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On behalf of:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

of the Federal Republic of Germany

Building Partnerships for a
ENVIRONMENTAL PROTECTION made in Germany
Sustainable Infrastructure

Factsheet series:

Fuel cells for distributed power supply

Part 3: Mini-grids

Status: September 2021

Brief summary

Stationary fuel cell systems enable lasting and reliable energy provision on site. This climate-friendly alternative is particularly interesting for emerging and developing countries because mains power supply is to a large extent, neither stable nor available in all parts of the country. Instead of fuel cells (FC), backup generators with fossil fuels like diesel and petrol are currently used to power areas with poor grid access or to ensure uninterruptible power supply.

Using diesel causes:

- High transport costs
- High maintenance costs
- Price uncertainty
- High level of emissions (CO_2, NO_x, VOC, particulate matter and noise)
- High risk of diesel and equipment theft
- Deterioration of stored diesel and wax formation at cold temperatures

Stationary fuel cells offer:

- Alternative fuels and simplified logistics
- Relatively high efficiency
- High level of operational reliability and low maintenance costs
- Small unit size
- Zero local emissions (depending on the fuel zero CO_2 emissions)
- Low noise emission

References: [1-4]

Using fuel cells in mini-grids -high potential for positive environmental impacts

Mini-grids* already provide access to electricity for around 47 million people worldwide in rural or remote regions. Yet around half of these existing mini-grids are dependent on diesel or heavy fuel oil as their primary energy source[5], which has a negative impact on the environment, security of supply and the quality of life of the local population. At the same time, with around 759 million people lacking electricity supply[6], there is still a high global demand for electrification, which the expansion of mini-grid technologies can contribute significantly to meeting[5] and thus setting the course for sustainable socio-economic development[7].

In order to advance electrification in a sustainable manner, reduce prime costs and ensure adequate supply quality, renewable, distributed energy sources are now an established standard to supply the consumers of mini-grids. Due to the inherent variability in electricity-production of the renewable energy sources used, which in specific cases is coupled to local climatic peculiarities (such as rainy seasons), solutions that enable short-, medium- and even long-term bridging times and seasonal energy storage are gaining in importance[8]. Hydrogen and fuel cell technologies offer the possibility of decarbonising existing diesel/heavy fuel oil grids and, in combination with renewable energy sources and batteries, can ensure the security of supply of autonomous systems, even over a longer bridging period and scalable to higher performance classes. Compared to grid expansion, they thus represent a fast and in many cases more reliable option for energy supply.

*Mini-grids are energy supply systems that use one or more central energy sources to supply electricity to consumer points in a specific, limited area. Their key characteristic is the completely independent operation, which enables mini-grids to supply rural regions, regions that are difficult to access or regions that are remote from the main grid. Mini-grids can be isolated from the main grid, i.e. operated off-grid, or have a connection to a larger grid, while at the same time being self-sufficient in operation.

Status quo

High economic potential for replacing diesel generators in mini-grids:

3.3 billion USD
profit potential p.a. for mini-grid developers between 2019 and 2030[5]

10,000 inhabited islands worldwide
with around 750 million islanders, whose states pay a significant share of their GDP for energy supply with imported fuels[9]

28 billion USD
is the estimated investment volume of the diesel networks currently installed worldwide[5]

A large proportion of the mini-grids worldwide in operation rely heavily on diesel or heavy fuel oil as their primary energy source or as a complementary source in hybrid grids:

20-30 million
locations of diesel generators, of which around 25% supply electricity to mini-grids[10]

Around 50%
of the mini-grids installed to date use only diesel/heavy fuel oil for power generation[5]

47 million people
are served by approximately 19,000 1st and 2nd generation mini-grids, most of them in South and East Asia, Africa and the Pacific[5]

Availability, logistics, storage and price uncertainty pose particular challenges for energy supply based on fossil fuels[11] In addition, the operation of diesel generators requires a high level of maintenance, which is reflected in high operating costs[12].

High noise emissions and the emission of particular matter, NOx and VOCs lead to considerable environmental pollution[10].

