FARADAY INSIGHTS - ISSUE 3: OCTOBER 2019

THE FARADAY INSTITUTION

# Bringing Cheap, Clean and Reliable Energy to Developing Countries

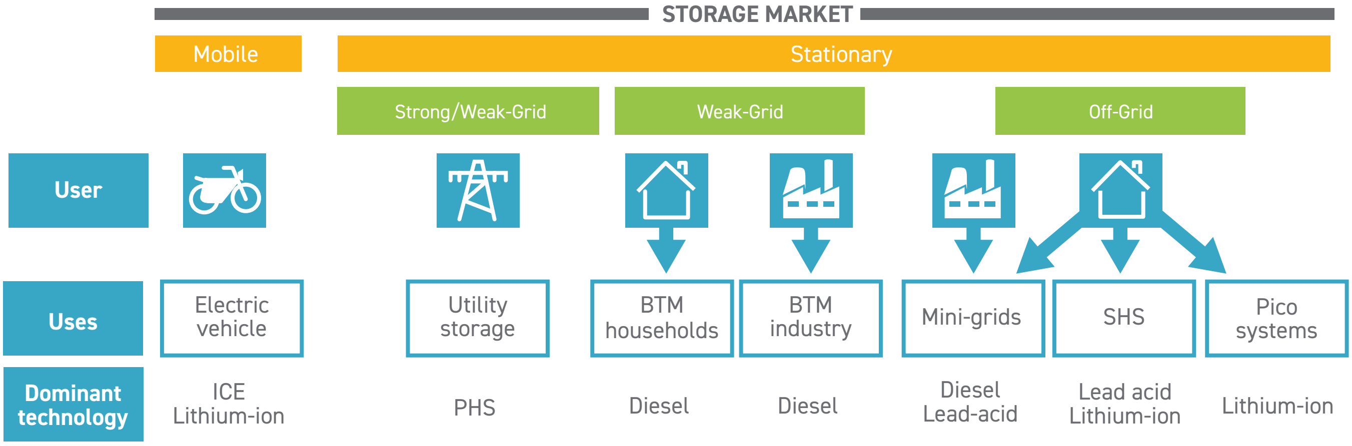
**Over 800 million people worldwide do not have access to electricity and, of those that do, many suffer from an unreliable supply. Diesel and petrol generators commonly used in developing countries bring problems of noise, air quality and climate impacts. Energy storage technologies including batteries have the potential to replace generators and provide cheap, clean and reliable electricity to millions of people.**

## Energy Storage has an Important Role to Play in Developing Countries

Energy storage plays a vital role in improving consumer access to reliable electricity in developing countries. Storage applications provide access to clean energy, support emissions reduction targets and wider development objectives, as well as enabling the integration of renewable energy generation sources such as wind and solar on the grid. Renewable integration is even more vital in developing countries as it enables energy access to off-grid households when combined with solar home systems or mini-grids.

Uses of energy storage technologies include both mobile storage (i.e. electric vehicles) and stationary storage applications across strong, weak-grid and off-

**Figure 1: Overview of the mobile and stationary energy storage market in developing countries**




**Source:** Vivid Economics

**Definitions:** See page 3

grid connections (Figure 1). In developing countries, the cumulative demand for energy storage is projected to be around 2,900 GW over the 2020 to 2030 period.[1] This consists of 2,050 GW of demand by electric vehicles, 720 GW from weak-grid and off-grid stationary energy storage (of which 560 GW is from a potential market replacing or complementing diesel generators) and 130 GW of new on-grid or utility-scale demand.[2]

Whilst there is a vital role for energy storage in the future, many communities in developing countries currently rely on high emission and relatively expensive fuels such as diesel to maintain power and support businesses and livelihoods. Lack of access to reliable energy is also estimated to have an economic cost to African economies of around 1-2% of GDP.

