Microgrid Activities in South Korea

November 1, 2022

Seul-Ki KIM

Korea Electrotechnology Research Institute

Policy and Legislation

- Renewable energy sourced (RES) generation goal has sharply increased towards net-zero carbon emission by 2050

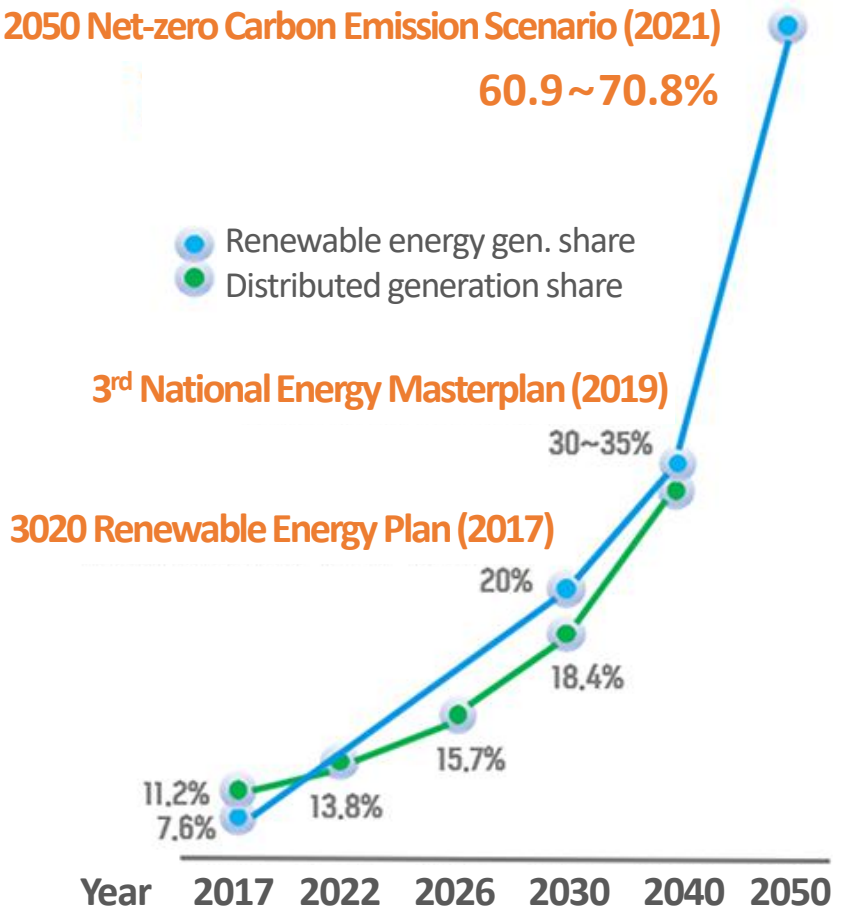
✓ RES gen. share goal

20% (2030) → 30-35% (2040) → 60-70% (2050)

✓ Distributed gen. share goal

18.4% (2030) → 30% (2040)

✓ Currently, RES gen. share is about 7%, and 78% of total capacity is small-sized



Source: Korea Energy Technology Evaluation and Planning Institute

Distributed Energy Promotion Strategy (June 2021)

Vision

Deployment of Distributed Energy Systems which generate, consume and trade low carbon energy in a smart way near the demand

Distributed gen. share: 17% ('25) → 19% ('30) → 30% ('40)

Infrastructure

- **Increase the hosting capacity of electric power grid**
  - – Energy Management System(REMS, ADMS, etc)
  - – ESS and Sector coupling(P2G, P2H, V2G)
  - – Energy superstation (Hybrid charging station)

Decentralization

- **Decentralize energy generation & consumption**
  - – Incentives for decentralized load and generation
  - – Incentives for RE sourced self-generation
  - – Deployment of community Microgrids

Market

- **Create a new market and institutions for active participation of DERs**
  - – Electricity market reform
  - – Virtual power plant(VPP)
  - – Distribution System Operator (DSO)
  - – Regionally differentiated network tariffs

DE Promotion Act ('22) → DE Special Districts ('23) → DER deployments

Distributed Energy Promotion Act

- Proposed in June 2021, and pending approval
- Intended to legislate for
  - ✓ regular establishment of national “Distributed Energy Promotion Plan”,
  - ✓ mandatory installations of distributed energy resources,
  - ✓ licensing DE service providers such as community energy supplier, VPP, DE generator, demand response supplier, etc.,
  - ✓ distribution grid management with high share of DERs such as curtailment, grid reinforcement, direct power purchase, etc.,
  - ✓ DE special districts for new businesses and services, and etc..

Energy Superstations: Charging Station Pilots

- MG operation with PV, ESS and/or fuel cell for EV/FV charging services, and V2G service in some pilots
- Institutionally and legally not ready for business
- SK T&E plans nation-wide deployment after testing out the technology
- Look to participate in aggregated ancillary services

EV charging station, PV and ESS

H_2 storage and Charger

Concept of SKE Energy Superstation

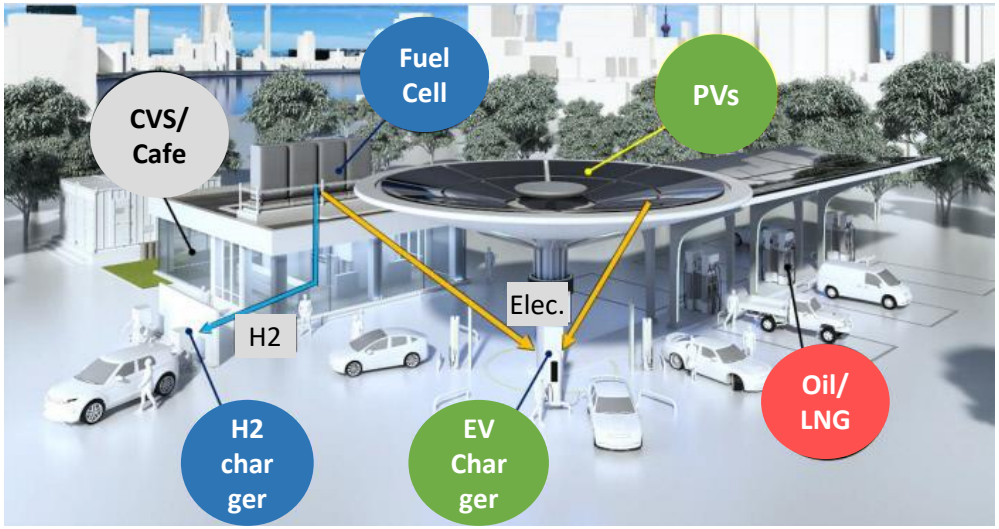
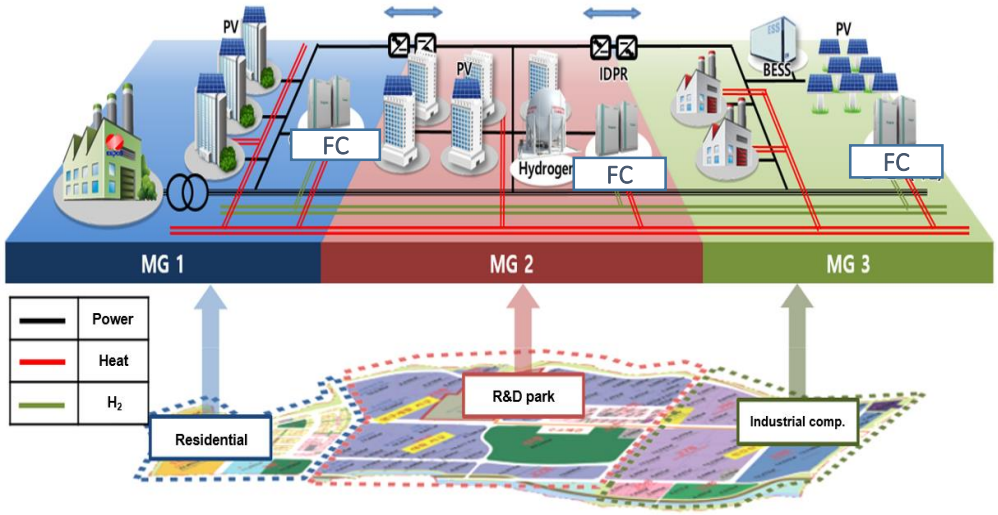


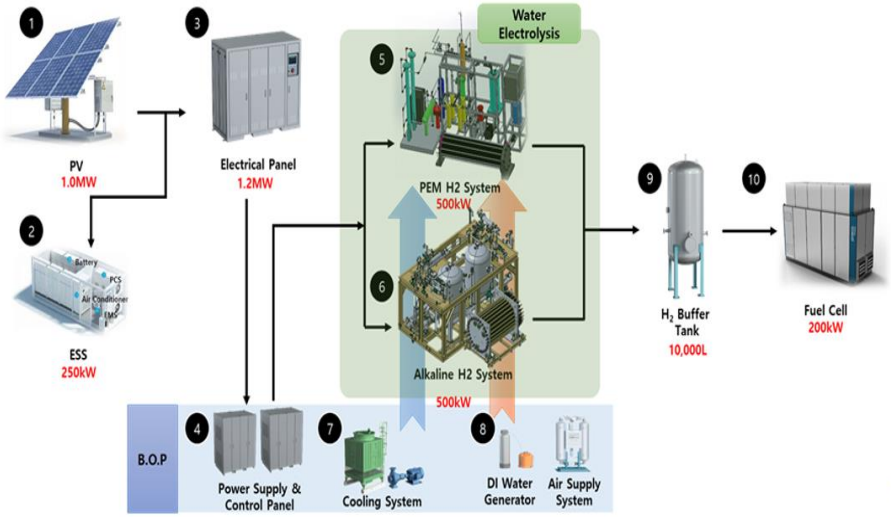
Image sources : Yangjae green car station, Seoul, Korea, www.H2news.kr, and SK Energy

P2G Based Multi-MGs

- Residential, R&D complex and Industrial MGs in Ulsan Industry Complex)
- Resources: PV 1MW, ESS 250kW/500kWh, Electrolyzer 1 MW, and FC 200kW
- Optimal management of electricity, heat and hydrogen in on-grid/off-grid
- Digital Grid Power Routers (BTB converter) for power trading btw. MGs
- Complete construction in 2022 and field-test for next 5 years



Multi microgrid and energy trading

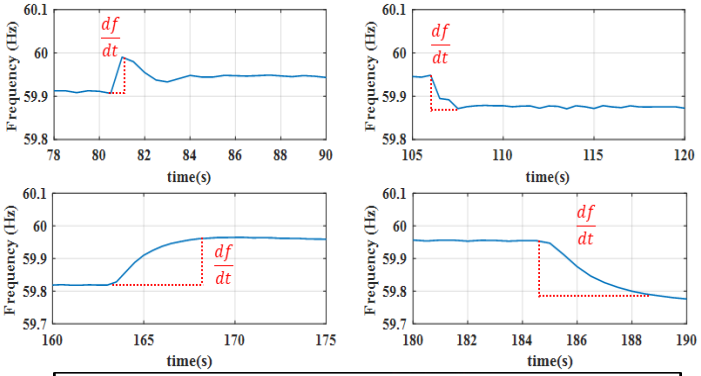


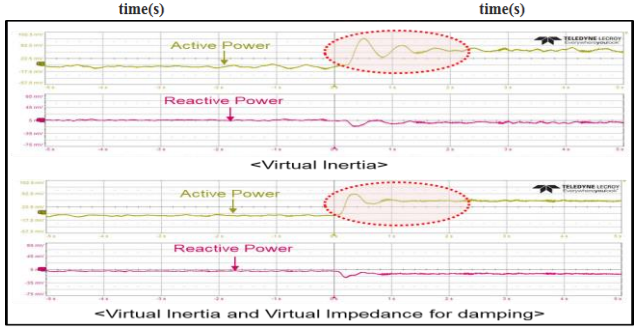
Sector coupling of electric power and H_2

Source: KEPCO Research Institute

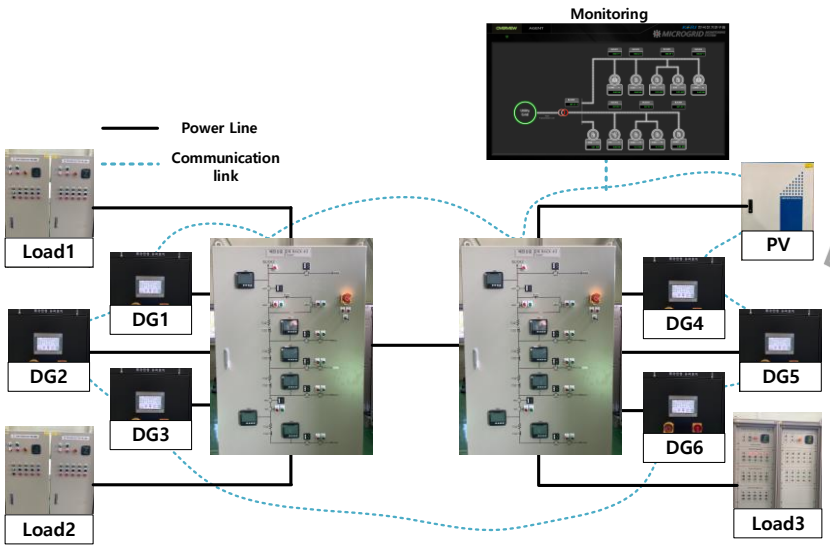
Grid-forming Inverters for Advanced MGs

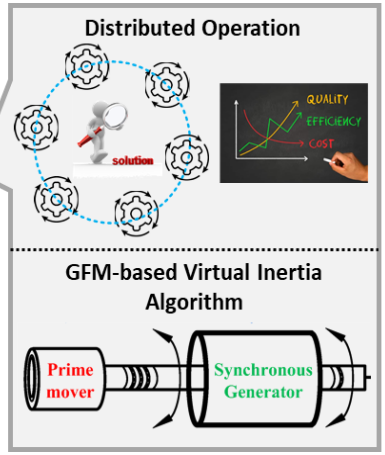
- Virtual inertia injection and oscillation damping
  - ✓ Improving frequency stability of MG with inverter DGs (6 ESS units of 10kW in parallel)
- Coordinated operation of multiple grid-forming inverters during contingency
  - ✓ Droop-controls and self-restoration
- Currently working on aggregation of virtual Inertia of DGs for ancillary service

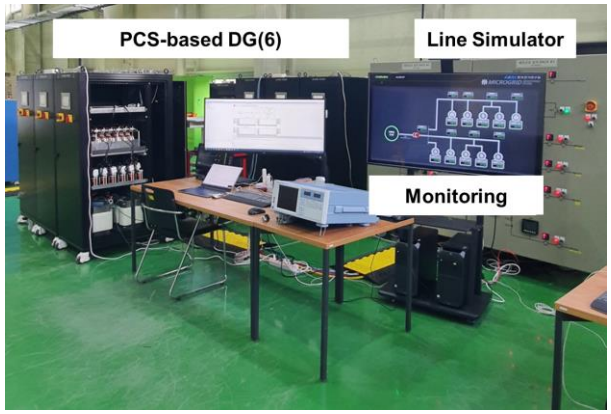




<Experimental results>





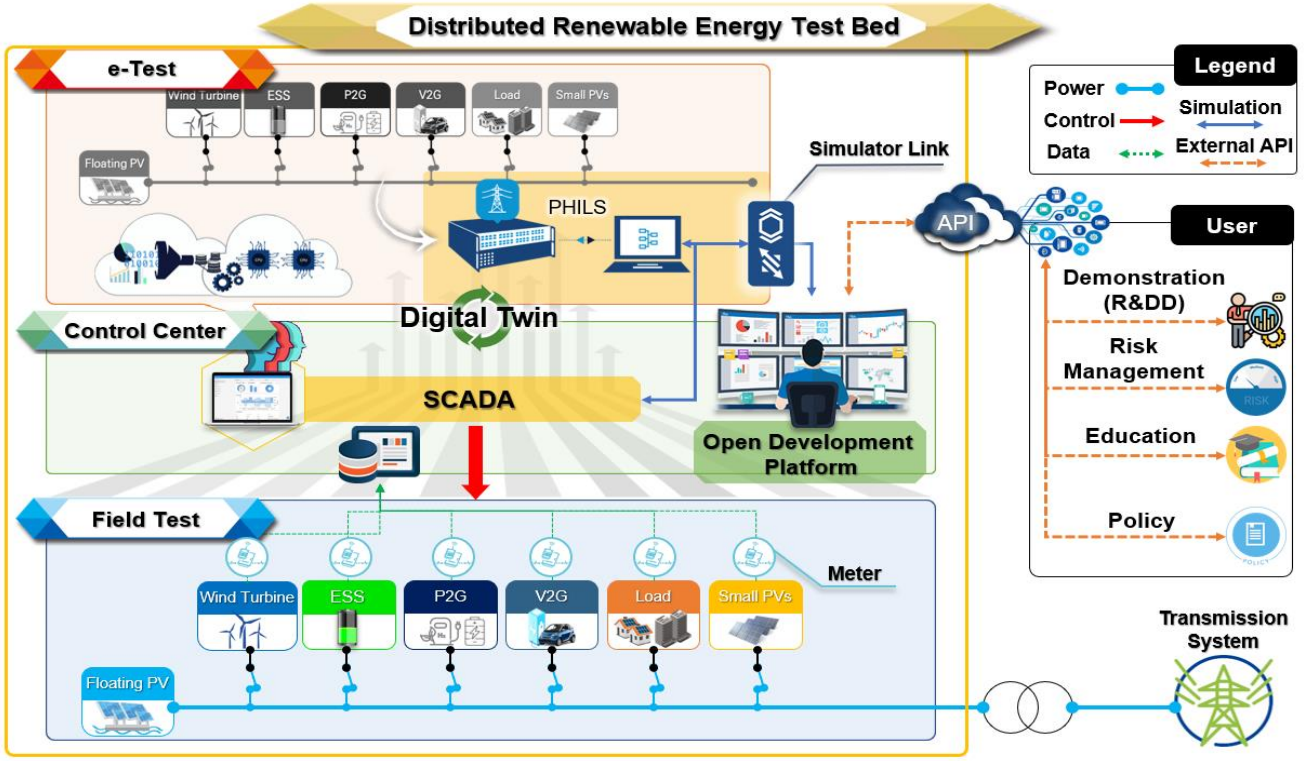


<Power Conversion system-based MG Pilot Plant>

Sources : Korea Electrotechnology Research Institute

Distr. Renewable Energy Testbed (2021~2026)

- National testbed for multi purpose experiments and verifications
  - ✓ Simulation (Digital twin), Hardware-In-Loop Simulation, Piloting
- Open development platform for external users
  - ✓ Businesses and services (MG, VPP, DSO, Energy/ancillary service, etc.)
  - ✓ Performance and Reliability of new DER technologies



Source: Korea Energy Technology Evaluation and Planning Institute

R&D: Advanced AC/DC Hybrid Distr. Network

Develop key components and grid technologies for MVDC grids, and pilot AC/DC hybrid networks to verify integrated performances

Main Areas > **Project Scope** (2022~2028) $222 million (Gov. $159M, PS $63M) > **Follow-up Project** (2029~2031)

1) AC/DC Hybrid Grid Components

- Core parts and devices (Hardware)
- Power conversion system, DC circuit breakers excl. secured HVDC/LVDC tech.

