Resilience Microgrid Architectures For Indonesian Islands To Deal With Natural Disasters

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OUTLINE

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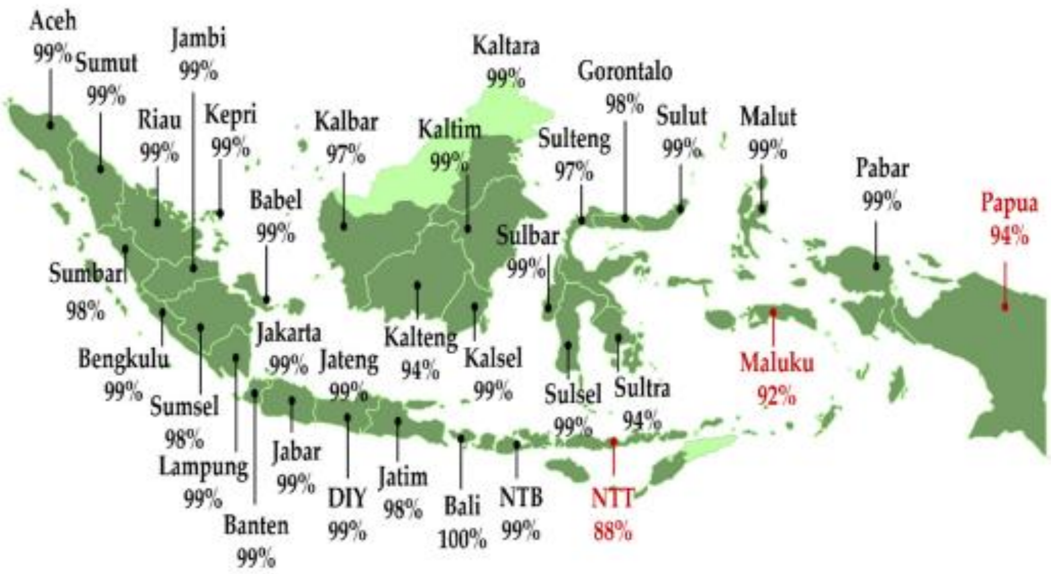
Introduction : Problems in Microgrid

Geographical and Policy Condition

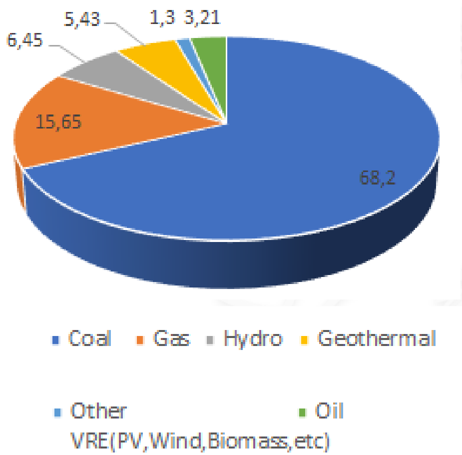
Energy source	Potential (MW)
Geothermal	29.544
Hydro	75.091
Mini-micro Hydro	19.885
Bio-energy	32.654
Solar	207.898 (4,8 kWh/m^2/day)
Wind	60.647 (≥4 m/s)
Ocean	17.989

- Thousand Island Archipelago with five main islands (Sumatera, Java, Kalimantan, Sulawesi and Papua)
- Renewable Energy (RE) has the energy mixed target 23% (in 2025) and 31% (in 2050)

Electrification of Indonesia



Energy Mixed



- Systems Voltage : 7 high voltages (150, 275 & 500 kV), 200 medium voltages (20 kV), ≥ 900 off grid (380 V)
- Energy Mixed 68% Coal, 15,65% Gas, 3,21% Oil and 13,18% RE

Electrifying Indonesia

Technology	MW	% MW	% MWh
A. Renewable Energy			
Geothermal	2.529	3,9%	5,49%
Hydro Power	4.790	7,4%	6,10%
Mini Hydro	541	0,8%	0,83%
PV Solar	83	0,1%	0,04%
Wind Energy	131	0,2%	0,15%
Biomass	135	0,2%	0,13%
Subtotal	**8.208**	**12,7%**	**12,74%**
B. Fossil			
Coal	32.812	50,8%	66,03%
Combined Cycle	12.430	19,3%	13,12%
Simple GT & Gas Eng.	6.905	10,7%	5,89%
Diesel	**4.198**	**6,5%**	**2,22%**
Subtotal	**56.345**	**87,3%**	**66,03%**
TOTAL	**64.553**	**87,3%**	**87,26%**

