GOGLA

The Voice of the Off-Grid Solar Energy Industry

Powering Climate Adaptation and Justice: The Critical Role of Off-Grid Solar Technologies

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If we want to ensure we 'leave no one behind' and achieve an inclusive clean energy transition, getting modern electricity to the 675 million people still living in the dark must be a priority.

Thomas Opande
Lead, Africa Energy Access Initiative, WWF

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About this Paper

Focus of this paper

By sharing impact data and insights drawn from publicly available research and data sets, this paper sets out to profile different ways that innovative off-grid solar technologies can boost resilience and adaptation in energy poor communities in sub-Saharan Africa, South and SouthEast Asia and beyond.

Climate-smart technologies specifically explored in this paper are:

- solar energy kits, including solar lanterns and home systems, with accompanying communications appliances,
- solar water pumps,
- solar-powered fans,
- solar refrigeration units, and
- solar-powered walk-in cold rooms.

These can be used in homes, businesses and communities where there is no access to electricity, or where there is 'weak' or intermittent access to electricity due to prolonged or frequent blackouts which destabilise supply. The paper does not focus on nascent technologies such as solar powered agri-processing, e-mobility and e-cooking. However, these and other emerging energy services also have the potential to provide powerful contributions to a climate-smart future in countries hindered by low levels of electrification and beyond.

The paper aims to profile the link between inequality of electricity access and increased climate vulnerability, the role of off-grid solar in driving positive adaptation outcomes, the ways in which it is contributing to CO_2e reduction and the maturity, reach and affordability gap for each technology. As the stage and scale of different off-grid solar technologies is wide-ranging, the latter has been included to help illustrate the timescales and actions that would be needed to unlock the full potential of each.

The paper proposes that enhanced climate resilience and improved adaptation, particularly for the most vulnerable, can be realised through increased access to electricity and electricity services. Delivery of these energy products and services can be achieved by social enterprises working in the private sector with the strategic partnership of public, philanthropic and development actors. Indeed, hundreds of millions of people around the world are already benefiting from solar lanterns and home systems, and hundreds of thousands from solar-powered productive use technologies, including solar water pumps and cold storage.

However, while some unelectrified families, businesses and communities are able to afford these products and services, hundreds of millions more will remain unable to do so without new mechanisms to reduce, mitigate or subsidise costs. As such the paper also highlights the relative costs of each technology profiled to aid discussion on the steps needed to ensure the very poorest and most at risk are not excluded from initiatives to build climate adaptation and resilience through increased electricity access.

The structure of the paper

In the introduction, the paper highlights the injustices of climate vulnerability and energy poverty and profiles the urgent need to address these interlinked challenges. In sections two and three it details the ways that off-grid solar technologies and business models can play a key role in enabling resilience and combating climate hazards, while in section four it profiles how these solutions are also creating significant impacts in CO_2e reduction. In section five, the paper provides a high-level overview of the current maturity and reach of the different technologies covered and shares details of the 'affordability gaps' which currently hinder low income families, farmers and entrepreneurs from accessing them. It concludes with a call to action for governments, development partners, investors, philanthropies and the private sector.

About this Paper

Limitations

This paper aims to capture the positive climate impacts created by the off-grid solar industry, as well as potential adaptation impacts that the industry could help to catalyse. However, most data profiled within the publication was not gathered with the specific intention of exploring climate resilience, adaptation and mitigation. Therefore, while this paper illustrates areas where off-grid technologies, services and business models show clear links to these outcomes, more research is needed to ensure that:

1. the complexities of the relationship between access to off-grid technologies and climate adaptation and mitigation are better understood, in a range of contexts,
2. there is greater knowledge around the risks of non-adaptation and maladaptation and how these can be mitigated, and
3. efforts are made to uncover ways in which positive impacts and potential impacts can be optimised, to ensure the greatest possible outcomes for climate-vulnerable communities.

Introduction

Introduction

Those living without electricity are commonly the most vulnerable to climate change.

Figure 1 - Share of total population with access to electricity[3]

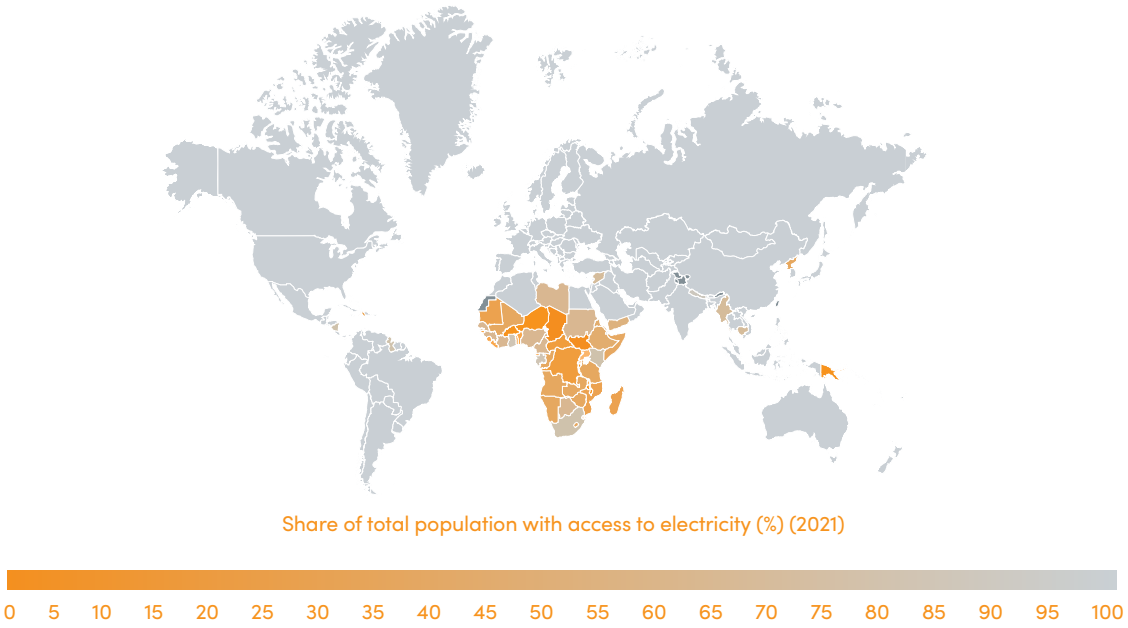
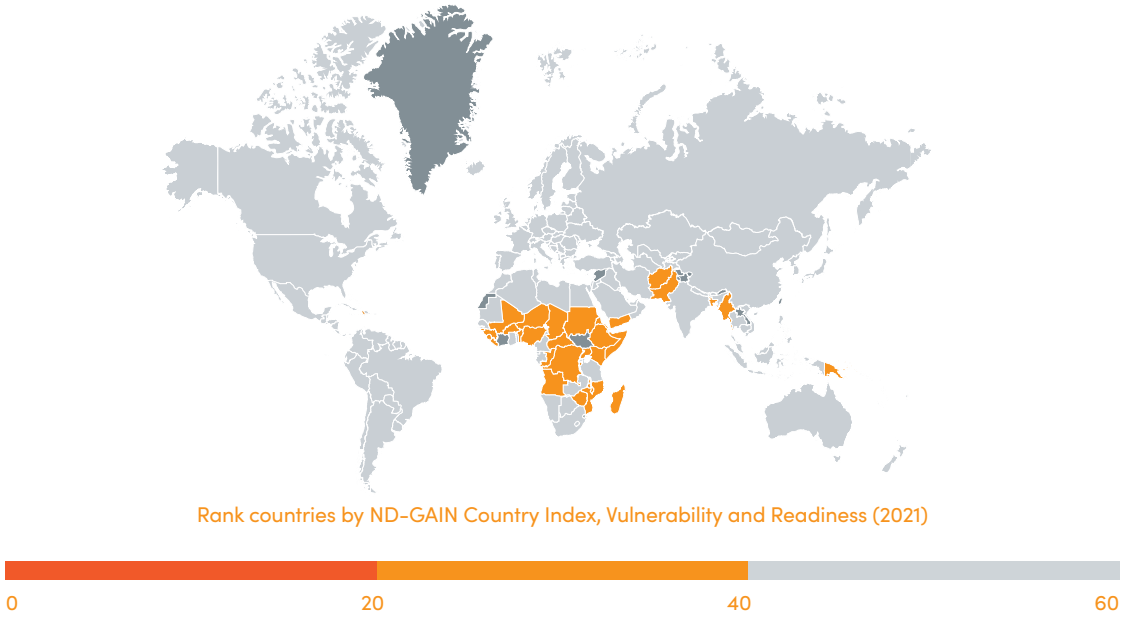


Figure 2 - Countries ranked by ND Gain Country Index, Vulnerability and Readiness (2021)[4]



Powering climate justice

Those most vulnerable to climate change have contributed the least to this urgent challenge. Worse still, they cannot access the resources they need to protect themselves from the extreme weather events they are now forced to endure. For hundreds of millions of people, this includes a lack of electricity and the life-enhancing and life-saving appliances and services it powers.

675 million people are living without electricity access, while over a billion more have unreliable access to the grid.[1&2] Greater numbers still are unable to afford basic electric-powered services: cooling, irrigation, processing and communications. This gap leaves many households and communities around the world without power for clean water, sanitation, agriculture and healthcare, or to access vital information.

The majority of those without electricity access are living under the poverty line of $3.20 a day, most lack formal employment and are heavily dependent on agriculture.[5] Amongst them are even more vulnerable groups, including those on extremely low-incomes, subsistence farmers, one income, often female, headed households, marginalised communities, itinerant workers and those who have been displaced by climate and humanitarian crisis. In many unelectrified and under electrified regions, there are rapidly growing youth populations who are growing up with the daily threat of climate change, yet without the dignity, opportunity and security created by access to clean energy services.[6]

If we do not place energy poor communities at the heart of the clean energy transition, it cannot be fair, just or inclusive. Yet by putting them at its heart, a transformation is possible.

One where millions of people are better able to withstand climate hazards and can access the electricity services they need to unlock climate-smart livelihood opportunities enabled by energy access.

1 IEA, IRENA, UNSD, World Bank, WHO. 2023. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC.
2 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
3 IEA, IRENA, UNSD, World Bank, WHO. 2023. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC.
4 University of Notre Dame (2023). ND Gain Index. Accessed in August 2023.
5 IEA, IRENA, UNSD, World Bank, WHO. 2023. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC.
6 UNCTAD. Key statistics on LDCs. Accessed in July 2023.