**Energy storage technologies could save up to 100 million tonnes of $CO_2$ emissions per year (excluding China) by replacing 25 million diesel and gasoline generators in developing countries.***

As markets in developing countries grow, the range of storage technologies which could play a role in meeting demand include:

- electrochemical battery storage technologies: lithium-ion, sodium-ion, redox flow, zinc-air and lithium-sulphur;
- mechanical storage technologies: pumped hydropower, compressed air, flywheels;
- thermal storage technologies: ranging from molten salt to pumped electric heat storage; and
- hydrogen storage.

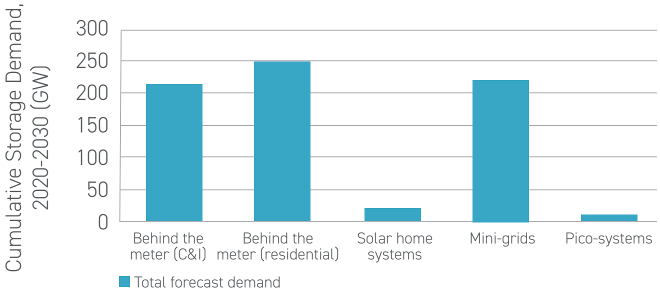
This Faraday Insight focuses on three markets where electrochemical battery forms of energy storage could be particularly effective: (1) weak-grid and off-grid applications; (2) replacement of diesel generators; and (3) utility-scale energy storage applications.

### (1) A Substantive Market for Weak-Grid and Off-Grid Energy Storage

The cumulative demand for energy storage from weak-grid and off-grid users could total 720 GW over the 2020-2030 period. Around 40% of this demand is expected to come from commercial and industrial applications. Figure 2 shows the breakdown by different types of uses, with 160 GW from new demand and 560 GW from a potential market replacing diesel generators.

Over this period, around 110 million people are expected to gain access to energy through mini-grids (rather than through expansion of centralised grid infrastructure). Sales for solar home systems are also expected to total 150 million and reach 470 million for pico-solar systems.

**Figure 2: Total weak-grid and off-grid demand in developing countries over the 2020-2030 period**




**Source:** Vivid Economics; Faraday Institution analysis

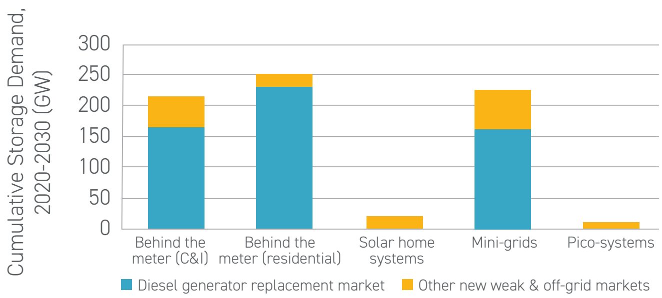
Battery forms of energy storage are likely to be particularly effective for weak-grid and off-grid applications, as they benefit from an ability to provide multiple storage services (from frequency response to energy time shift), modularity and geographical flexibility. Cheaper and modular formats of energy storage, such as solar home systems and mini-grids, will also be in demand in locations with dispersed populations.

### (2) Replacing Diesel Generators is a Specific but Large Market Opportunity

Within the weak-grid and off-grid market, energy storage technologies offer a specific and large opportunity in the replacement of diesel generators, especially when combined with energy generation technologies such as solar panels. Diesel generator capacity (excluding Europe, USA, and Latin America) is estimated currently to be 350 GW and, with growing demand in India, Nigeria and China, cumulative replacement demand could reach 560 GW over the 2020-2030 period. Figure 3 shows the replacement demand for diesel generators across different types of uses.

Diesel generator users are varied and include standalone households, commercial users in off-grid areas, behind-the-meter users facing unreliable grid connections and community mini-grids. Diesel generators provide back-up power services in much the same way as energy storage technologies, but with a different cost balance of lower upfront costs but higher ongoing costs.

**Figure 3: Diesel generator replacement in developing countries over the 2020-2030 period**




**Source:** Vivid Economics; Faraday Institution analysis

* Source: IFC (2019). The Dirty Footprint of the Broken Grid.

[1] Vivid Economics (2019). Rapid Market Assessment of Energy Storage in Weak and Off-grid Contexts.

