EFFICIENCY FOR ACCESS

Efficiency for Access Design Challenge

Challenge Brief

UKaid from the British people

UK ENGINEERS WITHOUT BORDERS

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Overview

There are still over 800 million people who do not have access to electricity, and time is running out on to achieve the UN's goal of universal access to electricity for all by 2030. The climate emergency the world is facing makes it even more important that modern energy services are powered by renewable energy and more inspired innovators are needed who understand the day-to-day challenges people face.

The Efficiency for Access Design Challenge is an invitation to be part of a wider movement aiming at driving access to clean energy services through designing and improving super-efficient appliances for remote populations.

Over the year, you have the opportunity to join students from around the world in developing the best solutions for improving living conditions in off-grid settings and to be part of this rapidly growing industry. The Efficiency for Access coalition and Engineers Without Borders UK are excited that you are part of the competition, and we are looking forward to the solutions you will submit.

This document will give you the required understanding of the context, help you frame your project and design your solution.

More resources and details on the competition are available **here**.

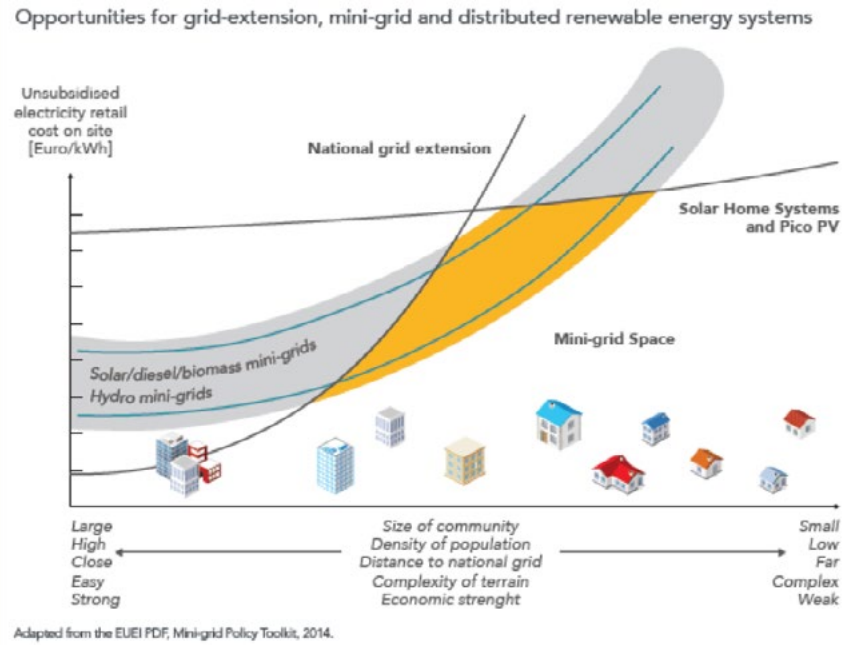
Context

The UN Sustainable Development Goals recognise that access to affordable, reliable and modern energy services such as electricity is crucial for poverty reduction, food security, sustainable agriculture, quality education, gender empowerment, productive employment and resilience to climate change. Delivering access to energy is widely regarded as a prerequisite for economic development.

Distributed clean energy technologies such as off-grid solar some systems (SHSs) and standalone solar mini-grids are enabling people and microenterprises to access life-changing modern energy for the first time. Improvement and expansion of existing grid infrastructure will play an important role in achieving universal access to energy. The International Energy Agency has estimated that off-grid Solar Home Systems and solar mini-grids are the most economic ways to reach around 60% of those still not connected to the grid. As off-grid communities continue to gain access to mobile phone networks, 'Pay as you go' financing is enabling households and micro-enterprises to access affordable electricity in a flexible way in line with their income. Customers will usually pay an upfront deposit, with regular payments (often via SMS or mobile money) enabling them to own the solar home system outright. It is predicted that more than 500 million people in sub-Saharan Africa will need to be served by off-grid renewable solutions by 2030 to meet the UN goal of universal energy access.

