

Policy discussions around the topic of energy access frequently have an emphasis on 'concrete action,' reflecting frustration with both the slow pace of development in the sector and the perception that research is too abstract. Nevertheless, a forward-looking research agenda that cuts across disciplinary lines to support widespread access to sustainable energy has not been laid out. Such an agenda is needed because research plays an important part not just in generating new knowledge, but also in challenging established views in the energy access debate, and ensuring it is firmly rooted in the wider energy dialogue.

Towards a cross-cutting research agenda

To meet the challenges of achieving sustainable energy for all, it is necessary to organize research around problems rather than disciplines [30]. To ground the design of an energy access research agenda, interdisciplinary depth and collaboration need to be encouraged.

In that context, research programs could be organized around the groups of questions that follow. These questions involve integrating technological and behavioral issues (and other forms of knowledge) with respect to energy access, transforming energy access interventions, and the role of fossil fuels. They also encompass approaches to data and measurement, better understanding of preferences and incentives, linking energy issues to other important parts of the development agenda, and co-benefits.

Firstly, *how do we best measure, track, and improve data and planning for sustainable energy access* [31]*?* How can this be tied to improved and appropriate modeling and planning tools [32]? In particular, how can we usefully project energy needs for countries currently suffering from huge unmet demands due to very low access, sometimes in conflict or post-conflict situations? And—how can we incorporate knowledge from stakeholders outside the research community? Integrated assessment analyses being undertaken at a number of institutions, including the International Institute for Applied Systems Analysis (as part of their Global Energy Assessment) and International Energy Agency (as part of their World Energy Outlook and Energy Technology Perspectives reports), offers a good start. Remaining challenges include calibrating models to more fully reflect stakeholder interests, and

Table 1. Disciplinary approaches to sustainable energy access and development.

Approach	Key researchers	Focus of concerns
Engineering	Physicists, other scientists, engineers	Technology-based initiatives, e.g. improving energy end use devices such as cookstoves, or technologies for smart grids, mini-grids, and rural and peri-urban electrification.
Economics and finance	Economists, finance experts	Improve understanding of finance and investment models for energy services in emerging economies. Causal links between energy and development. Analysis of economic benefits, and implications of different approaches to market development and regulation.
Political science and international relations	Security experts, defense analysts, specialists in public policy and governance	Linking aspects of a lack of energy access to energy security, urbanization, and migration. Vitality of civil society institutions, collective action dilemmas arising from energy access problems. Linking governance metrics and indicators to energy planning and access programs.
Environmental science	Natural scientists, environmental scientists, some life scientists	Evaluating the relationships between energy service provision and environmental degradation.
Legal studies	Lawyers, ethicists, philosophers	Exploring issues related to social acceptance and energy infrastructure. Also design and legal frameworks for new types of energy regulation and institutions, and assessing social justice concerns.
Sociology and anthropology	Anthropologists, sociologists	Social implications of patterns of energy access and use, evolutionary analysis of customs and attitudes toward energy availability and use.
Spatial analysis	Geographers, Geographic Information Specialists	Spatial attributes of energy systems and their implications for energy availability and quality.
Business	Business scholars, organizational theorists, business administration experts	Business models, market creation and evolution, and corporate behavior.
Psychology	Psychologists, behavioral economists	The individual or organizational behavior of energy users and other actors.
Public health	Epidemiologists, demographers, health-care professionals, geographers	Environmental health impacts of traditional energy use, energy use and gender, empowerment.

linking qualitative information with quantitative analyses. An important example is the development of appropriate tools for power system planning [33]. The growing use of geo-spatial modeling tools also is a welcome step forward. For example, it allows analysts to improve upon the over-simplified dichotomy between on- and off-grid systems [34–36].

Another important challenge under this theme is combining more general or abstract technological and scientific knowledge with contextual, place-based knowledge reflecting societal needs [37]. Such inclusivity can enhance the robustness of research by incorporating additional knowledge about social structures, systems of cultural meaning, and processes of change. One element of this should also be making more and better use of experimental methods for assessing behavioral responses to energy access opportunities [38].