2) AC/DC Hybrid Grid Operation

- Design, protection and operation (SW)
- Hybrid operation technology of MVDC grid with existing AC grid

3) AC/DC Hybrid Grid Pilot Plant

- Building AC/DC hybrid grid pilot plant
- Secure track records for components and grid operation, and verify performance and safety

AC/DC Hybrid Grid Technology > **AC/DC Hybrid Grid Pilot Plant** > **Field Demonstration**

< Project 1>

	* Lab. Test
Grid Compo -nents	Power conversion
	Circuit breaker
	Protection device
	Measurements
	•••

< Project 2 >

Grid Operat -ion	Grid design
	Operation & control
	Protection & safety
	•••

< Project 3 >

MVDC Grid Pilot Plant

(Total operation system, Grid/components testing, etc.)

MVDC components testbed

* Linking the on-going testbed project

Fast EV charging Networks

Source: Korea Energy Technology Evaluation and Planning Institute

Smart Grid Research Division

Thank you

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Energy Research Institute @ NTU

Renewable Energy Integration Demonstrator Singapore (REIDS)

Grid of Grids Platform

Prasanna I V, Program Manager

24 Oct 2022

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https://erian.ntu.edu.sg/REIDS

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REIDS

Renewable Energy Integration Demonstrator – Singapore

An ERI@N Flagship Project

Grid of Grids Platform

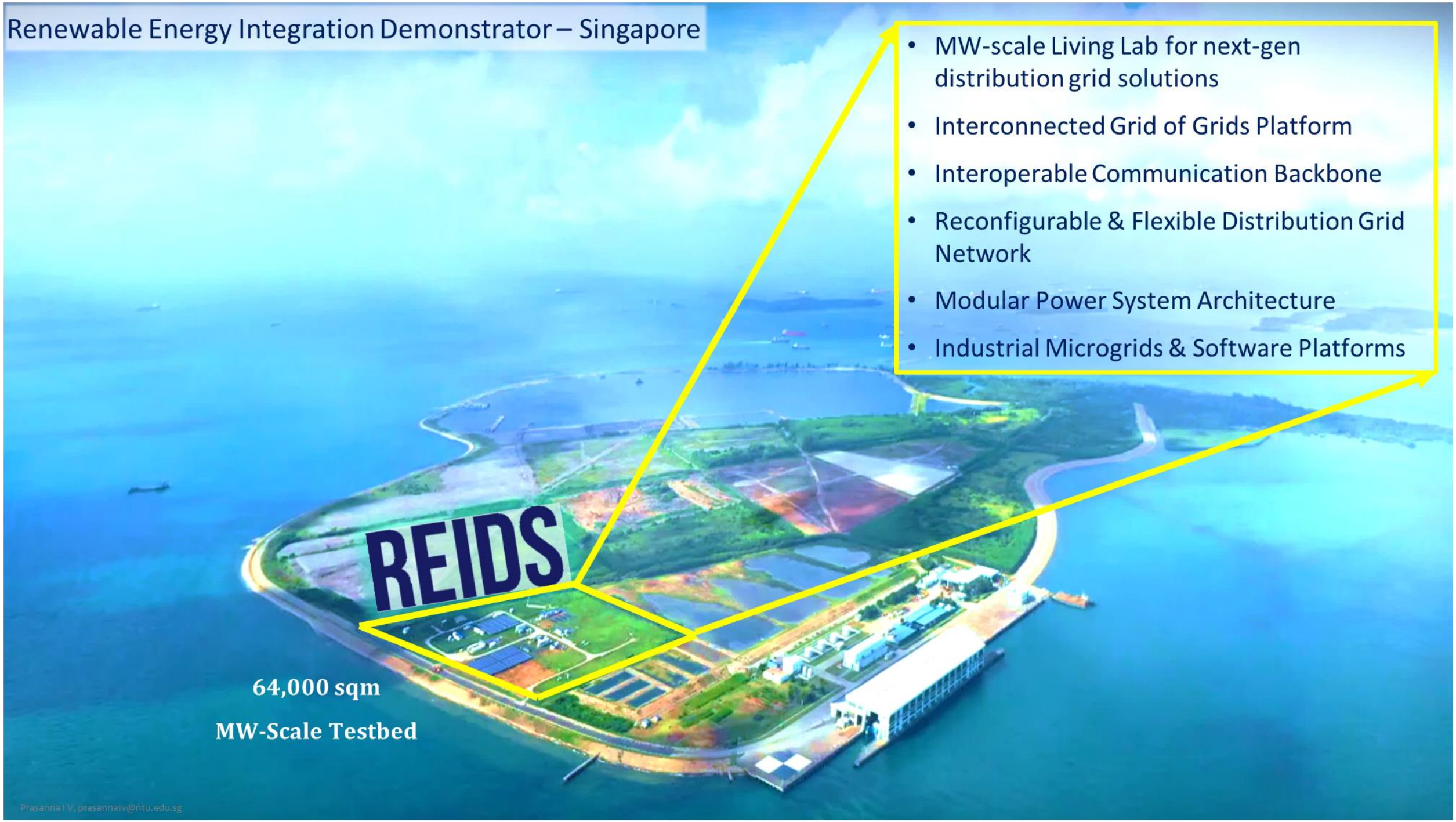
Research Leader

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Energy Research Institute @ NTU

Supporting Agencies

EDB singapore | National Environment Agency Safeguard · Nurture · Cherish | Energy Market Authority Smart Energy, Sustainable Future | National Research Foundation

Renewable Energy Integration Demonstrator – Singapore



- MW-scale Living Lab for next-gen distribution grid solutions
- Interconnected Grid of Grids Platform
- Interoperable Communication Backbone
- Reconfigurable & Flexible Distribution Grid Network
- Modular Power System Architecture
- Industrial Microgrids & Software Platforms

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Integrated Grid Services - Reconfigurable Electrical & Communication Network

Software Platforms

Cluster Grids

Hardware Systems

Independent Grids

Rockwell Automation

REIDS Hub

NTU MG

MG 0

MG 1

MG 2

MG 3

MG 4

MG 5

MG 6

MG 7

NEA

250kW

500kW

400V 2500A

6.6kV 1250A

50kVA Diesel | Planned | 200kWp Solar | 200kWh ESS | 350kVA Load

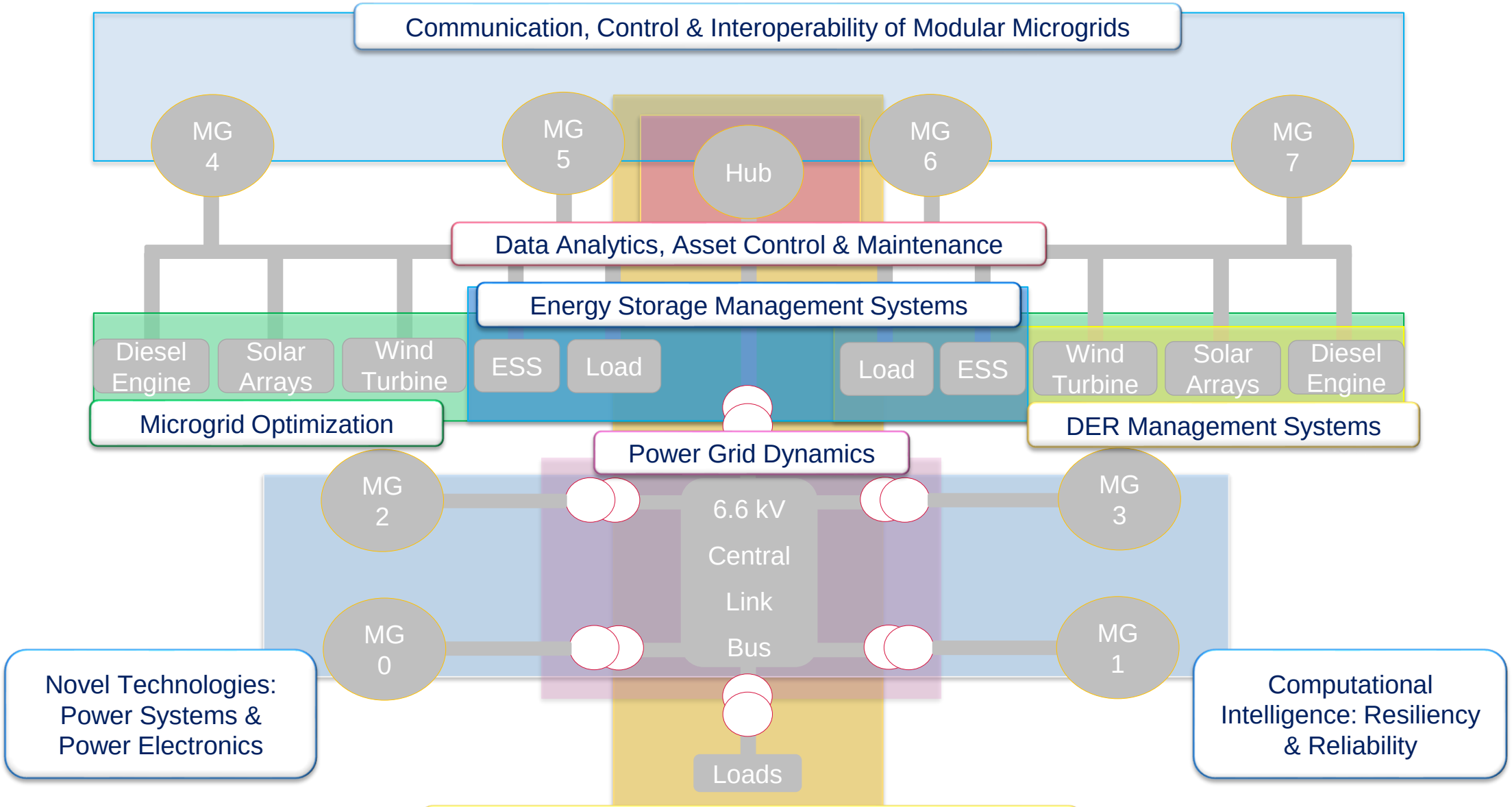
350kVA Load | 200kWh ESS | 200kWp Solar | Planned | 50kVA Diesel

Interoperable & Autonomous Smart Energy Grid Clusters

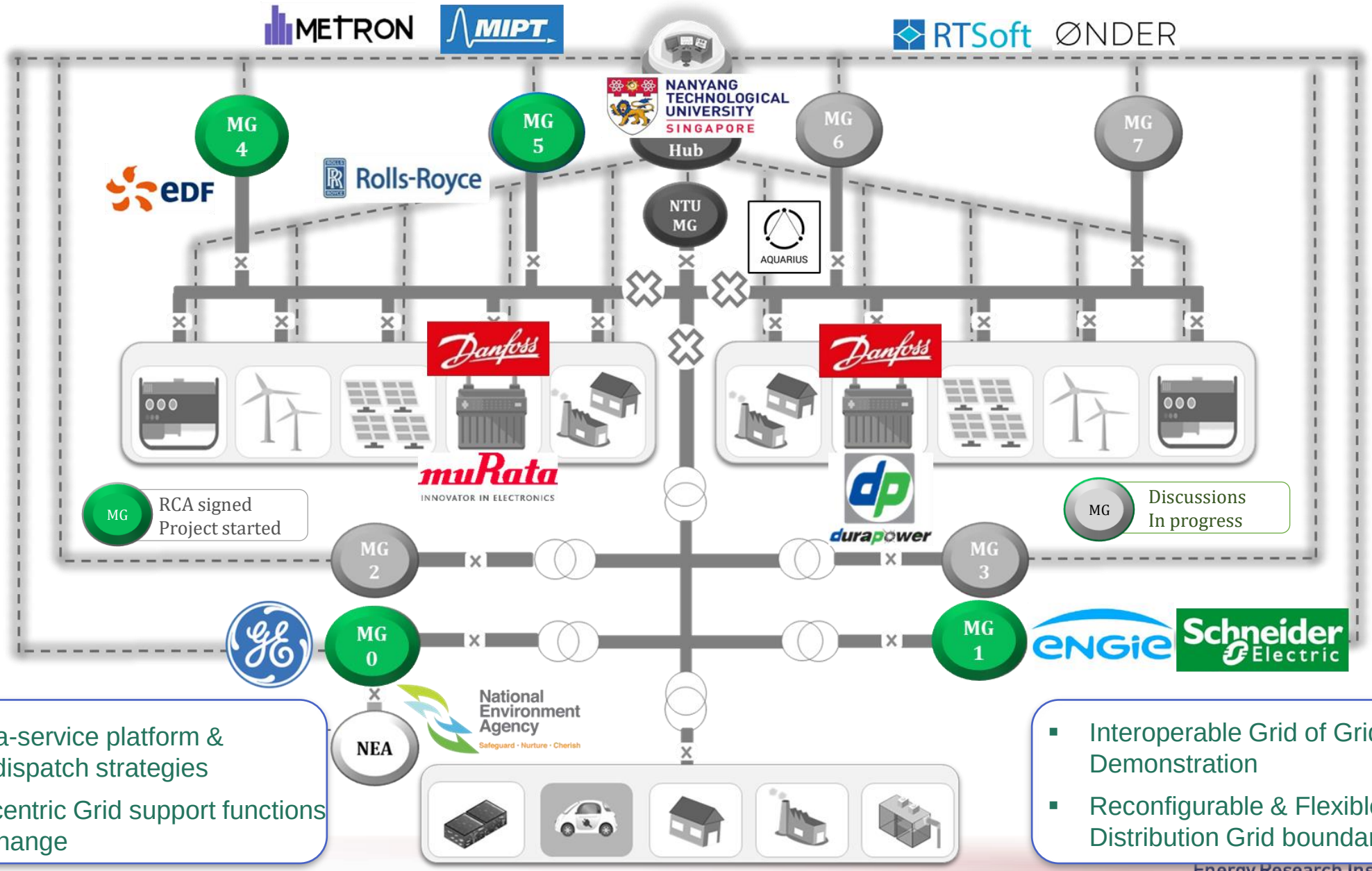
Nov 2017 - Design Proposal & Approval

Feb 2021 - Successful Demonstration

Reconfigurable System Capable of Testing Multiple Urban Mesogrids Scenarios



Next-gen Distribution Grid Industrial Solutions - Multi-vendor Ecosystem - Deployment & Demonstration



- Energy as-a-service platform & Integrated dispatch strategies
- Prosumer-centric Grid support functions & Data exchange

- Interoperable Grid of Grids Network Demonstration
- Reconfigurable & Flexible Distribution Grid boundaries

REIDS Grid of Grids Interoperability | Automation & Intelligence | Grid Resilience & Energy Security

ENGIE — 500kW REIDS-SPORE multi-energy-system management. Demonstration Towards Carbon Neutrality with Hydrogen

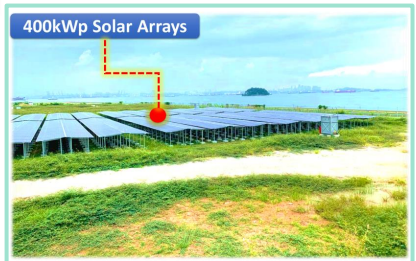
EDF — 100kW MASERA Microgrid, Seamless transition of Grid Operating modes for rural & urban applications.

