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Sustainable mini-grid systems in refugee camps: A case study of Rwanda

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Headlines

- The investment in cleaner, long-term energy solutions has the potential to substantially reduce the costs and the environmental impact of humanitarian operations, as well as promoting more resilient and productive livelihoods for displaced populations.
- Limited energy supply and the lack of data on energy use and energy demand, together with the absence of coordinated strategies and funding opportunities have resulted in inefficient, expensive and polluting energy practices in humanitarian assistance, which are frequently powered by fossil fuel systems.
- A lack of dedicated financial resources and technical expertise of humanitarian organisations hampers the implementation of cleaner energy solutions in humanitarian settings.
- Organisations willing to invest in clean infrastructure face high risks because of the perceived uncertainty about the long-term future of displacement settings.
- Rwanda has one of the most ambitious targets and progressive policy frameworks for rural electrification, where off-grid mini-grids play a key role in remote areas.
- Many different sustainable mini-grid designs are available to adapt to the specific economic and environmental objectives of humanitarian organisations.
- Coordination between different stakeholders including humanitarian agencies, private sector and national governments is critical to enable the scale-up of cleaner energy solutions in displacement settings.

Contents

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Energy in a humanitarian context

Barriers to cleaner power

By the end of 2018, almost 70.8 million people[1] were forcibly displaced worldwide, setting a record high. As a result, humanitarian needs are rising globally, an estimated $25bn of funding was required in 2019, with a funding coverage of only 54%[2]. Despite being a key enabler of the provision of basic services and assistance, energy supply has often not been considered a priority of humanitarian assistance in the past. As a result, many humanitarian organisations do not have a coordinated strategy for addressing their energy use and the sector has historically had a poor working knowledge and a fragmented approach to energy supply interventions[3].

Meanwhile, decentralised off-grid energy systems such as renewable mini-grids have emerged as a sustainable and reliable solution for electricity provision in areas where the grid supply is not available, while also enhancing the livelihoods opportunities for isolated displaced populations[4].

Despite the potential for sustainable technologies in humanitarian contexts, several challenges have compromised their uptake and the scale-up of successful projects to date:

1. **Technical barriers:** Difficult access to field locations, scarce data on energy use, limited technical expertise and poor in-house energy management often result in premature failure of systems.

2. **Financial barriers:** Despite the plummeting costs of renewable technologies, the deployment of large renewable energy solutions is hampered by the substantial upfront investments required and the long payback periods involved. This is combined with a lack, or inconsistency, of funding and so energy interventions are often reliant on short-term funding characteristic of humanitarian assistance.

3. **Policy barriers:** The long-term regulatory uncertainty around displacement settings discourages private and public investors from investing in energy infrastructure, further marginalising the treatment of displaced populations in national energy-access agendas.

Box 1: Diesel dependency in humanitarian aid

The United Nations (UN) has recently launched an ambitious 10-year Climate Action Plan[5] with the objectives to reduce greenhouse gas (GHG) emissions in their operations, cutting them by 25% by 2025 and by 45% by 2030 compared to 2020 levels, accompanied by the promotion of renewable energy technologies. However, there is still a heavy dependence on fossil fuels in humanitarian assistance. In displacement settings on-site diesel generators are standard practice for providing electricity, representing a significant source of emissions in UN field operations.

It is estimated that humanitarian agencies spend 5% of their annual budget on fossil fuels, totalling $1.2 billion on polluting fuels globally in 2017[6]. The introduction of more efficient energy practices and cleaner technologies could bring operational savings of over $517 million per year, which could help to address the existing shortage in humanitarian funding, representing 5% of the funding gap of UNHCR (the UN refugee agency) in 2017[6].The transition towards cleaner energy sources would also drastically reduce the environmental footprint of humanitarian organisations in vulnerable areas, aligned with the ‘do no harm’ principle of humanitarian assistance. The UNHCR Global Strategy for Sustainable Energy[7] outlines the action areas required to provide energy in a safe and sustainable manner in humanitarian contexts including refugees, host communities and other stakeholders.

Diesel generator system installed in Mahama refugee camp, Rwanda. Photo credits: Meshpower Ltd.

