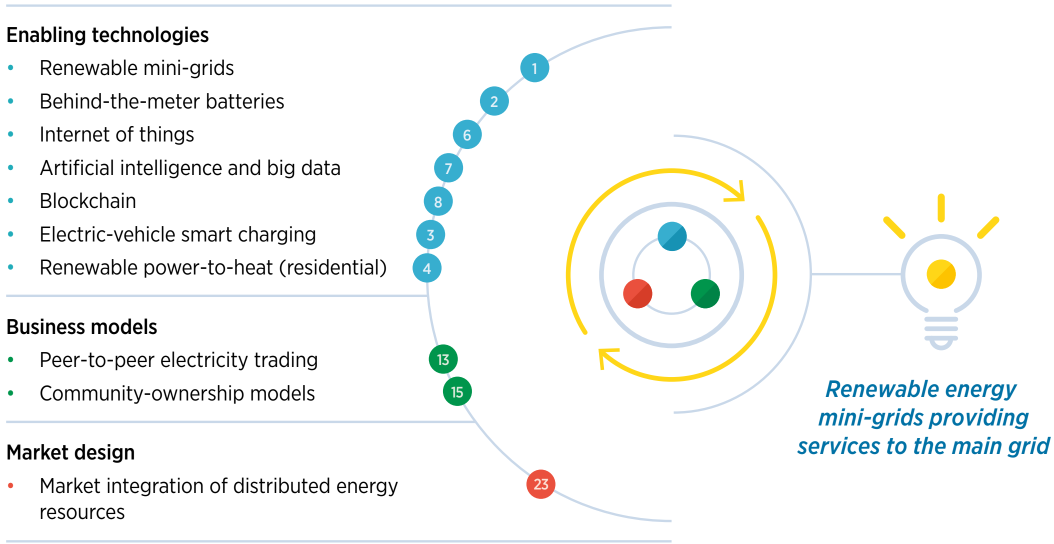
SOLUTION VIII

Renewable energy mini-grids providing services to the main grid

Figure: Synergies between innovations for enabling mini-grids to provide services to the main grid



As an **enabling technology**, renewable mini-grids are integrated energy infrastructures combining loads and renewable energy resources. Mini-grids combine power demand with distributed energy resources into a single controllable entity that can be operated separately from the grid. Mini-grids enable renewable energy deployment in both connected areas (allowing local generation to provide independence from the main grid at times) and developing areas, where distributed generation can power remote communities. *(Key innovation: Renewable mini-grids)*

All types of distributed energy resources may be connected to a mini-grid, including distributed generation plants such as rooftop solar PV, battery thermal management, EVs, residential heat pumps and demand response, among others. *(Key innovations: Behind-the-meter batteries; Electric-vehicle smart charging; Renewable power-to-heat)*

These assets, connected to the mini-grid, can be individually owned by consumers or shared by a community. Community ownership (CO) models are **innovative business models** that enable the sharing of ownership and management energy-related assets, such as energy generation systems, energy storage systems, energy efficiency systems, and district cooling and heating systems. CO models allow the sharing of costs, enabling participants to own assets with lower investment amounts. This encourages people to unite and act on energy and other socio-economic challenges that are specific to their local areas and communities. It also encourages solidarity and co-operation within communities. *(Key innovation: Community-ownership models)*

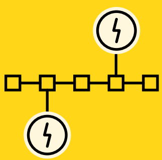
Often, mini-grids can enable peer-to-peer (P2P) electricity trading between participants. The P2P concept involves a platform-based business model of an online marketplace where consumers and distributed energy suppliers transact electricity at the desired price. This energy can be bought by any consumer with whom there is a direct connection. An emerging innovation that facilitates P2P transactions is blockchain. *(Key innovations: Peer-to-peer electricity trading; Blockchain)*

If connected to the distribution network, the mini-grid can provide flexibility services to the main grid if the **market design** allows. Recent breakthroughs are positioning renewable energy mini-grids as an innovative solution, as these advancements can facilitate the provision of ancillary services to the main grid and improve efficiency and cost effectiveness. Intelligent sensors can be employed for monitoring the operations of the national grid, to automatically switch between the national grid and the mini-grid.

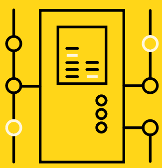
In switching between grids, DC mini-grids offer an additional advantage as they can quickly connect/disconnect from the national grid. They do not need frequency synchronisation, unlike AC mini-grids, thereby ensuring a continuous supply of electricity for critical applications such as large data centres. Additionally, mini-grids can help in reducing the congestion in interconnections between the mini-grid and the national grid. These systems can enable demand-side response by choosing to connect with the national grid during periods of low demand and disconnecting from the national grid during periods of peak demand. For these services to be properly remunerated, distributed energy resources that are connected to the mini-grid need to participate in wholesale markets. *(Key innovation: Market integration of distributed energy resources)*

- However, matching local demand with local generation in a mini-grid requires the complex tools of an operator. Only digital **enabling technologies** allow a mini-grid to automatically forecast demand, adjust generation, optimise reserves, control voltage and frequency, and connect or disconnect from the main grid (if possible). The more effectively these sources are balanced, the cheaper the generation costs for the mini-grid and the higher the revenue from the additional services it can provide to the main grid. *(Key innovations: Internet of Things; Artificial intelligence and big data)*

Companies such as Power Ledger and LO3 Energy, and research initiatives like The Energy Collective, have been experimenting with P2P trading with local mini-grids using blockchain technology. With smart contracts, trades can be made automatically throughout the network using price signals and real-time renewable energy production data. Companies are now working on intelligent grids that use digitalisation and smart contracts to automate the monitoring and redistribution of the mini-grid energy.