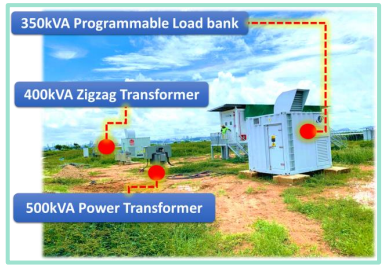
Rolls-Royce — 250kW Reconfigurable Microgrid Control System Testing, Validation & Implementation.

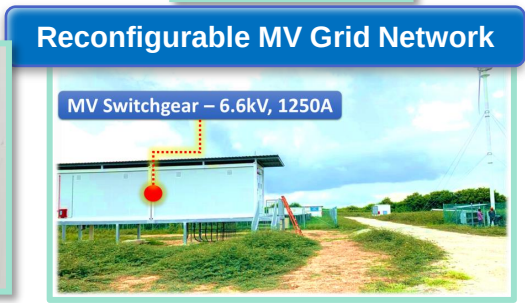
muRata (INNOVATOR IN ELECTRONICS) — Performance analysis of a 200kWh Energy storage system in view of grid services

Danfoss — 200kW Bidirectional Power Converters in Energy Storage Integration, Control & Management.

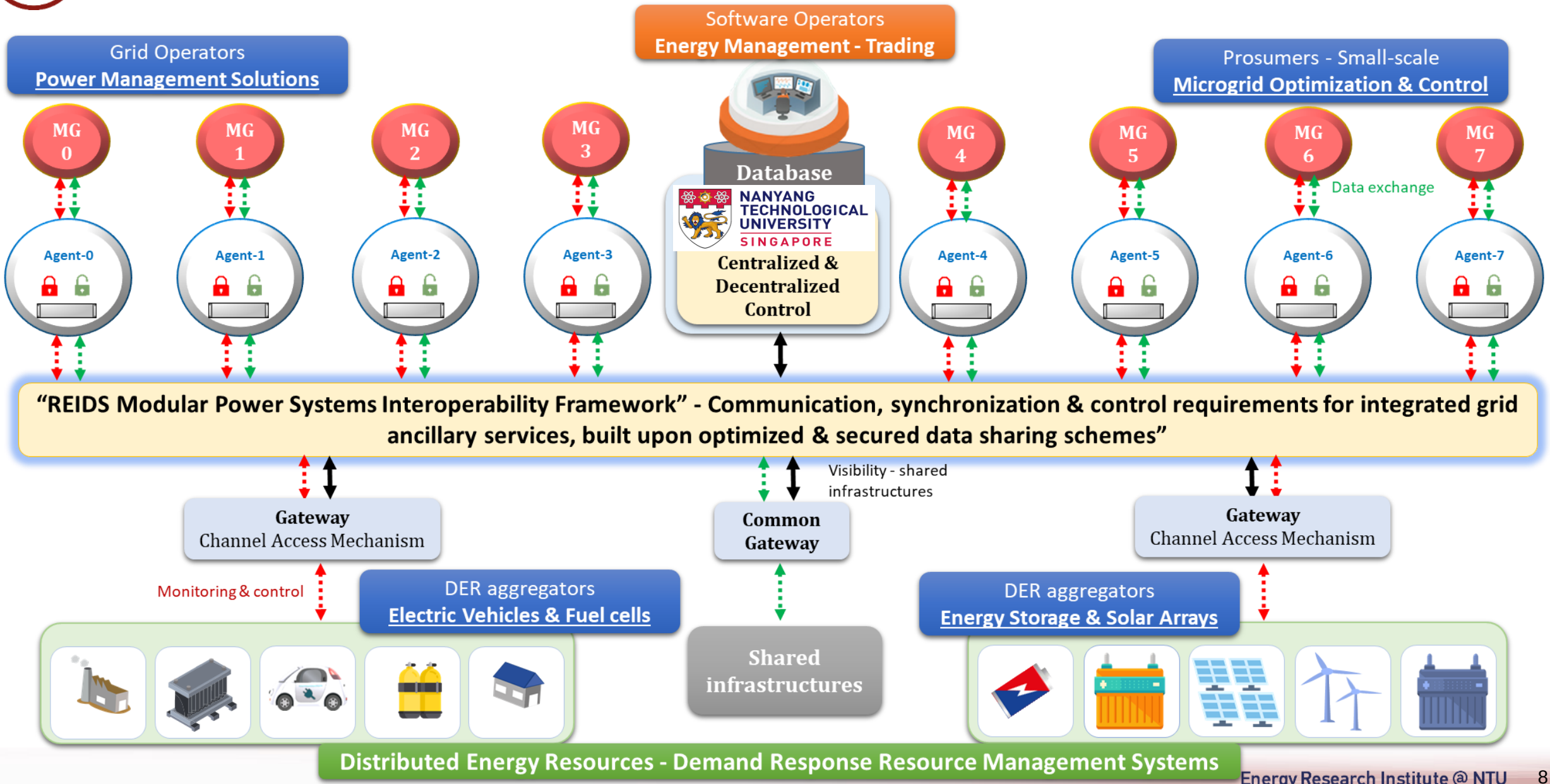
durapower — Implementation of a 200kWh Second life EV battery storage in grid-scale applications





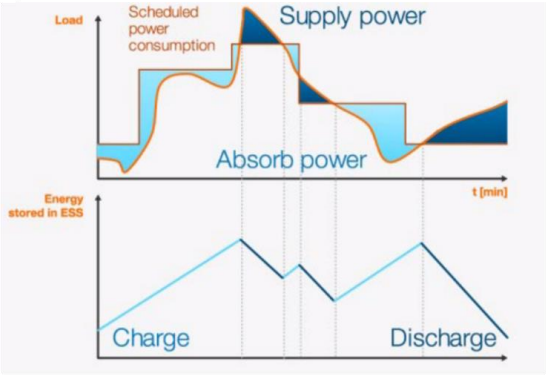


Grid of Grids Interoperability

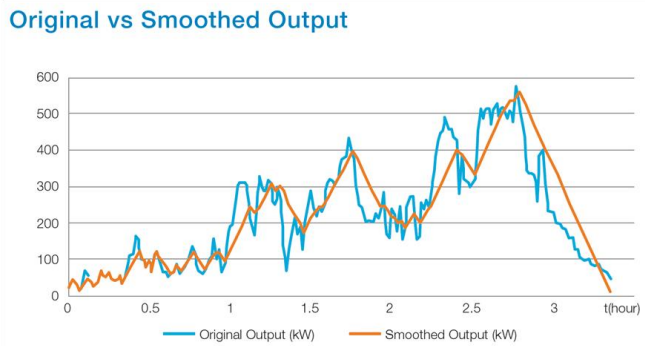


Grid Ancillary Services

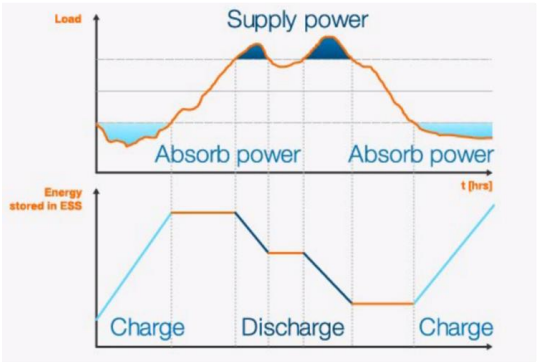
Peak Shaving



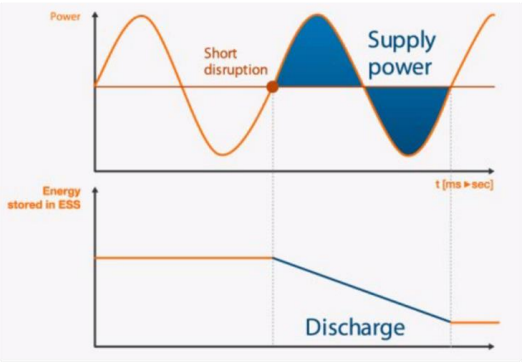
Ramp Rate Control



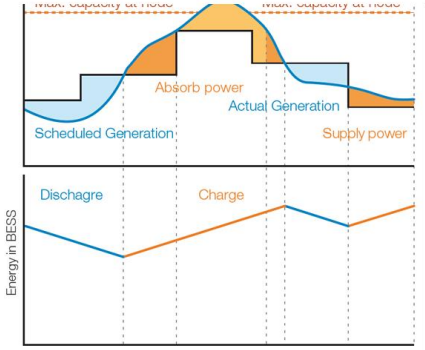
Load Levelling



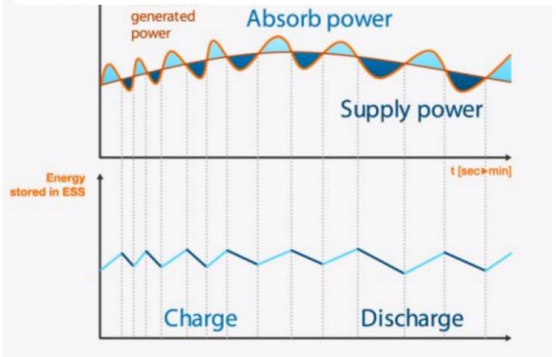
Power Quality / Voltage Support



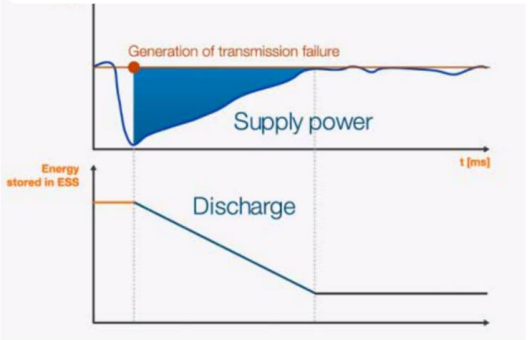
Congestion Relief



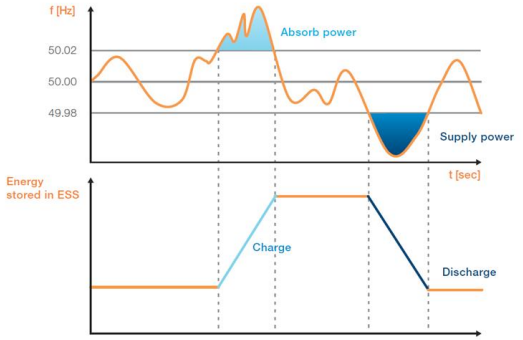
Capacity Firming



Spinning Reserve

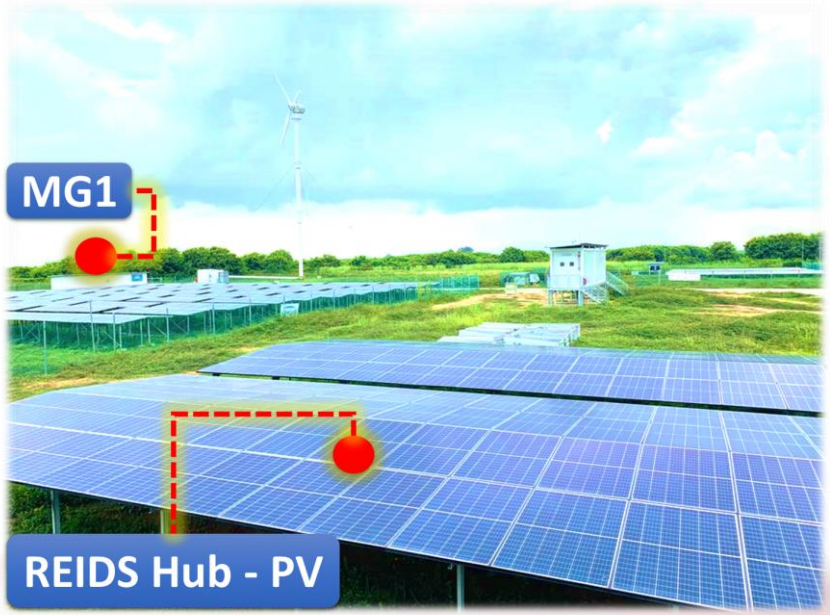


Frequency Regulation



In Progress

Integrated Site Acceptance Tests of both Electrical Network & Communication backbone – Feb 2021



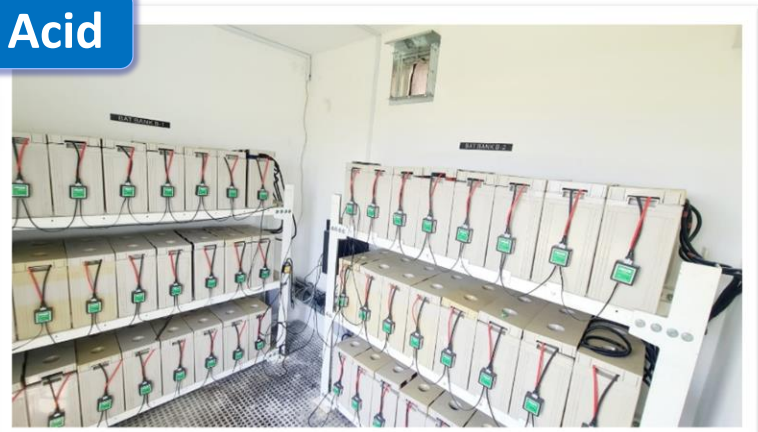
Distributed Energy Storage Systems for Aggregated Flexible Capacity & Grid Services

70kW Hydrogen

200kWh Li-Ion LFP Murata

250kWh Li-Ion LFP Samsung

140kWh Lead Acid



180kWh Li-Ion NMC Durapower 2nd life EV

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The REIDS-SPORE Platform: Demonstration Towards Carbon Neutrality with Hydrogen

100kW Wind Turbine

Hydrogen ESS : 2x25kW P2P & 70kVA PCS

HRS: ~20 Vehicles/day

150kVA Gensets

200kWp Solar

Fuel Cell EV: 44kW/70HP

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REIDS Testbed RD&D Opportunities

Power Conversion, DER Integration, Power quality management

Resiliency & Reliability Study of Next-gen Distribution Grids

AC/DC Hybrid Grid Control, Optimization & Data analytics

Smartgrid Clusters Network Management & Adaptive Protection

System of Systems Interactions & Interoperability

Grid of Grids Transactions & Cybersecurity

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Thank You

Renewable Energy Integration Demonstrator – Singapore

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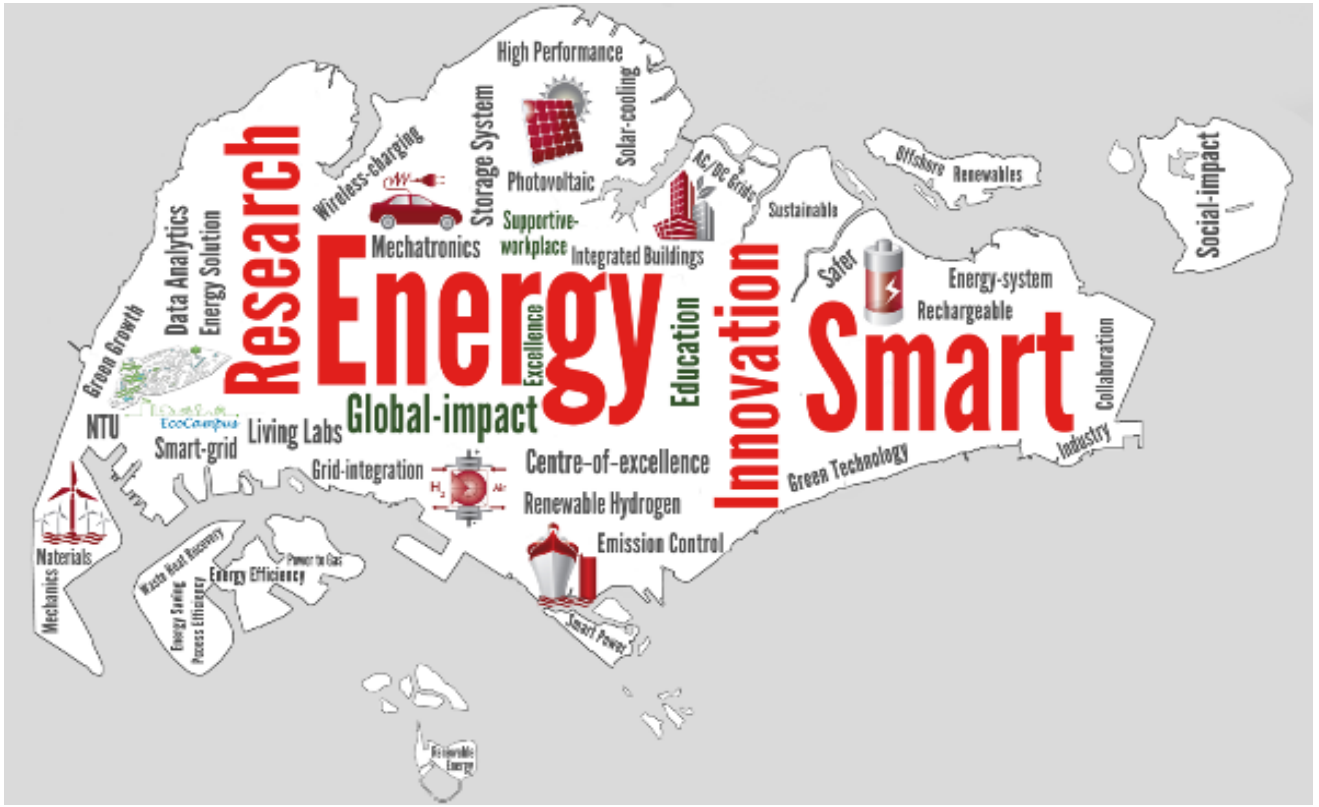
For more information,
Please contact reids@ntu.edu.sg
Energy Research Institute @ NTU – ERI@N