Solar Home Systems (SHSs) are stand-alone photovoltaic systems that offer a cost-effective mode of supplying power to remote off-grid households. A solar home system typically includes one or more photovoltaic modules consisting of solar cells, a battery to store energy and a charge controller which distributes power and protects the batteries and appliances from damage. Currently, a typical solar home system operates at a rated voltage of 12V direct current (DC) and provides electricity for low power appliances such as LED light bulbs, radios and small TVs for about three to five hours a day.

A mini-grid, also sometimes referred to as a micro-grid, can be defined as a set of electricity generators and possibly energy storage systems interconnected to a distribution network that supplies electricity to a localised group of customers. They involve small-scale electricity generation ranging from 10kW to 10MW (typically photovoltaic modules, micro-hydro and/or back-up generators) which serves a limited number of consumers via a distribution grid that can operate autonomously without being connected to a centralised grid, often known as 'standalone'.



This diagram shows the most economical way to achieve electrification in different settings. For dense, highly populated cities, grid extension remains the cheapest option, whereas for remote rural areas, Solar Home Systems are much more viable. There is a sweet spot in between where mini-grids appear to be the preferable options to power communities, living in villages for example.

LEARN MORE:

Integrated Electrification Pathways for Universal Access to Electricity: A Primer, SEforAll

Conventional, inefficient appliances consume too much energy to be useful and/or economical with off-grid energy systems like solar home systems and mini-grids. The combined energy demand of inefficient appliances can overload these energy systems, contributing to load shedding and power outages.

As a result, appropriately-designed, highly energy-efficient, cost-effective appliances are essential to delivering modern energy services to underserved communities around the world at the lowest possible social, economic and environmental cost.[1] These efficient appliances can contribute to reduced greenhouse gas emissions by replacing incumbent power generation systems and reducing demand for future carbon-intensive energy supplies.

Just as super-efficient LED technology has unlocked modern lighting for tens of millions of households and microenterprises, super-efficient appliances promise to unlock life-changing modern energy services—like cooking, cooling, mechanisation, power management and refrigeration—for millions more. A great deal of technical progress and market development is still needed to reach this goal.

Over 90% of households that replaced toxic kerosene lamps with solar alternatives report that they have experienced improvements in both health and feelings of safety.[2]

[1] https://efficiencyforaccess.org/publications/low-energy-inclusive-appliance-technology-summaries

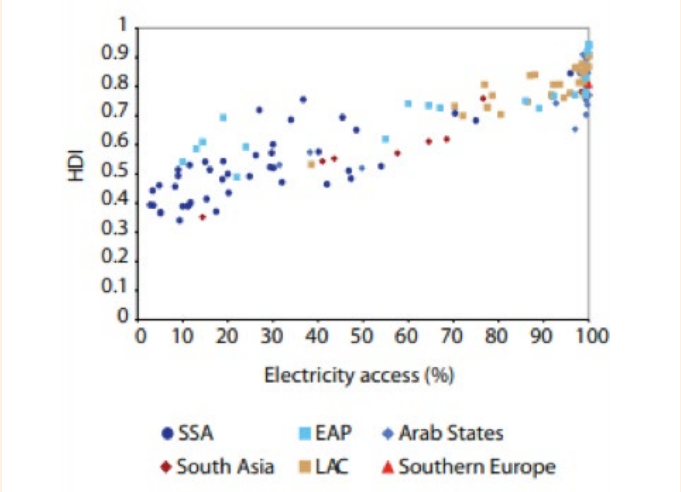
[2] GOGLA (2018). "Powering Opportunity: The Economic Impact of Off-Grid Solar."

Scope of the competition

The Efficiency for Access Design Challenge is an opportunity for you to work at the forefront of energy access by designing affordable, super-efficient appliances that can be used in an off-grid context, i.e. being powered by a solar home system or a mini-grid. You will need to design an appliance for people in one of the lowest 50 countries in the Human Development Index, an index closely correlated with the lack of access to clean energy and other basic services.

We are interested in designs of new appliances or improvements to existing appliances, that improve people's lives by either improving quality of life in their home or increasing productivity of their micro-enterprise. A micro-enterprise is a small business employing roughly ten or fewer people, or someone working for themselves, such as a smallholder farmer, a small retail shop or a bar.

