Europa-Universität Flensburg

Department of Energy and Development
Sustainable Energy and Development (SEDev)

Divergent Microgrid Development Pathways in Developing and Developed Off-grid Contexts. Comparing Cases from Bangladesh, Indonesia and Scotland.

Dr. Mominul Hasan

Content

Divergent Microgrid Development Pathways in Developing and Developed Off-grid Contexts.

Bangladesh	Indonesia	Scotland

Motivations
Development strategies
Operation and Maintenances

Synthesis & Lessons Learned

Ba-Ind-Scot









Metric	Bangladesh	Indonesia	Scotland
GDP (Nominal)	~$450 Billion	~$1.4 Trillion	~$230 Billion
Population	~175 Million	~280 Million	~5.5 Million
Per Capita Energy Consumption	~3,500 kWh	~8,800 kWh	~26,400 kWh
Electricity Access (% of pop.)	100%	99.8%	100%
Energy Fun Fact	Off-grid electrification pioneer with more than 6 Million Solar Home System	It is made up of over 17,000 islands and there 8 major grids and more than 1000 mini-grids	Windiest area in Europe, often generate more energy from Wind than it needed

Introduction

- **Defining Microgrids/Mini-grids:** Small-scale electricity grids for communities, supplied from centralized sources.
- **Comparative Objectives:** Exploring the shift from basic energy access/poverty alleviation in developing nations to self-sufficiency and decarbonization in developed contexts.
- **Data & Methodology:** Scientific literature, Previous onsite research, observations and field experience, case study.