RE contribution to electricity fuel mix is **12,7%** (dec 2021)

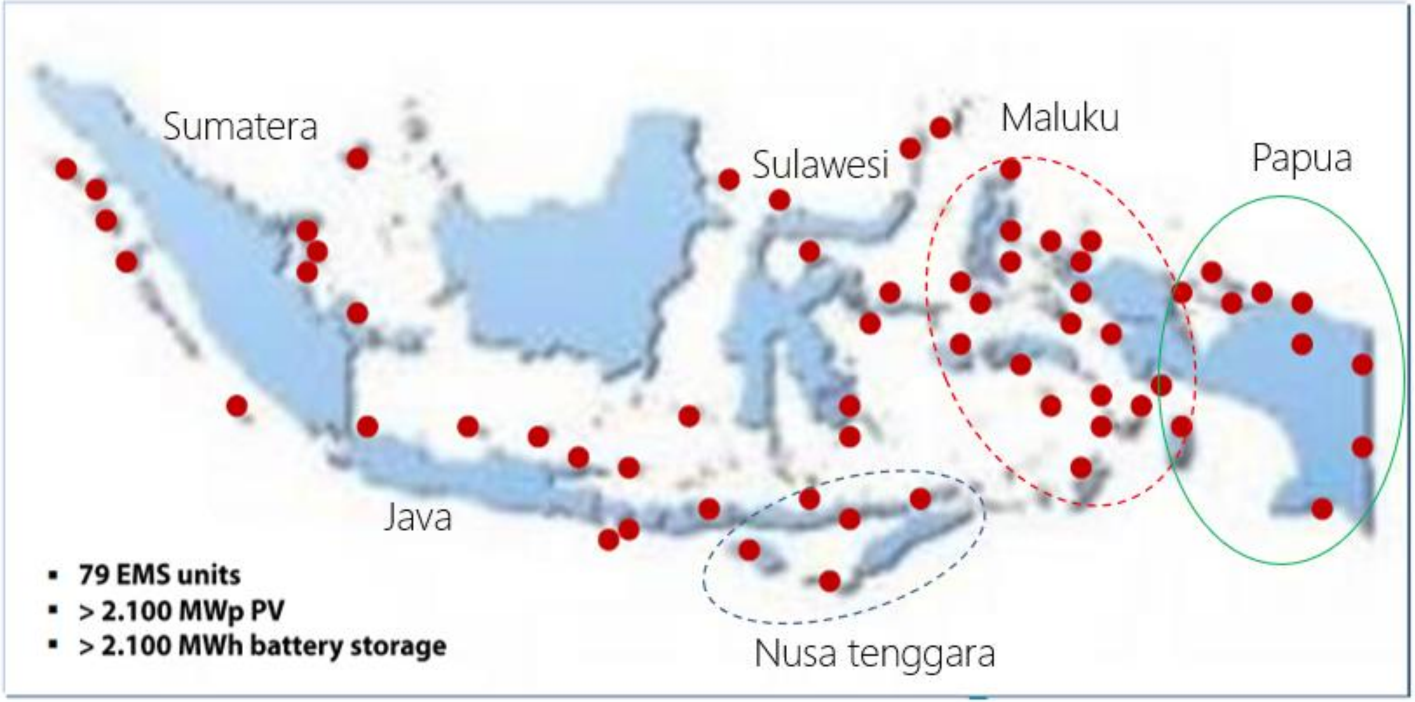
LCOE
Cents/kWh

Hydro	**4,2**
Coal Fired	4,5
Gas Fired	17,8

Diesel:

- LCOE 22.97 cent$/kWh
- CO2 emission 2,66 kgCO2/L
- Imported Fuel Oil (consum 3,1 Mil KL/year)
- Isolated scattered areas/islands (5.196 units)

Potential Microgrid



Mostly east part of Indonesia such Maluku, Papua and Nusa Tenggara.
Some island around Sumatera, Java and Sulawesi