The focus is on energy consumption and the appliance's primary source of energy should be solar generated electricity (DC - Direct Current), meaning that the appliance must be connected directly to a solar home system or a standalone DC mini-grid. You are not allowed to design an AC appliance which connects to an inverter. Energy generation is out of the scope.



Human Development Index versus electricity access rate.

LEARN MORE:

The energy access situation in developing countries, WHO

The UN Human Development Index (HDI) is a combined measure of life expectancy, education and standard of living in a country.

Choose one of these two tracks

Improving quality of life in homes

THE PROBLEM

Despite the rapid increase of off-grid electricity supply, off-grid homes are still vastly different to on-grid homes. Affordable and efficient appliances that are powered by solar DC electricity could replace the less economic and more polluting alternatives and contribute to improving people's comfort, safety and health.

THE CHALLENGE

Design an affordable and efficient appliance, or an improvement to an existing appliance, that could help improve quality of life in homes based in an off-grid setting.

Increasing productivity of microenterprises

THE PROBLEM

Despite the rapid increase of off-grid electricity supply, affordable and efficient appliances that run off solar DC electricity are limited. Many income generating activities that could be undertaken with the usage of appliances are still done manually or with the support of expensive and polluting fuels.

THE CHALLENGE

Design an affordable and efficient appliance, or an improvement to an existing appliance, that could help increase productivity of microenterprises based in an off-grid setting.

The next sections provide a number of themes which you may explore when formulating your problem definition. Each theme contains examples of projects to bring to life what you could develop. These themes are representative of the main trends in the off-grid appliances industry, but don't feel limited to these alone. You are free to choose your own theme as long as you can clearly present the following;

- The intended end-user
- Improvements offered over existing alternatives
- Intended impacts on the end-user's life
- Scalability of the design

Space cooling

Beyond basic comfort and productivity, access to cooling appliances like fans can reduce mortality and morbidity during severe heat waves and increase overall wellbeing. Fans are in high demand among off-grid consumers however mainstream fans still consume as much as 10 times the amount of electricity compared to lighting in the same setting.

SPOTLIGHT ON: FANS

There are a number of challenges to improving fans used in off-grid settings. These fans include table, pedestal and ceiling fans.

Research suggests that technological improvements could include[3]:

- Improved motors for use in off-grid fans that both increase energy efficiency and are affordable and durable e.g. improved brushless DC motors;
- Enhanced blade designs that increase air delivery and lead to overall service improvement;
- Smart functionalities that can improve the overall efficiency, affordability, performance, or user experience, e.g. occupancy sensors and remote based functions;
- Improved electronic controls for adjusting the speed of a motor efficiently;
- Alternative approaches and designs for fans in space cooling.

FIND OUT MORE

Chilling prospects: Cooling for All

K-CEP: why cooling?

In the countries most vulnerable to high temperatures, **over 1 billion people** face significant risks from extreme heat every year.[4]

A 2017 study predicts that by the end of this century, if carbon emissions continue on their current trajectory, **three-quarters of humanity will face deadly heat.**[5]

Using **brushless DC motors**, which utilise permanent magnets and are electronically commutated, instead of the induction motors that are typically used, **can improve ceiling fan efficiency by 50%.** Improving the design of fan blades can improve the ceiling fan efficiency further by 15%.[6]

[3] https://storage.googleapis.com/e4a-website-assets/Guidance-for-applicants.pdf

[4] https://www.k-cep.org/insights/news/million-cool-roofs-launch/

[5] http://www.who.int/globalchange/publications/heatwaves-health-guidance/en/

[6] Phadke, A. A., Jacobson, A., Park, W. Y., Lee, G. R., Alstone, P., & Khare, A. (2015). Powering a Home with Just 25 Watts of Solar PV: Super-Efficient Appliances Can Enable Expanded Off-Grid Energy Service Using Small Solar Power Systems.

Agriculture

40% of the global population rely on agriculture as a main source of income, many without energy access. Tending crops through time-intensive physical labour, their yields are inconsistent and weather-dependent compared to farmers with access to energy and agricultural appliances. Solar powered agricultural appliances (from incubating eggs, to pumping water or milling grain) offer a promising option for farmers living in off-grid areas.

