Imperial College London

# Supporting Rural Electrification in Developing Countries

**PHILIP SANDWELL, SCOT WHEELER, PROFESSOR JENNY NELSON**

## Project Overview

### Introduction

The United Nations Sustainable Energy For All (SE4ALL) initiative estimates that over 1.1 billion people around the world lack access to electricity and many more live without reliable, safe, or legal connections. The vast majority of these people live in rural and remote areas of developing countries in Sub-Saharan Africa and South Asia where the provision of basic electricity services is the most challenging. Technological solutions for providing energy access must be practical and affordable enough to supply power to the poorest communities in society. Solutions must also operate within regulatory frameworks to receive the support required to make an impact. Whilst governments, NGOs, businesses and communities across the world are working towards increasing the level of access and quality of electricity, many significant challenges remain.

The extension of the national grid network is a policy favoured by many governments to increase electrification rates and provide high quality power. However, large infrastructure costs, challenging geographies and intermittent supply have led to limited progress. Solar home systems have been widely used to provide affordable basic services such as lighting and phone charging to individual households but can be limited by the size of the system in their ability to increase energy access to the levels required for economic growth and development. Power generation at a larger scale and with greater capacity is required to power agro-processing equipment, provide electricity to local businesses and to supply home industries. Community-scale minigrids, independent from the national network and connecting tens or hundreds of households, provide decentralised power but need to be carefully designed and managed to make sure they continue to effectively meet the electricity needs of the community long after they are installed. All three of these approaches will be needed to meet the needs of communities without electricity around the world. This work focuses on the role that minigrid systems can play and how they can be used most effectively.

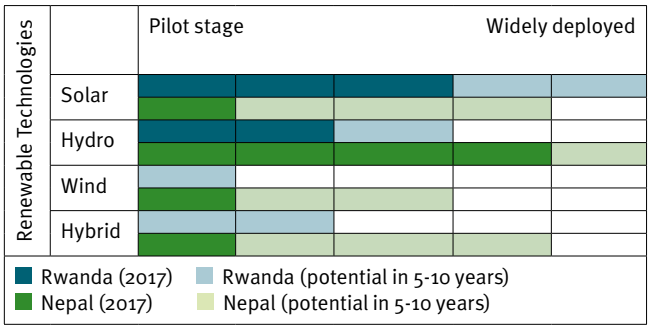
### About this Project

Many organisations, including SE4ALL, consider the transfer of state-of-the-art knowledge and technologies to countries with a less developed energy infrastructure to be an essential part to the expansion of sustainable energy. This project has supported the transfer of technologies and solutions to rural electrification in two countries, Rwanda in Sub-Saharan Africa and Nepal in South Asia. It has done so by considering the ways in which minigrids can overcome local challenges, and what further research will be required to maximise their potential. Interviews with stakeholders from both countries, ranging from government agencies, international development organisations, micro-utility companies, NGOs, minigrid developers and think tanks have contributed to this work.

The minigrid simulation and optimisation tool developed by the Grantham Institute, called CLOVER, has been used to quantitatively assess current minigrid electrification solutions and answer questions about the suitability of different technologies in meeting the needs of rural communities. Locations for case studies described in this report and strategies to improve energy access were suggested by stakeholders who were interviewed as part of the study. This helped to ensure that the project tackled the issues they were interested in, but lack the capacity to assess reliably.

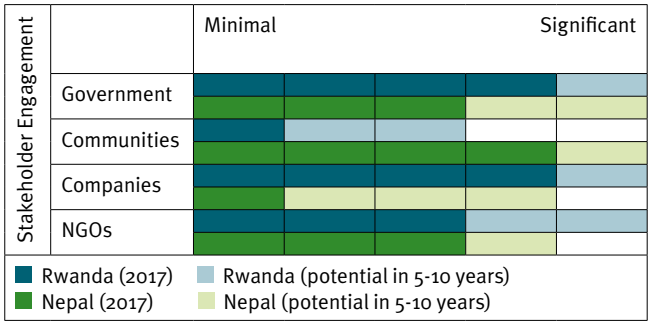
## Country Comparison: Rwanda and Nepal

Countries around the world face similar issues in using minigrids to achieve rural electrification but their strategies in meeting these challenges often vary significantly based on their available resources, unique geography, community customs, demographics and other factors. Here we present a qualitative comparison between the circumstances in Rwanda and Nepal.