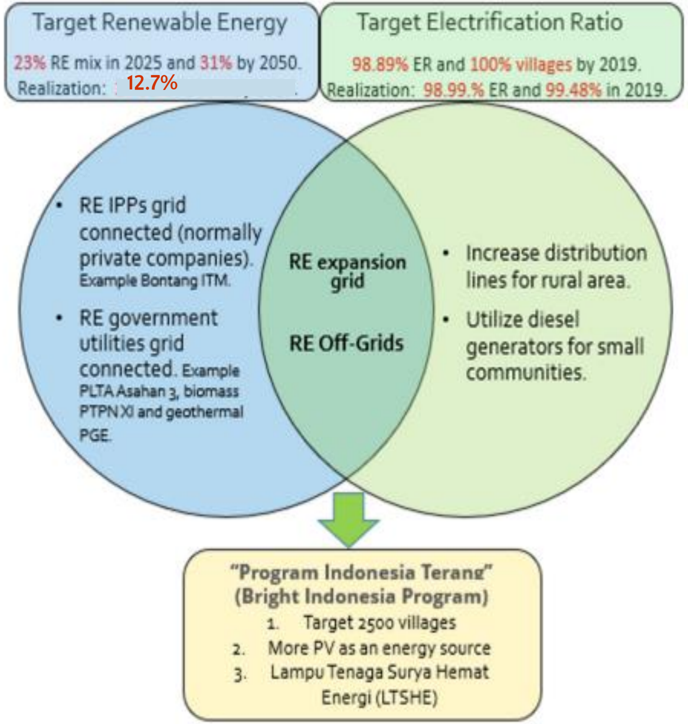
Microgrid Classification and Main Characteristic

Large remote microgrids • Normally used for mining, refuge, or military base • To reduce operational cost for commercial or industrial • As an emergency power for refugee camp or base. Examples: PV Bontang ITMG, Biogas Petapahan (PT Ramajaya) and Damit Hulu (PT Gawi).	**Small remote microgrids** • Isolated area • Mainly focus on diesel replacement • Limited power for housing Examples: Buta, Borme, Berau, Miang Island, Matutuang island, Lakatuli NTB, and Kariango, Ogan hilir, and Hydro Silina Baru, Nias.
Examples: PV Oelpuah, PV Gorontalo, Hydro Lubuk Sao II and Cibareno, Geothermal Ulumbu and Matalako, Biowaste Cengkong Abang • To inject power to grid • Connect to medium or high voltage grid (strong grid) • Can be used as an island mode **Large grid-connected microgrids**	Examples: Pramuka island, Nusa Penida, Medang, Semau, Mini Hydro Sindang Cai, Biowaste Kuala sawit, Sumut. • High load demand • To inject power to grid • Help long distribution line from voltage drop (weak grid) **Small grid-connected microgrids**

Solar Panels in Prai Witu Village in Sumba, Indonesia on February 16th, 2022.
Photographer: Rony Zakaria for Bloomberg Green

Source: Simatupang et al, "Remote Microgrids for Energy Access in Indonesia...."
https://doi.org/10.3390/en14216901