SPOTLIGHT ON: SOLAR MILL

Communities without energy access often mill grains by hand, a time-consuming task typically performed by women and children. For those with purchasing power, the only off-grid option is diesel-powered mills – a polluting, energy inefficient technology that is not viable for sparsely populated and remote regions.

Smallholder farmers with fewer than five acres can increase their yield by 30% with just one piece of modern processing equipment, reducing physical burden while increasing productivity[7].

Recently developed solar mills offer a sustainable alternative, consuming far less energy than diesel mills, while increasing productivity, and proffering financial growth.

Research suggests that improvements could include:

- Improved motors for use in solar mills that both increase energy efficiency and are affordable and durable e.g. improved brushless DC motors;
- Improved power electronics;
- Adaptable machines for different purposes;
- New applications relevant to specific local contexts.

EXAMPLE:

Shevamma and Shivamurthy are working with SELCO foundation

Agsol's solar-powered products include rice polishers and hullers, coconut scrapers and cassava scrapers

There are nearly 500 million small-scale farmers worldwide. Studies show that a 10% increase in agricultural productivity for smallholder farmers in sub-Saharan Africa leads to a **7% reduction in poverty**.

FIND OUT MORE

FAO: Page 185 - Case study: Solar-powered domestic rice processing in Papua New Guinea

IDH: From smallholder to small business

[7] https://efficiencyforaccess.org/themes/agriculture-energy-efficiency

SPOTLIGHT ON: SOLAR WATER PUMPS

Moving water using solar pumping systems offers a clean and simple alternative to diesel-driven pump sets. Solar water pumps are often used for agricultural operations in remote areas or where the use of an alternative energy source is desired. If properly designed, they can result in significant long-term cost savings and increased agricultural productivity to farmers.

Research suggests that technological improvements could include[8]:

- Remote monitoring systems, including low-cost sensors and controllers;
- High efficiency motors – e.g. brushless DC motors. Experts indicate that the cost for a BLDC motor can be 50-100% more expensive than a comparable brushed motor[9];
- Improved Saline water tolerance and filtration;
- Modularity and operational requirements such as easy to use, easy to service, and availability of spare parts.

EXAMPLE

Zena Nyamagwira, Simusolar customer – Page 11

Tirus Mwangi – a dairy and spinach farmer from Kenya – Page 20

FIND OUT MORE

Use and Benefits of Solar Water Pumps (June 2019)

Solar Water Pump – Technology Road Map

Young Engineer's Solar Water Pumping Guide

Tanzania – Horticulture Value Chains and Potential for Solar Water Pump Technology

[8] https://storage.googleapis.com/e4a-website-assets/Executive-Summary-Solar-Water-Pump-Technology-Roadmap.pdf

[9] https://storage.googleapis.com/e4a-website-assets/LEIA-Technology-Summaries-2017-Nov.pdf

Refrigeration

Refrigeration provides a wide range of benefits, from improving health and productivity, to reducing domestic burdens, especially for women and children who are usually responsible for food gathering and preparation. It also enables income generating activities through the cold storage of drinks, food, and other perishable items for later sale. Essential for a sustainable agricultural sector, modern cold chain technology is still often out of reach in some markets due its prohibitive cost and high load requirements. Cold chains manage the temperature of perishable goods from farm or sea to table – maintaining quality and safety in the supply chain, reducing food loss, and enhancing income-generating opportunities.

The total value of food that is lost annually due to lack of refrigeration is $4 billion throughout all of Africa. In Sub-Saharan Africa, loss of perishable fruits and vegetables can reach up to 50% annually.[10]

SPOTLIGHT ON: FRIDGES

The majority of current household refrigerating appliance sales for off-grid use come from the sale of conventional, low price AC grid household refrigerator models that have been repurposed for their new setting. For example, they require inverters and/or charge controllers when used in off-grid situations. Most refrigerators cost around five times the combined value of all other appliances in the typical solar home system and are uneconomical for users and system suppliers.[11]

Research suggests that improvements could include:

- Improving variable speed compressors and their controls;
- High efficiency motors;
- Appliance and system controls including energy management, energy storage and Pay-as-you-go (PAYG) compatibility;
- Refrigerators that have low environmental impact, for example the use of low Global Warming Potential refrigerants;
- Modular cooling system designs for local assembly;
- Tools or software for technical sales to guide appliance selection based on technical parameters and appliance/power system compatibility checks;
- Increasing cooling capacity and temperature lift at times of high ambient temperature and high humidity;
- Technologies that improve the energy efficiency or effectiveness of ice-making or its end use for cooling, storage and transport of foodstuff;
- Approaches that could lead to practical exploitation of Peltier or other solid-state cooling technologies.