Powering adaptation and opportunity

Achieving universal access to electricity through climate-smart and resilient energy systems is one of 30 key goals adopted in the COP 27 Sharm El-Sheikh Adaptation Agenda.[7] Energy is also an enabler of several other Adaptation Agenda goals, including the expansion of sustainable irrigation, increasing crop yields through climate resilient, sustainable agriculture, halving losses in food production, providing basic and essential community services and enabling access to the tools and information required to integrate climate risks into decision making.[8]

Off-grid solar technologies are the primary way to power modern electricity services for most people who lack access today, for use both domestically and productively.[9] These technologies operate with their own standalone (solar) power source and do not require grid-connected infrastructure. In many cases, this makes them easier, faster and more affordable to sell or distribute than alternatives. In its latest Impacts, Adaptation and Vulnerability report, the IPCC recognised that there was strong evidence of the role of off-grid solar technologies in reducing vulnerability to climate change, especially amongst rural populations.[10]

Without off-grid solar solutions, millions will remain unelectrified in 2030 and beyond.[11] With them, communities can get the power and appliances needed to help modernise agriculture, boost food and water security, unlock connectivity, energise health infrastructure, drive green growth and create millions of clean energy jobs and enterprises.

The business models created by the sector also provide a platform for even greater impact. Off-grid solar companies are using their distribution networks to sell a wide range of additional low-carbon, high-impact products, such as clean cookstoves, water purification systems, smart phones and more; consumer financing mechanisms designed to help the poorest access electricity are bolstering financial inclusion; information channels between companies and their customers are being used to share climate-smart agricultural information; and companies in the productive use of renewable energy (PURE) space are linking their customers with enterprise opportunities and access to national markets.

In a significant number of cases, these same technologies and business models are also creating CO_2e reductions and eliminating toxic air pollution from kerosene lamps and diesel generators.

Prioritising adaptation

To date, the international focus on adaptation has been slow and underwhelming. The UN's latest Adaptation Gap Report (2022) shows that the current levels of international adaptation finance for developing countries are 5-10 times lower than their needs.[12] While the investment expected in the off-grid sector is anticipated to fall short of the amount needed to achieve universal electrification goals by USD $15 billion.[13]

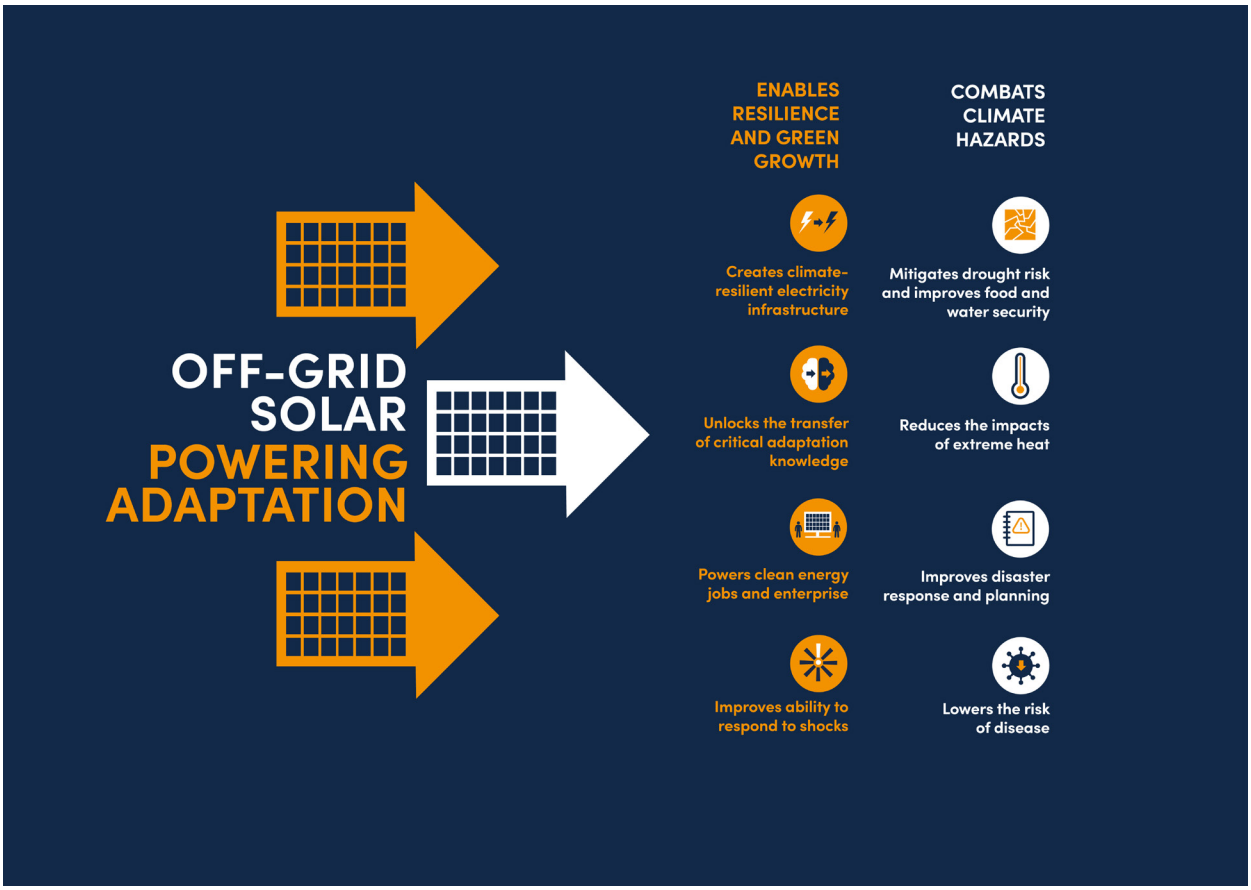
However, COP27 in November 2022 and the Summit for a New Global Financing Pact in June 2023 shone a much needed spotlight on the glaring adaptation finance gaps and the stark inequality between countries that have contributed the most to the climate crisis and those that will bear the brunt of its impacts. COP28 seeks to continue this momentum and ensure that the longstanding commitment of rich countries to provide $100 billion per year to poorer nations is finally met. 2023 also marks the mid-point of the implementation period of the Sustainable Development Goals (SDGs), leading to a stock take on progress and a

7 Race to Zero. COP27 Presidency launches Adaptation Agenda to build climate resilience for 4 billion by 2030. Accessed in July 2023.
8 Ibid.
9 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
10 IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.
11 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
12 UNEP. 2022. Adaptation gap report 2022 : too little, too slow: climate adaptation failure puts world at risk.
13 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: Outlook. Washington, DC: World Bank. .

renewed focus on their ambitions. Off-grid solar is critical for achieving SDG7, and contributes to almost all other SDGs.[14]

As the world reels from the impacts of extreme weather and high temperatures break global records again and again, it goes without saying that we cannot wait any longer. It is in this context that this paper showcases the potential of off-grid solar technologies and business models to help energy poor communities adapt to climate change, combat climate hazards and unlock clean energy opportunities.

Off grid solar: powering adaptation



14 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Powering Resilience and Green Growth

For over a billion of the world's poorest people, a just and clean energy transition has the potential to help modernise agriculture, catalyse enterprise and power life-saving health services: radically transforming their welfare and opportunities. Now imagine we don't do that. A 'Missed opportunity' doesn't come close to describing what we'd lose.

Hon. Okasaai Opolot Sidronius
Minister of State for Energy, Uganda

Climate resilient energy services for off-grid communities

Today, off-grid solar technologies are already powering millions of climate-vulnerable homes and businesses across sub-Saharan Africa, South and SouthEast Asia. At the family, community and national levels, they are providing access to modern energy services, creating energy security, reducing reliance on expensive and often imported fossil fuels, and enabling economic opportunities for those most in need.

As well as providing decentralised and democratised access to electricity, off-grid technologies are also more resilient to climate risks. The small and distributed nature of products such as solar energy kits and irrigation systems makes them portable if extreme climate events lead to forced migration. None rely on long distance cables and infrastructure, making them less affected by floods, high winds and cyclones. They are not susceptible to blackouts during heat waves. Nor are they affected by changes in rain patterns, as is the case when drought impacts large-scale hydropower. In addition, with no fuel supply chain, if it becomes impossible to transport fuel to a region affected by disaster, or should fuel costs rise out of reach, off-grid systems are still able to power essential services during critical periods.

These technologies, and the business models that support their deployment, create an opportunity to provide energy services to the hardest to reach. In turn, these energy services provide a wealth of positive impacts to households and communities living beyond the grid, which are explored throughout this paper.

Access to clean, modern electricity services

Almost half a billion people have already improved their energy service and security through solar energy kits (lanterns and solar home systems), with 214 million of them achieving Tier 1 electricity access and more than 120 million gaining Tier 2+ access.[15] Solar energy kits are also powering millions of micro and medium sized enterprises (MSMEs). They are often bundled with additional products and services such as phone charging, TVs and radios, enabling access to news, emergency announcements and vital adaptation knowledge (see Section 2.4). They are the least costly and most viable way to electrify 55% of those who lack modern electricity today, and to reach the SDG target of universal access.[16]

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15 The Tiers of energy access are described in the Multi-Tier Framework (MTF), developed by ESMAP. The MTF represents an effort to build global, aggregable metrics and a database for evaluating electricity access. Energy access is measured on a tiered spectrum, from Tier 0 (no access) to Tier 5 (the highest level of access).

16 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Powering Resilience and Green Growth

Access to productive use of renewable energy (PURE) technologies

With new innovations in technology, off-grid solar solutions are also increasing productivity and enabling income generation and livelihood activities. Solar irrigation systems and refrigeration units are now serving hundreds of thousands of farms and businesses and providing life-saving health infrastructure.[17] Emerging solar technologies such as walk-in cold rooms, cold storage for transportation and agricultural processing are also showing transformative potential.

While these technologies are less portable than smaller lighting and home system kits, they are also de-linked from grid-scale infrastructure, making them less vulnerable to blackouts and changes in fuel costs. As with other decentralised technologies, they can also be sold and deployed in unelectrified regions without the need to wait for the grid to arrive. Scaling these solutions is critical for communities to build the health and agricultural infrastructure needed to increase their resilience in response to extreme weather conditions brought about by a rapidly warming climate.

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17 Ibid.

Improving people's capacity to respond to shocks

Off-grid solar energy services can help families, businesses and communities to better respond to shocks including climate, and climate-related hazards. The specific green growth impacts they unlock and the ways they help to mitigate climate risks are explored in the subsequent sections of this report, with emergency response to climate disaster discussed in Section 3.3. However, off-grid services also help to improve the *overall* welfare of communities, creating stronger foundations for resilience.