Government Program



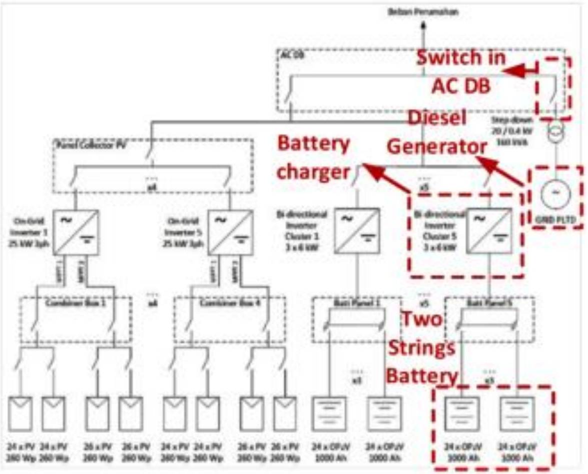
Source : MEMR Indonesia

Some Microgrids Facilities in Maluku

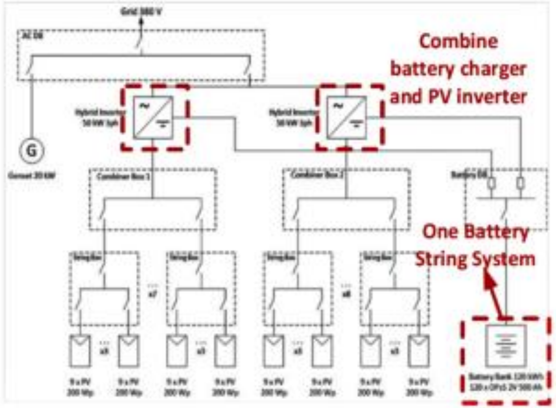
PV Desig-nator	Year of Operation	Location	Funded by	Type	PV Desig-nator	Year of Operation	Location	Funded by	Type
Site 1	4	Ambon	PLN	Off-grid	Site 9	3	Saumlaki	MEMR	Hybrid
Site 2	8	Ambon	PLN	Off-grid	Site 10	3	Tual	PLN	Hybrid
Site 3	3	Ambon	PLN	Off-grid	Site 11	2	Tual	MEMR	On-grid
Site 4	3	Masohi	PLN	Off-grid	Site 12	3	Saumlaki	MEMR	On-grid
Site 5	5	Masohi	PLN	Off-grid	Site 13	6	Tobelo	PLN	Hybrid
Site 6	5	Masohi	PLN	Off-grid	Site 14	2	Saumlaki	PLN	Hybrid
Site 7	3	Tual	PLN	Hybrid	Site 15	5	Tobelo	MEMR	On-grid
Site 8	4	Tual	PLN	Hybrid					

Source : PLN % MEMR Indonesia

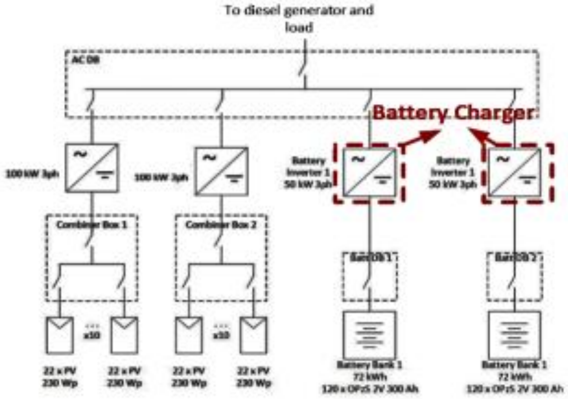
Typical Microgrid Facilities



100 kWp PV Diesel site 14



8 kW PV Battery site 1



PV Battery site 8

Source: Simatupang et al, "Remote Microgrids for Energy Access in Indonesia…."
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Microgrid Project

Research collaboration between Indonesia and Denmark

INDONESIA

1. UGM (DEIE)
2. PLN
3. National Energy Council
4. MEMR

DENMARK

1. Aalborg University
2. Southern Denmark University

Project Summary

- Tech-IN is aimed at overcoming the challenges associated with the **large-scale deployment of renewable-based microgrids** (MGs) in the **hazardous environment** of the Indonesian Islands that is prone to severe **natural disasters** (NDs).

- Indonesia is archipelago country with **suffering 3.622 NDs** including **tornadoes**, floods, and **landslides** occurred across the country in 2019.

Project Goal

(i) to **increase the renewable energy** while **reducing the fossil fuel dependence**
(ii) bringing electricity to **remote places and Islands**
(iii) provide high levels of **resiliency and availability** of electricity supply in front of natural disasters.