Country profile: Rwanda

A hub for innovative clean energy solutions

Rwanda is an example of rapid scale-up of electrification and energy access. Access to electricity in Rwanda rose from 6% of households in 2008 to 49% in 2019[8]. Several critical factors enabled this progress:

(i) A series of initiatives and support from the Government and institutions, including regulatory authorities and financing institutions
(ii) ambitious electrification plans and a firm commitment towards their implementation; (iii) development of a geospatial plan to identify more cost-effective technological solutions by region
(iv) effective financing strategies and programmes
(v) promoting the affordability of connections for household and utilities[8].

As a result, since 2014 renewable mini-grids have emerged as one of the most cost-effective options to provide electricity access in rural and isolated regions in Rwanda, like the areas where displacement settings are often located. In humanitarian settings, initiatives such as the Renewable Energy for Refugees (RE4R)[9] Project have been successful in implementing clean energy solutions in Rwanda, whilst at a global level, the multi-stakeholder Global Plan of Action (GPA)[10] and the Moving Energy Initiative (MEI)[11] are actively promoting sustainable humanitarian energy access around the world.

Energy policy and regulatory framework

The Rwandan government's ambitious plans are set out in the *Energy Sector Strategic Plan* (ESSP) which aims for primary universal energy access by 2024, of which 48% will be off-grid connections. Mini-grids were first recognised in the *National Energy Policy* (NEP, 2004 and 2015) and reinforced in the *Rural Electrification Strategy* (2016) as one of the main pathways to achieving sustainable rural energy access (Fig 1). The long-term vision of the NEP is complemented by the short-term specific measures outlined in the ESSP (2018).

In 2017, the *Renewable Energy Fund* was launched, financed by the World Bank and the Development Bank of Rwanda. As part of the *Scaling Up Renewable Energy Plan,* it provides direct lending for eligible mini-grid developers, technical assistance and project implementation support. Post-commissioning funding is also available through other programs such as EnDev[12]. The creation of the *Rwandan Energy Group,* vertically-integrated state-owned institution, has facilitated the implementation of national policies and planning in the power sector. Other secondary measures such as reduced custom duties and preferential tax rates and incentives for low-carbon technology investments have also supported the introduction of clean energy technologies.