30 %
SAVINGS in electricity costs for local residents



USD 0.28/KWh
Off-grid electricity cost

10 %
REDUCTION in energy consumption with DC mini-grid

Impact of mini-grids:

- **30% savings in electricity costs for local residents in a mini-grid in Germany that feeds the excess electricity generated into the grid.**

The village of Feldheim owns and operates a local mini-grid system consisting of solar-, wind- and biomass-based generation sources and a battery storage system. The solar plant produces over 2 700 MWh per year, the biogas plant can produce 4 GWh per year, and the wind turbines have a capacity of 74.1 MW. Excess electricity generated is fed into the national grid. Additionally, the mini-grid uses its battery storage system to provide flexibility services for frequency control to the main grid. As a result of the mini-grid system, local electricity costs have come down by over 30% (Eid, 2016; Guevara-Stone, 2014).

- **Plug-and-play mini-grid in Bulgaria can deliver off-grid electricity at a cost of USD 0.28/kWh.**

Bulgaria's International Power Systems has developed Exeron, a plug-and-play system that can effectively switch between multiple energy sources such as solar PV panels, wind and a battery system. This system can enable mini-grid operators to remotely monitor and control the total load and also helps improve the overall efficiency of the mini-grid system (Exeron, 2018). The system results in significant savings in operational expenses and can provide off-grid electricity at a cost of USD 0.28/kWh.

- **A mini-grid system is providing reliable and clean back-up to the Indian grid.**

IBM has installed solar PV-powered DC mini-grids for its data centre in Bangalore, India. The system can provide 50 kW of DC for 330 days a year and result in a 10% reduction in energy consumption as compared to AC power (IBM, 2011). The mini-grid system provides a reliable and clean back-up to the grid.

IMPLEMENTED SOLUTION

Connected mini-grids in the Netherlands

- In the Netherlands mini-grid pilot projects have been undertaken to focus on sustainable and smart energy management. These pilot projects, also referred to as the "SIDE system" (Smart Integrated Decentralised Energy system), are an integration of various renewable energy-based technologies for electricity and heating. The local mini-grids comprise solar PV for generating electricity and solar thermal systems, electric boilers and heat pumps for generating heat. A SIDE network uses an intelligent management system to integrate different components and to balance local supply and demand, reducing costs. For example, solar panels collect energy when the sun shines, and charge EVs. Any surplus power is either stored in a battery or sent by the system to power other houses in the community. The study data show that SIDE systems are less expensive than the conventional grid-powered systems in the long run and do not require expensive infrastructure upgrades (Wood, 2018).

The local mini-grid also is connected to the national grid and allows the feeding of excess power generated in the mini-grid into the national grid. Results from the pilot project showed that the cost of electricity was reduced greatly due to the solar PV, while the cost of heating also declined, albeit slightly, due to the cheaper solar thermal systems (de Graaf, 2018).

Connected mini-grids in Australia

- The Australian Renewable Energy Agency (ARENA) will be investing USD 8.7 million towards a USD 21.9 million 30 MW/8 MWh battery storage facility adjacent to the Wattle Point Wind Farm. This battery system will use local wind power and solar PV power to create a mini-grid system. The mini-grid system would provide fast response during outages in the main grid and reduce congestion on the interconnector linking South Australia with Victoria. The mini-grid also can island the local network using 90 MW of wind farm and solar PV modules (AGL, 2017).

Brooklyn Microgrid

- Brooklyn Microgrid, developed by the New York-based start-up LO3 Energy, is a pilot microgrid using blockchain technology that is intended initially to be a "virtual microgrid" operating over existing wires and eventually to include physical resiliency. Residents and businesses that produce electricity locally can sell their surplus to a network that is connected to other neighbourhood participants. The microgrid has the role of interconnecting the users in a reliable way, either using the main grid network or using a private community network if available.

The platform therefore allows peer-to-peer transactions that take advantage of blockchain. The software records and accounts for every unit of energy produced by members' energy systems. A Smart Contracts application makes surplus units of energy available on the TransActive Grid market to be bought and sold by local community members, with payments through their utility bills. The pricing in these contracts is market driven and based on the supply-demand curve. A fluctuating amount of supply is available from the sellers, while the producers set their bid price, and the trade represents a match between the two. The prosumers (producers and consumers) also may deal with typical suppliers if their bid is not high enough for local, clean energy. The current installation covers more than 50 participants in Brooklyn.

The concept of a smart microgrid using blockchain was brought in with two key objectives. First, it offers an alternate option for residents and businesses to monetise their surplus power. Residents with solar PV panels previously have been able to sell excess energy to utility companies, but they are limited to a single consumer at a pre-set price. Additionally, when a blackout occurred in the area, their PV systems would be switched off despite their capability to generate their own power. Since Superstorm Sandy caused a series of blackouts across the US in 2012, the reliability of the grid has been called into question.

SUMMARY TABLE: BENEFITS VERSUS COSTS OF MINI-GRID SOLUTIONS

Renewable energy mini-grids providing services to the main grid	Low	Moderate	High	Very high
BENEFIT				
Potential increase in system flexibility		●		
Flexibility needs addressed		from seconds to days		
COST and COMPLEXITY				
Technology and infrastructure costs			● mini-grid, smart meters, ICT	
Required changes in the regulation framework			●	
Required changes in the role of actors			● active consumers - automation as facilitator	

This document is extracted from a longer report:

IRENA (2019), ***Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables.*** International Renewable Energy Agency, Abu Dhabi (**ISBN 978-92-9260-111-9**).

The full report and related materials are available on the IRENA website (**www.irena.org**).