Second, *under which circumstances can particular technological configurations successfully deliver sustainable electricity access?* What scale should energy access interventions be best implemented? What types of partnerships and business models can accelerate access? Relatedly, how do we harmonize and include granular business or market data, when such information is usually confidential or proprietary? A specific focus on understanding the role of decentralization in access provision and the extent to which community and small-scale innovative access solutions can be scaled up seems desirable. Some interventions and partnerships may be best suited to household and smaller scales; others may require coordination among more diverse actors that transcend local, national, regional, and even global scales, making them polycentric [39–41]. Here, the World Bank's Global Tracking Framework and REN21's Global Status Report have had some success investigating general technological and policy trends, but have not yet adequately explored dimensions of governance, efficacy, and scale.

This area of inquiry could also include the wider issues of energy sector reform, from the design of electricity markets, to the establishment and governance of regulators, to tariff and subsidy design [42]. For example, how can technological improvements, including elements of 'smart grids' be employed in the establishment of new rural or pro-poor connections, and the improvement of existing infrastructure? [43] How must economic incentives and regulatory structures change, in order to provide a useful foundation for efficient and robust national utility companies, and private sector participation and innovation [44, 45]?

Third, *what sort of 'tipping points' might there be for dramatically scaling-up modern cooking, heating, and cooling, and what policies would be needed to support*

Table 2. Three energy access paradigms.

	Donor support approach (starting in 1970s and 1980s)	Market creation approach (starting 1990s)	'Sustainable energy' approach (starting in 2000s)
Actor(s)	Homogenous: bilateral development relationships between country and donor	Heterogeneous: multiple government agencies or donors, plus market participants	Polycentric: multiple public sector, private market, and community development stakeholders
Emphasis	Demonstration: diffusion of technical equipment	Viability of markets: efficiency, financial sustainability, and privatization	Sustainability: meeting economic, environmental and social needs over the longer term
Provision	Electricity or clean cooking	Electricity and clean cooking	Electricity and clean cooking integrated with broader economic development and co-benefits
Standardization	Limited: focus mainly on individual interventions	Moderate: some, especially between programs within the same sector	Extensive: including certification, testing regimes, and national standards
Capacity building	Rare: often limited to technical assistance and maintenance	Emergent: some focus on after sales service and business model development, as well as strengthening regulatory capacities	Integrative: efforts centered on maintenance and business model development coupled with strengthening public and private institutions
Monitoring and evaluation	Limited: perhaps at the end of a single disbursement	More complex: evaluations at beginning and end of programs, some uses of results-based financing	Adaptive: ongoing evaluation and monitoring, results-based disbursement
Ownership	Public: often given away	Private: sold to consumers or intermediaries	Tailored: use of cost-sharing, public-private partnerships, in-kind community contributions

such transformations? How can adoption of cleaner cooking devices and fuels be linked to development of infrastructure for fuel provision and transport? How does household cooking energy connect with other productive uses of energy by households and firms? The Global Alliance for Clean Cookstoves, as well as industry groups such as the LPG Association, have begun to investigate some of these issues, but work by these kinds of organizations needs to be complemented by more rigorous and independent peer-reviewed research insights. Ensuring that heating and cooling services are addressed within the broader agenda remains critical, and is still a considerable gap.

Fourth, *how do current and prospective developments in fossil fuel resources, technologies and markets affect widespread sustainable energy access?* For example, what are the implications of increased global access to low-cost natural gas supplies due to expanded exploitation of newly discovered resources and reduced costs of liquefied natural gas transport? This must include aspects of resource governance as well as links to demand for natural gas beyond power generation [46]. Researchers should also assess the extent to which liquefied petroleum gas can play a key role in expanding access to cleaner forms of cooking [47, 48]. Such concerns may bring to light tradeoffs between expanded access and other objectives such as mitigation of greenhouse gas emissions or energy security.

Fifth, *how do we better address linkages with other sectors such as health, water, food, and education* [49]*?* For example, how can we link community service provision (for hospitals, schools, cell towers, irrigation) with household access to electricity? How does availability of water affect the availability of different types of energy services [50]? These sub-questions underscore the emergence of recent 'nexus' thinking on energy issues, showing how they in fact interconnect with broader basic economic development goals as well as key sectors that can both constrain or enhance access to modern energy services.