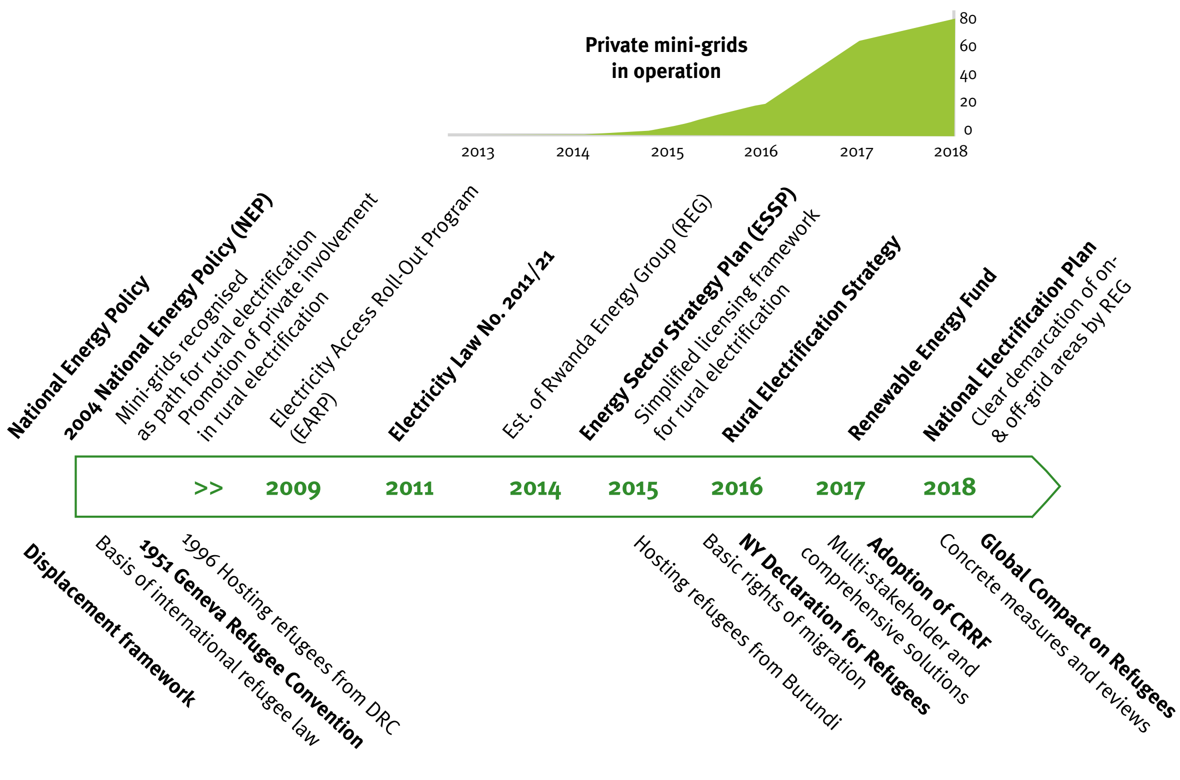

Figure 1: Energy and displacement regulatory and policy frameworks in Rwanda. Adapted from IRENA (2018)[8]

Displacement in Rwanda

Rwanda experienced a convulsive history during the second half of the 20th century, but it is now regarded as one of the most stable countries in Africa. It is also one of the most densely populated, with 11.6 million inhabitants, and despite its own challenges, Rwanda has welcomed refugees fleeing conflict from the Democratic Republic of the Congo (DRC) and Burundi. By 2019, Rwanda was home to 149,000 refugees, according to UNHCR (Fig 2). In 2018 Rwanda adopted the New York Declaration for Refugees and its Comprehensive Refugee Response Framework (CRRF). The local government and UN agencies are developing strategic partnerships including civil society organisations and private actors to deliver long-term sustainable solutions for these refugees. The CRRF includes giving refugees the right to work, access bank services, use the national health system, be issued ID cards and travel documents, and including children in the national education system.

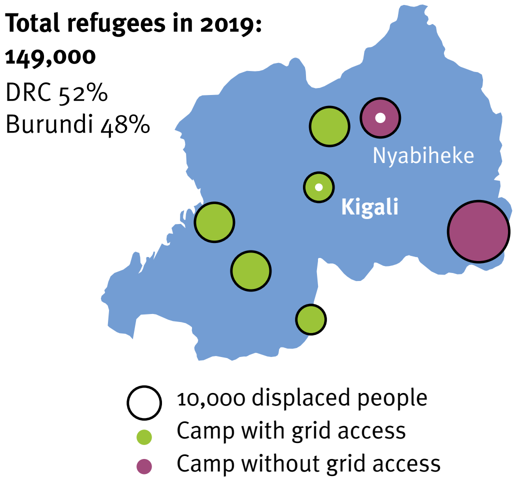

Figure 2: Main displacement settings and electricity access in Rwanda. Energy access in camps connected to the grid is still very limited, generally to institutions.

Box 2: Case study: Nyabiheke refugee camp, Rwanda

Nyabiheke Refugee Camp is situated in Eastern Province, Rwanda, and hosts more than 13,000 refugees since its creation in 2005. Due to the lack of grid access, a minimum of 13 kW of diesel generation capacity is needed to power its operational electricity requirements, which are currently met by either of two 60 kVA diesel generators. We estimate that humanitarian organisations pay $30,000 per year for the diesel needed for power, with greenhouse gases emissions equivalent to 101 tonnes of CO_2 (tCO_{2eq}) annually, mostly due to the fuel use[13] (Fig 3). Our techno-economic study investigated the benefits of the introduction of alternative mini-grid designs, including solar PV and battery energy storage technologies in Nyabiheke.

Our results show that the introduction of suitably designed hybrid (PV-battery-diesel) or fully renewable (PV-battery) mini-grid systems can drastically reduce GHGs emissions and pollution associated with humanitarian operations while also reducing total electricity costs over a lifetime of fifteen years. For instance, a 40% renewable hybrid system requires only $13,000 of additional capital funding compared to the incumbent diesel system. The resulting reduction of GHG emissions is 27% for the hybrid system, and 83% for a fully renewable system over its lifetime[13] (Fig 4). These environmental benefits are also accompanied by lifetime cost reductions of 22% for hybrid systems and of 32% for fully renewable systems[13]. This translates into MACs in the range of -$250 (40% renewable hybrid) to -$100 (100% renewable) per tonne of CO_2eq avoided compared with incumbent diesel in Nyabiheke. The payback periods of the initial investment in renewable assets were found to be around one and six years respectively due to the savings associated with the reduction of diesel use[13].

