



# Energy: A summary of IGC research

*Highlights of the IGC's research over the past 10 years*

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Access to reliable and affordable energy, as enunciated in Sustainable Development Goal (SDG) 7, is at the core of IGC's research on energy. Achieving reliable, widespread access to electricity will be transformative for many developing countries. It has significant effects on how households apportion their time and which methods and inputs are applied by productive enterprises. The IGC's energy research is motivated by this role that access to energy will play in defining the growth trajectories of low and middle income countries. To this end, we seek to provide answers to four key questions:

1. How can access to reliable electricity be improved, notably in rural areas not served by the grid?
2. How can reliability in electricity provision be enhanced?
3. How can investments in and the use of energy be efficient in view of driving economic growth?
4. How can the external costs associated with rising energy consumption be minimised?

Our research on energy is led by a network of world-class researchers working in partnership with policy makers, practitioners, and civil society actors in 14 developing countries. Through the IGC's bi-annual calls for proposals, it funds cutting-edge research on energy and development. Anyone is welcome to apply. For more information visit: [theigc.org/research-themes/energy](http://theigc.org/research-themes/energy).

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# 1. Electricity access

Over 1.1 billion persons worldwide live without electricity (IEA, 2017). As governments in low-income countries invest in achieving universal access to electricity, many questions remain unanswered. For example, when and where should grid expansion be prioritised over off grid? The IGC has been working closely with leading scholars and governments in view of addressing these concerns.

## Expanding grid access

- **[A global database on rural electrification](#) (Michael Aklin, S.P. Harish and Johannes Urpelainen, 2017).** With support from an array of international partners, low-income countries are investing a significant amount of resources in achieving universal access to electricity, as enunciated in SDG-7. In the absence of a comprehensive database, it is difficult to track progress, quantify impact, and draw lessons. This project compiles and makes publicly available data on access to electricity from 1960 for 124 developing countries. The study finds evidence of rapid progress in electrification, notably rural electrification. Estimates suggest that previous estimations, such as the World Bank's Global Tracking Framework (GTF), have significantly underestimated progress in electrification over the past decades. The study finds robust correlation between electrification and welfare. This comprehensive data sheds light on effective approaches to electrification.

- **[Lighting up Bihar: Electrification to sustain economic growth](#) (Michael Greenstone, Robin Burgess, Nicholas James Ryan and Anant Sudarshan).** Though remarkable, India's economic growth has been constrained by numerous challenges in its power sector. In the state of Bihar, 45% of electricity consumed is stolen, unbilled, or pilfered from the main grid. This study aims to test if an innovative group collective incentive can be used to increase payment rates, thereby reducing distributional losses. Groups of industrial and residential consumers are randomly assigned to a payment scheme wherein the amount of electricity supplied to the group is pegged to the group level electricity payment rate.

Preliminary results showed the scheme increased revenue per unit cost by 40%, which could fund a 9% increase in power supply. Upon completion, this project will provide insight into the latent demand for reliable electricity by firms and households. It will also expose the role of social norms in electricity consumption, such as the conception that electricity is a right, implying that governments should ensure accessibility to all by setting prices as low as possible. There is evidence that this conception threatens the financial sustainability of electricity utilities. Preliminary results from the study suggest that households' are willing to pay for reliable electricity supply. This study has informed IGC's energy research in Myanmar and Pakistan.

- **[Paying for power: Prepaid electricity and the spending patterns of the poor](#) (Kelsey Jack, Anja Sautmann and Kathryn McDermott, 2019).** Poor households in developing countries struggle to pay their monthly electricity bill. This poses a major challenge to electricity providers in terms of revenue collection. Switching from monthly billing to prepaid metering is increasingly

seen as a possible remedy to this challenge. Using a randomised control design, we expose electricity customers in Cape Town (South Africa) to varying levels of liquidity constraints and transaction costs to quantify the welfare impacts of prepaid metering. We find little evidence that behavioural factors, such as self-control, are driving the decrease in electricity use and the frequent purchases of electricity in small quantities, which has seen to be induced by prepaid metering. There is, however, evidence of significant transaction costs associated with purchases.