Sixth, *what are the most compelling societal co-benefits to investments in energy access?* These can encompass reduced morbidity and mortality as well as reductions in greenhouse gas emissions, economic diversification, and improved rural community vitality. Moreover, how are these co-benefits distributed in time—which ones come quickly to early adopters (such as improved health), and which ones are more long-term (such as mitigation of emissions or improved resilience)? The research community needs to focus particularly on longitudinal studies that help us to understand the security, social, economic, environmental, and health outcomes of energy access.

Changing approaches to energy access

There have been changes over the past 40 years in how energy access programs are designed, managed, and evaluated, as summarized in table 2. The columns in this table reflect three distinct approaches, or paradigms, that have developed sequentially over time. The rows indicate how the paradigms differed with respect to a number of factors, such as what actors participate and how capacity is developed.

The paradigm to energy development assistance most commonly utilized in the 1970s and 1980s focused mainly on single energy sources or technologies, implemented by a central agency, usually involving a single financier or borrower [51]. This approach was based on the premise that developed countries should provide technology and assistance to developing countries so that they could follow a similar energy development pathway.

A second paradigm arose in the 1990s, emphasizing reliance on markets supported by technical assistance. This approach prioritized private sector participation, competition, and market-led innovation to provide energy services at lower cost, with regulation designed mainly to promote and protect market entry opportunities along with financial sustainability. In terms of choice of technology, this approach assumed that if costs could be brought down beyond a certain threshold, the adoption of alternative or improved energy access technology would become self-sustaining [52].

A third paradigm emerging over past decade has been based on the view that focusing only on technology or price ignored other important social, cultural, political, and behavioral factors, as well as putting too little emphasis on significant societal goals such as environmental sustainability and broader economic development [53]. At the same time, there is growing recognition that energy transformation must ultimately be market-led, since the requisite capital flows necessary can be found only in the private sector [11]. Thus a simple model of top-down, bilateral technology transfer must give way to partnerships between public and private sectors, involving co-investment or private investment coupled with more comprehensive economic, social, and environmental incentives. It is this third paradigm that meshes well with our research agenda.

Conclusion

Investors, international development institutions, policymakers, and other stakeholders need greater clarity to make effective and robust decisions in today's dynamic and uncertain energy sector. This effort must necessarily integrate economic, environmental, and social impacts of providing energy access to billions of people in different and diverse societies.

Research has a key role to play in providing information that is relevant to developing countries, and that can foster innovative approaches to widespread sustainable energy access. To be more effective, however, research must address multiple energy systems, services, and scales, drawing on researchers trained in a variety of disciplines. Contributors to a broad, holistic energy research agenda can be found at a number of institutions—universities, think tanks, development banks, United Nations organizations, and other development partners—but most critically must also involve energy users and non-experts.

Development of such an agenda, one addressing emergent as well as traditional energy issues across many different types of cultures and markets inclusive of a heterogeneous pool of stakeholders, poses several challenges for researchers and research institutions. It also presents difficulties for international development and donor organizations, and developing country governments. The research agenda and its supporting paradigm outlined here requires significant changes in the design, implementation, and scaling up of many energy access policy interventions. The more complex and integrative kinds of research approaches we have sketched are more challenging, and may have higher risks than traditional approaches, but we believe they are necessary for research to have greater practical relevance as well as intellectual completeness.

Finally, quite apart from the structure and paradigm of research, is the current shortfall in availability of energy access funding. Energy issues in developing countries historically have been only a small part of research generally on energy technology, behavior, and policy. With a few important exceptions, moreover, financing for rigorous applied research on energy and development is largely flat or even decreasing in some institutions due to budget cuts, emergent crises, and the previously mentioned desire to 'do something' concrete on the ground with what funding is available. Continuation of the *status quo* on funding for energy and development research does not augur well for providing sustainable energy for all.