EXAMPLE:

JUMEME fish freezing in Tanzania

Cool clean water for the whole neighbourhood]

FIND OUT MORE

Off-Grid Refrigeration – Technology Roadmap

[10] Power for all FACT SHEET: Boosting Agriculture and Improving Nutrition

[11] https://storage.googleapis.com/e4a-website-assets/Refrigeration-Roadmap_FINAL.pdf

Cooking

The WHO reports that three billion people currently cook with polluting fuels, such as kerosene, coal or biomass, in poorly ventilated areas. Of that three billion, around 3.8 million people a year die prematurely from illness attributable to household air pollution. Manufacturers in the off-grid sector have designed super-efficient cook stoves, but challenges remain for cooking appliances to be affordable, efficient and considerate of traditional cooking methods.

Household air pollution causes noncommunicable diseases including stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer.[12]

SPOTLIGHT ON: ELECTRIC PRESSURE COOKERS

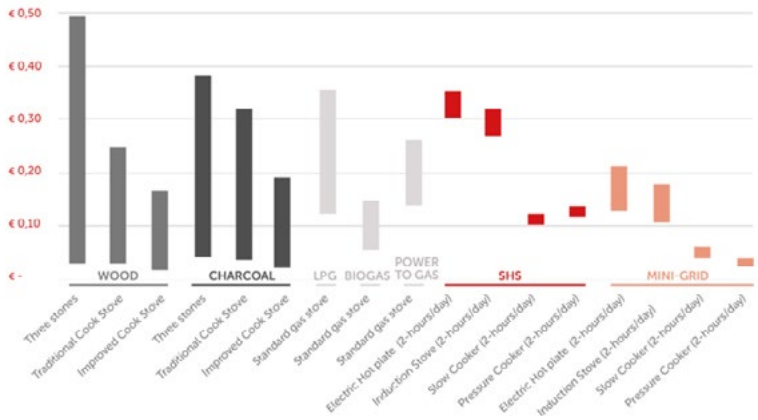
The electric pressure cooker (EPC) or multi-cooker is an appliance that is a combination of an electric hotplate, a pressure cooker and an insulated hotbox with a fully automated control system. Over a one-hour cooking period, a pressure cooker uses approximately one quarter of the electricity of an electric hot plate.[13]

Over a four-hour cooking period, the gains increase further: a pressure cooker is twice as efficient as a slow cooker, six times as efficient as an induction stove, and seven times as efficient as an electric hot plate.[14]

Research suggests that challenges to overcome include:

- Adapting EPCs to lifestyles of individual communities;
- Integrating EPCs into prevailing cooking habits;
- Limited ability to fry food;
- Reliability issues including pressure sealing rings, component burn out and circuitry on button interface models;
- Lack of manual heat control.

FIGURE ES1: COST RANGES OF VARIOUS COOKING TECHNOLOGIES (Per Person, Per Day, in EUR), 2019



EXAMPLE

The desirability of clean cooking in off-grid households

MECS E-cookbook

FIND OUT MORE

ElStove – Open Access Resources

MECS – Why Understanding Real Cooks is fundamental to going beyond fire

Beyond Fire – How to achieve electric cooking

Solar electric cooking in Africa: Where will the transition happen first?

[12] WHO, 2018 http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

[13] Beyond Fire – How to achieve electric cooking

[14] Beyond Fire – How to achieve electric cooking

Power management

The high cost of batteries is a significant barrier to the uptake of appliances in off-grid settings. Distributors often oversize them to ensure a constant and consistent supply of electricity to large appliances like fridges, that lead to an increased cost and reduction in efficiency. Improved power management can help reduce the size of batteries required, making it more likely for people to be able to afford larger appliances.