Reducing poverty and creating financial safety nets

Higher incomes, more savings and a wider range of income streams are critical for reducing vulnerability. Without this financial capacity, following a disaster, failure of rains or the myriad other negative events we are seeing today, families living below or near the poverty line may be forced to sell off productive assets to survive, undermining their very ability to recover.[18] Off-grid solar technologies improve resilience through their impacts on poverty reduction in a variety of ways. These include improving a household's potential to make savings, helping to diversify their income streams and enabling them to generate more income. The 2021 Uganda Poverty Report found that new electricity access, including via solar home systems and kits, had the highest impact of any public good on the reduction of poverty levels within the country, leading to a decrease in poverty of over 10%.[19]

Off-grid technologies can also improve income generation by helping businesses to stay open longer, become more connected to market opportunities and/or benefit from key services such as greater access to water and cooling. Off-grid solutions can also help communities restart their economic activities faster after disasters. In some cases, companies selling off-grid solar technologies are also helping to improve financial safety nets, by helping purchasers to access other financial services, such as loans and insurance.[20]

Improving health

Vulnerability to climate and other shocks is also increased by ill health. Families that experience illness often lose vital revenue streams and need to shoulder the additional costs of healthcare,

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18 World Bank (2013) Poverty and Disasters—Why resilience matters. Accessed August 2023.
19 Ugandan Ministry of Finance, Planning and Economic Development (2021) Poverty Status Report 2021.
20 MKOPA. Web page. Unlock progress with a fair and flexible payment plan. Accessed in August 2023.

medicines and travel.[21] In some cases, this can lead to the sale of assets that further compounds and entrenches poverty. Off-grid solar technologies can help families to avoid illness and contribute to improvements in medical infrastructure (see Section 3.4). For example, 89% and 92% of solar home system customers in East Africa respectively report that the technologies improve health and safety, while solar irrigation and cooling systems improve access to clean water and food, which can help reduce water borne illness and malnutrition (see Section 3.1).[22]

Enhancing the capacities of women

Women are disproportionately affected by economic shocks and climate disasters.[23] In regions that lack modern electricity services, agricultural equipment and readily available supplies of clean water, women often bear the brunt of daily labour and water collection.[24&25] When income is drastically affected from sudden external pressure, school fees for girls are often the first to be curtailed. Worse still, in some regions they are at risk of becoming locked into child-marriages as families make desperate choices to survive.[26&27] For example, in the Horn of Africa, the devastating drought that began in 2020 has led to a 50% increase in child marriage, with reports of girls as young as 12 being married to men five times their age.[28] While electricity is no 'silver bullet', its impacts on resilience, poverty reduction and food security have the potential to positively affect the health and safety of women and girls.

Several off-grid solar companies and initiatives are also working to empower women within the clean energy workforce, providing them with the skills and opportunities they need to boost their income and enhance their self-reliance. For example, women-led social enterprises, Solar Sister, Smiling through Light and Frontier Markets have developed business models that specifically enable women as entrepreneurs, prioritising and supporting them in roles such as sales agents, managers and technicians. A wide-range of off-grid companies are also mainstreaming positive gender practises into their operations, working to ensure they have more women in their workforce, and increasing the number of women in technical and management positions.[29] As a young industry, the off-grid sector can be a powerful agent for change if these and other efforts can be built upon and expanded.

© **Power Africa**

21 Ibid.
22 GOGLA (2020) Powering Opportunity.
23 UNFCCC (2022) Why Climate Change Impacts Women Differently Than Men.
24 IUNC (2021) The role of women in water governance. Accessed in August 2023.
25 IFAD (2011) Women and rural development.
26 UNICEF (2022) Child marriage on the rise in Horn of Africa as drought crisis intensifies.
27 UNFCCC (2022) Why Climate Change Impacts Women Differently Than Men.
28 UNICEF (2022) Child marriage on the rise in Horn of Africa as drought crisis intensifies.
29 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Powering livelihoods, creating green jobs and increasing income

Off-grid technologies are already being used in over 10 million micro, small and medium sized enterprises (MSMEs) and creating huge numbers of full-time equivalent (FTE) employment opportunities. Savings generated by owners of small solar products, who no longer need to pay for kerosene, are also often redeployed as investments into livelihoods.[30] Greater income, savings and diversity of assets allow vulnerable populations to bounce back faster from the economic shocks created by climate hazards, while driving climate-smart green growth.

The off-grid sector itself has also unlocked hundreds of thousands of clean energy jobs, most in countries across sub-Saharan Africa and South Asia with fast growing populations and high levels of climate risk.[31] This is especially important given rising youth unemployment and the need to develop new, climate-resilient industries.

Powering MSMEs

Off-grid technologies are providing light, power and connectivity to a wide range of MSMEs, extending the opening hours of shops and restaurants, powering video halls, tailors, barbershops and hair salons, helping informal workers connect with job opportunities, and more. They are improving the financial resilience of energy poor communities and harnessing the use of clean energy to drive economic activity and job creation.

Beyond the provision of light and power, off-grid solar electricity is increasing the use of mobile phones and access to the internet within MSMEs (see Section 2.4). Mobile technology is a key enabler of economic growth, with estimates suggesting that it is responsible for $10 of every $100 of growth seen over the last two decades.[32] In East Africa, an estimated 21 FTE roles are created for each 100 solar home systems sold, with eight FTE and four FTE being created per 100 systems in West Africa and South Asia respectively.[33]

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30 SolarAid (2015). 2015 Impact Report.
31 Power for All (2022). Powering Jobs Census 2022: The Energy Access Workforce.
32 GSMA (2020) Mobile technology and economic growth.
33 GOGLA (2020) Powering Opportunity.

Powering Resilience and Green Growth

Improving livelihoods by powering agriculture

Without the electricity needed to enable mechanisation, rapid improvements in food production, processing and preservation are not possible. In 20 years time, farmers in regions that currently lack electricity and productive use technologies will remain hampered in their efforts to transform their agricultural practices, adapt towards climate-smart farming approaches and increase the income they can gain from their land. Solar electricity and PURE technologies are a fundamental input for modernising agriculture and vital to drive green growth and increase food security (see Section 3.1). In addition, when sales of off-grid technologies are complemented with knowledge around improved agricultural practices, and/or efforts to link customers with regional and national markets, they can rapidly improve economic opportunity.

Within agriculture, solar irrigation systems are already reducing reliance on rain fed production and enhancing crop yields. In some cases they are even increasing the amount of land under cultivation or the number of harvests farmers can bring in. In many instances, this is leading to significant increases in income. In a survey of almost 1200 solar water pump customers in East Africa, 47% reported that the money they earned from the farm since purchasing the system had "very much increased" and a further 43% noted that it had "slightly increased" their income.[34] The three most common factors were greater food production, lower costs, and an increase in the amount of land used for farming.[35]

Refrigeration units, walk-in cold rooms and other cold storage facilities are meanwhile enabling food preservation and can also prove transformational for livelihoods and food security. For example, within two years, SokoFresh, an enterprise which runs 14 walk-in cold rooms across Kenya, has helped over 8500 farmers increase their incomes by up to 40% and created 40 permanent and 1200 seasonal jobs.[36] By taking a holistic approach to their business, the organisation has also been able to use its infrastructure to link cold room customers to new market opportunities and valuable knowledge on regenerative agriculture.
While still at an earlier stage of development, solar powered agri-milling, grinding and processing can also enable the mechanisation of agriculture in the longer term and unlock a range of other economic opportunities.

Jobs in the off-grid solar industry

The distributed renewable energy sector itself is also supporting over half a million direct jobs globally, of which 60% are formal jobs while the rest are informal.[37&38] While informal roles, such as commission-based sales agents, do not always provide a full income, they still play a valuable role in increasing resilience to climate (or other) shocks by improving and diversifying income streams. The majority of workers in the off-grid solar sector are located in rural regions with high levels of energy poverty, in which employment opportunities are often limited.

The potential for growth in sector jobs is significant. For example, to meet universal electrification targets, an additional 650 million people need to be reached with solar lighting and home systems by 2030 which will require an extensive workforce. Even greater numbers will be needed to support the roll out of off-grid solar for health, agriculture, enterprise, and more.[39]

34 Efficiency for Access Coalition and 60 Decibels (2021). Uses & Impacts of Solar Water Pumps. Insights from Kenya, Rwanda, Senegal, Tanzania, Uganda, Zambia.
35 Ibid.
36 Enviu (2022). Food Flow Impact Report 2022.
37 Power for All (2022). Powering Jobs Census 2022: The Energy Access Workforce. This number includes direct jobs in the mini grid and C&I sector.
38 Estimations calculated using the formal vs informal job split recorded for Kenya, India, Nigeria, Ethiopia and Uganda in Power for All (2022). Powering Job Census 2022: The Energy Access Workforce.
39 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Connecting to critical adaptation knowledge

Adapting to climate change and optimising green growth opportunities will require a monumental transfer of knowledge and entirely new systems, relationships and collaborations. Yet amongst those people most vulnerable to climate impacts, hundreds of millions are living without modern information and communications technologies (ICT). This drastically limits their ability to gain critical adaptation knowledge, such as that relating to regenerative agriculture or disaster planning, and hinders their access to information which can boost their overall resilience; for example, information around agricultural markets, economic opportunities and financial services. All of this compounds the inequalities between those that can access knowledge and those that cannot.

60% of the adult population in Africa lack access to smartphones, while over a third of the world's population have never accessed the internet; 96% of whom live in developing countries.[40&41] Greater connectivity is fundamental for providing people in danger of extreme weather events to life-saving emergency and adaptation knowledge. Access to energy and electricity is a key enabler in this regard.

Powering knowledge transfer

An estimated 4.3 million solar powered radios, 1.9 million solar TV's and 30 million off-grid solar energy kits with phone charging capacity have been sold to date; the majority to rural customers who struggle to access basic connectivity services.[42] These have reached over 165 million people.[43] Customer insights illustrate how valuable these are for gaining critical information. For example, surveys of thousands of customers in

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40 GSMA (2022) The Mobile Economy Sub-Saharan Africa 2022.
41 ITU (2021). Facts and Figures 2021: 2.9 billion people still offline.
42 Insights on solar-powered radios and solar energy kits with phone charging capacity are calculated using the data from GOGLA affiliate companies and the market estimation model developed by Open Capital Advisors for the Off-Grid Solar Market Trends Report 2022: State of the Sector. Data on solar-powered TVs uses data from GOGLA affiliates only as this is expected to make up a greater part of the total market.
43 Ibid.