- **Prepaid electricity metering: Costs, benefits and potential for scale-up (Kelsey Jack and Grant Smith, 2015)**. Post-paid electricity consumption via monthly billing remains the most widely used approach by utility companies in low-income countries. Recent studies have brought to attention the challenges inherent in this system, such as the costs of disconnection and loss of revenue when customers fail to pay their monthly bills. This project uses panel data from Cape Town (South Africa) to examine the effects of prepaid electricity metering on residential consumption and returns to the electric utility. Results suggests that electricity use falls by about 13% alongside an increase in the frequency of purchase. These findings point to an important role for metering technologies in expanding energy access for the poor.

## Welfare effects of electrification

- **The social and economic impacts of electrification: Evidence from Kenya (Edward Andrew Miguel, Catherine Wolfram and Kenneth Lee, 2018)**. Access to electricity remains very low in sub-Saharan Africa, with nearly 600 million people (i.e., 70% of the population) without electricity. This study estimates the demand for electricity and the impact of electrification on the socioeconomic livelihoods of rural households in Kenya. Through a randomised controlled experiment, rural households are incentivised to connect to Kenya's national electrical grid. The main result suggests that connection to the grid has very limited impact on the socioeconomic livelihoods of rural households. In addition to extending the national electrical grid, there is a need to address other constraints, such as access to credit, bureaucratic red tape, and the reliability of supply.
- **Solar electrification of schools: Achievement impacts and the efficiency of private and public investments into education (Michael Greenstone and Samuel Seo, 2017)**. The government of Tanzania has an ambitious rural electrification programme, with a focus on connecting rural schools to electricity. The impact of electrification on schooling remains unclear, though intuition would suggest a positive impact. This study examines the impact of partial school electrification on 11th grade student's performance in rural Tanzania. Using a randomised controlled experiment, 164 schools were assigned into six groups: G1 schools received two 0.12 kWh solar home systems, including lights and TVs ("facilities"); G2 received solar facilities and English videos; G3 received solar facilities and bilingual videos; G4 received English videos only; G5 received bilingual videos only; and control schools received no additional facilities. After one year, the intervention did not produce significant improvements in test scores, although G2 schools (solar and English

videos) reported large and significant increases in video-based instruction hours, and G3 schools (solar and Bilingual videos) achieved the highest test score gains. These first year results imply that ensuring that students actively interact and engage with newly provided facilities is very important in raising performance in junior secondary schools in sub-Saharan Africa.

- **The role of electrification on Africa's growth: A macroeconomic analysis (David Lagakos and Stephe Fried, 2016)**. Ethiopia is undergoing rapid structural transformation with increased contribution of the industry and service sectors to economic growth. Industrialisation is taking place along with massive investments in expanding access to electricity. Using panel data from rural Ethiopia, this project evaluates how to optimally allocate funds for rural electrification across heterogeneous regions, from both a theoretical and quantitative perspective. The project results suggest that electrified villages have a higher share of off-farm income and lower rates of out migration. Rural electrification can help stem rural-urban migration.
- **The impact of electric stoves and electricity subsidy on charcoal consumption in urban Africa: Evidence from a randomised controlled experiment in Tanzania (Yonas Alem, Peter Berck and Martin Chegere, 2018)**. Though charcoal use is seen as a major driver of deforestation and forest degradation, it remains a dominant source of energy for cooking in low-income countries. Intuition suggests that as income rises, households would resort to cleaner energy for cooking, such as gas. This project aims to explain why households in Dar es Salaam still continue to use charcoal as their main source of cooking energy, even when income increases. Using a street-level randomised control trial, households are incentivised to adopt a subsidised liquefied petroleum gas (LPG) cooking stove package. The main result indicates that access to LPG cooking stoves significantly reduces the amount of charcoal used. This implies that easing credit constraints, so as to enhance LPG cooking stove adoption, would significantly reduce charcoal usage.

**Let them buy light: The welfare benefits of electricity for rural households and enterprises (Michael Greenstone, Robin Burgess, Nicholas James Ryan and Anant Sudarshan)**. Out of the over 1,3 billion persons living without electricity worldwide, 300 million live in rural India. This project estimates the potential of micro-grid products in bridging the gap in electricity access in rural Bihar. Using a randomised controlled trial, rural households are incentivised to buy a solar micro-grid product. Baseline results suggest a positive correlation between electricity access (not necessarily treatment) and household welfare outcomes. Girls in households with electricity access are more likely to attend school. Households with access to electricity are more likely to use their cell phones for business purposes. This implies that rural households can productively use electricity.