Solar home systems and mini-grids have limited power supplies. They have to balance generation and storage through batteries with a limit on the number of appliances that can be run at any one time. Smart scheduling and balancing ensures that people have the services needed and that systems are used optimally.

Developments could include:

- Systems that intelligently integrate appliances or allow them to talk to each other;
- Widgets that can be included into a range of equipment so that they can connect to each other;
- Lower cost embedded controllers and other components for implementation of connectivity/control protocols;
- General data communication for appliances and power supply modules;
- Smart batteries: collection and optimisation of data using machine learning to improve the overall system efficiency and performance.

And many more ...

SPOTLIGHT ON: ELECTRIC REELING MACHINES

Resham Sutra has developed a range of affordable electric reeling machines– many powered by solar energy – that vastly improve working conditions and create a predictable, dramatically higher income for over 9,000 silk workers.

SPOTLIGHT ON: WELDING

Half of young people between 15 and 24 are unemployed in Sub Saharan Africa. **Mobisol solar workstation** runs welding machines, electric drills and saws – opening up the potential of a small business to more people.

SPOTLIGHT ON: EGG INCUBATION

Many houses in Africa keep chickens for eggs and meat. A hen can hatch about 20 to 30 chicks per year but using the same hen with an incubator one could get up to 300 chicks per year (Sure Hatch 2018).

SPOTLIGHT ON: ICE MAKERS

Ice can be used to store freshly caught fish, or cool drinks. Ice making can be done on a small scale to make a living, particularly in remote and hot areas.

What is the judging panel looking for?

The assessment framework below provides some guidance on what the judging panel will be looking for in your solution. It should be useful in helping you to structure your project submissions. The appliance you choose to work around does not matter, as long as you demonstrate it addresses a need and represents an improvement compared to existing alternatives. All criteria may not be applicable depending on what your solution is.

		SCORING (1-5)	1	2	3	4	5

INNOVATION How does your design improve on solutions that are currently available to your target end-user?

Judges will want to see that you have demonstrated and understood the technological context that you are targeting, and that you have gone through a well-informed design process to improve on solutions currently available to the end user.

What is the potential of your design to improve energy efficiency compared to existing alternatives? Consider how you define energy efficiency (energy used per service provided) and what the baseline is for comparison.	**Potential to improve efficiency**	Poor	Moderate	Strong
What is the potential of your design to reduce production costs compared to existing alternatives? Consider materials used, price of components and cost of assembly.	**Potential to reduce production cost**	Poor	Moderate	Strong
What is the potential of your design to improve usability compared to existing alternatives? Consider its ease of use, reliability and safety.	**Potential to improve usability**	Poor	Moderate	Strong
Is your design improving the environmental impact throughout its lifecycle compared to existing alternatives? Consider materials used, reparability and end of life.	**Potential to improve environmental impact**	Poor	Moderate	Strong

SOCIAL IMPACT What xdifference does your design make to people's lives?

Judges will want to see how you have researched the needs of your target end-user. They will want to understand why you think your design will improve peoples' lives, and how you have considered social inclusion and equality in your solution.

How well has your target end-user been considered in the design?	**Research and understanding of end user**	Limited	Some	Detailed
What is the likely potential of the design to improve quality of life for your target end-user?	**Potential to positively impact the target end user**	Poor	Moderate	Strong
How well has your design considered the SDG commitment to '**leave no one behind**'? In particular, consider gender equality and disability inclusion.	**Research and understanding**	Limited consideration & understanding	Some	Detailed

SCALABILITY How feasible is it that your design could get to market at scale?

Judges will want to see that you have considered the business case. Including considering the market opportunity, including market size, for your solution, and demonstrated how people will be able to access and afford this.

How well have you considered the potential market for your product? Consider the target customer, size of market and customer value proposition.	**Research and understanding of market**	Limited consideration & understanding	Some	Detailed
How well have you considered how people will be able to access and afford your product? In your business case, consider affordability, potential customer payment models, existing supply chains, distribution channels and local partners.	**Research and understanding of accessibility and affordability**	Limited consideration & understanding	Some	Detailed