References

[1] Eberhard A *et al* 2011 *Africa's Power Infrastructure* (Washington, DC: The World Bank) (http://ppiaf.org/sites/ppiaf.org/files/publication/Africas-Power-Infrastructure-2011.pdf)

[2] Bairiganjan S *et al* 2010 *Power to the People: Investing in Clean Energy for the Base of the Pyramid in India* (Washington, DC: World Resources Institute)

[3] Saadi N, Miketa A and Howells M 2015 African clean energy corridor: regional integration to promote renewable energy fueled growth *Energy Res. Soc. Sci.* **5** 130–2

[4] Birol F 2014 Achieving energy for all will not cost the Earth *Energy Poverty: Global Challenges and Local Solutions* ed A Halff *et al* (Oxford: Oxford University Press) pp 11–20

[5] World Bank 2015 Global Tracking Framework, Washington DC (http://worldbank.org/en/topic/energy/publication/Global-Tracking-Framework-Report)

[6] Lelieveld J *et al* 2015 The contribution of outdoor air pollution sources to premature mortality on a global scale *Nature* **525** 367–71

[7] IEA 2012 *World Energy Outlook 2012* (Paris: OECD) ch 2

[8] Bazilian M, Nussbaumer P, Gualberti G, Haites E, Levi M, Siegel J, Kammen J and Fenhann J 2011 Informing the financing of universal energy access: an assessment of current financial flows *Electr. J.* **24** 57–82

[9] Gualberti G, Singer C and Bazilian M 2013 The capacity to spend development funds in the energy sector *Util. Policy* **9** 36–44

[10] Gualberti G, Martins L and Bazilian M 2014 An econometric analysis of the effectiveness of development finance for the energy sector *Energy Sustainable Dev.* **18** 16–27