[2] Throughout this Insight we have quoted demand in GW rather than GWh. Box 1 of the Vivid Economics report provides a description of the difference and the methodology to convert between the measures.

In addition to reducing air and noise pollution, switching to energy storage technologies would help consumers save over USD 40 billion currently spent annually on diesel fuel.[3] Around 60% of African businesses stated access to reliable energy is a constraint on their growth with many relying on diesel to maintain and support businesses and livelihoods.[4]

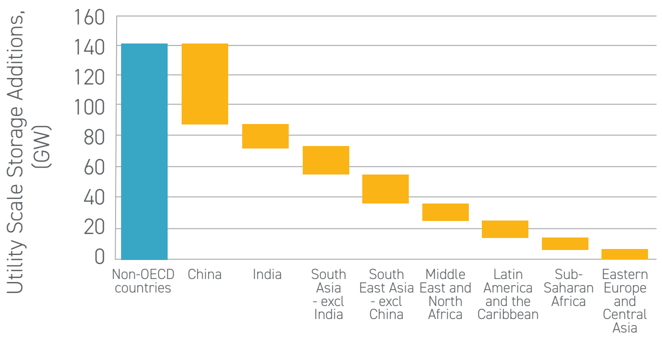
Energy storage solutions can perform more favourably over their full lifetime due to the high maintenance and fuel costs of diesel generators. Factors which restrict uptake of storage alternatives include fossil fuel subsidies, access to finance for the higher upfront cost and uncertainties over payback time.

### (3) Utility-Scale Grid Storage in Developing Countries

Over 130 GW of utility-scale capacity is expected to be installed between 2020 and 2030, driven by increasing renewable investment. Developing countries with large populations and particularly ambitious renewables targets will be the largest markets, e.g. China and India are expected to account for 38% and 12% of projected utility-scale storage demand to 2030 (Figure 4).

As well as enabling integration of renewable energy sources on to national grids, energy storage can also be used as an alternative to grid infrastructure expansion or upgrades. However, there are barriers to greater deployment of utility-scale storage including those related to finance and costs, as well as government policies that favour traditional energy generation technologies.

**Figure 4: Utility-scale storage demand in developing countries over the 2020-2030 period**




**Source:** Vivid Economics

Approximately 96% of the world's utility-scale energy storage in 2017 was pumped hydropower.[5] However, the rapid improvement in the performance of Li-ion batteries, coupled with falling costs, is fuelling a rise in the use of batteries and other electrochemical energy storage technologies.

### Battery Technology Outlook to 2030

Commercial opportunities in developing countries are expected to increase substantially, primarily as a result of lower costs. The cost of lithium-ion batteries has already fallen by over 70% since 2010, driven by the scale of battery production for electric vehicles, and are projected to fall by a further 60% by 2030. Sustained research efforts are expected to drive future improvements in performance in cycle life and safety. Lithium-ion is likely to remain the dominant technology for solar home systems for the next 5 to 15 years and will increasingly be deployed in mini-grids as part of hybrid storage solutions.

Redox flow batteries could support lithium-ion in mini-grids and utility-scale applications. Redox flow has a higher cycle life than lithium-ion and larger depth of discharge. Their high cycle lives allow them to provide a lower lifetime cost of energy. High upfront costs, mainly from the use of vanadium in the electrolytes, and perceived system complexity, are restricting the uptake of this technology.

Zinc-air, sodium-ion and lithium-sulfur batteries are based on lower cost materials, potentially reducing their up-front costs, and so may be preferred in niche markets where a smaller scale of production is not a constraint. These batteries might find their primary use in those applications where cost is the over-riding feature, rather than size or weight, such as in stationary storage.

Lead-acid batteries will continue to play a part for a number of applications, including in mini-grids, despite their relatively poor performance and potential toxicity. Their low upfront costs make them the preferred solution for many developers. But as markets in developing countries grow, and costs continue to fall for other storage technologies, they are likely to lose their dominant position.