## Off grid electrification

- **Rural electrification: The potential and limitations of solar power** (Tessa Bold and Anna Aevarsdottir, 2016). Expanding access to electricity is a major priority for policy makers in sub-Saharan Africa, where over 600 million persons live without electricity. However, based on current grid expansion plans and population growth, most of rural sub-Saharan Africa will not have access to electricity for the next 30 years. This project estimates the impacts of non-grid small scale electrification on labour supply, health, and income in rural Tanzania. Subsidies towards a solar lamp are offered to 30 randomly selected households in each of 60 schools. The project finds that solar lamps have a positive impact on household expenditure, labour supply, and household income. This result suggests that non-grid small scale electrification is a viable strategy to reach out to rural populations that may be hard to reach with the electrical grid.

## Natural resources

- **Poverty, militancy, and demands in natural resource-rich regions: Randomised evaluation of the oil profits dividend plan for the Niger Delta** (Kosuke Imai and Graeme Blair, 2013). Civilian populations often suffer the brunt of armed conflicts. Interventions to end or alleviate the impact of arm conflicts are often designed on the basis that civilians are victims. This study explores the role and behaviour of civilians in the prolonged civil war in the Niger Delta, the oil production region of Nigeria. It examines the relationship between the civilians and militant groups. This study uses survey data collected from the study site. It finds evidence of substantial interaction between communities near militant camps and the operations of militant financiers. This implies that programme benefits aimed at non-combatants will likely spill to combatants. Programmes that are instead designed to benefit both groups are more likely to succeed.
- **On the mechanics of the political resource curse: Behavioural measurements of information and local elite behaviour in Mozambique** (Pedro Vicente, Ines Vilela, Antonio Cruz and Alex Armand, 2018). As Mozambique gears up to exploit a recently discovered substantial natural gas reserve, there will be need for stronger institutions to ensure accountability and proper management of the resources generated through the export of liquefied natural gas. This project estimates the effect of disseminating information about natural resources on the behaviour of political elites. Communities are randomly given access to information about natural resources. The project finds that when information is given to local leaders only, elite capture of the benefits of natural resources increases significantly. The results suggest that campaigns to disseminate information about natural resources can be effective in minimising rent seeking behaviour.

## 2. Reliability in energy provision

Unreliable electricity impedes economic development. In 2015, sub-Saharan African economies suffered an average 690 hours of outages inducing a 2 percentage point loss in GDP (World Bank, 2017). The IGC has been playing a leading role in quantifying the impact of electricity outages on firms and households.

- **Crowdsourcing to evaluate and improve electricity supply in Tanzania (Davida Wood, Bharath Jairaj, Shantanu Dixit and Sisty Basil)**. In Tanzania, power cuts and voltage fluctuations are common and unpredictable making it difficult for businesses to operate smoothly. Many businesses and households have to resort to costly back-up power supplies. Using a simple plug-in device to an electricity socket, this project generates independent data on the quality of electricity supply to households and businesses in Dar es Salaam. Data from the first four months of monitoring revealed interesting findings. A total of 372 hours, which is over 15 full days of power outages, was recorded over four months of monitoring across the five locations. Therefore, the burden of power cuts and voltage dips to businesses and households in Dar es Salaam is considerable.
- **Analysing the extent and sources of productivity losses from electricity shortages for small and medium-sized enterprises (Patrick Opoku Asuming, Ama Baafr Aabeberese and Charles Ackah, 2018)**. According to the World Bank Enterprise Survey, about 60% of firms worldwide experience some form of electrical outage, with over 30% identifying electricity as a major constraint to growth. This project makes use of an electricity rationing programme to quantify the impact of electricity outage on firm productivity in Ghana.