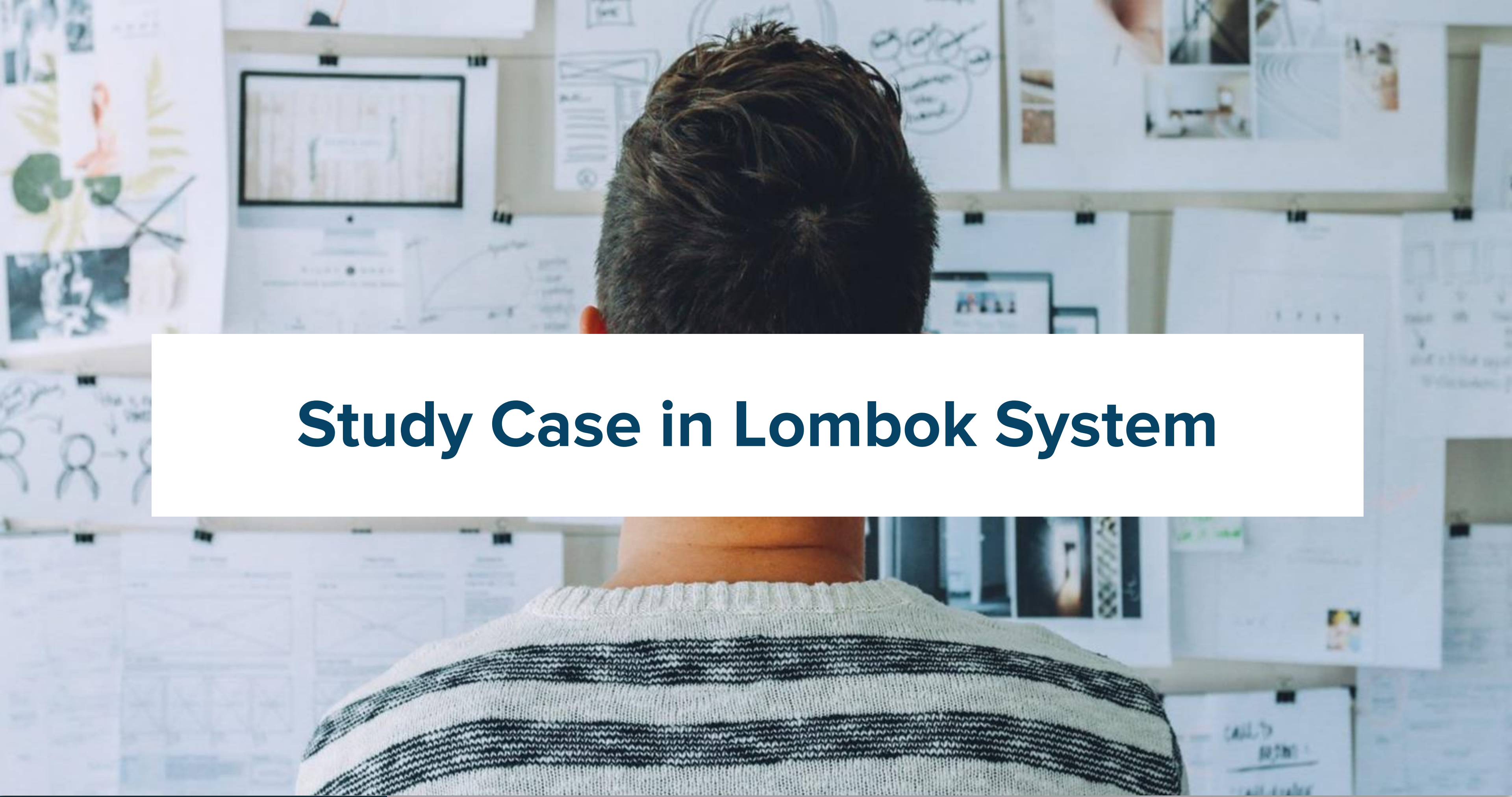
Objective

The objective of Tech-IN is two folds:

- To **propose sustainable and cost-effective solutions** for bottom-up electrification substituting diesel generators by MGs with high renewable energy penetration.
- To develop MGs with unprecedented levels of portability, scalability, and resiliency in front of natural disasters.