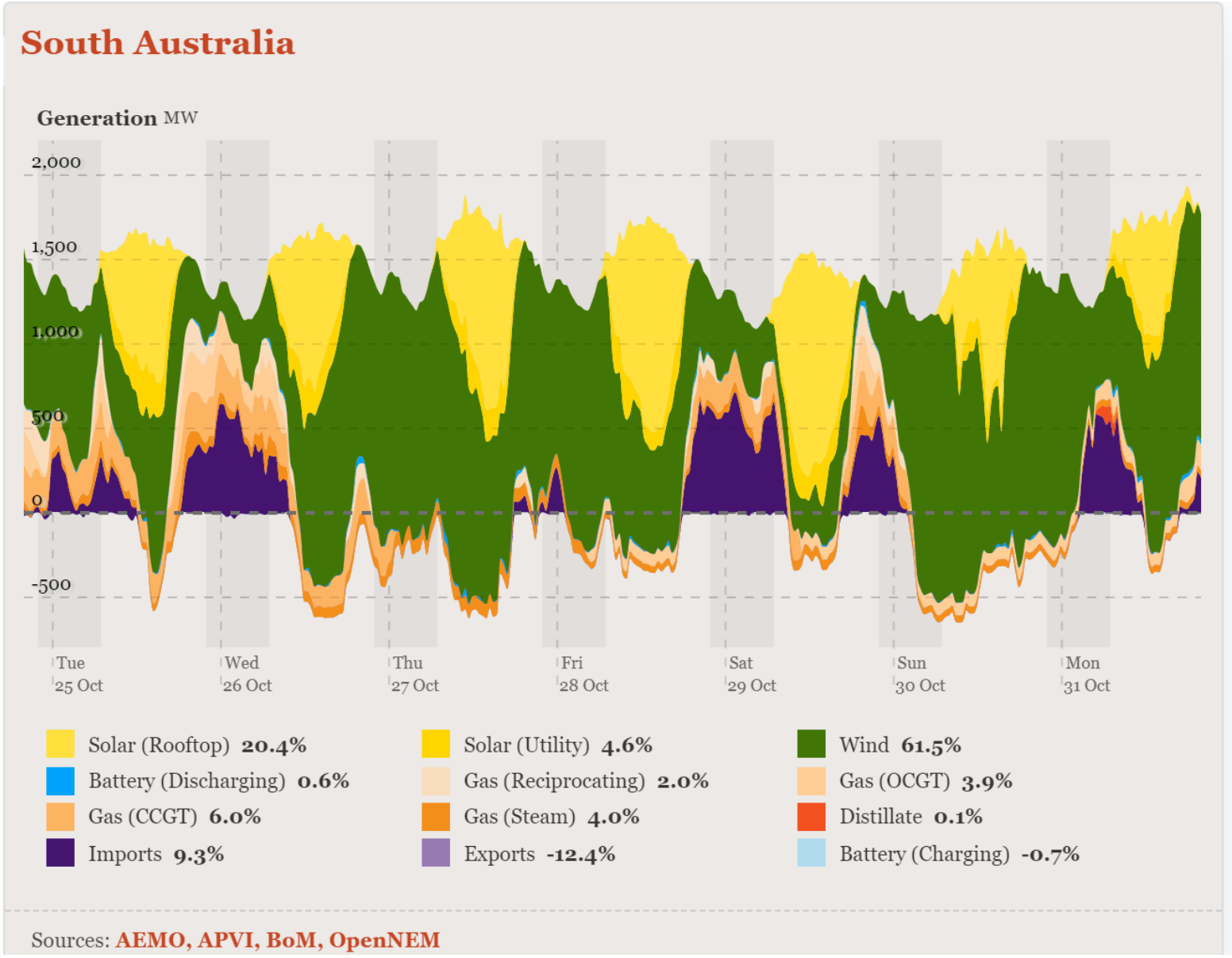


Thank you!

https://erian.ntu.edu.sg/REIDS

For further information please contact:
Executive-Director ERI@N
Email: D-ERIAN@ntu.edu.sg

Why microgrids in Australia



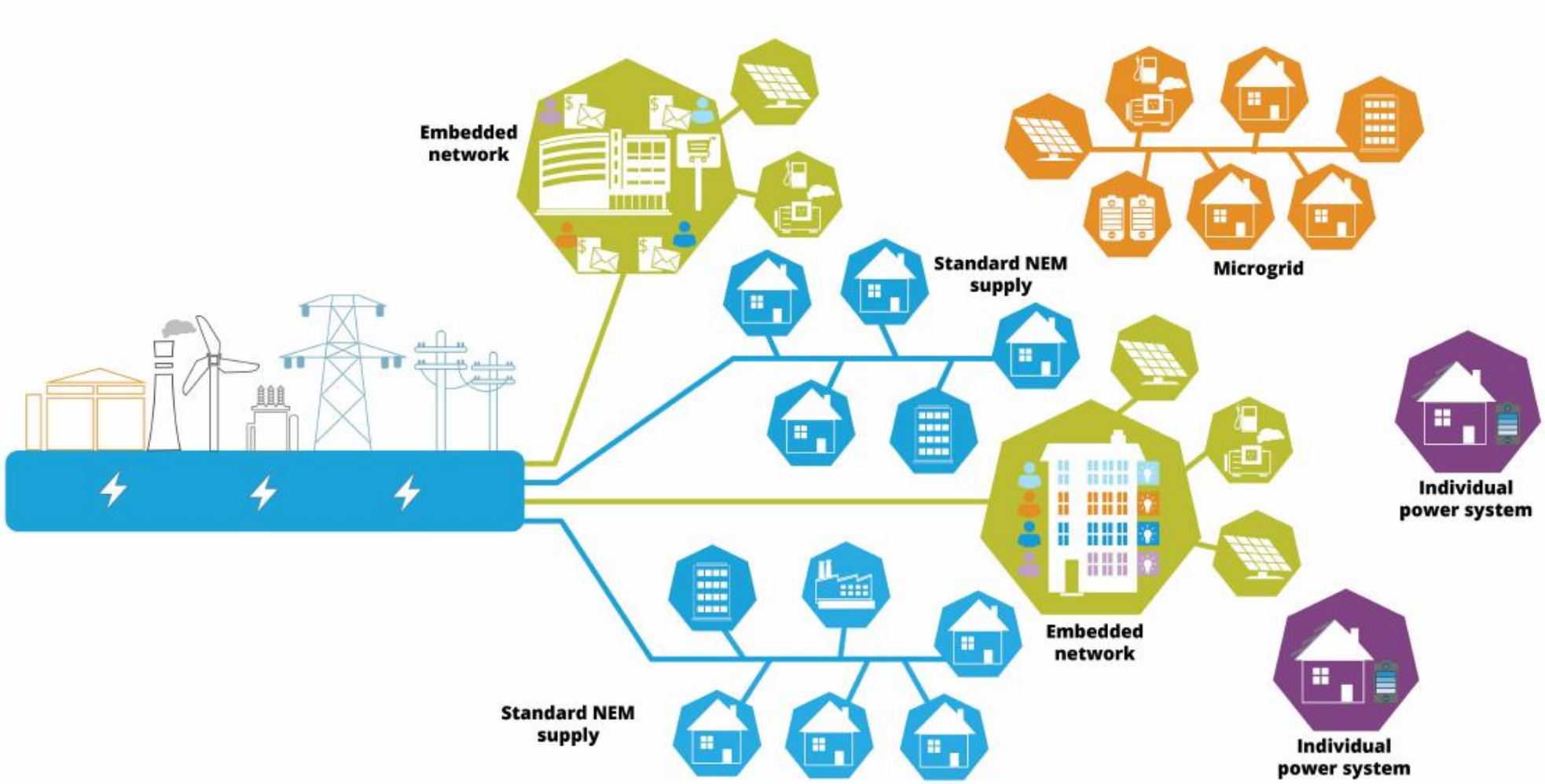
Why microgrids in Australia

Source: Victoria Government

- *Fringe of the grid*:
  - Avoid reinforcement costs in long network
  - Improve reliability
    - Long, unreliable connections
- Microgrids to potentially provide *resilience* against bushfires, flooding, etc.
- *Isolated communities* and *islands*, where network connection may be too costly or infeasible
  - Replacing diesel generators
- *Community energy systems*, especially based on:
  - Solar PV and batteries
  - *Community batteries*
- *Demonstration projects* to test new technologies, equipment and control strategies

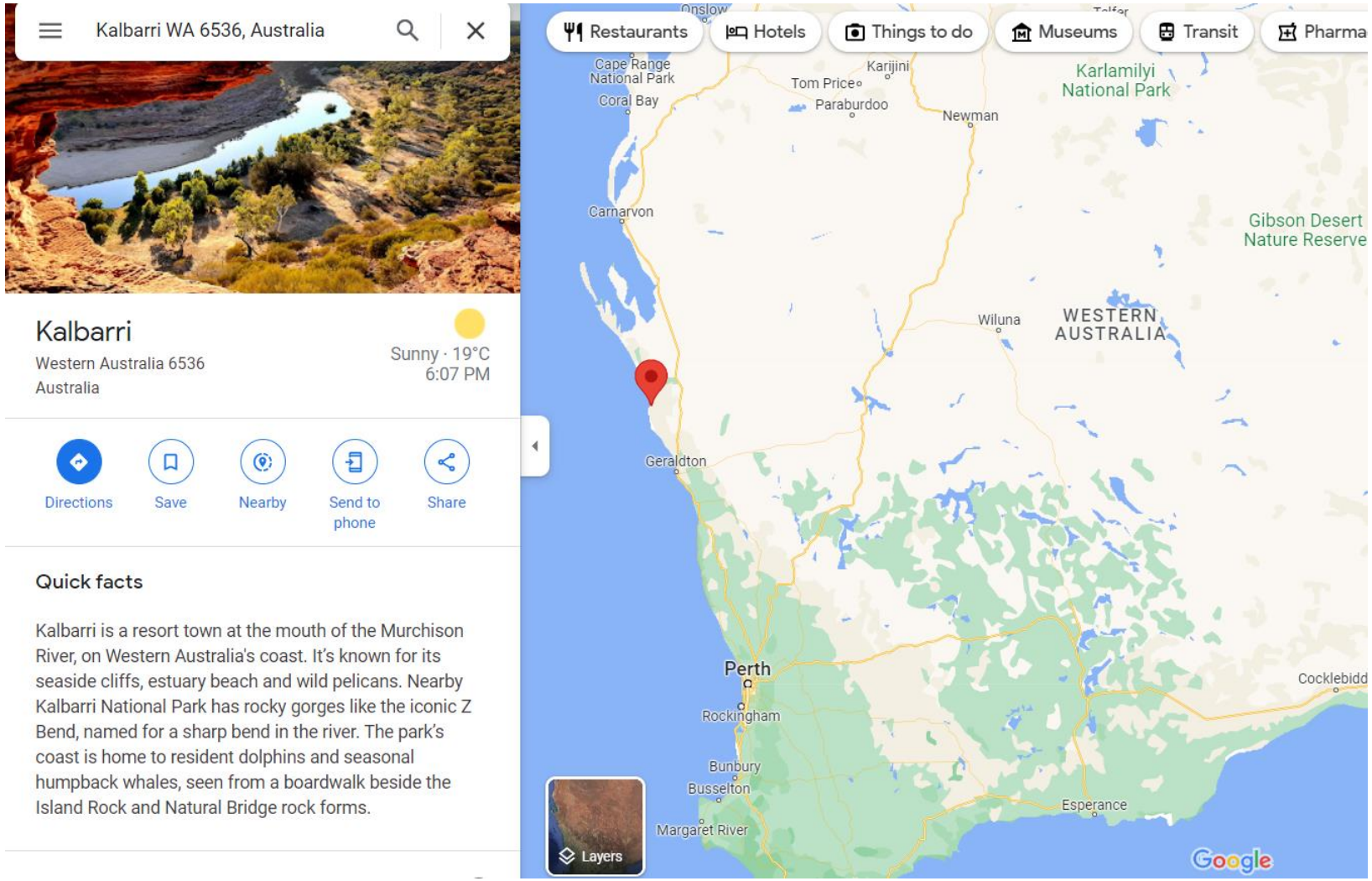
A lot, and growing in number and scope

Four models of electricity supply…
not without creating any confusion…



Source: AEMC

The Kalbarri microgrid



The Mid West town of Kalbarri is connected to the network via a 140km long rural feeder line from Geraldton which is exposed to the elements. Interference on the line can cause extended outages.

The Kalbarri microgrid is expected to eliminate 80 percent of outages experienced by the town, and can significantly reduce the length of outages depending on how the power usage being drawn from the microgrid.

Source: Wikipedia and *Western Power,* https://www.westernpower.com.au/our-energy-evolution/projects-and-trials/kalbarri-microgrid/?utm_source=google&utm_medium=cpc&utm_campaign=powering-our-lives&gclid=CjwKCAjw5P2aBhAlEiwAAdY7dFK5TLuRSkVCNcatAlSCue901RVLG53GyhBcXpc2GkS20ok1lgDjYBoCS28QAvD_BwE

The “Power Melbourne” project

WORLD-LEADING BATTERY POWER FOR MELBOURNE

TIMELINE

The Power Melbourne initiative will scale over three years, from 2022 to 2025.

The project's initial focus will be to deliver a demonstration network of up to 500 kW / 1MWh batteries at city-owned or managed locations from 2023 onwards. We will then design and launch a retail solution, supported by the battery network.

Subject to demonstration of commercial viability, the battery network and retail offering will be expanded through strategic partnerships in 2023–24, demonstrating how the model can be replicated.

FEASIBILITY 2021/22

Phase 1

Techno-economic feasibility study supported through Victorian Government Neighbourhood Battery Initiative

Collaborate with Distribution Network Service provider: Citipower/Powercor/United Energy

Release Expression of Interest to engage technology providers and market participants

INITIATE 2022/23

Phase 2

Innovate with industry to refine delivery model

Commercial feasibility for battery network and plan for retail partnership

Select tender to appoint commercial delivery partner(s)

DELIVER 2023/24

Phase 3

First battery on City of Melbourne assets

Establish network of batteries with partners, demonstrate proof of concept

Launch retail electricity offering for community members

SCALE 2024/25

Phase 4

Expand network of distributed batteries with partners across Greater Melbourne

Scale in partnership with leading organisations

Source: City of Melbourne

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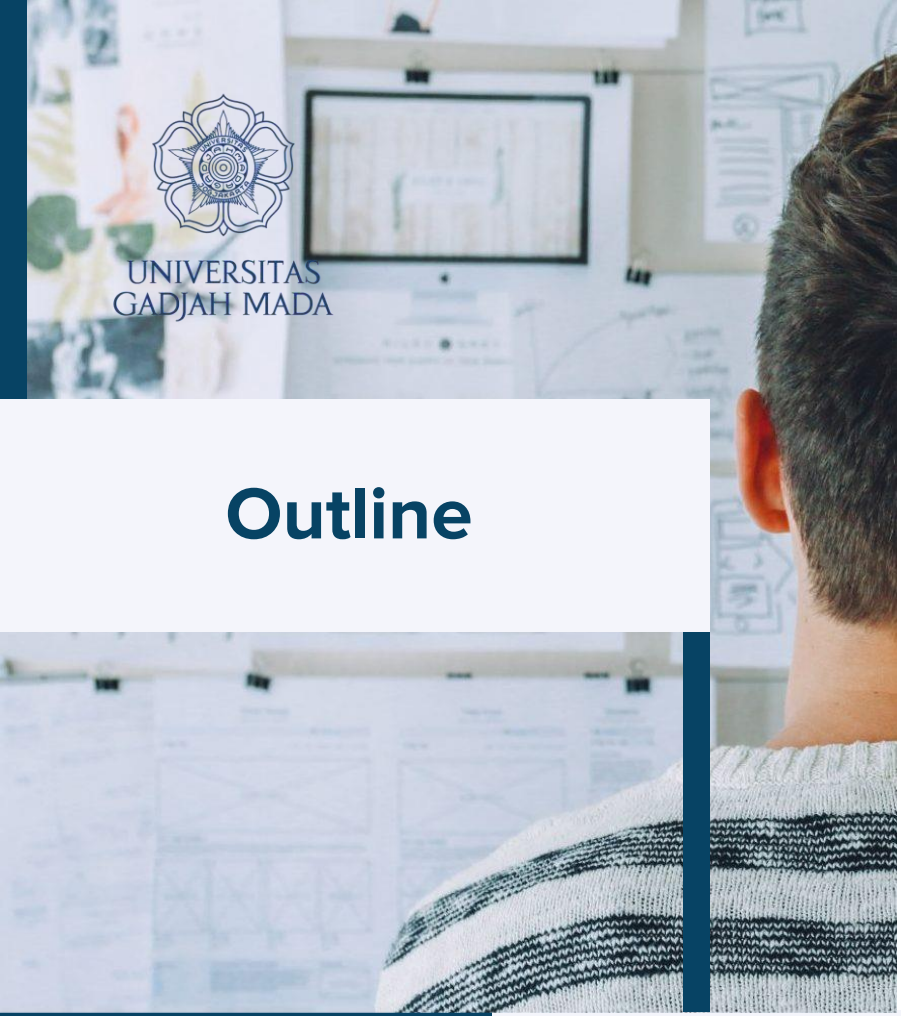
Overview Microgrid in Indonesia