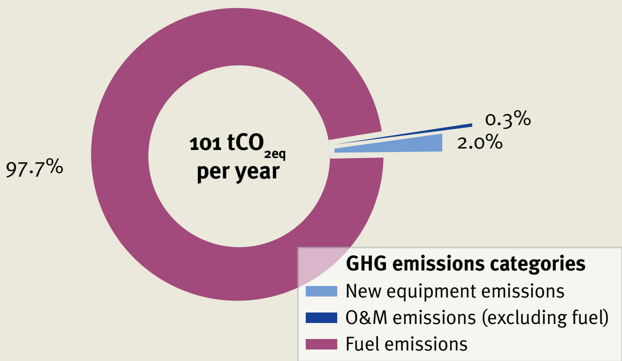

Figure 3: GHG emissions breakdown of a 13 kW diesel-based mini grid for institutional use in Nyabiheke refugee camp, Rwanda, powering basic services for 13,000 refugees.

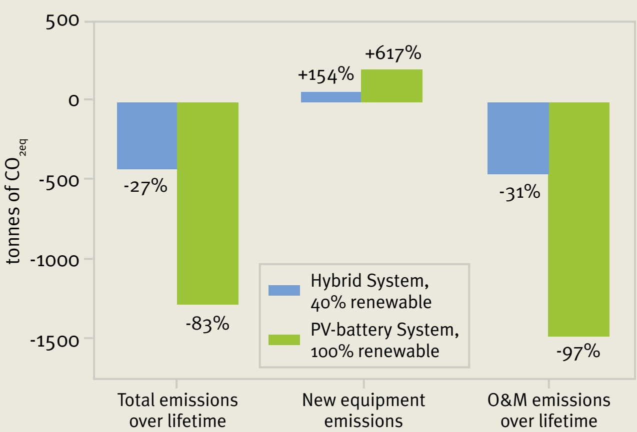

Figure 4: GHG emissions over 15 years for a hybrid and a fully-renewable mini-grid system compared to the incumbent diesel system in Nyabiheke.

Economic and environmental decision metrics

Renewable mini-grids can bring humanitarian organisations substantial benefits, both in environmental and economic terms, in addition to the health benefits associated with the improved air quality, according to the "do no harm" principle of humanitarian assistance. The large institutional loads in displacement settings, such as from health centres, water pumping and offices, can act as an anchor for power demand and provide a stable source of revenue for mini-grid developers. In addition, the high concentration of potential individual users presents an opportunity for the engagement of private mini-grid suppliers and the development of local economic activity. However, the costs and GHG emission savings are dependent on the characteristics of the energy demand and the technology mix selected for the mini-grid system. The humanitarian organisation's economic and environmental objectives and resources will determine the "most suitable" renewable fraction in the optimum mini-grid design[14].

In economic terms, the systems with greater usage of renewables displace more energy from diesel generation and have lower system costs over its lifetime, thus providing cheaper electricity. However, these systems require significantly higher upfront investment (Figure 5), which represents a short-term but significant barrier to their deployment. Organisations often do not have access to the required up-front investment or lack the capability to establish long-term contractual agreements with private actors, which could facilitate the deployment of capital-intensive renewable infrastructure by paying off the investment over time[15]. As an alternative, organisations can opt for hybrid systems composed of renewables and diesel, which typically have a smaller amount of renewable capacity installed. These systems can provide shorter paybacks due to the lower upfront investment than a fully renewable system that is better matched to short-term humanitarian funding cycles. The overall benefits of systems with renewables are enhanced when the energy demand is concentrated during the daytime, reducing the need for energy storage capacity to meet the night-time demand and thus reducing the total costs of the system. Introducing productive and income-generating activities, whose energy use during the working day generally matches well with solar generation, could improve the cost-effectiveness of renewable systems[13]. Many mini-grid design options are available to match the specific requirements of different humanitarian organisations, and so evaluating potential systems is important in identifying the most suitable investment.