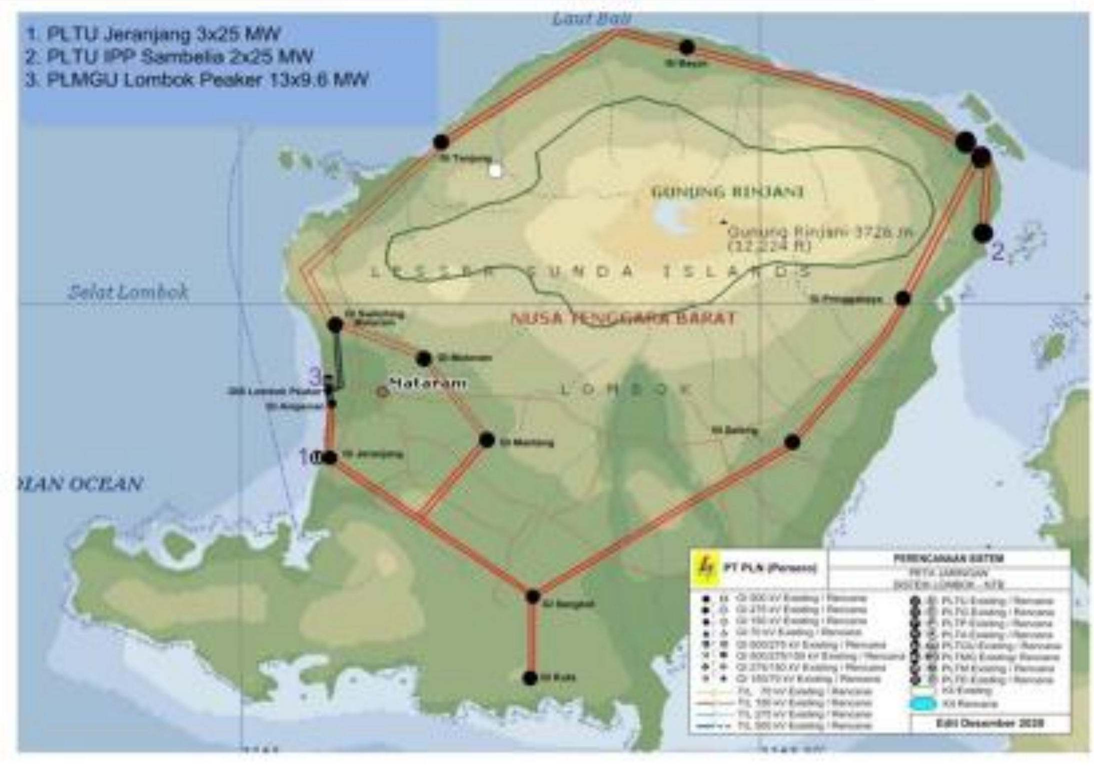
Work Package Project

1. Techno-socio-economic feasibility of MGs in Indonesia
2. Resilient ad-hoc and Community MGs
3. Networked microgrids
4. System Integration and Laboratory Testing
5. Development impact analysis and recommendations for country-wide adoption



Study Case in Lombok System

Lombok System



Total power plant 416.16 MW.

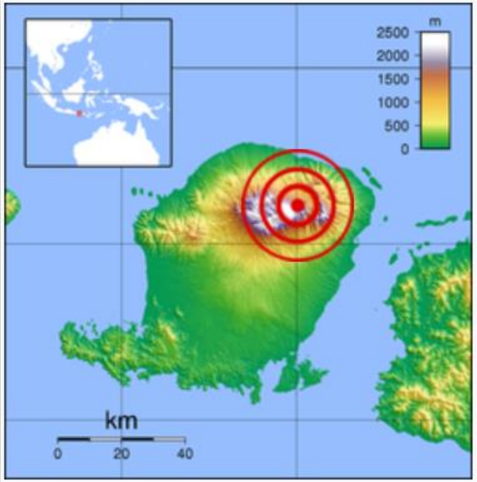
- steam : 140 MW
- gas : 126,88 MW
- diesel : 112,5 MW
  microhydro: 15,95 MW
- PV : 20,82 MW.

The daily load ranges are between 160 MW to 256 MW.

Earthquake :

- July 29, 2018
- August 5, 2018
- August 19, 2018
- March 17, 2019

Earthquake, August 5th, 2018 (Major Earthquake)



Date	Sunday, 5 Agustus 2018
Time	19:46:35 (WITA)
Magnitude	7,0 Mw
Deepth	15 km (9,3 mi) (BMKG)
Epicentrum	8.287°S 116.452°E
Disaster area	Bali dan Nusa Tenggara Barat, Indonesia
Intensity	VII (very strong)
Tsunami	Yes
Landslides	Yes
Victim	564 death, 1.447 injury, 67.875 house damage, 468 broken school, 352.793 people evacuate

Telecommunication network and power outages throughout Lombok.

Shortly after the earthquake, power outage in most areas of Mataram. Although some places in Lombok still have electricity, the load is only 50 MW, much lower than 220 MW on a typical day. Roads across Lombok were congested as traffic lights went out and roads were littered with rubble. The State Electricity Company stated that electricity had been restored to most of Lombok in the hours after the earthquake, but that 25% of the island's electricity was still out.

On Gili Trawangan, cafes and resorts were badly damaged.