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Outline

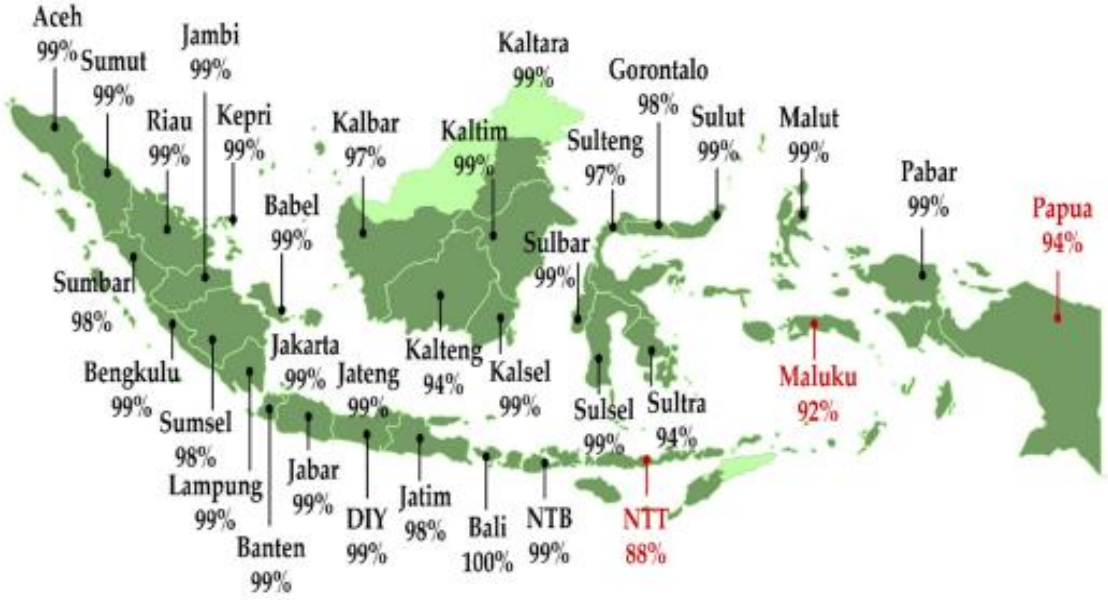
- **Electrification Ratio**
- **Classification of Microgrid**
- **Some MG Facilities**
- **Challenge**

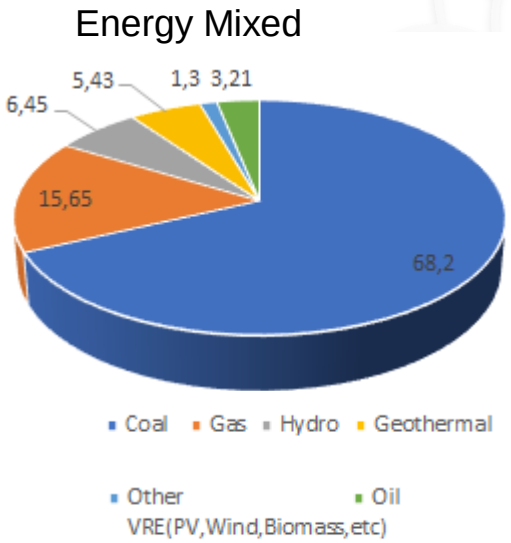
Geographical and Policy Condition

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/m2/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) (Government Policy No 30 2007).
- **Net zero emission in 2060**, one of the theme of **G-20** in Indonesia (Goverment Policy)

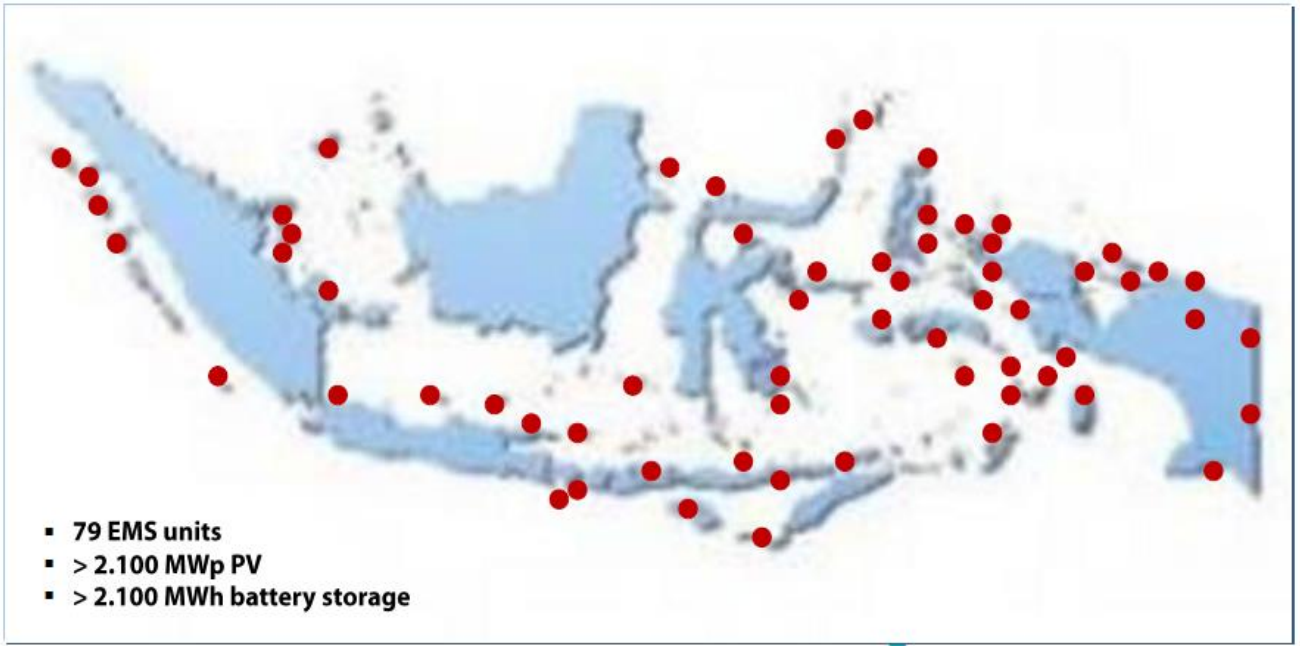
Electrification of Indonesia





- 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

Existing and Potential MG



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

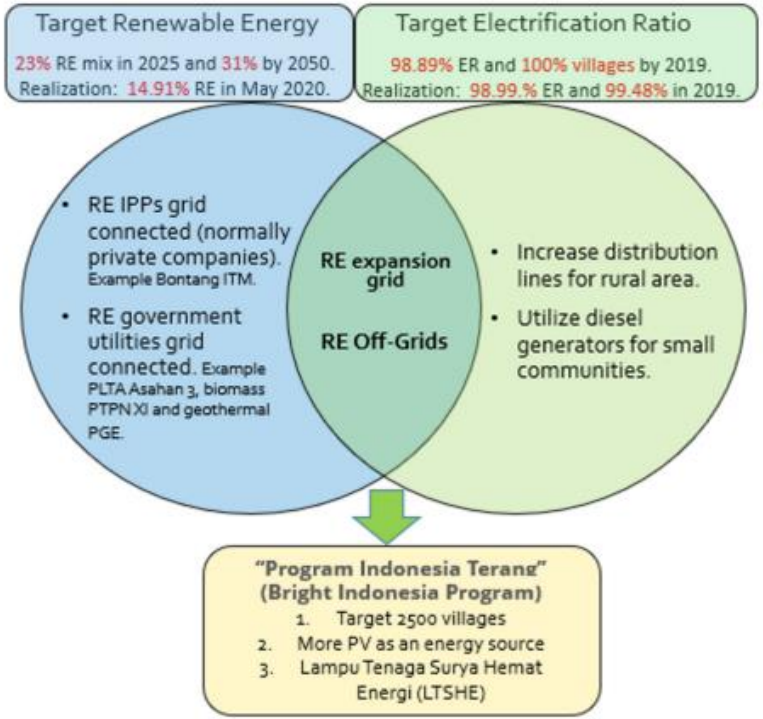
Microgrid Classification and Main Characteristic

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**

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

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

Government Program

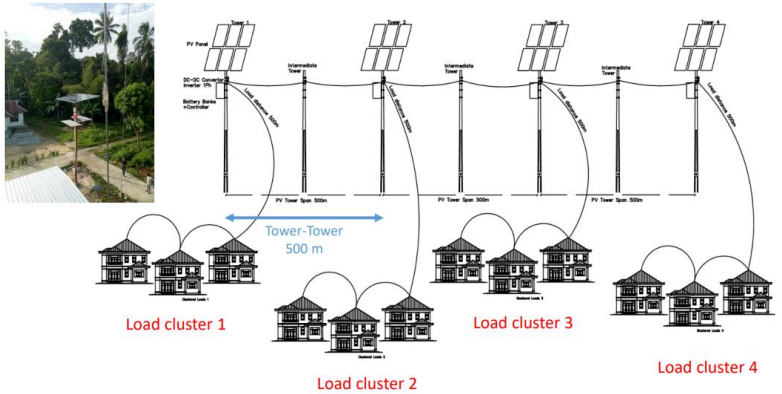


Source : MEMR Indonesia

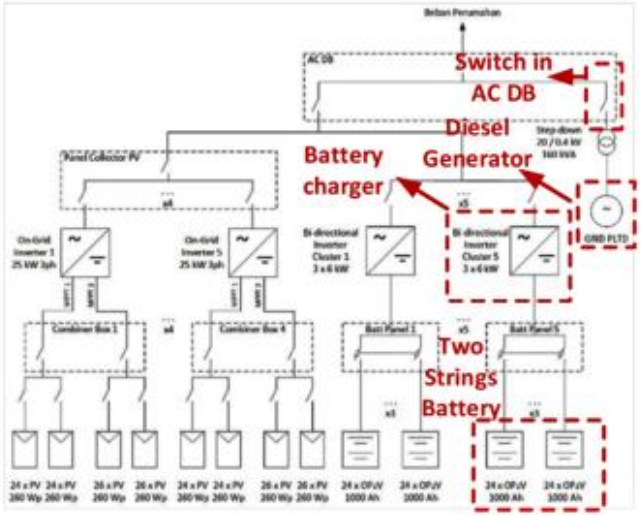
Some Microgrids Facilities in Maluku

Source : PLN % MEMR Indonesia

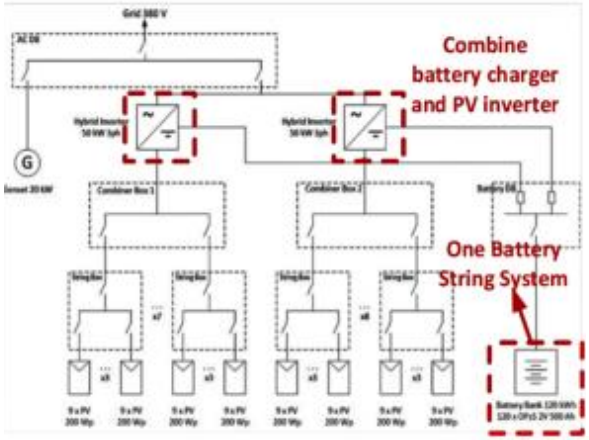
PV Desig-nator	Year of Operation	Location	Funded by	Type	PV Desig-nator	Year of Operation	Location	Funded by	Type
Site 1	4	Ambon	PLN	Off-grid	Site 9	3	Saumlaki	MEMR	Hybrid
Site 2	8	Ambon	PLN	Off-grid	Site 10	3	Tual	PLN	Hybrid
Site 3	3	Ambon	PLN	Off-grid	Site 11	2	Tual	MEMR	On-grid
Site 4	3	Masohi	PLN	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					



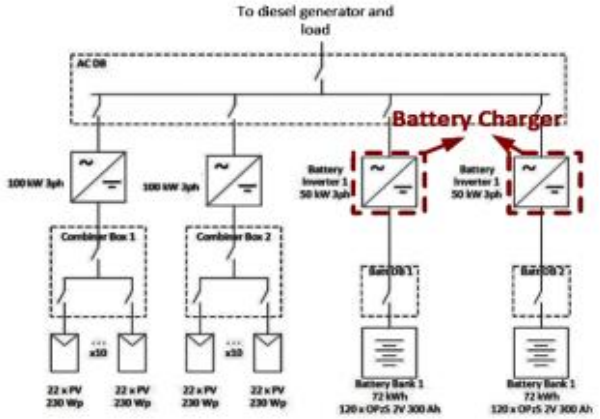
Typical MG Facilities



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….”
https://doi.org/10.3390/en14216901

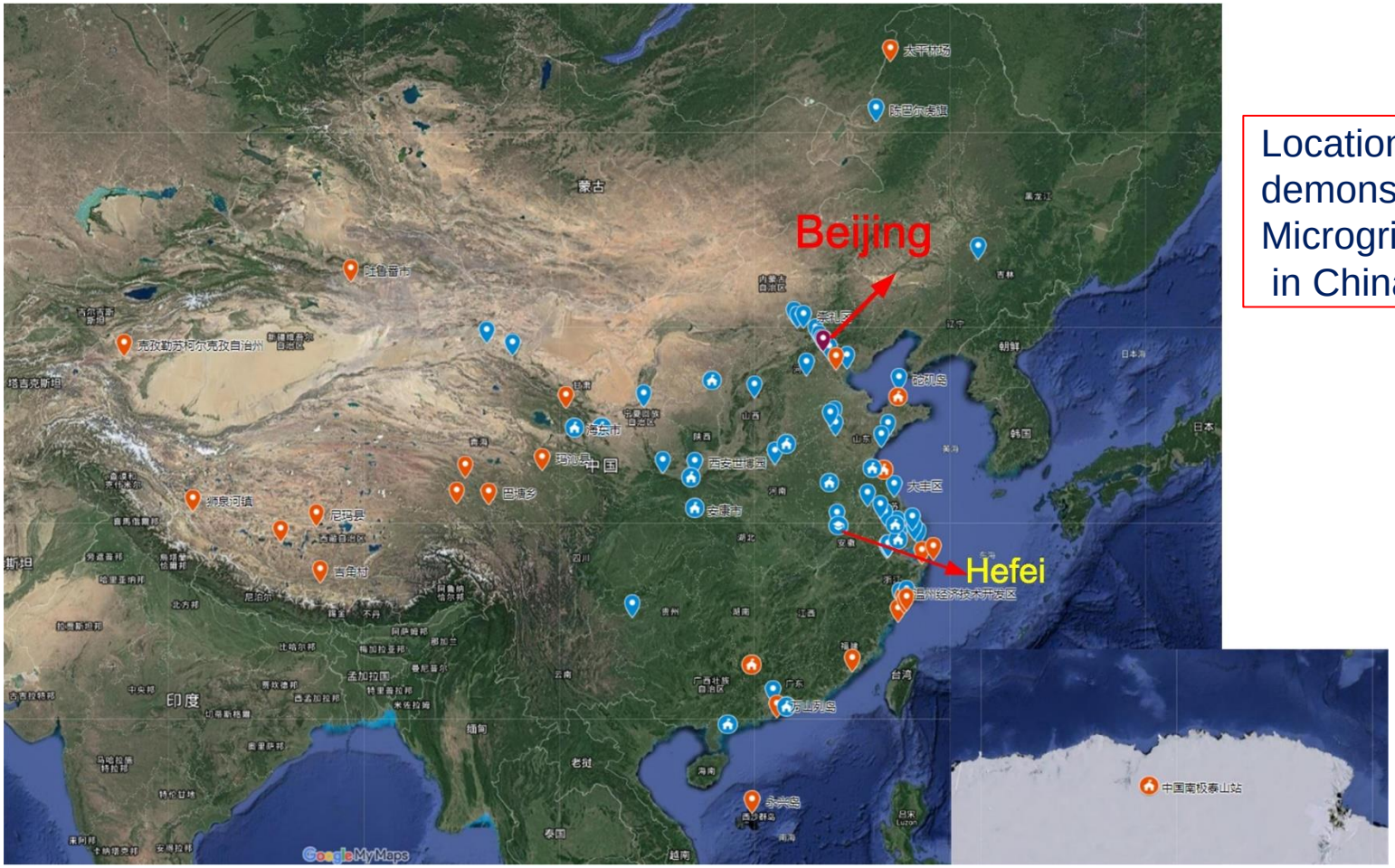
Challenges

Abandoned many MG Facilities

- Human resources capabilities
- Local people lifestyle
- Local people affordability to pay electrical bill
- Poor coordination between central and local governments
- Vandalism

Microgrid Activities in China

- It is reported about **100** microgrid-related projects have been built up to 2019*. No accurate microgrids demonstration projects were publicly reported in 2020 and 2021, however, at least **20** newly-built microgrids can be found from different public sources.