The study finds that eliminating outages could lead to a 10% increase in firm productivity. In addition, strategies adopted by firms, such as using a generator or switching to less electricity-intensive production processes, do not attenuate the loss in productivity induced by electricity outage. This finding suggests that the array of coping strategies available to small businesses in Ghana may not be effective to attenuate the loss in productivity induced by electricity outage. Other options such as sharing generators among small businesses should be explored.
- **The vicious circle of blackouts and revenue collection in developing economies: Evidence from Ghana (James Dzansi, Steven L. Puller, Brittany Street and Belinda Yebuah-Dwamena, 2019)**. Utilities in developing countries face a major challenge in ensuring that customers pay their bills. Low payment rates of electricity bills pose a major financial risk to electricity providers. In response to low payment rates and limited supply capacity, electricity providers often resort to load shedding and rationing. This study uses household-level data on bill payment and power outages before and after a power crisis in Ghana, to estimate the impact of quasi-random exposure to power outages on subsequent bill payment. The study finds evidence that exposure to outages leads to accumulation of unpaid bills. These findings suggest a negative feedback loop in which power outages induce households to pay bills at lower rates and, thus, weaken the utility's financial sustainability.

- **Does electrification cause industrial development? Grid expansion and firm turnover in Indonesia (Dana Kassem, 2018).** The impact of electrification on economic development remains elusive. This study combines newly digitised data from the Indonesian state electricity company with rich manufacturing census data to quantify the impact of grid expansion on firm entry and exit. Using colonial incumbent infrastructure and geographic cost factors to address the endogeneity of grid placement, the study finds that electrification induces industrial development, represented by an increase in the number of manufacturing firms, manufacturing workers, and manufacturing output. Electrification increases both firm entry and exit rates leading to a reallocation of resources in favour of firms located in electrified areas. This is consistent with electrification lowering entry costs, increasing competition and forcing unproductive firms to exit more often. This implies that electrification can potentially play a screening role in industrial development.

### 3. Efficiency in energy use

There are many reasons to improve energy efficiency. Efficient use of electricity reduces emissions, alleviates the burden of electricity subsidies, and reduces the costs of electricity to consumers. To this end, the IGC has funded cutting edge research in view of identifying feasible and effective approaches to energy efficiency.

- **Asymmetric information and the energy-efficiency of durable goods: Evidence from cooking stoves in India (Anant Sudarshan, Nicholas James Ryan and Prabhat Barnwal, 2015).** The Government of India heavily subsidises Liquid Petroleum Gas (LPG). Over 15 million Indians are adopting LPG every year. One way to improve access to LPG, while alleviating the subsidy burden, is to promote the use of energy efficient appliances. This study measures the effect of providing information on the thermal efficiency of an energy-star label LPG stove on customer demand for more efficient models. In collaboration with oil marketing companies (OMCs), this study randomises access to information on the thermal efficiency of energy-star label LPG stoves at the market level in three states in India.
- **Non-price energy conservation and household energy consumption: Experimental evidence from Bangladesh (Ahsanuzzaman A, Asadul Islam and Liang Choon Wang, 2017).** Bangladesh is facing many challenges in its electricity sector leading to blackouts in the summer. Improving the reliability of electricity provision requires customers to use electricity more efficiently. Using a randomised controlled field experiment, this study examines the relative effectiveness of information in influencing residential energy consumption in Bangladesh. Households are randomly given access to expert advice on electricity conservation, information on their neighbour's electricity consumption, or average electricity consumption in their city. The study finds significant reductions in electricity consumption for households that received expert advice on electricity conservation. The magnitude of the reduction increases over time. This implies that non-price interventions can be effective in achieving energy efficiency.





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## 4. Externalities from energy use

Industrialisation has created millions of jobs and helped reduce the incidence of poverty in many low-income countries. These benefits have come at a cost: Pollution and climate change. The IGC has been working with an array of stakeholders in order to identify effective regulatory measures.

### Climate change

- **[Estimating the social cost of carbon in Africa and India](#) (Michael Greenstone, Solomon Hsiang, Robert Kopp, Ashwin Rode and Amir Jina, 2017)**. Extreme weather conditions are increasingly common and pose numerous risks to develop and developing countries alike. This project aims to develop for India and Africa, a spatially-disaggregated estimate of temperature sensitivities for a range of socio-economically relevant outcomes. The study uses gridded and historical data on mortality rates, work hours, agricultural yields, conflict incidence, and crime rates from around the world. This data allows one to flexibly estimate temperature sensitivities as a function of a location's adaptive capacities proxied by measures of physical and socioeconomic characteristics. The study finds evidence across India and Africa that extreme heat exposure leads to a substantial loss of human life, work hours, and rice yields, and sharp increases in crime and conflict.