Mini-grid PV system in Bangladesh



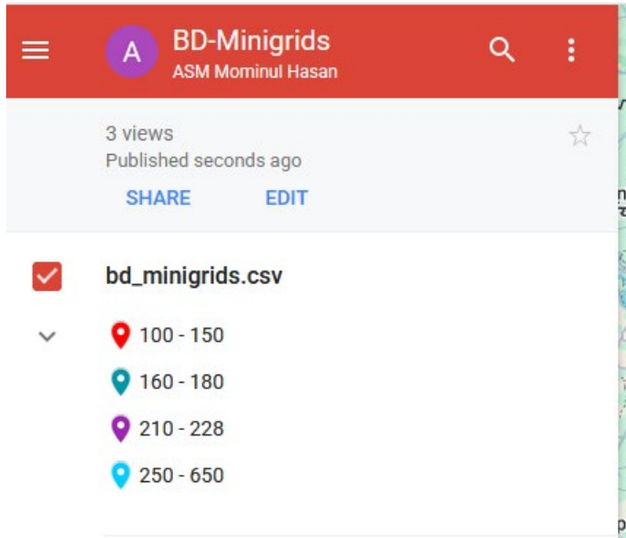
Mini-grid PV system in Indonesia



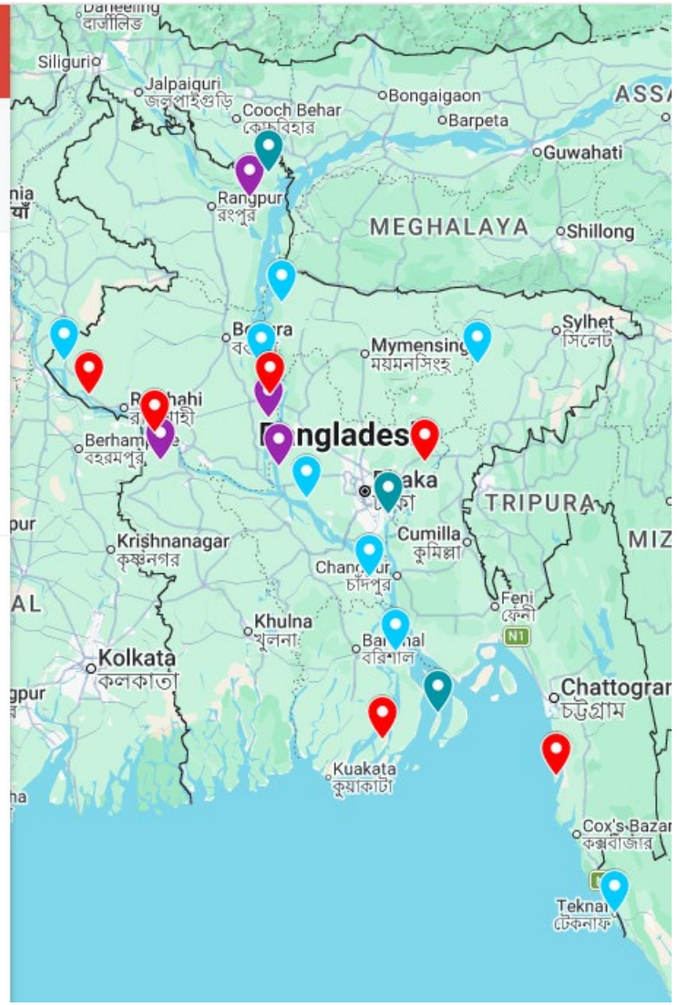
Mini-grid PV system in Scotland

Bangladesh

Off-grid Mini-grids in Bangladesh



Map doesn't show exact location but the admirative zone

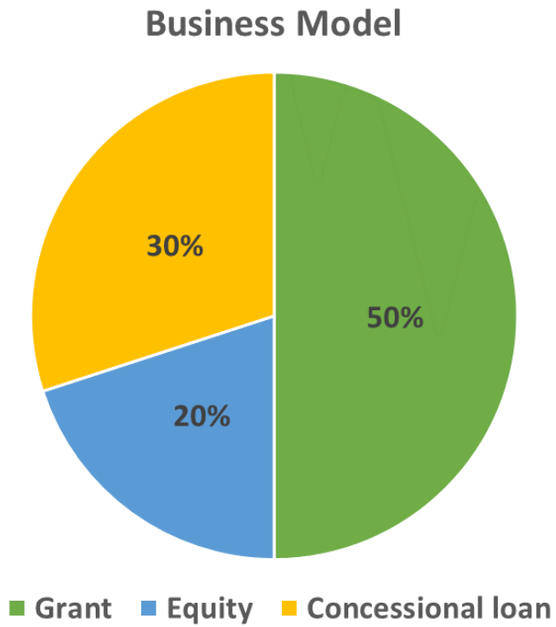


Map, Author, Data: SREDA, 2026

- **Motivation:** Off-grid electrification and Last mile energy access, political
- **Total capacity** of Microgrid in Bangladesh: 5.8 MW (100-650 kW)
- An 11 MW PV mini-grid is under construction
- **No. of Microgrid**: 28
- Total Beneficiaries: >20,000 people

Development Strategies and Practices

- **System Configuration:** PV + Battery + Diesel
- **Demand:** Residential + Business + Social + Agriculture + Cottage industries
- **Hours of Service:** 24 Hours
- **Grid:** According to the standard of Bangladesh Rural Electrification Board (REB) grid
- **Developer:** Private sectors
- **Ownership:** Developers
- **Key stakeholders:** SREDA, IDCOL, World Bank, KfW etc.
- **Business Model:** Grant, Soft Loan & Equity



Development approach

Developer identifies location → Perform feasibility study and Develops proposal → Apply for grant and soft loan to IDCOL → Implement upon approval

Current Operational status Bangladesh Mini-grids

- The first mini-grid installed in 2009, has been abandoned 10 years of Operation. 2/3 other mini-grids have similar situation.
- Others are facing challenging time due to national grid extension.
- Utilities (REB &PDB) have acquired about 25 mini-grids through Power purchase agreement (PPA).
- When utilities take over, off-grid inverters and batteries remain unused.
- Distribution lines also often abandoned and developed as new.
- Lack of understanding between developer & utilities





Based on a personalised interview with mini-grid operator on 07.06.2026

Indonesia

Mini-grids in Indonesia



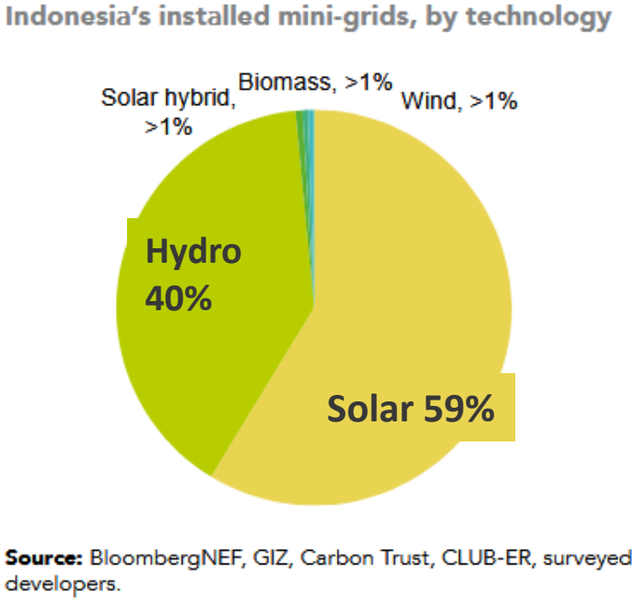
Map IV: Location of surveyed PV powered Mini-Grids (2013-2015). (Source: KPI survey)