Locations of part demonstrated Microgrids in China

Grid-tied Islanded

Existed MGs up to June, 2018

Grid-tied Islanded

Newly-reported MGs from July, 2018 to July, 2019

* https://www.china5e.com/news/news-1075828-1.html

China's Government's Activities on Microgrid and RES

2020.9.22

- Announce carbon neutrality **"3060 Goal",** which states to strive to achieve carbon peak by 2030 and carbon neutrality by 2060

2020.12.22

- Commit to achieving over **1,200 GW** installed solar & wind power capacity for China by 2030 and increasing the share of non-fossil fuels in primary energy consumption to around 25% by 2030

2021.3.15

- Propose to establish a "**new type of renewable energy dominant power system**" in the near future

2021.6.20

- Attempts to boost the **development of residential roof small-scale PV systems** in the selected pilot counties

2021.7.23

- Aims to install over **30 GW of new energy storage** by 2025

2021.8.5

- Beijing announces to promote the development of intelligent microgrids, modern energy internet, flexible DC grid and

China's Government's Activities on Microgrid and RES

2021.8.12

- The second batch of Intelligent PV demonstration projects is launched, 3 projects are Microgrid-related.

2021.8.12

- Tianjin reveals "14th Five-Year Plan for Scientific and Technological Innovation", says "…perform the high-efficient integration of Microgird research… "

Up to 2021.9

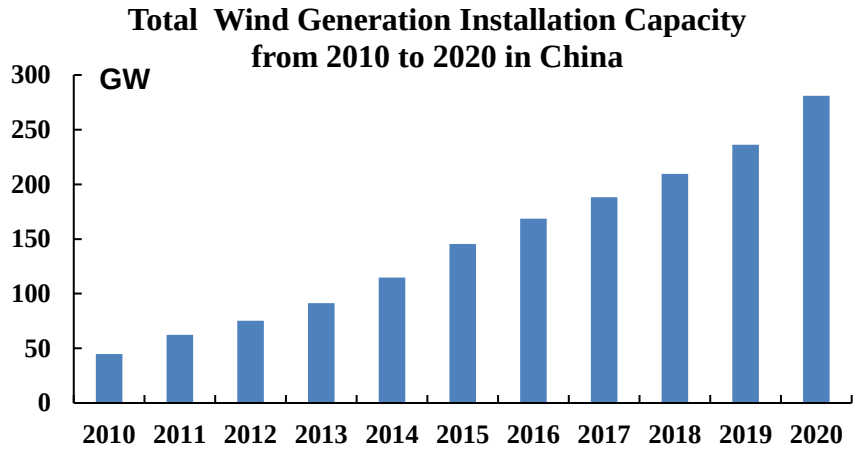
- More than **10** provinces in China have announced **Energy Storage Systems Development** Plan
- About **25** provinces have submitted "whole-county" residential PV systems development plan, over 100 GW **distributed PV systems** are in construction or under planning
- More than **20** provinces have announced Hydrogen Industry Development Plan

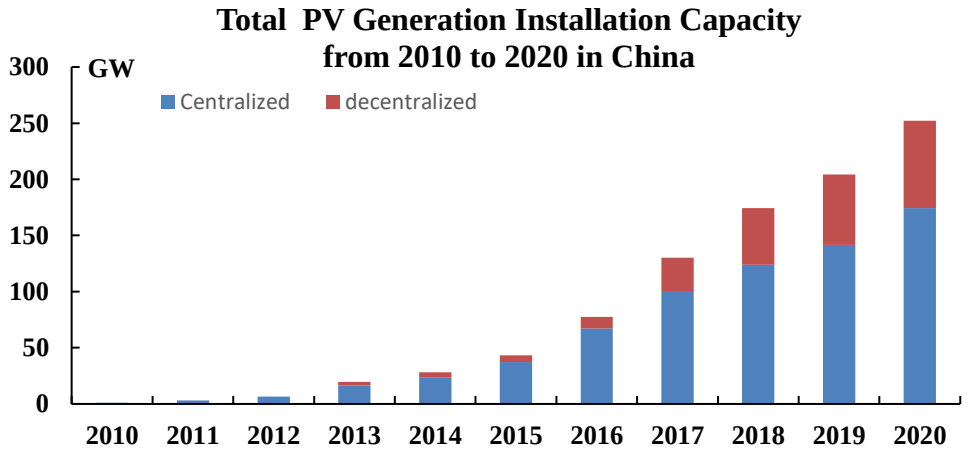
- **Motived by these national and regional polices, the devolvement of RES and ESS accelerates in China.**
- **Microgrids, which can effectively integrate the RESs, ESSs, EVs and hydrogen systems, are seen as the important parts and organic cells in the establishment of the new type of renewable energy dominant power system in China**

China's Government's Activities on Microgrid and RES

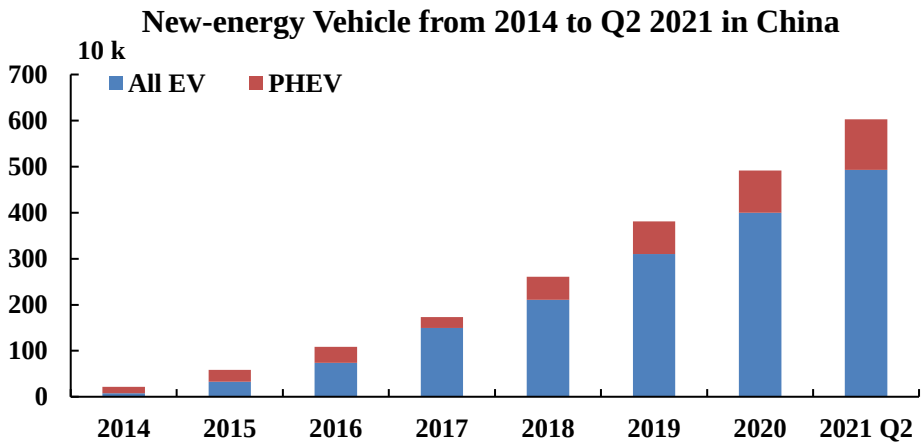
Some facts:

- ✓ The total installation capacity of PV and wind generation reaches **534GW** up to the end of 2020. Their generated electricity accounts for over **9.5%** of the total electricity generated in 2020.





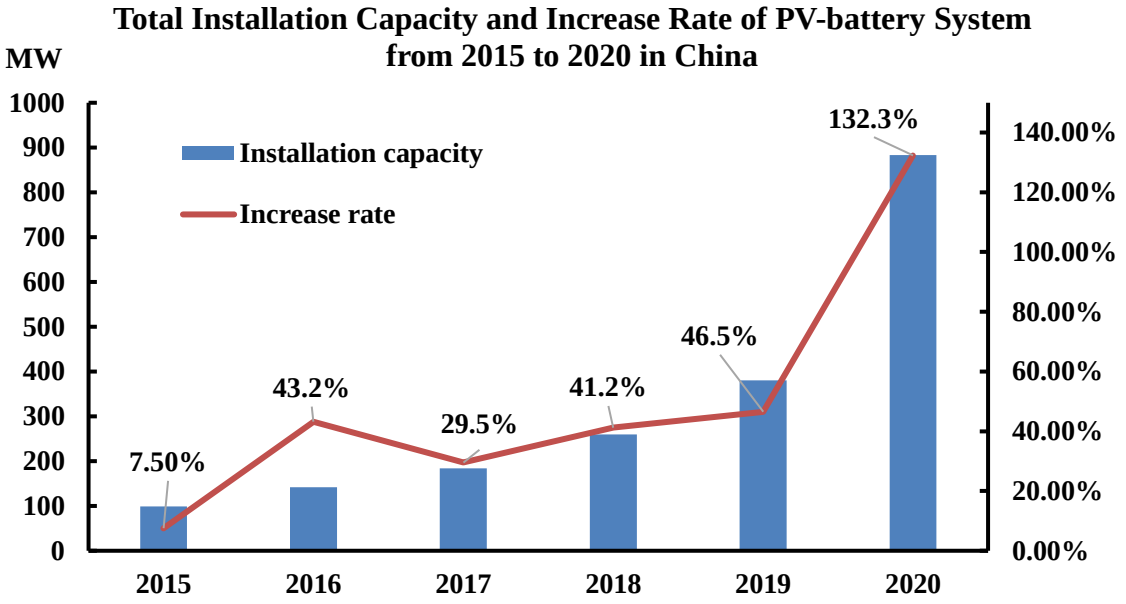
- ✓ The total new-energy vehicle in China is over **6 million**, All-EV accounts for **81.8%**



China's Government's Activities on Microgrid and RES

Some facts:

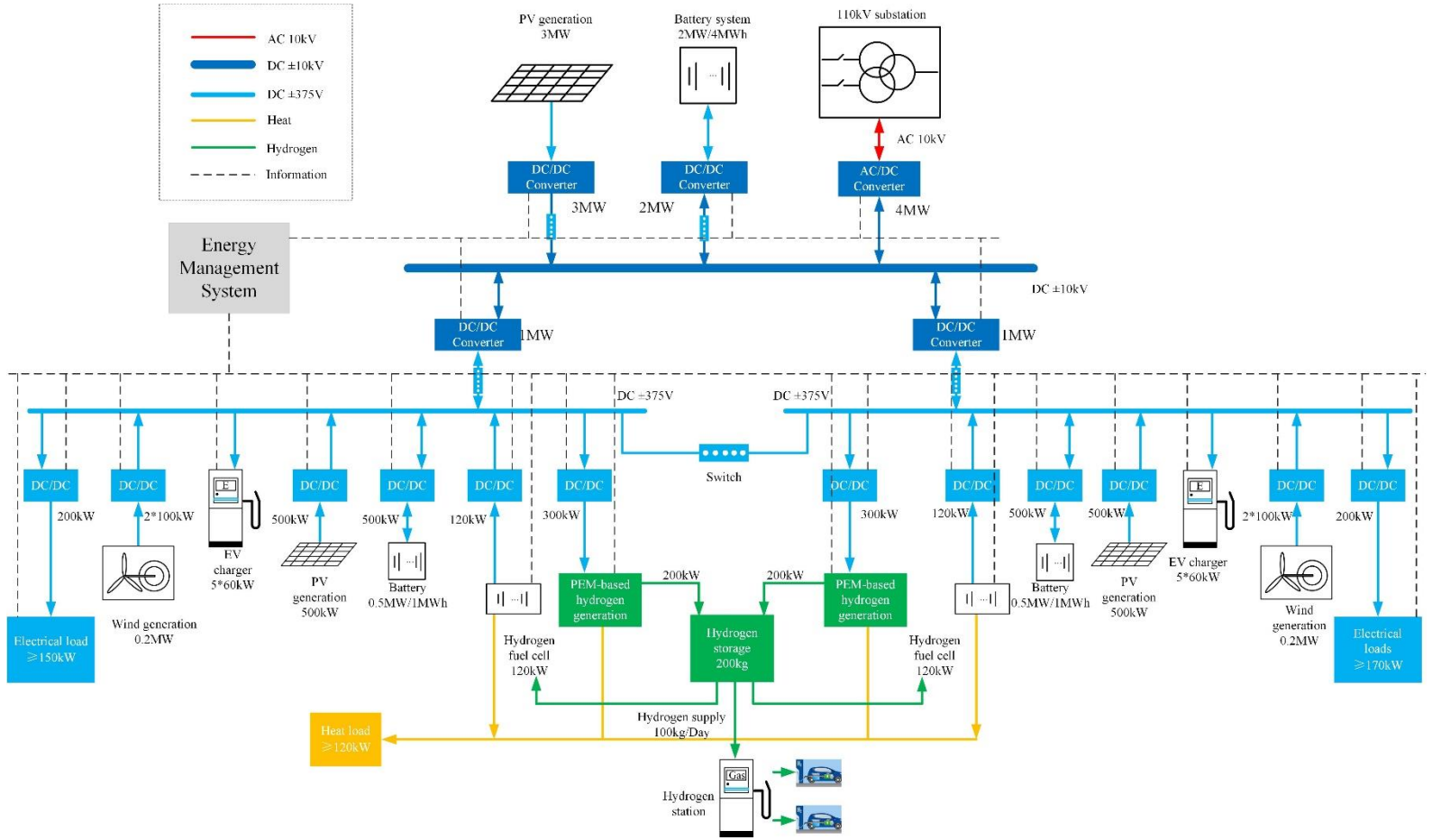
- ✓ About **35.6 GW** energy storage system is installed by the end of 2020 in China, in which, **3.3 GW** installation are electrochemical energy storage systems. The newly increased electrochemical energy storage systems in 2020 is about 2.5 times of that in 2019.
- ✓ The total installation capacity of "PV+ESS" systems reaches **883 MW** in 2020, The centralized and decentralized systems are **669 MW** and **214 MW** respectively.



Typical Microgrid Projects in China 2020-2021

◆Wind/PV/Hydrogen Fuel Cell DC integration and stability control technology demonstration * (in process)

* https://www.china5e.com/news/news-1116119-1.html



- ✓ Approved **in 2020**. Tt is estimated to be accomplished in **June,2022**
- ✓ The first **±10 kV DC interconnection system with the coupling of electricity/hydrogen/heat/vehicle** in the world is expected to be built.
- ✓ Total renewable energy generation including PV, wind generation will be over **3MW**, hydrogen generation will be over **400 kW**, total battery storage will be over **3MW/3MWh**.

Typical Microgrid Projects in China 2020-2021

◆**Ningde Baijiwan Wind/PV/battery microgrid * (built)**

- ✓ The first fishing boat Wind/PV/battery microgrid in Fujian province, it is put into operation in **June, 2021**
- ✓ PV, wind generation and battery systems are integrated and managed by the intelligent energy management system.
- ✓ Optimization and coordination of sources, loads and ESS can be achieved.

* http://fjnews.fjsen.com/202106/06/content_30747691.htm

Typical Microgrid Projects in China 2020-2021

◆ **Dongguan DC microgrid project ***

- ✓ Accomplished in **April, 2021**.
- ✓ It consists of mobile energy storage system, EV charging station, data center, PV generation and 5G communication base station
- ✓ Overall energy conversion efficiency is over 95%

* https://www.sohu.com/a/476386978_161795

Typical Microgrid Projects in China 2020-2021

◆Xiong'an New Area Wangjiazhai green intelligent microgrid demonstration project *(in process)

- ✓ The first regional energy internet project based on **wind/PV/ESS coordination and cooling/heat/electricity grouping regulation & control** in China.
- ✓ The **100%** end-use electricity consumption and **100%** distributed renewable energy consumption will be reached in this project.
- ✓ Three sub microgrids will be established, **the loads flexible interaction, dynamic optimization of sources and loads, multi energy carriers grouping regulation and control, demand side response and virtual power plant** technologies will be researched.
- ✓ **Digital Twin microgrids** will be constructed with the physical microgrids.

* http://fjnews.fjsen.com/202106/06/content_30747691.htm

Typical Microgrid Projects in China 2020-2021

◆Gansu Lanshi battery microgrids* (built)

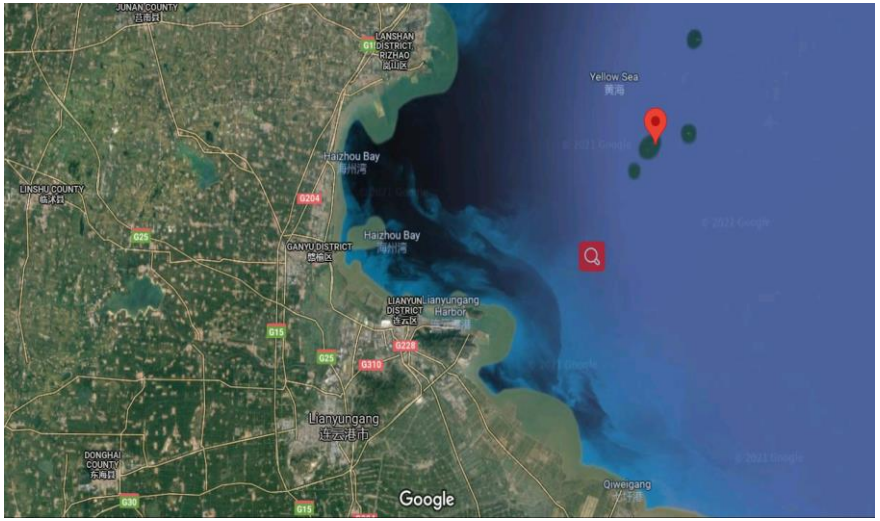
- ✓ It is the first **battery cascade utilization demonstration project** in Gansu province and is built **in 2020**.
- ✓ Composed by two sub-microgrids, one is **4MW/1.5MWh** battery microgrid and another is **6MW/2MWh** battery microgrid .
- ✓ **10 MW** roof PV plant, EV chargers, PV-EV charging station are integrated as a typical PV/battery/EV charging microgrids demonstration.
- ✓ It is estimated that **13 million** kWh electricity will be generated, **4180 t** standard coal can be saved and **10869 t** CO2 can be reduced per year.