Powering Resilience and Green Growth

East and West Africa found that having a solar home system enabled the vast majority to use their phone more (89% and 93% respectively).[44] While data from solar TV customers found that more than 50% reported that their knowledge and education had significantly improved and another 45% said that it had improved a little.[45] 90% reported improved access to the news.[46]

By helping to provide a better power supply, and creating access to consumer financing plans, the off-grid sector is also enhancing access to the web. A study in Cote d'Ivoire found that mobile internet penetration jumped by 31% when customers had access to PAYGo solar, most likely a result of better phone charging and financial inclusion.[47]

Several off-grid companies have diversified their product ranges in recent years to become leading sales channels for mobile phones, tablets and other ICT services.[48] For example, OffGridBox has added wifi to the services provided by some of its solar 'hubs' to enhance rural connectivity, while M-KOPA extended its product line to include smartphones in 2020 and gained one million customers in the first year alone.[49&50] The company reported that 40% of its smartphone customers bought one for the first time, and 45% of them are using their phone to start or support a business.[51]

All of these channels are vital for sharing knowledge that can help to unlock green growth and mitigate the risks of climate hazards. Further insights on the importance of solar-powered knowledge sharing for food security and emergency planning and response can also be found in sections 3.1, 3.2 and 3.3.

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44 Efficiency for Access Coalition & 60 Decibels (2020). USE & IMPACT OF SOLAR TVS Lean Data insights from Kenya, Rwanda, Tanzania, Uganda.
45 Ibid.
46 Ibid.
47 GSMA (2020). The Value of Pay-As-You-Go Solar for Mobile Operators Insights from customer journeys in Benin and Côte d'Ivoire.
48 Ibid
49 Coldewey, D. (2018). OffGridBox raises $1.6M to charge and hydrate rural Africa with its all-in-one installations. Accessed in August 2023.
50 MKOPA (2021)2021 Impact Report.
51 GSMA (2022). M-KOPA: Applying the pay-as-you-go model to smartphones in Africa

Combating Climate Hazards

© Alexey Demidov Unsplash

Those least responsible for climate change are the worst affected by it. We must give them the tools they need to combat the droughts, floods and storms that they are already suffering. Today.

Patrick Tonui
Head of Policy, GOGLA

Reducing drought risk and food and water insecurity

Since 2000, the number and duration of droughts has risen by 29%.[52] This has had devastating consequences. Linked economic losses have reached USD 124 billion globally.[53] The number of undernourished people has also dramatically increased.[54] For example, the drought in the Horn of Africa since October 2020 has led to 23 million people at risk of starvation and 7.5 million acutely malnourished children.[55] 3.3 million people have been displaced.[56] These impacts are worsening. By 2050, droughts could affect over three quarters of the world's population, and reduce yields in West and Central Africa by 13%.[57] At the same time, the sub-Saharan African population is expected to double.[58]

Droughts are already leading to extensive loss of life, incalculable suffering, and chronic impacts on the physical development of children. They are destroying political, economic and social systems and adding to the burden of migration: with rural populations seeking refuge in urban centres and young people fleeing areas ravaged by destitution. There is an urgent need to help drought prone communities.

Off-grid solar irrigation has a vital role in providing access to clean safe drinking water and for food production, while solar cooling systems are critical for preservation of agricultural produce. Solar communications technologies, such as radios, phones and TV's, are also critical conduits for sharing knowledge on climate-smart and regenerative agriculture.

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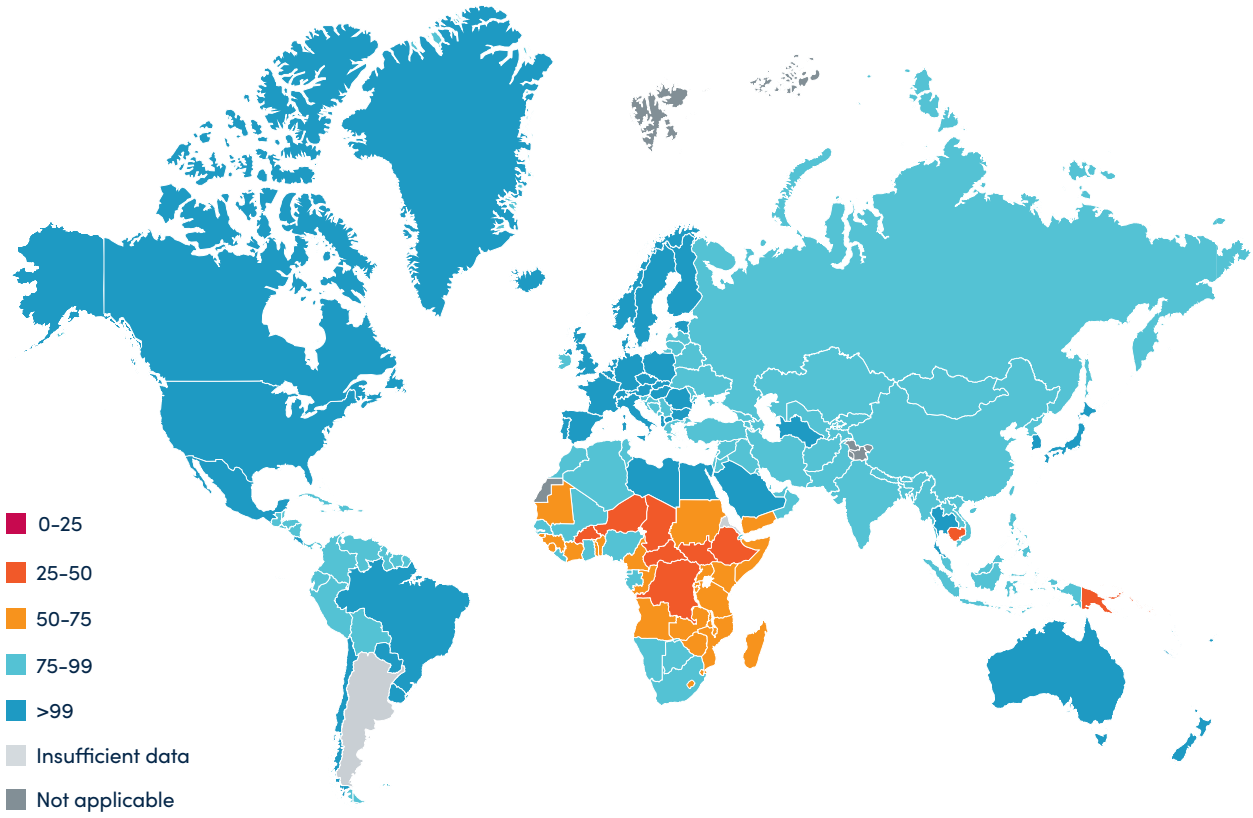
52 UNCDD (2022) Drought in numbers 2022.
53 Ibid.
54 UNFCCC (2020) Web article. Climate Change Is an Increasing Threat to Africa. Accessed in August 2023.
55 The World Economic Forum (2020). Web article. Drought is putting millions at risk in the Horn of Africa. Accessed in August 2023.
56 Ibid.
57 UNFCCC (2020) Web article. Climate Change Is an Increasing Threat to Africa. Accessed in August 2023.
58 The Economist. (2020). Africa's population will double by 2050. Accessed in August 2023.

Combating Climate Hazards

Improving access to potable water

1.42 billion people, including 450 million children, live in areas of high or extremely high water vulnerability.[59] Most are located in regions that are also seeing the most acute impacts of climate change, with its effects compounding risks.[60]

Figure 3 - Proportion of the population using at least basic drinking water services (%)[61]



Rapidly deployable solar water pumps (SWPs) provide a key solution. In recommendations by UNICEF's 'Re-imagining WASH: Water Security for All' research and campaign, SWPs are profiled as a critical tool for achieving climate-resilient WASH services. To help achieve its goals, UNICEF has already installed over 4600 community solar water pumps in Nigeria, recognising that they are both cleaner and more cost effective than alternatives.[62] Another example of the use of SWPs to provide clean water is the UNHCR Project Flow initiative, which is expected to reach 800,000 refugees and host community members in Ethiopia, Mauritania, Rwanda, Sudan, South Sudan and Zambia.[63]

59 UNICEF (2021). Water Security for All.
60 WHO (2021.) Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the SDGs.
61 Ibid.
62 UNICEF (2022). Web article. UNICEF water pumps: a source of life, health and resilience. Accessed in August 2023.
63 UNHCR (2022). Web article. New green UNHCR initiative to transform refugees' access to clean water. Accessed in August 2023.

Combating Climate Hazards

Potential maladaptation
While the potential of SWPs and irrigation systems to improve water supply in areas of drought is significant, if not approached correctly, the use of these technologies can also present a risk. Unintended overuse of water could lead to the depletion of groundwater supplies, especially in times of drought.[64] This must be mitigated. In addition, ground water supplies may be lower than usual in drought periods, limiting the amount of water available. Without knowledge around water management this could lead SWP users to assume that there will be a greater availability of water than available in reality. Appropriate review of water sources before the sale or deployment of an SWP, alongside education of SWP users on the optimal use of their system, is therefore critical to the successful adoption of the technology.

Increasing crop yields and food security

Solar irrigation systems are boosting crop yields and have a huge potential for impact. For example, better irrigation in sub-Saharan Africa could lead to a 50% improvement in agricultural productivity.[65] Research by 60 Decibels on SWP customers in Kenya, Rwanda, Senegal, Tanzania, Uganda, Zambia found that 65% reported that their productivity 'very much increased' due to their system, with a further 31% advising it was 'slightly increased'.[66] In the same study, 41% of SWP users also reported that the area of land that they were cultivating was 'very much increased', with 28% reporting that it was 'slightly increased'.[67] Solar irrigation is anticipated to play a crucial role in the production of food in climate vulnerable regions.