- **Motivation:** Off-grid electrification and Last mile energy access, political
- **Total capacity of** Microgrids in Indonesia: ~40 MW (5 to >1000 kW)
- **No. of Microgrid**: > 1000
- **Total Beneficiaries**: > 300,000 People, >2,000 Social Institution and > 3,500 business

Source: Author, based on GIZ KPI Survey data

Development Strategies and Practices

- **System Configuration:** Micro Hydro, PV + Battery, Hybrid
- **Demand:** Residential + Business + Social
- **Hours of Service:** 16 and 24
- **Developer:** Local government
- **Ownership:** Local government
- **Operator:** Community/Cooperative
- **Key stakeholders:** Community leaders, Local government (Governor/Regent), MoEMR, EnDev
- **Business Model: Various,**
- **Example:** 100% Grant, Minimum tariff to cover basic O&M Costs
- **Funding Organisation:** EBTKE, MoHA ,KUKM, Local Initiative



Source: BloombergNEF, GIZ, Carbon Trust, CLUB-ER, surveyed developers.

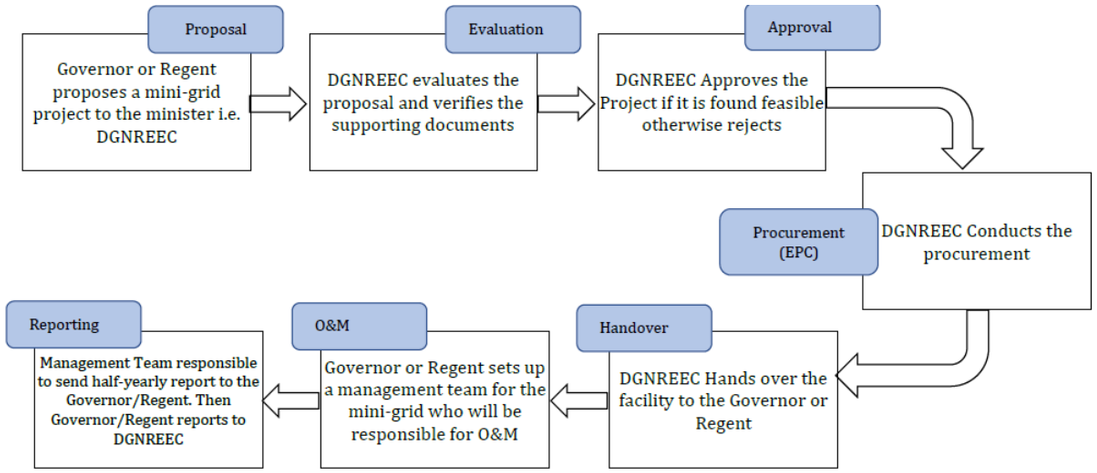
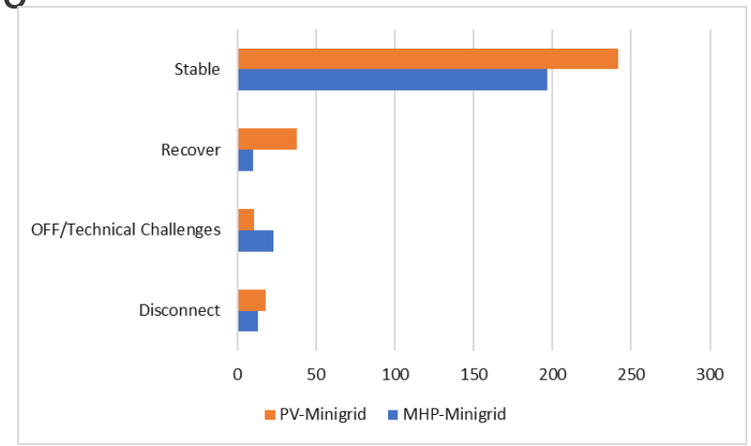