*http://gansu.gansudaily.com.cn/system/2020/01/22/017339151.shtml

Typical Microgrid Projects in China 2020-2021

◆Cheniushan island microgrid (built [1])

1. https://www.china5e.com/news/news-1103228-1.html



Location of Cheniushan island (In the Yellow sea)

Overall scenery of Cheniushan island

- ✓ **0.06km²** area, the first **AC/DC hybrid intelligent island microgrid**
- ✓ **Configuration**: **50 kW wind generation, 30 kW roof PV, 100 kW diesel generator and 30 kW/120 kwh battery.** One set of 5t/d Desalination system

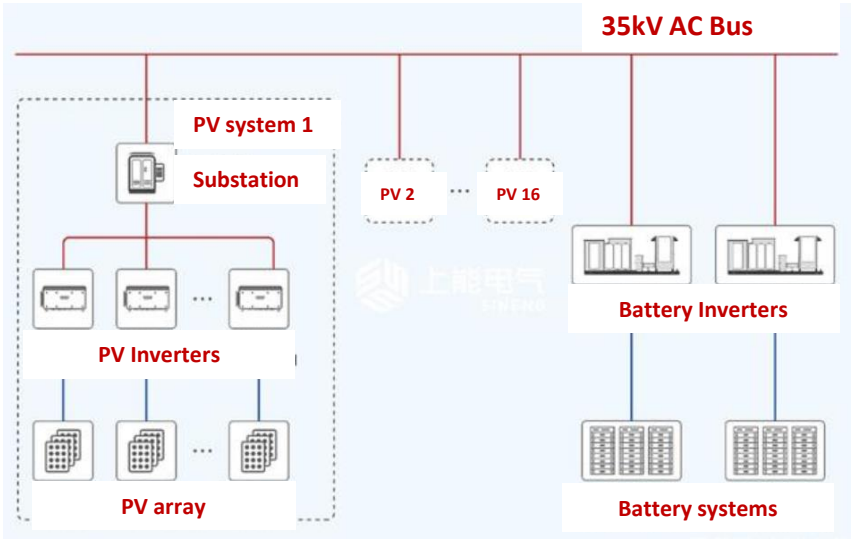
◆Zhangbei new-energy microgrid (built [2])

2. https://solar.in-en.com/html/solar-2360850.shtml

- ✓ One of the first batch of 28 new-energy microgrid projects announced by NDRC
- ✓ Two sub-microgrids are included. Total installation capacity is **220 MW**, including **120 MW** wind generation, **80 MW** PV generation, **20 MW** battery system.
- ✓ It is estimated that **45 million kWh** electricity will be generated per year, renewable energy penetration is **over 100%.**

Typical Microgrid Projects in China 2020-2021

◆ **PV/battery desertification control project in Inner Mongolia ***

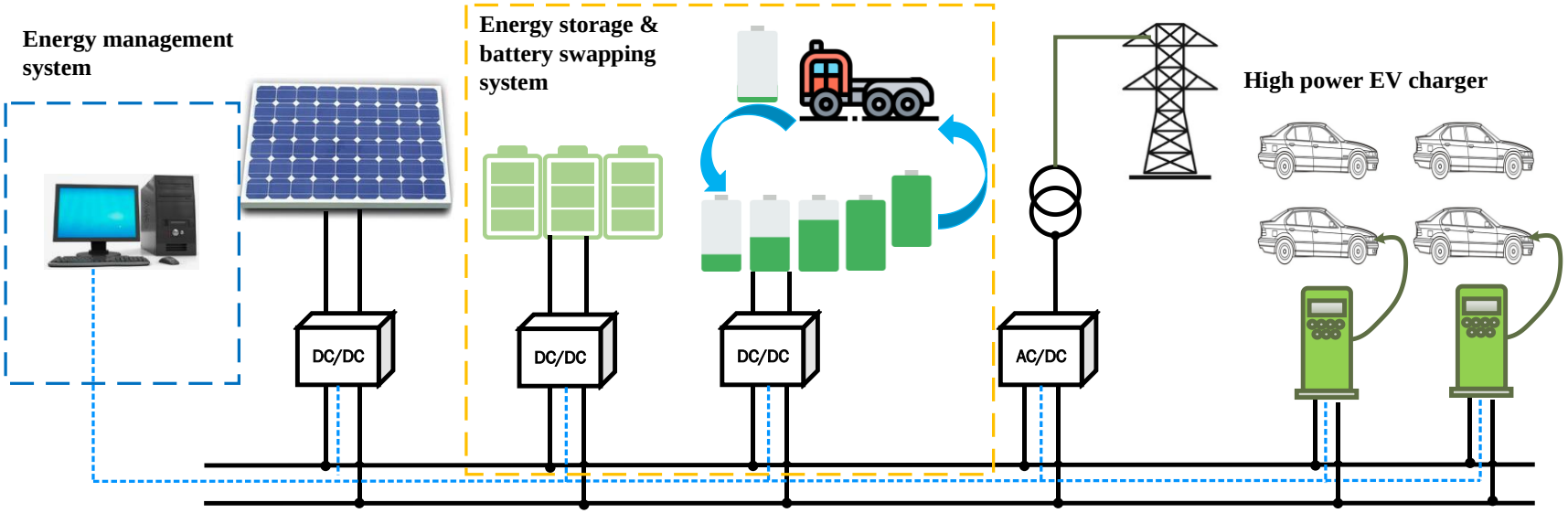


- ✓ The first-phase of the project was accomplished in 2021.
- ✓ PV：**50 MW (16*3.15 MW)**
- ✓ BESS: **5 MW/MWh (2*2.5MW)**
- ✓ PV and battery are integrated via 35kV AC bus
- ✓ Total PV installation capacity will be **100MW.**
- ✓ **217 million kWh/year** electricity will be generated, and **86.8k** ton standard coal and **216k** ton CO2 will be saved or reduced per year.

* http://www.wptchina.com.cn/ReadNews.asp?rid=2073

Typical Microgrid Projects in China 2020-2021

◆ Zhangjiakou integrated ultra-fast charging station



- ✓ Based on the Winter Olympics Technology Demonstration Platform in Zhangjiakou, Hebei, the **integrated ultra-fast charging station for new energy vehicles** will be built and put in application in **Jan-Mar,2022.**
- ✓ The demonstration system includes PV, super fast charging system, battery swapping system for truck and V2G chargers.

■ **Fast charging area**

✓ **Technical indicators**: charge 5min at -20°, endurance mileage 150km;

✓ **Exhibitions**: low temperature super fast charging, battery safety monitor.

■ **Truck swapping area**

✓ **Technical indicators**: area 150㎡, 6-10 chargers, swap time 5min

✓ **Exhibitions**: Single-side heavy truck battery swapping process.

Typical Microgrid Projects in China 2020-2021

◆ **PV/Battery/Hydrogen/Charging demonstration in Sungrow Industry Park**

- ✓ Built **in 2020**
- ✓ **3.4 MW** roof PV generation system
- ✓ 1MW/1MWh battery
- ✓ **500 kW** hydrogen generation with 100Nm3/h generation capability
- ✓ **200 kW** EV charging station

Typical Microgrid Projects in China 2020-2021

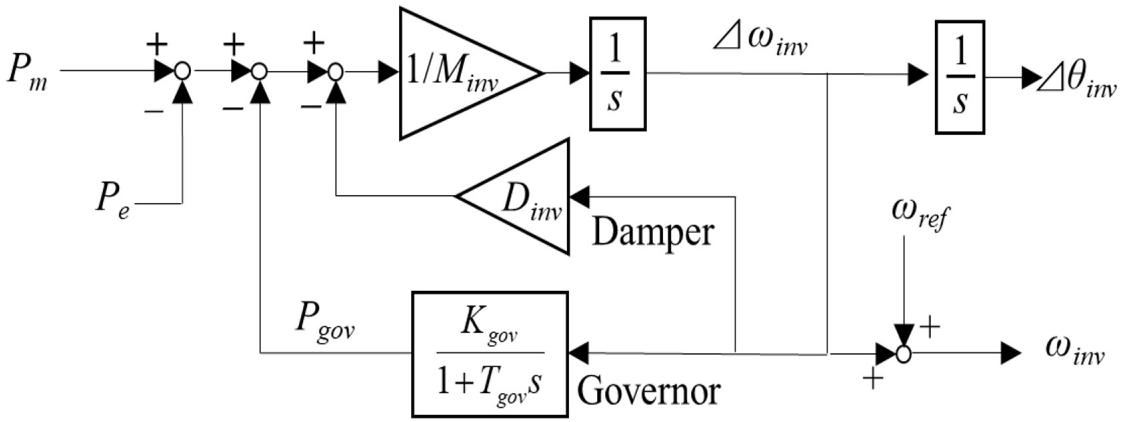
◆ **PV/Battery/EV Charging demonstration in Yuhu electric power company [1]**

- ✓ Built **in Sep. 2021**
- ✓ **150 kW** roof distributed PV generation**,** **500 kWh** battery system and **46** AC and DC EV chargers are constructed.
- ✓ **0.165 million kWh** green electricity can be generated per year, and **160 t CO2** can be reduced per year.

1 https://www.china5e.com/news/news-1123986-1.html

A grid-forming Inverter based Microgrid

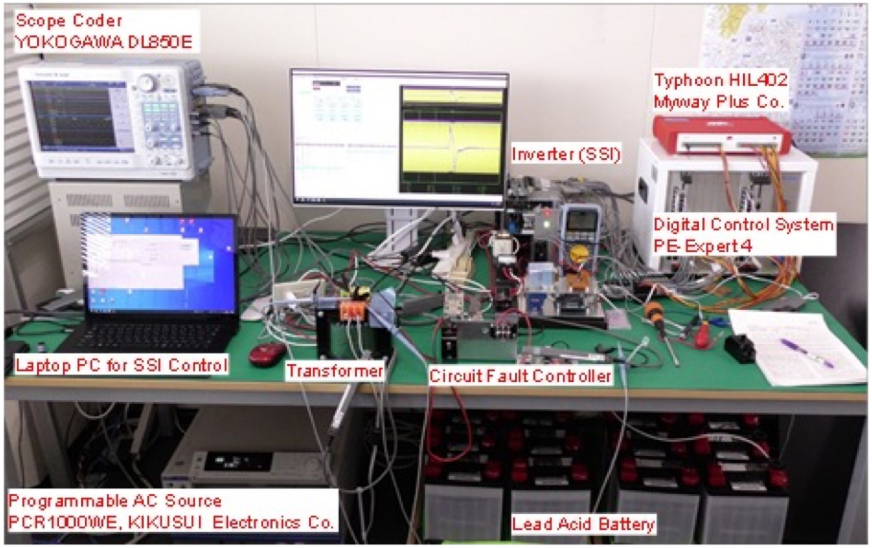
- Development of basic technology to cope with reduction of system inertia in power systems **(NEDO Project)**
- Power system stabilization effect of the grid-forming (GFM) inverter when it is installed in distribution systems
- Construction of resilient microgrid (MG) by GFM inverters
- Design concept of the single-phase synchronous inverter (SSI) based on Core/Shell design **(HU project)**

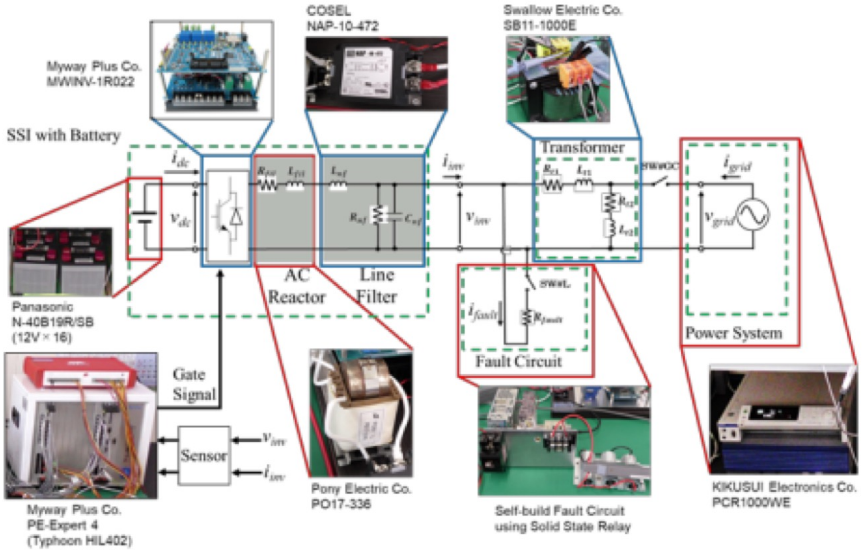


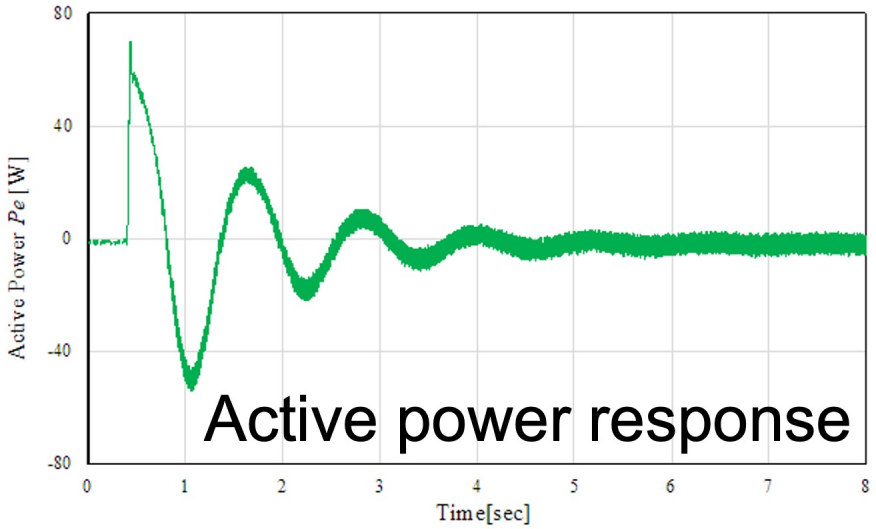
An example of a virtual synchronous machine (VSM)

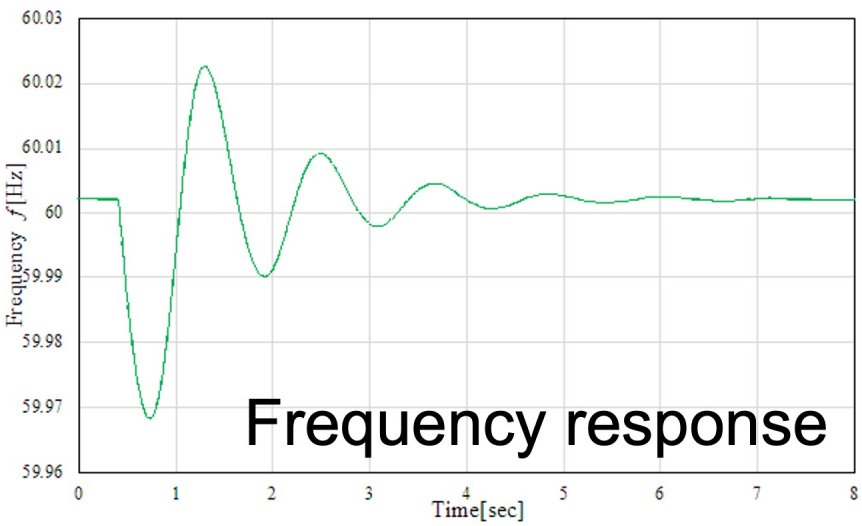
Demonstration of GFM Inverter NEDO Project

Rated capacity: 1kVA, Rated voltage: 100V (Single-phase)



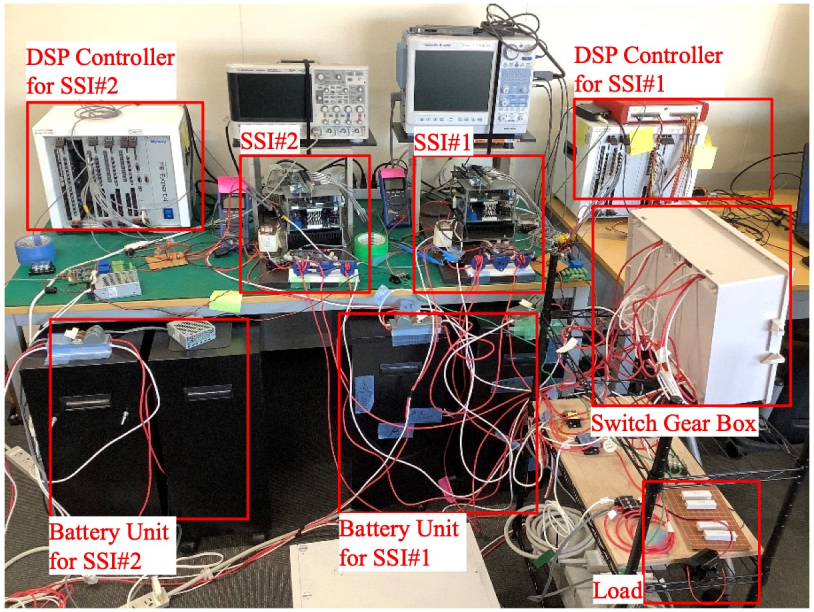


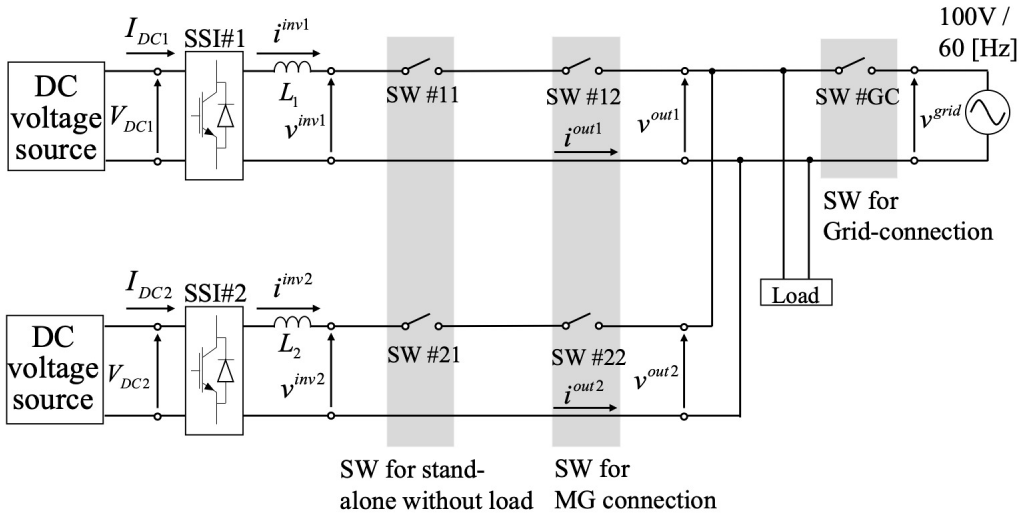




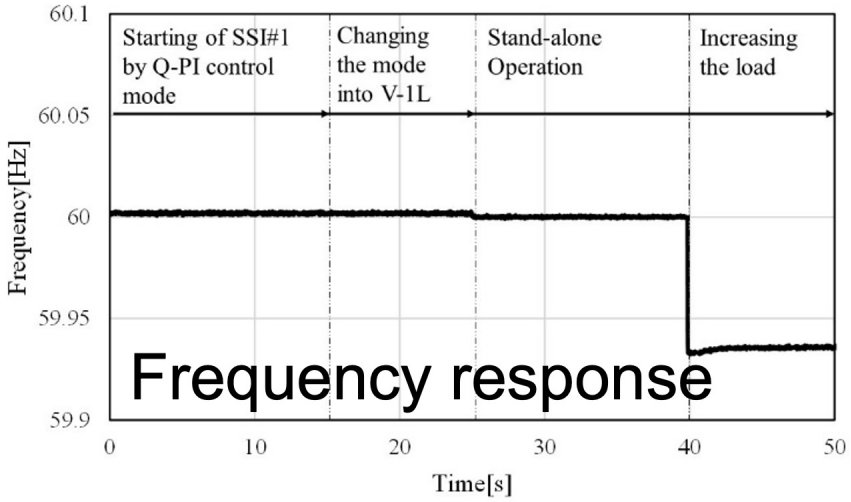
Demonstration of GFM-based MG HU Project