As noted in Section 2.4, greater access to information is critical for building resilience and adaptive capacities. This is especially true in the agricultural space where interventions to enhance access to solar irrigation or cooling can be used to help increase access to knowledge on other resilience measures such as climate-smart agriculture and water management. Household surveys by the IMF in Ethiopia, Malawi, Mali, the Niger and Tanzania found, among other factors, that broadening access to information on food prices and weather (even with simple text or voice messages to inform farmers on when to plant, irrigate or fertilise) has the potential to reduce the chance of food insecurity by 30%.[68]

An example of solar-driven connectivity being used to enhance the capacities of smallholder farmers is SunCulture's use of data to help their customers improve their yield size. By analysing real time usage insights from their solar water pumps, alongside complementary data such as weather observations and forecasts, they can model how particular usage patterns result in better yields. From this analysis they can then tailor advisory messages to customers via SMS.[69]

Preserving food and boosting nutrition

Today, 14% of food is lost unintentionally between harvest and distribution, with the number jumping to an estimated 37% in sub-Saharan Africa.[70&71] Solarised cold storage units used within the agricultural value chain can rapidly change this dynamic, with recent market assessments for Nigeria, India and Kenya recognising their particular promise for storing fresh fruits, vegetables and dairy produce.[72] For example, EcoZen in India has already developed 850+ cold storage units, reaching more than 70,000 farmers, and has complemented their cold storage solutions with their EcoConnect platform to link farmers to markets.[73] Solar cold storage solutions are also being explored for different parts of the value

64 Efficiency for Access, International Water Management Institute (2021). Sustainable expansion of groundwater based on solar water pumping for smallholder farmers in sub-Saharan Africa.
65 Ringler, Claudia; Mekonnen, Dawit Kelemework; Xie, Hua; Uhunamure, Agbonlahor Mure. 2020. Irrigation to transform agriculture and food systems in Africa South of the Sahara. In 2020 Annual trends and outlook report: Sustaining Africa's agrifood system transformation: The role of public policies. Resnick, Danielle; Diao, Xinshen; and Tadesse, Getaw (Eds). Chapter 6, Pp. 57-70. Washington, DC, and Kigali: International Food Policy Research Institute (IFPRI) and AKADEMIYA2063.
66 60 Decibels (2021) Uses and Impacts of Solar Water Pumps.
67 Ibid.
68 World Meteorological Organization (2023). State of the Climate in Africa 2020.
69 GSMA (2021) Digital Innovation for Climate Resilient Agriculture.
70 Efficiency for Access (2020) Creating a more resilient food system through sustainable refrigeration.
71 WRI (2021). Web article. How to Reduce Food Loss and Food Waste in Africa. Accessed in August 2023.
72 Efficiency for Access (2023) Web page. Key Cold Chain Infrastructure Markets. Accessed in August 2023.
73 Ecozen (2023). Web page. Ecoconnect. Accessed in August 2023.

chain, to help preserve food from 'farm to fork'. As well as walk-in cold rooms, this includes the cold storage of food during transportation from farms to local markets, and local markets to regional or national centres. For example, recognising the need to preserve produce at all times, ColdHubs, which operates across 28 states in Nigeria, expanded their business model to include refrigerated trucks.[74]

Solar-powered refrigeration units are also helping to reduce food wastage for MSMEs, in the home, and within key industries such as fishing and dairy. Over 120,000 people are currently benefiting from access to highly efficient solar refrigeration units.[75]

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74 ColdHubs (2023) Web article. ColdHubs Moves From 22 To 28 States In Nigeria. Accessed in August 2023.
75 GOGLA (2023). Global Off-Grid Solar Market Report: Semi Annual Sales and Impact Data. Jul - Dec 2022.

Adapting to heat stress

The past eight years are the warmest on record.[76] This has led to periods of extreme heat around the world, with many of the most affected regions located within sub-Saharan Africa, South Asia and Southeast Asia.[77] For example, in India, prolonged temperatures of over 40 degrees centigrade contributed to a loss of 5.6% of GDP in 2021 due to a sharp drop in productivity, damage to infrastructure and impacts on agriculture and crop failure that even led to a ban on the export of wheat in 2022.[78&79] For hundreds of millions of people, extreme heat has impacted health and livelihoods, hundreds of thousands have died.[80]

Under high-emissions climate scenarios, extreme heat events are 20x more likely to occur after 2050.[81] This will have profound impacts on productivity, agriculture and public services. In addition, extreme heat will become an ever increasing threat to life. Globally, 1.2 billion people in poor rural and urban settings are already at high risk due to the lack of cooling.[82] Rapidly rising temperatures will place more people at the limits of physical endurance. Intensive heat of 31-35+ degrees Celsius combined with humidity affects the human body's ability to cool and can lead to the failure of key organs and loss of life.[83]

Solar-powered fans provide vital space cooling in temperatures up to 35 degrees Celsius.[84] They are particularly critical for communities who have no access to air conditioning systems and those living in areas where grid power becomes overwhelmed during heat waves. Solar -powered communications are also a key mechanism for information sharing in advance of, and during, periods of extreme heat.

Solar-powered space cooling

Globally, solar space cooling has the potential to benefit 318 million people who lack access to electricity and live in countries with the highest risk of extreme-heat.[85] Solar fans are less expensive to purchase and less costly to operate than air conditioners, making them a fast and effective way to reach weak and off-grid communities. High-performing solar-powered fans are currently benefiting over 7.5 million people and are being used in over 43,000 businesses, predominantly in South Asia.[86] These are creating significant benefits for comfort and productivity. In a survey of 1600 fan customers in Bangladesh, 81% said that their quality of life had improved due to the technology and households reported 2 hours 20 minutes of extra productive time a day on average.[87] There is huge scope for the deployment of solar-powered fans to be accelerated.

Given the rise in extreme heat across unelectrified areas and regions where grid infrastructure can become overwhelmed at times of peak temperature, the companies active in the off-grid industry are also well placed to use R&D funding to accelerate the development of new efficient cooling appliances that can also provide cooling solutions for conditions that reach over 35 degrees. As temperatures continue to increase, such products will be vital for the health and safety of millions.

Driving adaptation through vital knowledge sharing

As with knowledge sharing to help mitigate the impacts of drought on agriculture, timely information is crucial for planning for, and responding to, extreme heat. For example, in the recent heat waves across India, affected states implemented Heat Action Plans where phones, TV, radio and the internet were used to disseminate early warnings of extreme heat, practical information on preventative measures, and the location of 'cooling centres'.[88]

76 World Meteorological Organization (2023) State of the Global Climate in 2022.
77 SEforALL (2023) Web page. Rural poor at risk in 2022. Accessed in August 2023.
78 The Lancet. (2022). The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels.
79 Reuters (2022). Web article. India bans wheat exports as heat wave hurts crop, domestic prices soar. Accessed in August 2023.
80 The Guardian (2022). Web article. Revealed: how climate breakdown is supercharging toll of extreme weather. Accessed in August 2023.
81 Fischer, E.M., Sippel, S. & Knutti, R. Increasing probability of record-shattering climate extremes. Nat. Clim. Chang. 11, 689–695 (2021). https://doi.org/10.1038/s41558-021-01092-9.
82 SEforALL (2023) Web article. Global access to cooling gaps in 2022. Accessed in August 2023.
83 The Guardian (2022). Web article. Why you need to worry about the 'wet-bulb temperature'. Accessed in August 2023.
84 WHO (2018) Web page. Heat and Health. Accessed in August 2023.

85 SEforALL. Webpage. Global access to cooling in 2020. Accessed in August 2023.
86 GOGLA (2023). Global Off-Grid Solar Market Report: Semi Annual Sales and Impact Data. Jul - Dec 2022.
87 Efficiency for Access (2020). The Socioeconomic Impact of Super Efficient Off-Grid Fans in Bangladesh.
88 EOS (2021). Web article. Specifically Tailored Action Plans Combat Heat Waves in India. Accessed in August 2023.

Improving disaster response and planning

Today, 86 million people are at risk of flooding due to increases in heavy rains.[89] By 2030, climate and demographic change will add 25 new countries to the 32 already experiencing increasing floods.[90] Countries in South and SouthEast Asia are at particular risk: as exemplified by the devastating flooding in Pakistan in 2022 which saw over 7.5 million people displaced.[91] Countries in Sub-Saharan Africa are amongst those facing rapid increases in flood risk.

Cyclones and their knock-on effects are also intensifying due to climate change. For example, in early 2023, cyclone Freddy tore into Madagascar, Mozambique and Malawi. It became the longest lasting tropical cyclone ever recorded, intensifying an unprecedented seven times in its month-long duration. Cyclones are expected to become more powerful as a result of climate change, with sea level rises also exacerbating coastal damage and storm surges. In the context of such extreme weather events, disaster planning and response can be the difference between life and death.

Power for early warning alerts and coordinating aid

As with heatwaves, ensuring that vulnerable communities gain early warning alerts and practical information on risk reduction through radio, TVs and mobile phones can save lives. For example, recent research from Bangladesh found that households changing their energy source to a solar home system was associated with a 64% reduction in disaster damage, indicating significantly improved resilience.[92]

Compact and portable solar energy technologies also provide a crucial input to disaster response by powering communications to connect aid agencies with communities in affected regions, providing cold storage for vital medical supplies and supplying light and phone charging services for emergency shelters. For example, in the aftermath of cyclone Idai in Mozambique, the grid stopped operating for several days and communications infrastructure was severely hampered. Solar energy kits with lighting and phone charging capabilities were provided to NGOs by off-grid companies to support response efforts and help them coordinate aid.[93] The planned use of off-grid solar to power early warning information and relief efforts could provide far greater benefits to emergency response efforts.

The importance of off-grid solar in humanitarian settings

Since 2008, an average of 21.5 million people a year have been forcibly displaced due to climate hazards, such as floods, storms, wildfires and extreme temperatures.[94] As climate disasters escalate, so too will the number of people forced to flee their homes. While off-grid solar can play a role in supporting adaptation and resilience to reduce displacement, it can also play a part in improving the welfare of those who are living in humanitarian settings as a result of the climate emergency. For example, off-grid technologies can help to provide light and power for displaced families, enable them to stay connected to their community networks, support them to build micro-enterprises, power access to potable water, or provide them with irrigation and cooling to help grow and preserve food. In 2022 alone, at least 1 million solar energy kits were provided to people in areas of humanitarian crisis.[95]

89 Tellman et al. (2021) Satellite imaging reveals increased proportion of population exposed to floods.
90 86 million people are now exposed to floods – how can satellite data help? - Climate Champions (unfccc.int).
91 Pakistan floods: Six month wait for water to recede, warn relief agencies | UN News.
92 Solar energy and natural disasters: Exploring household coping mechanisms, capacity, and resilience in Bangladesh - ScienceDirect.
93 The role of solar lights and solar home systems in modern day disaster relief | GOGLA.
94 UNHCR (2016) Web page. Frequently asked questions on climate change and disaster displacement. Accessed in August 2023.
95 GOGLA analysis of global sales and impact data for 2022, gathered for the semi-annual Global Off-Grid Solar Market Reports.

Minimising the impacts of disease

Climate change has increased the risk of nearly 60% of all known diseases, including malaria, Zika and dengue.[96] For example, changes to warming and precipitation increase the geographic range for common carriers of disease, such as mosquitoes, ticks and fleas, whilst more flooding increases the prevalence of wastewater and the transmission of diseases such as norovirus and hepatitis.[97] Warming also has a positive impact on the 'bite rate' of mosquitoes and increases the virulence of heat-resistant viruses that are better able to cope with the human body's main defence: fever.[98] Risk of disease is further increased by the extreme situations that people are being placed in due to climate change. For example, risk of disease is greater amongst those forced to drink unsafe water after flooding, or who have become malnourished as a result of drought.[99]

Off-grid solar can play a critical role in both reducing the risk of disease and in treating the impacts of illness.