Reducing fuel use from diesel generation with renewable technologies translates proportionally into higher GHGs emissions reductions. Due to the long-term savings associated with the introduction of renewable generation and the displacement of diesel, the marginal abatement cost (MAC – defined as the cost or savings resulting from offsetting one tonne of GHG emissions) of sustainable mini-grids are negative for both cases, meaning that they save both costs and GHG emissions. However, the MAC of offsetting diesel emissions over the system's lifetime experiences a diminishing return at higher renewable fractions[13]. This is due to the higher costs from the greater storage requirements of systems that use higher proportions of renewable energy. Therefore, hybrid systems, with smaller renewable capacity and lower storage requirements, can offset emissions more cost-effectively than larger and more capital-intensive fully renewable systems. Nevertheless, both approaches represent a significant opportunity to both reduce cost and emissions of humanitarian operations.

Metric	Diesel	Hybrid	Fully Renewable
Long-term cost (LCOE)	$ $ $	$ $	$
Upfront cost	$	$ $	$ $ $
Operational cost	$ $ $	$ $	$
Payback period	-	🕒	🕒 🕒
GHG emissions reduction	-	✓ ✓	✓ ✓ ✓
Marginal Abatement Cost (MAC)	-	✓ ✓ ✓	✓ ✓
Asset management requirements	✓ ✓ ✓	✓ ✓	✓

Figure 5: Comparison between diesel, hybrid and fully renewable mini-grid systems to power humanitarian operations. The payback periods, emissions reduction and MAC are compared to incumbent diesel systems. Detailed figures for the case study of Nyabiheke can be found in Box 2 and in reference 13.

The opportunity for greener humanitarian operations

Humanitarian organisations have the opportunity to reduce the cost and environmental footprint of their operations. Furthermore, this clean, reliable and affordable energy supply also has the potential to be extended to displaced people themselves to promote self-reliance of refugees, local economic growth, generate more productive livelihoods and facilitate better integration within host communities.

Increasing environmental awareness and recent initiatives are paving the way for the humanitarian sector to better understand its energy use and environmental footprint. The need for the sector to make its operations greener is becoming more apparent[3,9,10,11]. However, organisations' overstretched resources are making this change difficult.

Restructuring humanitarian funding mechanisms and donor practices, and policy changes are needed to increase access to capital and establish the multi-year financing cycles necessary for the successful scale-up of these solutions globally.

To realise the benefits of renewable power, governments, private actors and the humanitarian sector need to work together. In addition to continuous public support, the increasing engagement of the private sector in the delivery of these solutions will be crucial to facilitate the financing and long-term management of renewable assets, reducing the risk for humanitarian organisations and ensuring the financial and social sustainability of projects.

Recommendations for the private sector

- Establish partnerships with multinational and humanitarian organisations to design tailored financial mechanisms that facilitate the introduction of capital-intensive renewable systems.
- Explore new funding sources and mechanisms, such as peer-to-peer (P2P) lending and crowdfunding, to tackle the high capital costs and unlock the long-term economic benefits.
- Identify local partners to facilitate the commercialisation and distribution of energy products in remote locations.
- Facilitate the financing and access to productive appliances to stimulate energy demand for businesses and improve the profitability of mini-grids.

Recommendations for policy makers

- Provide a supportive framework for mini-grid development for off-grid electrification, facilitating the engagement of the private sector in off-grid areas.
- Account for the long-term nature of displacement settings to de-risk the investment in energy infrastructure, which will facilitate the deployment of long-term, cost-effective solutions.
- Work closely with humanitarian organisations providing the administrative and financial advice and assistance needed during financing, installation and operation phases.
- Include displaced populations in national electrification plans, providing equitable livelihoods opportunities and preventing tensions with surrounding host communities.
- Facilitate the access of displaced population to basic services and rights such as work permits, which will boost the potential energy demand by untapping economic growth in displacement settings.

Renewable mini-grid system installed by Meshpower Ltd. in partnership with Imperial College London, in Mahama refugee camp, Rwanda. Meshpower Ltd. is a developer of mini-grids for rural off-grid and displaced people. Photo credits: Arthur Santos.

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Study methods

This study is based on a techno-economic analysis of mini-grid systems for Nyabiheke refugee camp, using the CLOVER[16] optimisation tool and demand data collected in the field through smart-meters. The quantitative research was complemented through a literature review and 15 semi-structured interviews held remotely and in Kigali, Rwanda, with different experts in the humanitarian energy sector between May 23 2019 and June 24 2019. The interviewees included civil servants, academics, private sector representatives and non-profit practitioners. They aimed to cover a wide range of perspectives towards the existing humanitarian energy challenges. The interviews were analysed qualitatively through thematic content analysis to identify relevant themes and stories.

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