Green mini-grid technologies play a key role in global electrification until 2030 and beyond

759 million
people without access to electricity, especially in Sub-Saharan Africa, South-East Asia[6]

84%
of the population without access to electricity live in remote areas[6]

210,000 new mini-grids
will be needed by 2030 to supply 490 million people with electricity[5]

Market potential for hydrogen applications in mini-grids

Market outlook

- Large market potential for replacing generators that provide power for mini-grids based on diesel or heavy fuel oil. This potential is reinforced by a continued high demand for electrification solutions, especially in sub-Saharan Africa and Central and South-East Asia[6]. It is estimated that meeting this demand holds a profit potential of around USD 3.3 billion p.a. for mini-grid project developers between 2019 and 2030[5].
- The growing integration of renewable energy sources and their variability, which affects the supply of electricity to mini-grids[5], is forecast to increase demand for seasonal energy storage solutions by 2030[13]. With the help of hydrogen and fuel cell technologies, a larger power spectrum can be covered complementing renewable energy sources and batteries.
- Policies for off-grid solutions are being developed faster and designed more market-friendly than policies for on-grid solutions for electrification and therefore favour the development of mini-grids[6].

Technical requirements

Requirements for hydrogen and fuel cell systems depend on dimension, consumer structure and location of a mini-grid:

- Smooth supply during regular operation, even with seasonal fluctuations in energy demand (e.g. tourist season; electricity production from renewable sources, e.g. due to rainy seasons).
- Requirements based on different load profiles, including commercial / producing consumers ("productive use of energy" PUE) and their secure power supply
- Inclusion of renewable energy generation sources in mini-grids for electrolysis (volatility)
- Scalability of the system due to increasing demand for power supply, as well as advancing technology development and inclusion of different types of consumers.

Technical solutions

- Use of different fuel cell technologies such as polymer exchange membrane (PEM), direct methanol (DMFC) and solid oxide fuel cell (SOFC) depending on system requirements.
- Electrolysis (e.g. PEMEL, AEL, AEM, plasmalysis) enables the complete integration of renewable energies and the self-sufficiency of mini-grids. In particular, the operation under fluctuating loads and the system size are decisive factors for the choice of technology.
- H2 storage system and back-up battery as further system components.

Transfer potential

- Mini-grids whose power supply primarily depends on diesel generators are suitable for the use of hydrogen and fuel cell technologies, which can increase supply security and drive decarbonisation. In particular, locations that are subject to seasonal fluctuations in renewable generation capacity or in the electricity demand offer great potential for the use of these technologies.
- The further development of business models offers additional market opportunities considering additional customers for the produced hydrogen and the by-products oxygen and heat for heating or cooling.

Case study: mini-grids in Indonesia

The framework conditions create an attractive market environment

4.5 million people
in Indonesia still without access to electricity, many of them on the approximately 1,000 inhabited islands with a high population density that cannot be supplied by the main grid[8]

3-4 GW
Installed capacity of diesel mini-grids and continued high imports of diesel generators show high potential for replacing diesel technologies[8]

900
mini-grids in Indonesia rely on diesel as a primary energy source. Around 500 MW of diesel capacity have been installed in Bali alone[14]

High costs of security of supply with backup generators

17%
of government expenditure accounted for subsidies for fuel and electricity in 2014[14]

LCOE
of energy provided by diesel in Indonesia is approx. USD 0.38 kWh[14], while expecting an increase in diesel prices in the future[8]

The fuel cell in Indonesia's mini-grids

- High application potential for replacing diesel generators in mini-grids as well as application potential with regard to the locally seasonally varying PV irradiance should be proven by demonstrators
- Growing expansion and integration of renewable energies for planned mini-grid projects can pave the way for integration of H_2/FC technologies

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NOW GmbH
Fasanenstraße 6
10623 Berlin

+49 30 311 611 6100
kontakt@now-gmbh.de
www.now-gmbh.de

Layout

Jette Thiele
Dönhoffstraße 36a
10318 Berlin

+49 176 87 91 91 36
hello@jette-thiele.com

Authors

Sabine Ziem-Milojevic, NOW GmbH
Catharina Horn, NOW GmbH
Sammy Wittop, NOW GmbH
Dr. Julius von der Ohe, NOW GmbH

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Federal Ministry
for the Environment, Nature Conservation
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Contact:
exportinitiative@now-gmbh.de