Improved access to potable water

Contaminated drinking water can transmit diseases such as diarrhoea, cholera, dysentery, typhoid and polio and is estimated to cause 485,000 diarrhoeal deaths each year.[100] As explored in Section 3.1, solar water pumps are driving access to clean water, which significantly reduces the risk of disease. For example, the WHO estimates that 10% of all global disease can be avoided if underserved communities gain access to safe drinking water.[101] In addition to the potential for solar-powered pumps to increase access to potable water, early research suggests that the risk of diarrhoea due to low-quality water supply can be reduced by almost 40% through the use of solar disinfection technologies.[102]

Greater access to health information

As highlighted in Section 2.4, off-grid solar technologies are also powering knowledge transfer. Greater communications around public health can provide a valuable boost to governments and health agencies. This was demonstrated extensively during the COVID-19 pandemic where ICT was used to disseminate health and safety information. The pandemic also saw off-grid companies using their own infrastructure to reach customers with life-saving information. For example, in the Democratic Republic of Congo, Bboxx retrained its call centre staff so that they could inform their customers about health and safety information from the Government and international health organisations.[103]

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96 Mora, C., McKenzie, T., Gaw, I.M. et al. Over half of known human pathogenic diseases can be aggravated by climate change. Nat. Clim. Chang. 12, 869–875 (2022). https://doi.org/10.1038/s41558-022-01426-1.
97 Ibid.
98 Ibid.
99 Ibid.
100 WHO (2022) Web page. Drinking Water. Accessed in August 2023.
101 Hulton, Guy & World Health Organization. (2012). Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage. World Health Organization. https://apps.who.int/iris/handle/10665/75140.
102 Soboksa, Negasa & Donacho, Dereje & Alemu, Bezatu & Gari, Sirak & Beyene, Abebe. (2020). Effectiveness of solar disinfection water treatment method for reducing childhood diarrhoea: a systematic review and meta-analysis. BMJ Open. 10. 1-11. 10.1136/bmjopen-2020-038255.
103 Power Africa (2020) Web article. Serving and Supporting Off-grid Customers During COVID-19. Accessed in August 2023.

Combating Climate Hazards

Vaccine storage

Since 2017, Gavi has delivered more than 40,000 solar direct drive (SDD) fridges to 36 African countries.[104] The Head of the organisation's Health Systems and Immunisations Strengthening team credited the off-grid equipment for achieving a 25% jump in child vaccination rates in Africa between 2010 and 2020.[105] At least 30 countries, including Sao Tome and Principe, Nigeria, Togo, Somalia, Indonesia, Kyrgyzstan have also procured, or are procuring, cold chain equipment such as solar direct drive refrigeration units using funds from Gavi and the World Bank.[106]

SDD systems are also being used in areas that have been hit by climate disaster. For example, in Malawi, the devastating impacts of Cyclone Freddy compromised the country's hydro electricity plant, stopping electricity supply in some regions. UNICEF worked with local health teams to deploy SDD fridges to affected areas, allowing them to get vaccinations back on track.[107] The organisation was already operating in the country, having supported the roll out of 450 SDDs. All those previously deployed were reported as operational after the cyclone, indicating their relative resilience.

Electricity for health centres

Two thirds of health facilities in low and middle income countries lack access to reliable electricity, and in Sub-Saharan Africa the proportion without power reaches three quarters.[108] Since 2017, the UNDP has supported the solar electrification of 1,000 health centres and storage facilities in 15 countries, and the World Bank is supporting 25 countries to power health centres with off-grid solar.[109&110] The impacts of healthcare electrification are immediate. For example, in India, primary health centres in the state of Chhattisgarh with off-grid solar supply admitted over 60% more patients and conducted almost twice the number of child deliveries in a month than those operating without solar.[111] As well as powering cold-chain equipment for vaccine storage, off-grid electricity can power clean water, lighting and life-saving medical equipment. Smaller solar solutions are also being deployed to rural clinics. For example, over 13 million mothers and newborns served in health centres using 'solar suitcases' specifically designed to aid in childbirth.[112]

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104 Gavi (2023). Web article. How solar power is revolutionising immunisation in the most remote parts of the world. Accessed in August 2023.
105 Reuters (2020) Web article. Can solar fridges helping vaccinate African children work for COVID-19? Accessed in August 2023.
106 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
107 GAVI (2023) Web article. Sunny with a chance of cyclones: Malawi's cold chain goes solar powered. Accessed in August 2023.
108 UNDP. Web page. Solar for Health. Accessed in August 2023.
109 Ibid.
110 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
111 Ramji, Aditya & Patnaik, Sasmita & Mani, Sunil & Dholakia, Hem. (2017). Powering Primary Healthcare through Solar in India Lessons from Chhattisgarh. 10.13140/RG.2.2.11406.66886.
112 We Care Solar. Web page. Our Impact. Accessed in August 2023.

Minimising CO_2e Emissions

There are no magic bullets that will solve all of our greenhouse gas problems, but replacing kerosene lamps is low-hanging fruit, and we don't have many examples of that in the climate world.

Professor Kirk Smith,
University of California Berkeley

Minimising CO_2e Emissions

Eradicating kerosene lanterns

Billions of litres of kerosene are still being used to light homes, businesses and communities at night.[113] The poorest households are most affected by its toxic emissions, with women and children disproportionately affected.[114&115] As well as CO_2, kerosene lamps emit toxic black carbon in the form of soot that has extremely high warming potential. Research to equate the global warming potential of this black carbon with CO_2 shows that, on average, for every kerosene lantern avoided, 431 kg of CO_2 equivalent (CO_2e) is saved per year.[116] Without including black carbon, the replacement of a kerosene lantern with a solar alternative is still estimated to avoid 92 kg of CO_2 per year.[117]

When the full CO_2e impact of replacing kerosene lanterns with solar is calculated (e.g., including black carbon), an estimated 190 million metric tons of CO_2e has been avoided to date. This is equivalent to taking 51 coal fired power plants off-line for a year.[118&119]

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113 Brookings (2013). Black carbon and kerosene lighting.
114 The poorest households predominantly use kerosene lanterns with open flames, such as those made from tins and cans. Some slightly wealthier households that use kerosene may still use open flames but others may purchase a covered hurricane or pressurised lamp, which helps to capture the black carbon and thus reduce emissions and air pollution.
115 Lam, Nicholas & Muhwezi, Godfrey & Isabirye, Fred & Harrison, Kat & Ruiz, Ilse & Amukoye, Evans & Mokaya, Tom & Wambua, Margaret & Bates, Michael. (2017). Exposure reductions associated with introduction of solar lamps to kerosene lamp-using households in Busia County, Kenya. Indoor Air. 28. 10.1111/ina.12433.
116 GOGLA (2020) Standardised Impact Metrics for the Off-Grid Solar Energy Sector.
117 Namene. Web page. Carbon credits. Accessed in August 2023.
118 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
119 US Environmental Protection Agency. Web page. Greenhouse Gas Equivalencies Calculator. Accessed in August 2023.

Displacing diesel

In countries which lack electricity, or where the grid provides only intermittent supply of power, off-grid solar solutions are also beginning to replace the use of diesel generators.[120] Backup generators are estimated to emit over 100 million metric tons of CO_2e every year. 25 million were deployed in developing countries in 2016 alone, producing the equivalent power to 700-1000 coal fired power plants.[121]

Diesel is also used to power 'direct drive' technologies such as solar water pumps. Here too the potential CO_2e reduction that can be generated by switching these for solar-powered alternatives can be significant. For example, the KUSUM scheme in India, focussed on switching diesel powered water pumps and irrigation systems with solar-powered alternatives, aims to avoid emissions of up to 27 million tons of CO_2e each year.

Solar home systems provide an important alternative to diesel generators. For example, real time energy use tracking in Nigeria reveals that, at their current rate of energy consumption, over 50% of MSMEs could be serviced by an off-grid solar system of 300Wp or below.[122] Off-grid companies are also beginning to sell larger solar generators. For example, A2EI has already deployed over 1000 solar generators in Nigeria, with CO_2e reductions accredited by the Gold Standard.

© **Village Power**

120 IFC (2019). The Dirty Footprint of the Broken Grid.
121 Ibid.
122 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Minimising CO_2e Emissions

Avoiding food loss emission

Efficient solar cold chain solutions, such as walk-in cold rooms and refrigerated transport, can significantly reduce the amount of high-global warming potential refrigerants in use and displace the use of diesel (where this is currently used to run systems). They are also a key contributor to the reduction of food loss waste. Reducing food loss waste significantly increases the amount of emissions that can be avoided through use of these technologies. In the off-grid context, emissions savings are made by avoiding the use of manure and fertiliser for food that is wasted, avoiding the transportation of spoiled produce and avoiding the release of emissions from rotting food.[123]

For example, when exploring the greenhouse gas (GHG) reduction potential of off-grid cold rooms, recent research found that, if food losses are avoided across sub-Saharan Africa via off-grid cold rooms, it could lead to a reduction of 5.5 million tonnes of CO_2e per year by 2030; in South Asia GHG reductions would be 12.8 million tonnes of CO_2e a year, equal to taking 2.8 million cars off the road.[124&125]

© GIZ WE4F

123 WRI (2015) What's Food Loss and Waste Got to Do with Climate Change? A Lot, Actually.
124 Efficiency for Access (2023). Lifecycle Greenhouse Gas Emissions Assessment of Off- and Weak-Grid Refrigeration Technologies.
125 EPA (2023). Greenhouse Gas Equivalencies Calculator. Accessed in August 2023.

Minimising CO_2e Emissions

Avoiding carbon lock-in

Off-grid solar solutions are the fastest and most effective way to reach hundreds of millions of people with clean energy services. They will also enable a low emissions pathway to achieving universal electricity access and help to avoid further 'lock-in' to high carbon alternatives. For example, providing first time electricity access to 130 million households in sub-Saharan Africa via off-grid solar solutions, rather than fossil fuel infrastructure, will save over 200 million tonnes of CO_2e.[126] Replacing the 9 million diesel generators currently in use with solar gen-sets will save a further 226 million tonnes.[127] Combined, this is more than the annual emissions of the United Kingdom.[128]

Emissions can also be avoided by low carbon electrification of industries such as agriculture, enterprise, health and transport. For example, net food-related GHG emissions from the food sector would rise by 10% if cold chain was introduced into sub-Saharan Africa that has the same efficiency levels as that currently used within the United States. Adoption of more efficient, low carbon alternatives such as highly efficient DC appliances powered by off-grid solar, is therefore vital. Emissions growth can only be avoided if the countries who contributed least to the climate disaster are supported to develop using climate-smart technologies.