Figure 7: PV powered Mini-grid development process in Indonesia (source: a presentation of EnDev ID)

Operational status of Indonesian Mini-grids

According to Key Performance Indicator Survey by EnDev until 2016





When the grid arrived at 199 hydro-based mini-grids:

- 140 were **abandoned** due to poor management or higher tariffs than PLN.
- 50 **operated in parallel** due to cheaper rates or better service.
- 9 successfully sold all or excess electricity to PLN

Source: Author, based on EnDev KPI Survey data 2016, Minigrid Partnership Report 2022

Isle of Eigg, Scotland

Mini-grids on th Isle of Eigg in Scotland

- Eigg System
  - PV : 180 kWp
  - Wind: 24 kW
  - Micro Hydro: 106 kW
  - Battery: 1.3 MWh
  - Inverter: 216 kW
  - Diesel Generator: 76 kW & 64 kW
  - Distribution System: 11kV Underground





Table 4-2: Electricity consumption in a year for households and businesses (2023)

Item	Consumption in a year (MWh)	Share	Number of buildings	Average consumption per building (MWh)
Households	164	65%	64	2.5
Business	89	35%	26	3.4
TOTAL	**253**	**100%**	**90**	**5.9**

Report: International Class Report 2024, Data: Eigg Electric

Mini-grids on th Isle of Eigg in Scotland

- **Major Motivation: Decarbonisation**
- **Total users: 64**
- **Fund raising:** Eigg Community raised fund and received subsidies for developing the microgrid
- **Community Management:** Owned by Eigg Electric (a subsidiary of the community heritage trust), the pathway emphasizes "sufficiency". Residents adapt behavior to a 5 kW household cap (10 kW for businesses) through a **"traffic light"** system that signals renewable availability
- **Future Goals:** Eigg's current focus is sector coupling, electrifying heat and transport to achieve Net Zero by 2030





Source: IC 2024

Synthesis & Lessons Learned

Synthesis: Divergent Pathways

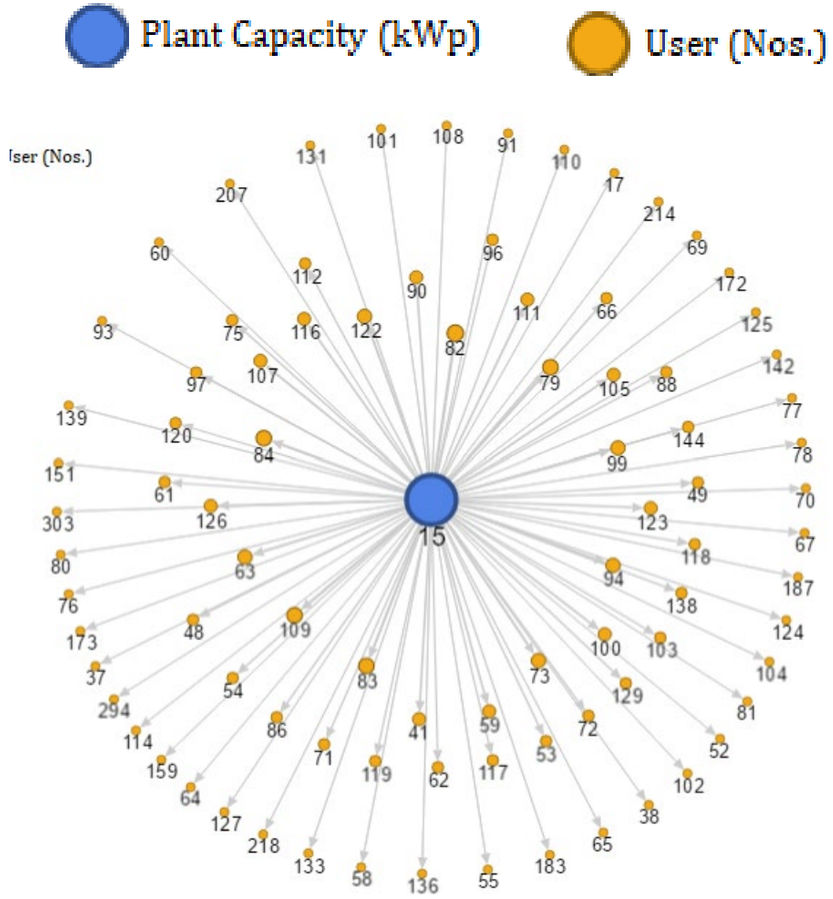
The pathways diverge primarily in their objective and definition of success.