The research team is currently engaging with governmental panels within the United States (US) and abroad. Results from this research were presented by Michael Greenstone to a joint hearing of the US House Subcommittees on Environment and Oversight on February 28 2017. The results were also presented to the Norwegian Minister for Climate and Environment and to



Senior officials at the World Bank. The results of this study have informed the International Rescue Committee's effort on prototyping a real-time seasonal forecasting tool that can guide crime and conflict prevention efforts.

The methods developed in this project can also potentially serve as a near-term forecasting tool. It can be a useful tool for resource allocation in extreme weather conditions. The data compiled and made publicly available by this study represents a significant public good to researchers and policy makers.

- **[Contract and market design for land-based carbon offsets](#) (Kelsey Jack, Oluyede Ajayi, Samuel Bell, Raymond Guiteras and Paulina Oliva).** Governments and international organisations have spent billions of dollars in recent years on incentives for land use changes that improve environmental outcomes. This project examines the importance of option value in take-up and compliance with voluntary land-based carbon offset programmes in rural Zambia. Small holder farmers are randomly selected for training and offered incentives to take up fertiliser trees (*faidherbia albida*). The study finds that the probability of take-up is decreasing the cost of inputs but not the probability of tree survival, which depends more on monitoring. This result implies that reducing inputs costs alone may not produce the desired results.

## Pollution

- **[Building environmental regulation that enables growth](#) (Michael Greenstone, Rohini Pande, Nicholas James Ryan and Anant Sudarshan, 2016).** Industrialisation has created millions of jobs in India and helped to decrease the incidence of poverty. However, the costs of industrialisation in terms of pollution have attained record and worrisome levels. This project quantifies the impact of improved regulatory monitoring on industrial particulate matter pollution. The study uses a randomised controlled trial design in which treatment plants install Continuous Emissions Monitoring Systems (CEMS), and researchers measure resultant pollution abatement decisions and regulatory actions over time. Preliminary results highlight the importance of addressing implementation challenges when switching to a CEMS.
- **[Health costs of energy related air pollution in South Africa](#) (Harald Winkler, Katye Elisabeth Altieri and Samantha Louise Keen, 2019).** In South Africa, where coal constitutes 97% of primary energy, exposure to fine particulate matter (PM) and the costs on human health and economic growth can be potentially high. This study quantifies the impact of exposure to fine PM on health outcomes using the United States Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP). It finds that 7.4% of all deaths in South Africa are due to chronic exposure to fine PM. These premature deaths cost the economy US\$20 billion (2011 International US\$), or 6% of South Africa's 2012 gross domestic product (GDP). This study highlights the need for increased fine PM monitoring around South Africa.
- **[Subways and urban air pollution](#) (Matthew Turner and Marco Gonzales-Navarro, 2017).** Urbanisation is intrinsically linked to economic development and presents opportunities and challenges to policy makers, notably, in

low-income countries. This project investigates the relationship between the opening of a city's subway network and its air quality. The project combines remote sensing data on air pollution with data on the location and date of opening of every subway station in the world. The data is from 2002 to 2015. This study finds that particulate concentrations drop by about 4% in a 10km radius disk surrounding a city centre during the year following a subway system opening. This result suggests that subways may play a moderately important role in determining exposure to particulates (Aerosol Optical Depth) in a city.