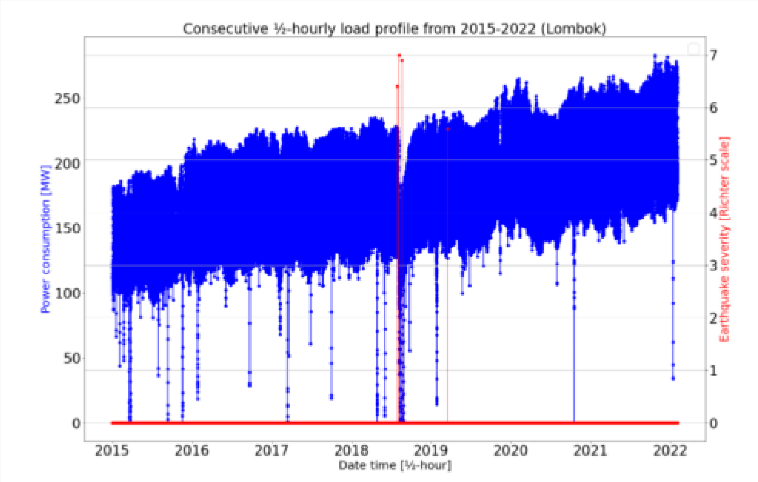
https://id.wikipedia.org/wiki/Gempa_bumi_Lombok_Agustus_2018

Disaster : Earthquake

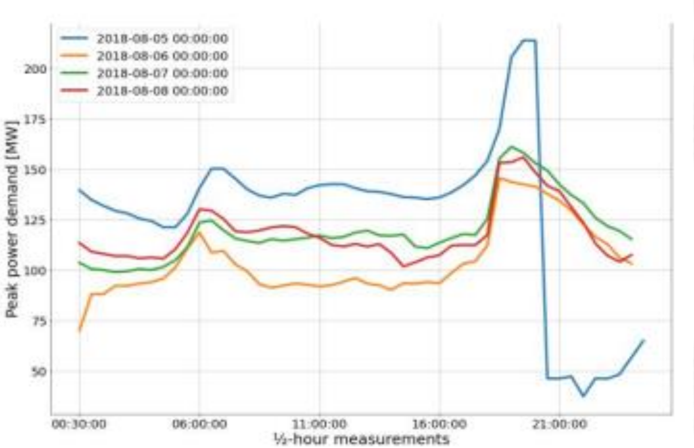
Table 1 Result overview for climate resilience components during natural disaster strikes

	Natural disaster events			
	29/07/2018	05/08/2018	19/08/2018	17/03/2019
	ND magnitude [Richter] (and epicenter)			
Component metrics	6.4 In the ocean, off Lombok north	7 Lombok north, inland	6.9 Northeast Lombok	5.6 East Lombok
Absolute power decrease	0	167.3 MW	136 MW	20.1 MW
Relative power decrease	0%	98.9%	78.3%	13.5%
The duration of decline	0	0.5 hour	0.5 hour	0.5 hour
Time at the "bottom" [hr]	0	2.5 (37-46 MW)	3 (1.2-1.5 MW)	0
Average restoration rate [MW/½ hour]	-||-	4.6	5.6	6.4
The duration of recovery time [hr]	-||-	4	10.5	1.5

Disaster Impact in Electricity Load Profile



The Electricity Consumption vs Earthquake Events in Lombok 2015-2021

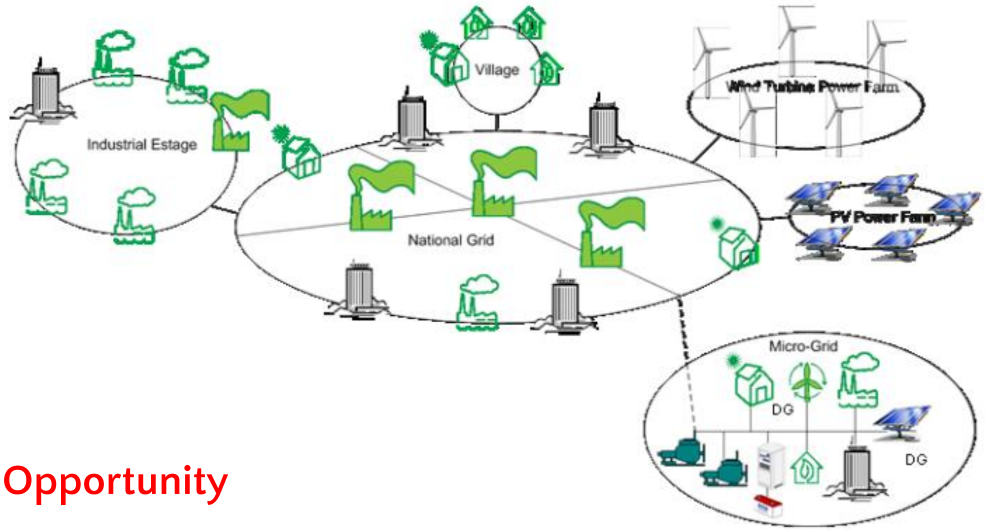


Load Profiles for Lombok on 5th – 8th August 2018

- Earthquakes in 2018 and 2019 cause the distribution power poles damaged and disconnect of several areas
- Need 50 days to fully recover.