© **Power Africa**

126 Shell Foundation, Rockefeller Foundation and Catalyst Off-Grid Advisors (2021). Unlocking Climate Finance to Accelerate Energy Access in Africa

127 Ibid.

128 UK Office for National Statistics (2022). Greenhouse gas emissions and other environment measures, UK and European countries 2020.

Technology Overview

Technology Overview

Introduction

While the off-grid technologies covered in this paper could enable significant resilience, adaptation and mitigation impacts, they are at different levels of technical and market maturity and present different value propositions for consumers. This section of the paper briefly explores the stage of development and level of deployment that each technology has reached and indicates the affordability for unelectrified and weak grid populations. The section aims to illustrate that, despite the fact that off-grid solar technologies are a critical tool for climate adaptation, they will not reach the communities that need them most, or be optimised, without a significant and holistic effort to support their adoption.

© Solaris Offgrid

Solar energy kits, with accompanying communications appliances

Scale and maturity of technology: Solar energy kits are the most mature off-grid technologies. These include solar lanterns, small solar home systems (SHS), large SHS and solar generators. As the size of products increases the number of people that they have currently reached decreases: a direct result of the higher cost of larger systems. This can be observed when looking at the global impact estimates. Of the 490 million people who are currently accessing solar energy kits, 370 million have an energy service that is below Tier 2, but only a third as many (120 million) receive a Tier 2+ energy service. Nevertheless, technologies at all system sizes are deemed mature, as are business models for lanterns and SHS. Business models that support the sale of solar generators are at an earlier stage but appear to be gaining significant traction.

Affordability: Solar lanterns are the most affordable off-grid solar technologies, with costs ranging from USD $4-40.[129] Larger lanterns come with additional benefits such as phone charging capacity or USB sockets that can be used to power a small radio. On a cash basis, 96% of unelectrified customers are estimated to be able to afford the smallest (light only) lanterns without overstretching their finances and needing to make trade-offs between purchasing the lantern and purchasing other primary goods, whilst 74% should be able to afford larger lanterns without such tradeoffs.[130] Consumer financing, which allows customers to pay for their products over time, may help extend affordability to more households but requires greater levels of infrastructure and receivables financing, and will become more challenging to deploy commercially for the lowest income households. However, this still leaves millions of families unable to afford solar lanterns without subsidy, support or business model innovation.

The prices for SHS start at around USD $33 for an 11-20Wp system, and can go as high as USD $1000 for a 100Wp system accompanied by DC-powered appliances.[131] Most SHS sold as solar energy kits (e.g. not built via component parts) automatically come with phone charging capacity and USB ports, and many are now sold with TVs, radios, or fans. 40Wp+ systems are commonly able to run a solar-powered TV, with some small and highly efficient TVs even able to run on a 20Wp system.[132] Radios can be charged by the smallest sized SHS. With consumer financing, such as PAYGo, 76% of unelectrified households are expected to be able to afford the smallest 'multi-light' kits without making tradeoffs, and 57% should be able to afford 11-20Wp systems.[133] Without tradeoffs, only 21% are able to afford 20-50Wp systems, 13% to afford 50-100Wp systems and 4% able to afford larger systems.[134]

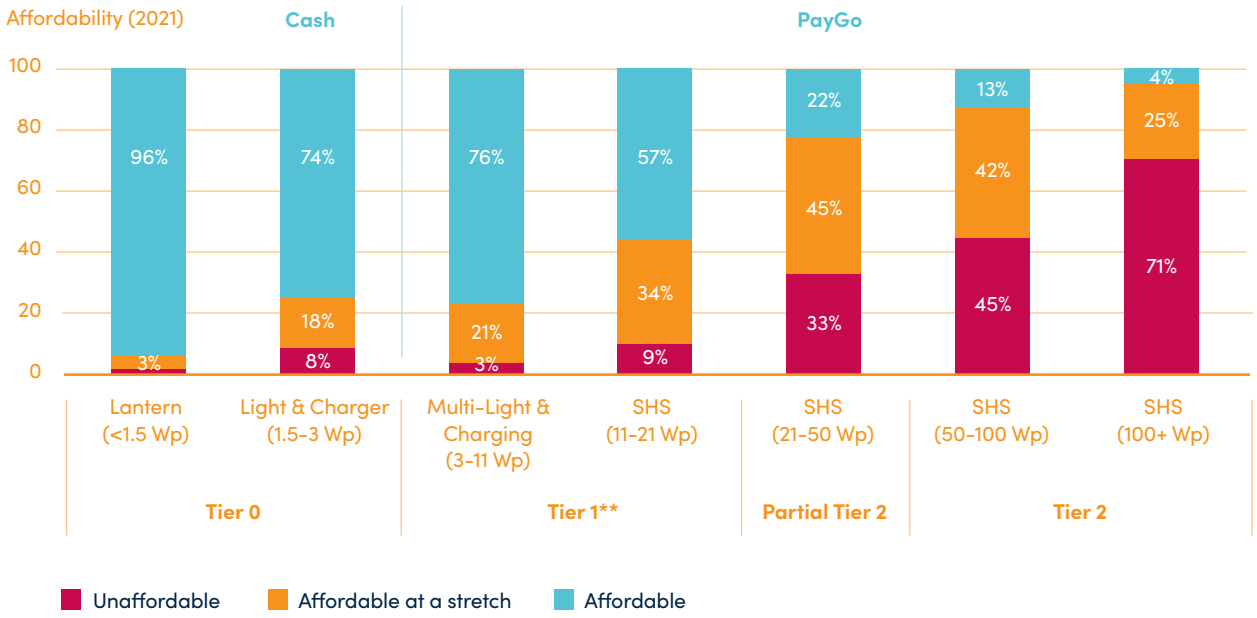
Solar generators, powered by PV panels larger than 350Wp and often over 1000Wp, can only be bought by a limited number of households. They are primarily being targeted at businesses that can increase their revenues to cover the cost of buying the generator over time, or who currently use diesel generators and can replace their payments for diesel with payments for a solar-based system, eventually making savings once they have bought it outright.

This illustrates that, while off-grid solar lanterns, SHS and generators can create significant benefits for consumers and help climate-vulnerable households access light, power and knowledge, for them to reach millions of the lowest income and most climate vulnerable homes, businesses and communities, dedicated support efforts are needed.

129 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
130 Ibid. Please note that the data shared uses 'ability to pay' analysis based on national income distribution. Ability to pay may be even lower for rural or hard-to-reach areas.
131 Ibid.
132 GOGLA analysis of SHS sold by their Members and affiliates.
133 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
134 Ibid.

Technology Overview

Figure 4 - Solar energy kit, ability to pay, based on national income distribution[135]



Definitions:

- Unaffordable: More than 15% of annual income
- Affordable at a stretch: Between 5-15% of annual income
- Affordable: Less than 5% of annual income

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135 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Solar irrigation

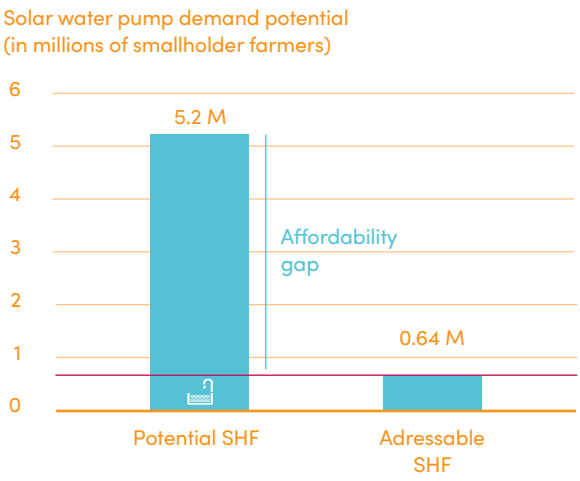
Scale and maturity of technology: There are a range of different off-grid solar irrigation systems, from community sized pumps and water systems, to those used for individual smallholder farmers. Data on the full size of the market is still unclear. However, the number of SWPs sold by companies affiliated with GOGLA, are now over 50,000, while almost 200,000 have been sold in India as part of the KUSUM scheme.[136] Thousands more pumps, and larger community irrigation systems have also been sold in other regions. This indicates that there is already a strong market for SWPs. The core components within solar irrigation systems, such as PV panels, pumps, hoses and nozzles, are also mature and systems can be bought as a complete unit or assembled together. However, extensive innovation is still underway around software to optimise the technology, such as sensors and PAYGo software, and ongoing R&D continues to improve efficiencies, durability and service.

Affordability: Affordability is a key challenge to the adoption of SWPs. To create the biggest (and critical) resilience impacts, small-holder farmers on very low-incomes or who sustain themselves only via their land must benefit from these and/or other irrigation technologies. Yet, as the cheapest SWPs cost over USD $100, they are out of reach for the majority of smallholder farmers. For example, in sub-Saharan Africa, an estimated 5.2 million smallholder farmers could benefit from SWPs, yet only an estimated 640,000 can afford them.[137]

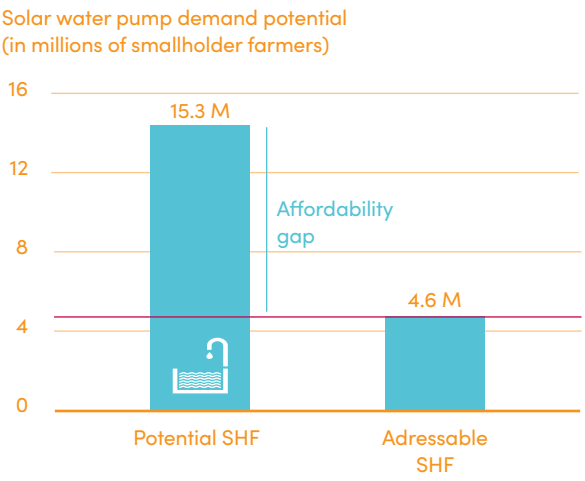
Although this analysis does not include data on the increased incomes that can be achieved through the use of the systems (which in many cases can help to cover the cost of buying the system in instalments, and lead to profit), or the role that consumer financing can play in smoothing costs, it still illustrates the challenge of affordability. What's more, even where incomes are improved, growth in farm yields may not be instantaneous, farmers' access to new markets to sell more produce may need to be built, and the cost of purchasing a system may still create a worrying level of risk for farmers and their families. Awareness and capacity building to raise people's interest and trust in solar irrigation and to share knowledge on its effective use is also a limiting factor in its deployment.