- **Arsenic contamination, nutrition and economic growth in Bangladesh (Mark Rosenzweig, Mark Pitt and Nazmul Hassan, 2015).** The government of Bangladesh invested considerable resources in digging tube wells in an attempt to roll back diarrheal disease in the 1970s and 1980s. However, by the late 1990s, evidence emerged suggesting that groundwater was contaminated by naturally occurring arsenic in 59 of the country's 64 districts. Using panel data linking rural family members residing in different localities, this project explores the link between arsenic ingestion and labour productivity in rural Bangladesh. It finds that exposure to arsenic contaminated water negatively affects health outcomes and productivity measures. Implementation of a policy that eliminates arsenic in water would have important economic and health benefits for Bangladesh.
- **Third-party environmental auditing (Michael Greenstone, Esther Duflo, Rohini Pande and Nicholas James Ryan, 2013).** The state of Gujarat, which represents about 5% of India's population and 19% of its manufactured output, stands out as one of the most polluted cities in India. The regulator, the Gujarat Pollution Control Board (GPCB), has not been able to hold industrial plants accountable for their emissions. This project quantifies the effect of a new auditing system, emphasising accountability of polluting plants behaviour. Therefore, industrial plants are randomly assigned to a new auditing system. The project finds evidence that the new auditing system induces significant reductions in pollution emissions. This implies that regulatory measures that emphasise accountability are effective in reducing emissions.
- **Does improved regulatory enforcement reduce industrial pollution? An evaluation of public and private sector approaches (Michael Greenstone, Esther Duflo, Rohini Pande and Nicholas James Ryan).** Industrial regulation in India has a history of heavy handedness, with industrial licensing and labour regulations impeding economic growth. This project examines how technology and market mechanisms can support environmental regulation policies that can minimise the social costs of energy consumption. The project uses a randomised controlled design, wherein auditors are randomly assigned to different payment schemes. In the original scheme, auditors are paid by the industrial plants they are assigned to inspect. Under the modified scheme, auditors are paid using a central pool of funds. The study found a reduction in pollution emissions from plants that were assigned auditors paid using a central pool of funds. This implies that auditor's independence can improve enforcement of industrial regulations.

## 5. Ongoing research projects

The IGC is working in close collaboration with an array of stakeholders in view of providing answers to pressing questions. Some ongoing projects are highlighted below.

- **Clarifying the nexus: Price-consumption-theft (Kelsey Jack and Molly Lipscomb)**. In close collaboration with the Ministry of Energy and Mineral Development and Umeme Ltd., the largest electricity utility in Uganda, the IGC has commissioned a project aimed at clarifying the relationship between electricity prices, consumption and theft.
- **Electrification from a blank slate (Michael Greenstone, Robin Burgess and Nicholas James Ryan)**. With only 34% of its population having access to electricity, Myanmar's government has ambitious electrification goals - electricity for all by 2030. The IGC is working closely with the government of Myanmar to quantify the welfare effects of its ongoing national grid expansion.
- **Sustainability of off grid renewable energy investments (Ioana Popescu, Serguei Netessine, Bhavani Uppari Shanker and Rowan Clarke)**. Financial sustainability remains a major challenge in promoting off grid renewable energy investments. The IGC has commissioned a project in Rwanda aimed at (1) understanding the main drivers of sustainability by scaling up an innovative revenue model for off grid renewable energy, (2) identifying how different pricing strategies affect consumer behaviour in the adoption and usage of clean energy, and (3) assessing the resulting impact on local communities.
- **Unreliable electricity and firm performance (Giovanna d'Adda, Jacopo Bonan and Farah Said)**. The IGC has commissioned two projects to quantify the impact of inadequate electricity supply on firm performance. These projects are ongoing in Zambia and Pakistan.

## 6. The way forward

The IGC's work on energy covers four important sub-themes: Accessibility, reliability, efficiency, and externalities. In accordance with IGC's model, our energy research has been conducted in close collaboration with public institutions, thereby enhancing the prospect for policy impact.

Despite the IGC's impressive work on energy, many questions remain unanswered. For example, the impact of electrification on welfare remains elusive. Though successful in developed countries, the effect of an Emissions Trading System (ETS) in a developing country context remains unexplored. The IGC is also looking to understand the impact of and solutions to pollution and climate change, and broadening our work on energy access and distribution. The IGC will continue to work in close collaboration with relevant stakeholders with the aim of providing answers to these and many other emerging questions.



The International Growth Centre (IGC) aims to promote sustainable growth in developing countries by providing demand-led policy advice based on frontier research. The IGC directs a global network of world-leading researchers and in-country teams in Africa and South Asia and works closely with partner governments to generate high quality research and policy advice on key growth challenges. Based at LSE and in partnership with the University of Oxford, the IGC is majority funded by the UK Department for International Development (DFID).