[11] Bazilian M, Economy R, Nussbaumer P and Yumkella K 2014 The scale of investment for universal access *Energy Poverty* ed A Halff *et al* (Oxford: University Oxford Press)
[12] Pielke R Jr and Bazilian M 2013 Making energy access meaningful *Issues Sci. Technol.* **29** 74–8
[13] Bazilian M D 2015 Power to the poor: provide energy to fight poverty foreign affairs (March/April 2015) (www.foreignaffairs.com/articles/africa/2015-02-16/power-poor)
[14] United Nations Development Program (UNDP) 2013 *Achieving Sustainable Energy for All in the Asia-Pacific* (Bangkok: United Nations Development Program-Asia Pacific Research Center)
[15] Hancock K J 2015 The expanding horizon of renewable energy in sub-Saharan Africa: leading research in the social sciences *Energy Res. Soc. Sci.* **5** 1–8
[16] Pachauri S, Zerriffi H, Foell W and Spreng D 2011 Clean cooking fuels and technologies in developing economies *Energy Policy* **39** 7485–8202
[17] Otte P P 2014 A (new) cultural turn toward solar cooking—evidence from six case studies across India and Burkina Faso *Energy Res. Soc. Sci.* **2** 49–58
[18] Jeuland M A and Pattanayak S K Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest, and climate impacts *PloS One* **7** e30338
[19] Magradze N, Miller A and Simpson H 2007 *Selling Solar: Lessons from More Than a Decade of Experience* (Washington, DC: Global Environment Facility/International Finance Corporation)
[20] Sovacool B K and D'Agostino A L 2012 A comparative analysis of solar home system programmes in China, Laos, Mongolia and Papua New Guinea *Progress Dev. Stud.* **12** 315–35
[21] Sovacool B K, D'Agostino A L and Bambawale M J 2011 The socio-technical barriers to solar home systems (SHS) in Papua New Guinea: 'choosing pigs, prostitutes, and poker chips over panels,' *Energy Policy* **39** 1532–42
[22] Casillas C E and Daniel M K 2012 The challenge of making reliable carbon abatement estimates: the case of diesel microgrids *Sapiens* **5** 1–9
[23] Blum N U, Sryantoro W R and Schmidt T S 2013 Rural electrification through village grids—assessing the cost competitiveness of isolated renewable energy technologies in Indonesia *Renew. Sustainable Energy Rev.* **22** 482–96
[24] Szabo S, Bodis K, Huld T and Moner-Girona M 2011 Energy solutions in rural Africa: mapping electrification costs of distributed solar and diesel generation versus grid extension *Environ. Res. Lett.* **6** 1–9
[25] Sovacool B K 2014 Energy studies need social science *Nature* **511** 529–30
[26] Sovacool B K 2014 What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda *Energy Res. Soc. Sci.* **1** 1–29
[27] Irwin A 1995 *Citizen Science: A Study of People, Expertise and Sustainable Development* (New York and London: Routledge)
[28] Lema *et al* 2015 Introduction to low-carbon innovation and development: insights and future challenges for research *Innovation and Development* **5** 173–87
[29] Pachauri S and Spreng D 2012 Towards an integrative framework for energy transitions of households in developing countries *Environment & Policy* vol 52 (Netherlands: Springer) (doi:10.1007/978-94-007-2333-7)
[30] See e.g. Andrews M 2012 *The Limits of Institutional Reform in Development* (UK: Cambridge Press)
[31] World Bank 2015 *Global Tracking Framework* (Washington, DC: World Bank) (http://trackingenergy4all.worldbank.org/)
[32] Ramde E, Nussbaumer P and Bazilian M 2015 Measuring and reporting on energy poverty: insights from West African countries *Afr. J. Sci. Technol. Innov. Dev.* **7** 509–17
[33] See, e.g. Bazilian M and Chattopadhyay D 2016 Power system planning in fragile states *Cambridge EPRG Working Papers (Cambridge, UK)*
[34] Fuso Nerini F, Broad O, Mentis D, Welsch M, Bazilian M and Howells M 2015 A cost comparison of technology approaches for improving access to electricity services *Energy* **95** 255–65
[35] Mentis D *et al* 2015 Assessing the technical wind energy potential in Africa a GIS-based approach *Renew. Energy* **83** 110–25
[36] Welsch M, Nerini F F, Broad O, Howells M, Bazilian M and Rogner H 2015 A GIS based approach for electrification planning—a case study on Nigeria *Energy Sustainable Dev.* **29** 142–50
[37] Martello M L and Jasanoff S 2004 Globalization and environmental governance ed S Jasanoff and M L Martello *Earthly Politics: Local and Global in Environmental Governance* (Cambridge: MIT Press) pp 1–29
[38] Lee K, Brewer E, Christiano C, Meyo F, Miguel E, Podolsky M, Rosa J and Wolfram C 2014 Barriers to electrification for 'under grid' households in rural Kenya *NBER Working Paper No. 20327*
[39] Ostrom E 2010 Polycentric systems for coping with collective action and global environmental change *Glob. Environ.Change* **20** 550–7
[40] Sovacool B K 2011 An international comparison of four polycentric approaches to climate and energy governance *Energy Policy* **39** 3832–44
[41] Dworkin M H *et al* 2013 Rethinking the scale, structure & scope of US energy institutions *Daedalus: J. Am. Acad. Arts Sci.* **142** 129–45
[42] See, e.g. World Bank 2005 Power sector reform in Africa *ESMAP* (*Washington, DC, USA*) (http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/ESMAP_PowerSectorReform_in_Africa.pdf)
Eberhard A *et al* 2011 Africa's Power Infrastructure
[43] Bazilian M *et al* 2012 Smart and just grids *Renewable Sustainable Energy Rev.*
[44] Jarvis D S L *et al* 2011 Conceptualizing and evaluating best practices in electricity and water regulatory governance *Energy* **36** 4340–52
[45] Jamasb T, Nepal R and Timilsina G 2015 A quarter century effort yet to come of age *World Bank Policy Research Working Paper* p 7330 (http://documents.worldbank.org/curated/en/2015/06/24687055/quarter-century-effort-yet-come-age-survey-power-sector-reforms-developing-countries)
[46] Demierre J, Bazilian M, Carbajal J, Sherpa S and Modi V 2015 Potential for regional use of East Africa's natural gas *Appl. Energy* **143** 414–36
[47] Smith K 2002 In praise of petroleum? *Science* **298** 1847
[48] Smith K R and Dutta K 2011 Cooking with gas *Energy Sustainable Dev.* **15** 115–6
[49] Howells M *et al* 2013 Integrated analysis of climate change, land-use, energy and water strategies *Nat. Clim. Change* **3** 621–6
[50] World Bank 2013 Thirsty Energy: Securing Energy in a Water-Constrained World (http//worldbank.org/en/topic/sustainabledevelopment/brief/water-energy-nexus)
[51] Barnes D F and Floor W M 1996 Rural energy in developing countries: a challenge for economic development *Annu. Rev. Energy Environ.* **21** 497–530
[52] Martinot E *et al* 2002 Renewable energy markets in developing countries *Annu. Rev. Energy Environ.* **27** 309–48
[53] Sovacool B K 2012 Design principles for renewable energy programs in developing countries *Energy Environ. Sci.* **5** 9157–62