Early subsidy schemes to help cover the costs of the system, such as the KUSUM scheme in India which provides a 60-80% subsidy for farmers, have shown significant success at accelerating the role out of SWPs, but even these have not yet reached their full ambition.[138&139] Lessons from these

Figure 5 - Solar water pump, ability to pay analysis, based on average income of smallholder farmers[140]



Estimated total potential and addressable market for solar warter pumps in millions of SHFs in SSA



Estimated total potential and addressable market for solar warter pumps in millions of SHFs in India

136 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.
137 Mercom India. Over 200,000 Farmers Have Benefited from PM-KUSUM: Power Minister. Accessed in August 2023.
138 Ministry of New and Renewable Energy. PM-KUSUM website. Accessed in August 2023.
139 International Energy Authority. PM-KUSUM Scheme for rural energy security. Web article. Accessed in August 2023.
140 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

pioneering programmes must therefore be learnt to help unlock the models and innovations needed to roll out SWPs and other solar irrigation systems at scale.

Community level SWPs: SWPs and irrigation systems are also used to increase community access to potable water. The costs of installing community irrigation systems are often borne by governments or development partners and, as such, are also subject to the availability of funds. However, these are now successfully making savings for public funders when contrasted with the costs of running diesel-powered systems over multiple years (see Section 3.1). Schemes are also being developed in which communities collect micro-payments from users to contribute to the partial payment for pumps as well as their ongoing maintenance, helping to ensure that the systems do not fall into disrepair.[141] However, as temperatures continue to rise, more finance and innovation to support innovative community SWP schemes to increase access to clean, potable water are urgently needed.

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141 GPRBA (2019) Web article. 165 Villages in Tanzania to Get Solar-Powered Water Pumps. Accessed in August 2023.

Solar-powered fans

Scale and maturity of technology: Solar-powered fans have been deployed extensively across South and Southeast Asia for several years and the technology is mature. Sales by GOGLA-affiliates since 2018 have already reached close to 2.8 million and are likely to represent only a limited portion of the market. In recent years, solar-powered fans have also been sold in significant numbers in Nigeria, and to a lesser extent in other West African and Central African off-grid solar markets like Côte D'Ivoire and the Democratic Republic of Congo. Recent innovations in the efficiency and durability of fans through the use of brushless DC (BLDC) motors, are expected to see their sales achieve a compound annual growth rate of 9.2% over the next decade, creating a USD $2 billion market by 2032.[142]

Affordability: Despite the anticipated growth in the sales of DC fans, they still remain out of reach for low income families. Solar-powered table fans can start at as little as USD $8 but on average cost over USD $30, while the average price of DC pedestal and ceiling fans are closer to USD $40.[143] Efficient BLDC fans are also more expensive than conventional alternatives.[144] Off-grid families buying fans will also need to buy a solar home system large enough to power the fan they purchase, adding to the overall affordability burden. Specific schemes will therefore be needed to ensure that those on the lowest incomes can access them.

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142 Market Decipher (2022). Web page. BLDC Fan Market Size, Statistics, Growth Trend Analysis, and Forecast Report, 2022 - 2032. Accessed in August 2023.

143 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

144 Market Decipher (2022). Web page. BLDC Fan Market Size, Statistics, Growth Trend Analysis, and Forecast Report, 2022 - 2032. Accessed in August 2023.

Solar refrigeration units

Scale and maturity of technology: Solar refrigeration units, such as solar direct drive (SDD) systems, have been used for several years within the health sector to help provide vaccines to regions that lack appropriate cold chains. Around 40,000 have been deployed by Gavi alone since 2017 via its Cold Chain Equipment Optimisation Platform (CCEOP).[145] However, a focus on expanding the use of solar refrigeration units by homes and businesses has been more recent. As with solar irrigation systems, data on the full size of the market is incomplete but since 2018, thousands have been sold commercially each year. While core component technologies are long-standing, software and business models are at an earlier stage of innovation, and technical improvements are ongoing.

Affordability: Similarly to SWPs, there is a huge gap between the number of people who can afford solar refrigeration units and those who need them. The average cost of a small refrigeration unit (<100L) is USD $264, whilst for a larger 200-300L unit it is USD $651.[146] This means that they are only affordable to a small proportion of unelectrified homes and businesses. In a recent survey of refrigeration unit customers across Kenya, Tanzania and Uganda. 80% reported using them in a business, with most business users able to use the system to increase revenue that could help to repay the cost of the system.[147] Almost 50% reported that the refrigeration unit had also led to an overall increase in income, with 24% seeing business growth.[148] However 48% reported that repayments were a burden, with 13% advising that repayments were particularly challenging.[149] This indicates that while some businesses benefit from solar refrigeration units when bought at a commercial rate, transforming the number of MSMEs that can access them will require new business models, appropriate financing mechanisms and subsidies. Reaching a wider audience, including MSMEs with smaller revenues and households, will require even greater levels of support.

Refrigeration units for health clinics: Solar refrigeration units sold within the health sector are usually procured using public finance. To provide an insight into the costs, the Gavi CCEOP programme has cost USD $400 million to date, with 60% of the 66,000 refrigeration units deployed using solar.[150] While the costs are high, their role in preserving vaccines and reducing the burden of disease are even greater. Use of adaptation finance to support their role out is vital for protecting the most vulnerable from the growing risk of disease.

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145 Gavi (2023). Web article. How solar power is revolutionising immunisation in the most remote parts of the world. Accessed in August 2023.
146 Ibid.
147 60 Decibels (2022) Uses and Impacts of Off-Grid Refrigerators.
148 Ibid.
149 Ibid.
150 Gavi (2023). Web article. How solar power is revolutionising immunisation in the most remote parts of the world. Accessed in August 2023.

Solar-powered cold storage for agriculture

Scale and maturity of technology: Solar powered cold storage units, such as walk-in cold rooms, are at an early stage of development. Although the components of the technology are relatively mature, several companies are still at a piloting phase where they are exploring and enhancing business models. A handful of companies have extensive operations, such as EcoZen in India with around 850+ cold room units and ColdHubs in Nigeria with 58 cold storage facilities and five refrigerated trucks.[151&152] However, in other countries, companies may only be operating a few units and using early learnings to rapidly innovate within their operations.

In addition, the potential of any one cold storage solution is linked to the availability of other infrastructure within the agricultural value chain. For example, in Rwanda, several cold storage facilities within town centres are underutilised as there is no means of transporting chilled produce to them from nearby farms. If produce perishes at any point from 'farm to fork', or refrigerated goods transported to regional or national markets don't get sold, it can make the cost of the cold storage intervention a wasted expense. This has led many cold storage companies to diversify their operations and provide solutions for multiple points in the value chain. For example, ColdHubs in Nigeria is now providing both farm gate storage and refrigerated transportation to regional centres to ensure there is no 'break' in the cold chain; while Soko Fresh has developed software to help its customers link with new markets by connecting them with off-takers for their produce (see Section 2.3).

While this is helping to enhance the effectiveness of solar-powered cold storage solutions, it requires significant capacity, innovation and finance. While pioneering companies are continuing to expand the solar cold chain rapidly, without smart and holistic approaches that help to crowd in finance and knowledge, a transformation of the sector cannot be achieved.

Affordability: Unlike other off-grid solar technologies, agricultural cold storage solutions tend to be operated using a service-based model, where farmers pay to use the cold storage facility with a fee based on the weight/size and duration of the produce stored. While this is less-risky for consumers, they still need to recoup the costs of storing their produce and create a profit. Given the limited amount of solar cold storage facilities available and the challenges of optimising these technologies via holistic 'farm to fork' approaches, hundreds of millions of smallholder farmers currently lack the opportunity to benefit from effective cold storage for their produce.[153]

© **Baridi**

151 Ecozen (2023). Home - Solar Cold Storage & Solar Pump Controller | Agriculture Technology - Ecozen. Web page. Accessed in August 2023.
152 ColdHubs (2023) Web article. ColdHubs Moves From 22 To 28 States In Nigeria. Accessed in August 2023.
153 Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors (2022), Off-Grid Solar Market Trends Report 2022: State of the Sector. Washington, DC: World Bank.

Call to Action

Call to Action

From powering green growth and opportunity, to combatting the impacts of droughts, floods and storms, off-grid solar solutions enable a wide range of positive climate adaptation impacts. However, unlocking the benefits of these technologies will take concerted support from development financiers, governments, philanthropists, and the private sector.

Ensuring the poorest get the energy and energy services they need to respond to a warming climate will require the use of philanthropic and development finance to de-risk the off-grid industry, need governments to partner with the sector to create an enabling environment for the rapid transformation of WASH, agriculture and energy systems, and necessitate extensive capacity building and innovation.

To this end:

- We call on climate and philanthropic investors and donors to help de-risk the off-grid solar industry through the targeted use of adaptation and development finance, and to prioritise off-grid solar for carbon credits and mitigation funding.
- We ask governments to recognize the role that off-grid solutions can play in driving their climate adaptation and resilience plans, and to support the industry by providing tax and tariff waivers and developing subsidy programmes and other initiatives that can help to catalyse electrification and modernise agriculture, health, and disaster response systems.
- We urge the development community to enhance and expand programmatic interventions that can unlock rapid change, such as results-based financing and accelerator schemes.
- We call on off-grid solar companies to implement sustainable and responsible business practices and pursue bold innovations in technology, business models and partnerships; and encourage commercial investors to use their capital to help scale financial innovations.

With concerted action, off-grid solar solutions can support the development of a powerful green economy across energy poor regions; one which is climate resilient, helps to combat climate change and ensures that those most vulnerable to are no longer left behind.

Let's get to work.

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About GOGLA

GOGLA is the global association for the off-grid solar energy industry. Our 200+ members provide millions of low-income and climate-vulnerable people with affordable, high-quality products and services; rapidly increasing customers' productivity, connectivity, and resilience. To enable sustainable businesses and accelerate energy access, we provide market insights, standards and best practice, and advocate for catalytic policies, programmes and investment. With the right support, our pioneering industry can improve the lives of 1 billion people by 2030.
To find out more, visit www.gogla.org.

About IKEA Foundation

The IKEA Foundation is a strategic philanthropy that focuses its grant making efforts on tackling the two biggest threats to children's futures: poverty and climate change. It currently grants more than €200 million per year to help improve family incomes and quality of life while protecting the planet from climate change. Since 2009, the IKEA Foundation has granted more than €1.8 billion to create a better future for children and their families. In 2021 the Board of the IKEA Foundation decided to make an additional €1 billion available over the next five years to accelerate the reduction of greenhouse gas emissions.

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