- Objective: Energy access vs decarbonization
- In Bangladesh and Indonesia, success is defined by "connection" and basic service, often ignoring further use potential.
- In contrast, Eigg treats the microgrid as a mature infrastructure asset, emphasizing high reliability (24/7) and local empowerment.
- However, all cases demonstrate that **capital subsidies are unavoidable**; even in developed contexts, residents cannot be expected to bear the full cost of infrastructure (Chimel and Bhattachariya, 2015)

Binary vs Multi-dimensional

Synthesis: Energy Use

- Motivation for Microgrid Varies
  - In Bangladesh and Indonesia key motivation is Access to Electricity
  - On Isle of Eigg, Air pollution, Noise and climate change awareness.
- Energy Consumption Per User
  - In Indonesia (MTF Tier 1 - Tier 3)
  - Bangladesh (MTF Tier 2 – Tier 3)
  - On Eigg (Tier 4 – Tier 5)
- Bonsai Effect vs Awareness
  - Users are often restricted by energy limiters even when systems have excess capacity.
  -



How many people share a 15 kW Solar Mini-grid in Indonesia

Lessons Learned (1/2)

- National Grid extension to mini-grid sites jeopardise the mini-grid operation
  - Mini-grids in Bangladesh have been suffering from this the most
  - Similar situation is also noticed in Indonesia
- Longer battery life
  - Hybridisation & convenient operating temperature of multiple sources reduces the use of battery leading to longer life, Eigg system is great example of this (PbSO4 battery lasted more than 15 Years)
- Energy awareness and local capacity help better system operation
  - Lack of local capacity reduces the operation time of the system, especially it has been noticed in Indonesia.
  - Eigg has skilled man power to repair minor to some major issues
- Ownership
  - High subsidy leads to lack of ownership & poor management
  - Local investment and local ownership leads to better management



- Adaptive Capacity
  - Systems highly oversized or undersized.
  -

Lessons Learned (2/2)
Power of Community Led Project

Drivers for community led microgrid project on Eigg

- ❑ Energy awareness
- ❑ Climate awareness
- ❑ Literacy rate
- ❑ Community mindset to solve larger problem together.
- ❑ Equity and Transparency
- ❑ Local capacity

Power of Community Led project

- ❑ Less issues with RE project development (eg. Higher acceptance)
- ❑ Local Investment
- ❑ Ownership
- ❑ Shared responsibility (lower maintenance, lower costs, lower faults)



Outlook

- Sector coupled microgrids combining
  - Electricity, Heat/Cold, Agriculture, Transport, Process Industries Etc

- Developing a better business model for the remaining off-grid inverter and batteries under grid-connected situation.



Grid Forming Inverters



References

- Aziz, S., & Chowdhury, S. A. (2021). Performance evaluation of solar mini-grids in Bangladesh: A two-stage Data Envelopment Analysis. Cleaner Environmental Systems, 2, 100003.
- Chmiel, Z., & Bhattacharyya, S. C. (2015). Analysis of off-grid electricity system at Isle of Eigg (Scotland): Lessons for developing countries. Renewable Energy, 81, 578-588.
- Hasan, A. S. M. M. (2017). Evaluation of Energy Access at RE Powered Mini-grid in Indonesia: A Multi-Tier Framework Approach [Master's thesis, Europa Universität Flensburg].
- Minigrid Partnership. (2024). State of the Global Mini-grids Market Report 2024.
- International Class Report (2024). Transition Pathways for Decarbonisation and Self Sufficiency on the Isle of Eigg: International Class 2024.
- ESMAP. (2015). Beyond Connections: Energy Access Redefined. World Bank.)

Europa-Universität Flensburg

Thank you

Contact:
Dr. Mominul Hasan
Tel.: +49 461 805 2555
mominul.hasan@uni-flensburg.de
Munketoft – MAD 013

Visiting Address:
Room: MAD 013
Munketoft 3b
24937 Flensburg
Germany

www.uni-flensburg.de/sedev