Resilience Microgrid Architectures

Complexity on operation and control on MG (optimizing wind, solar, micro-hydro and waste-to-energy power plants).



Challenges in research, including

a) stability,

b) operation system,

c) protection system,

d) power quality,

e) regulation, and

f) loss of grid.

Opportunity

Portable and scalable for special area (**remote area, isolated area**, research center, university)

Microgrid Concept

Planning and **control of community MGs**

Renewable-based MGs are inertia-less, so inertia will be emulated utilizing control algorithms, such as droop methods, virtual synchronous machines, or dispatchable virtual oscillators.

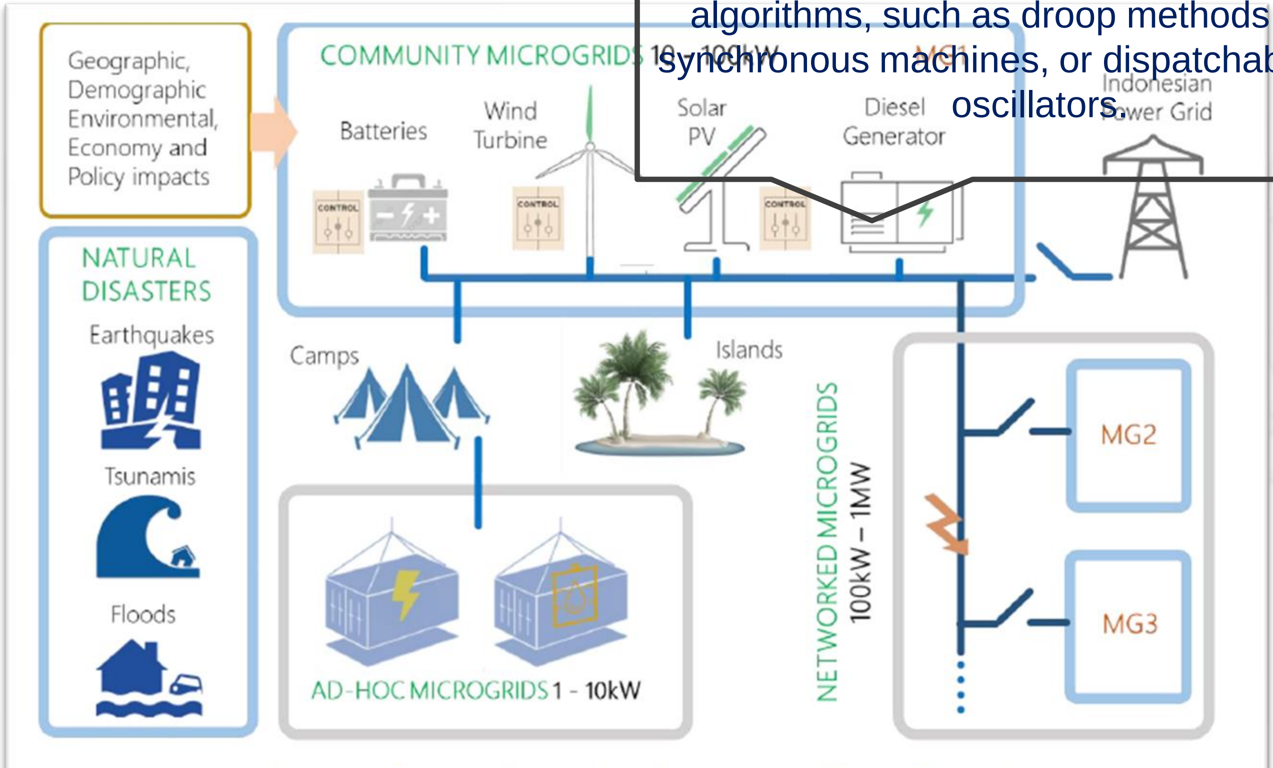


Fig. 1. Concept diagram illustrating the proposed three microgrid types.

THANK YOU