**Definitions**

**Strong grid:** households or businesses that have access to a reliable connection to the national grid

**Weak grid:** households or businesses that have an unreliable or poor-quality connection to the national grid

**Off grid:** households or businesses that do not have access to an electricity connection to the national grid

**Mini-grid:** off-grid local power distribution network with solar panel array and/or battery energy storage

**BTM:** behind the meter; storage installed on the customer side of a utility meter, to serve both commercial & industrial and residential customers

**ICE:** Internal combustion engine

**PHS:** pumped hydro storage

**Pico-solar system:** powering small appliances such as electric fans and lights

**SHS:** solar home system, powering lights, mobile phone charging, televisions and fridges

[3] BNEF (2017). Distributed-Energy-in-Emerging-Markets.
[4] World Bank (2019). Doing Business 2019.
[5] IRENA (2017). Electricity Storage and Renewables: Costs and Markets to 2030.

### What Needs to Happen?

The potential for batteries to provide cheap, clean electricity to millions of people is huge, replacing thousands of polluting diesel generators in the process. The Faraday Institution is supporting this effort by funding further research into new and existing battery technologies and is engaging with the World Bank and others to ensure that this potential is realised.

Further scientific research and changes in policy direction can catalyse the uptake of energy storage in developing countries. These include:

- Research into lowering material costs by exploring the potential of new battery chemistries;
- Delivering improvements in efficiency that can unlock system cost reductions;
- Strengthening the economic incentives and access to finance for households and businesses in order to increase the financial viability of energy storage business models;
- Setting standards to enable validated designs of new technologies; and
- Improving the awareness of new energy storage technology and investing in pilot projects demonstrating the performance and scale-up of these technologies.

### About the Faraday Institution and Faraday Insights

The Faraday Institution is the UK's independent research institute for electrochemical energy storage research and skills development. We bring together academics and industry partners in a way that is fundamentally changing how basic research is carried out at scale to address industry-defined goals.

Our 'Faraday Insights' provide an evidence-based assessment of the market, economics, technology and capabilities for energy storage technologies and the transition to a fully electric UK. The insights are concise briefings that aim to help bridge knowledge gaps across industry, academia and government. If you would like to discuss any issues raised in this 'Faraday Insight', or our wider battery research programme, please contact Stephen Gifford.

Sign up today to be added to the distribution list for future Faraday Insights www.faraday.ac.uk/subscribe

**The key battery technologies for future energy storage markets in developing countries**

**Lithium-ion** is currently the leading high energy density battery chemistry and powers everything from mobile phones and tablets to electric vehicles. It is also the leading high energy density battery technology in the energy storage market. 95% of certified pico-solar systems[6] use Li-ion batteries and they are also being deployed at scale in large utility-scale installations.

**Redox flow** batteries are a relatively mature technology that is well suited to larger energy and longer duration applications, such as mini-grids. A flow battery consists of two external tanks of liquid (the electrolyte) that is pumped past a membrane held between two electrodes. They can withstand a larger number of charge/discharge cycles over their lifetime and their larger depth of discharge means that they can provide more of their stored energy for longer.

**Sodium-ion** (Na-ion), **zinc-air** (Zn-air) and **lithium-sulfur** (Li-S) are among the newer battery chemistries that have the potential to compete with lithium-ion. All might lower material costs as they do not rely on relatively rare metals such as cobalt or nickel. Some have a higher theoretical energy density than Li-ion (Zn-air & Li-S) and perform better at higher temperatures (Na-ion & Zn-air) without the need for external cooling. Inherent design features in all of the above battery types mean they are potentially safer than Li-ion.

This publication was based on analysis by consultants Vivid Economics, who conducted a rapid market and technology assessment of storage in weak- and off-grid contexts for the Faraday Institution.

[6] Based on analysis of off-grid products of 0-10W - Dalberg Global Development Advisors (2018). Lighting Global: Off-Grid Solar Market Trends Report 2018.

CONTACT
Stephen Gifford
Head of Economics & Market Insights
stephen.gifford@faraday.ac.uk
www.faraday.ac.uk
01235 425125
07741 853068