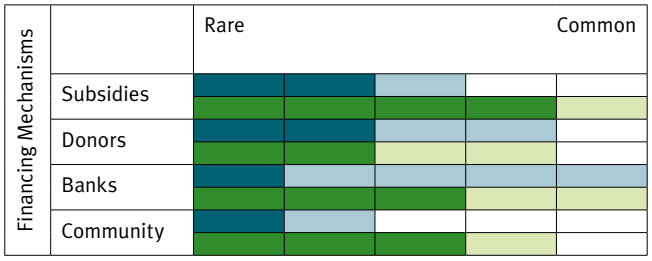



The ease of deployment of solar has led to widespread use in Rwanda, mainly through solar home systems, whilst Nepal lags behind in rural areas despite suitable levels of sunlight. For hydropower, however, Nepal leads Rwanda both in terms of historical deployment and future potential. Nepal also has the natural resources needed to build wind power minigrids, although these are in the pilot stage, and hybrid systems using existing

hydropower infrastructure in conjunction with other generation technologies. Rwanda may have more opportunity for grid-connected minigrids as the national grid expands to communities with an existing minigrid installed.




Strong governmental regulation provides support and challenges in both countries. In Rwanda minigrids are most commonly commercial ventures rather than community-owned projects, whereas the reverse is true for Nepal. This difference is reflected in the relative engagement of private companies and communities. NGOs in both countries play a significant role in facilitating minigrid deployment, especially through access to financing and donor capital.




In Rwanda and in Nepal most minigrid projects would be impossible to finance without subsidies. Foreign donor agencies provide access to capital in both countries, mainly through government programs, through capital grants and by facilitating effective financing mechanisms. Communities usually contribute towards the cost of minigrids in Nepal, with additional financing from commercial banks through loans. In Rwanda, community finance is far rarer: instead, private minigrid companies cover the costs which they earn back over the lifetime of the system.

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Lotus Energy Pvt. Ltd.
Peak Power Pvt. Ltd.
Practical Action Nepal
Saral Urja Pvt. Ltd.
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## About the authors

**Philip Sandwell** is a research postgraduate in the Department of Physics and the Grantham Institute – Climate Change and the Environment at Imperial College London. He explores the potential of solar photovoltaic technologies to mitigate greenhouse gas emissions, in particular in the context of rural electrification in developing countries. During his PhD, Philip developed the modeling, simulation and optimisation framework used by CLOVER and expanded on in this project.

**Scot Wheeler** is a research postgraduate in the Department of Physics and Chemistry and the Centre for Plastic Electronics at Imperial College London. His research focuses on using optoelectronic techniques to study organic photovoltaics and hybrid organic-inorganic lead halide perovskite photovoltaics. Scot integrated new renewable technologies into CLOVER's modeling capabilities, refined the coding structure and helped expand the work to new countries.

**Professor Jenny Nelson** is Mitigation Team Leader at the Grantham Institute – Climate Change and the Environment at Imperial College London. She heads the Institute's research into emissions mitigation using low-carbon technologies, energy systems modeling and mitigation policy, and led the current research. Jenny is also a professor in the Department of Physics, where she researches the properties of electronic materials and their application to solar energy conversion. She was elected as a Fellow of the Royal Society in 2014.

## Grantham Institute, Imperial College London

The Grantham Institute is committed to driving research on climate change and the environment, and translating it into real world impact. Established in February 2007 with a £12.8 million donation over ten years from the Grantham Foundation for the Protection of the Environment, the Institute's researchers are developing both the fundamental scientific understanding of climate and environmental change, and the mitigation and adaptation responses to it. The research, policy and outreach work that the Institute carries out is based on, and backed up by, the worldleading research by academic staff at Imperial.