Rated capacity: 1kVA, Rated voltage: 100V (Single-phase)





V_{DC1}, V_{DC2} = 192 [V], L_1, L_2 = 10 [mH], Load = 0 or 40 [W]



- Single-phase microgrid operation in laboratory experiments
- The proposed controllers are implemented into two SSIs

I. Grid-connected operation
II. Stand-alone operation by a SSI
III. Islanded microgrid operation by two SSIs

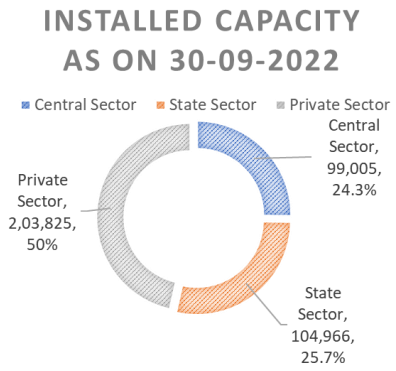
Federation of Microgrids in Emerging Economies - A Case of India

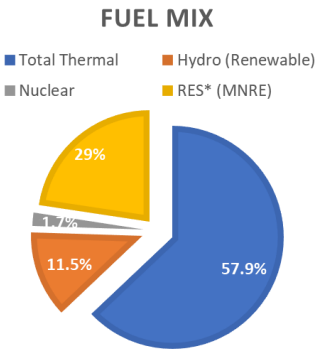
Dr. Kumudhini Ravindra

Innomantra Consulting

Bangalore, INDIA

Indian power sector





Source: CEA 2022

Current Energy Landscape

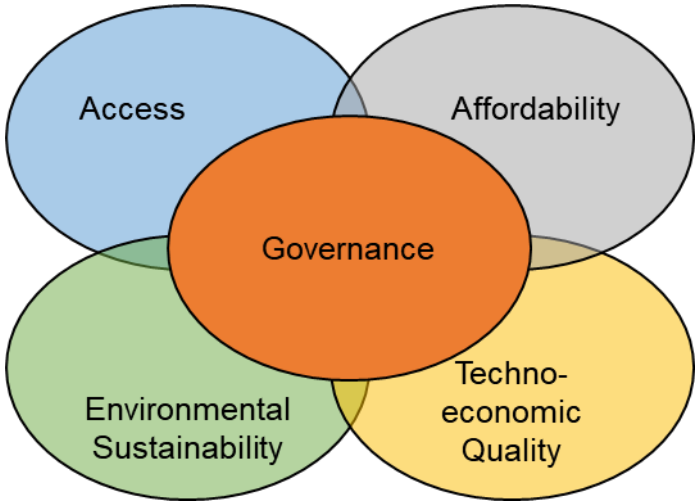
Supply side Challenges	Demand side Challenges

• Climate change
• Running out of easy oil
• Unreliable power in 2/3 of the world
• Lack of energy to rural areas
• Energy owned by large oil companies
	• Demand – Supply Gaps
	• Lack of 24/7 three phase power
	• Lack of grid support in rural areas expanding
	• Singular solutions due to
	  • greater risks and operational costs
	  • time lag to bring solution to scale

Indian Power Sector challenges

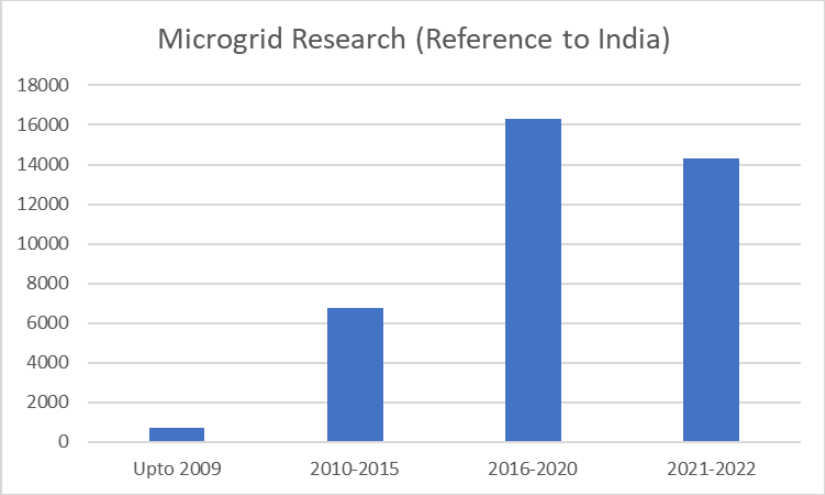
- Inefficient coal linkages leading to huge losses
- Lower than expected growth of electricity demand
- Financial stress to the generating companies
- Inefficient distribution companies
- Low R&D spends
- Use of Renewables in the energy mix
- Grid inflexibility and PQR issues

What customers really need…



Microgrids in India – The present story

Microgrids in India



Some interesting Statistics

- Renewable Energy Policy introduced
- Solar capacity increased from 2.6 GW to more than 46 GW (over past 7.5 years)
- Renewable energy - 26.53% of total installed generation capacity
- Grid connected rooftop solar PV introduced
- India is investing Millions for establishing Microgrids both private and public funding

Microgrids Status

- Solar Microgrids For Rural Electrification predominantly being financed/ supported
- 3 States have come out with Solar Policy supporting grid connected rooftop systems
- For instance, the Rockefeller Foundation and Tata Power partnered to build 10,000 microgrids by 2026. Also, the project aims to provide irrigation to over 400,000 local farmers, aid 100,000 rural companies, and offer 10,000 new green jobs.

Some Players in the Market

- MNRE & State REs
- Tata Power
- Husk Power
- GramPower
- IElectrix
- ABB, GE, Hitachi, Honeywell, Schneider, Seimens,…

Microgrids need to be viewed from a value-based paradigm

- Microgrids can be much more in an emerging country context
- Microgrids can be suitably designed to meet needs like
  - access to modern energy
  - energy independence
  - local resource utilization
  - specific consumer end use requirements
  - livelihood generation
  - power quality and reliability requirements
  - sustainable development
  - and their combinations

We need smart microgrid solutions for emerging economies

Solutions should Include…

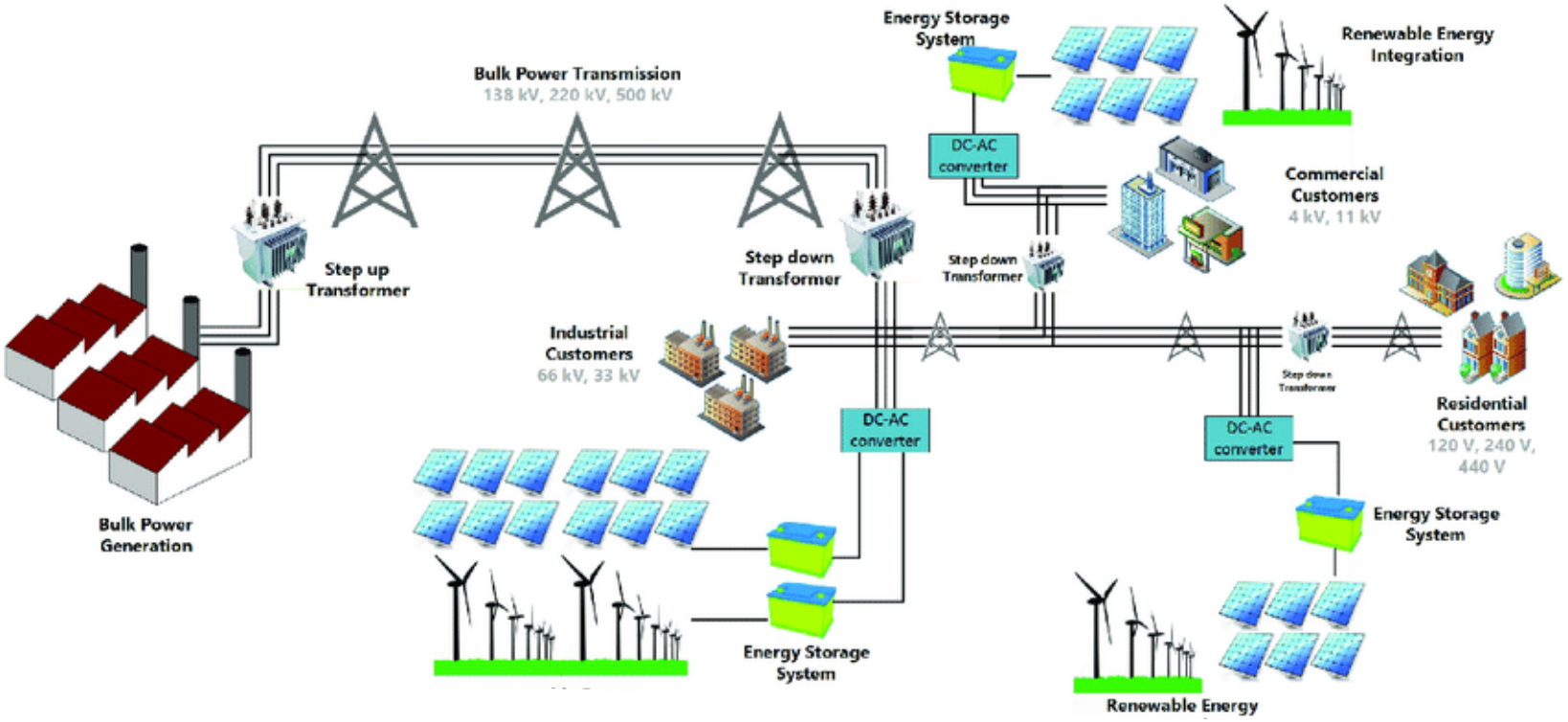
- Turning waste into renewable energy
- Augmenting energy input with solar, wind, water, biogas & other options
- Closed loop model - zero waste
- Energy to a local industrial partner and surrounding rural community through each microgrid plant
- Energy infrastructure to enable 24/7 three phase power
- Solutions that are GHG negative

…should Provide and Enable

- Energy Security
- Improvement of Local Livelihoods
- Reduction of Pollution
- Industrial Growth & Development
- Decentralized Growth Trajectory
- Local Solutions at Global Standards
- Customized R&D and Agronomics
- Empowering energy investments for all
- Triple Bottom Line
- Meeting SDGs

Redefinition of the Microgrid on a value-based paradigm

- "a group of interconnected loads and distributed energy resources within clearly defined boundaries that acts as a single controllable entity
  - designed on the basis of **the local consumer's or communities' energy needs and end uses**, where the loads and energy uses are qualified and segregated based on their reliability requirements
  - that **optimally matches these end uses and locally available clean environmentally friendly energy resources** without the need for transporting the fuel, **with or without the grid**
  - that **may or may not be connected** to the centralized grid
  - that can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode (if it is connected to the grid)
  - that can **communicate with the grid using ICT and enable demand response**."



Microgrids

Microgrids are a future power system configuration providing clear economic and environmental benefits compared to expansion of our legacy modern power systems

Microgrid choice in India will depend on

Grid availability	Energy security needs	Local conditions	Techno-economic efficiency requirements	Reliability requirements	Environmentally sustainable development

Microgrids for emerging economies – Potential Models


Net Zero Model


Resource based Model


End Use focused Model


Livelihood Model


PQR based Model


Environment Focused Model


Combinations of the above

Microgrids can be the next best alternative and can co-exist with centralized grid systems ☺

Focusing on any one technology is imprudent ☹

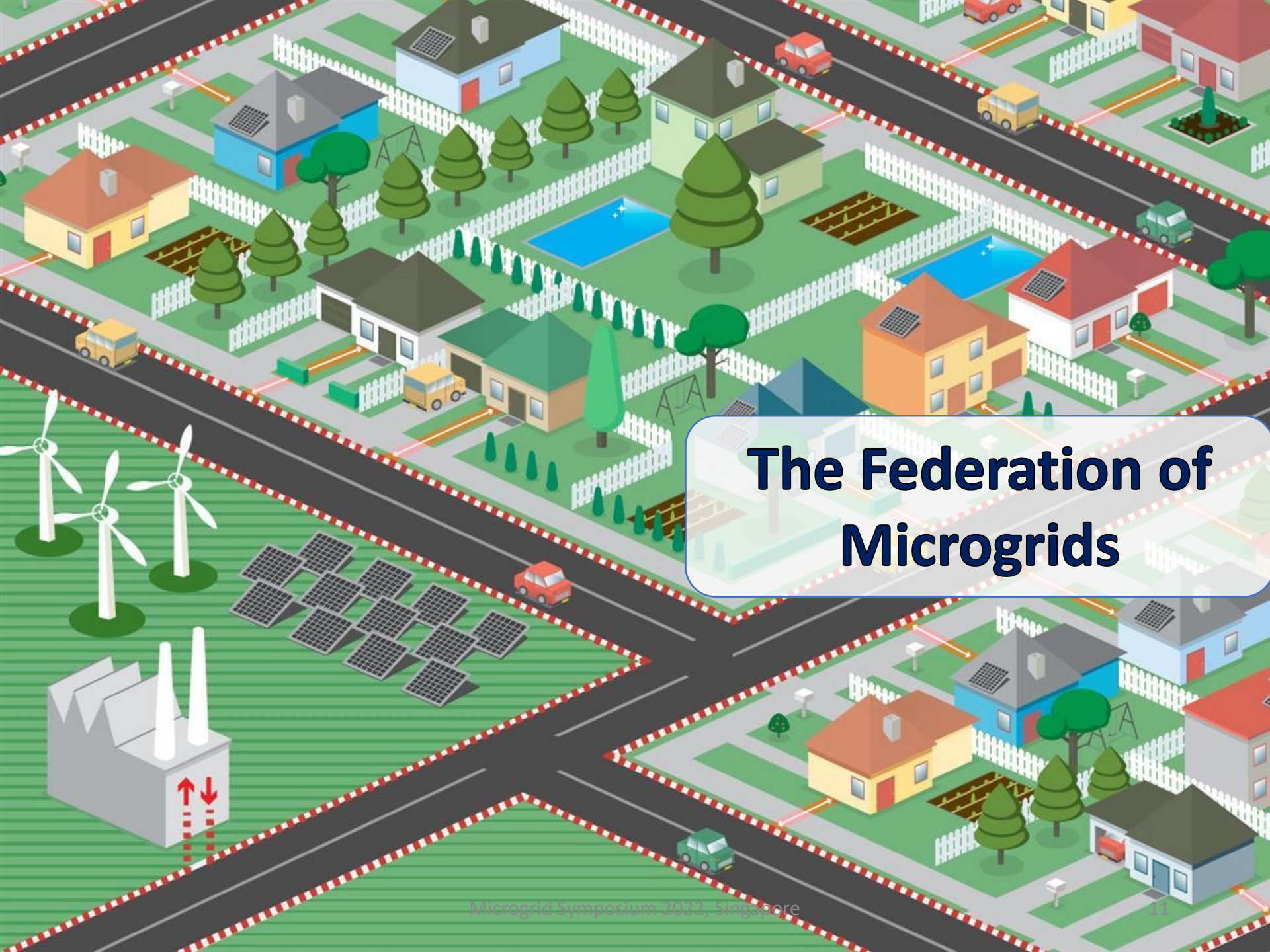
We need multiple hybrid solutions ☺

Where are microgrids found in India??? But not referred to as such…

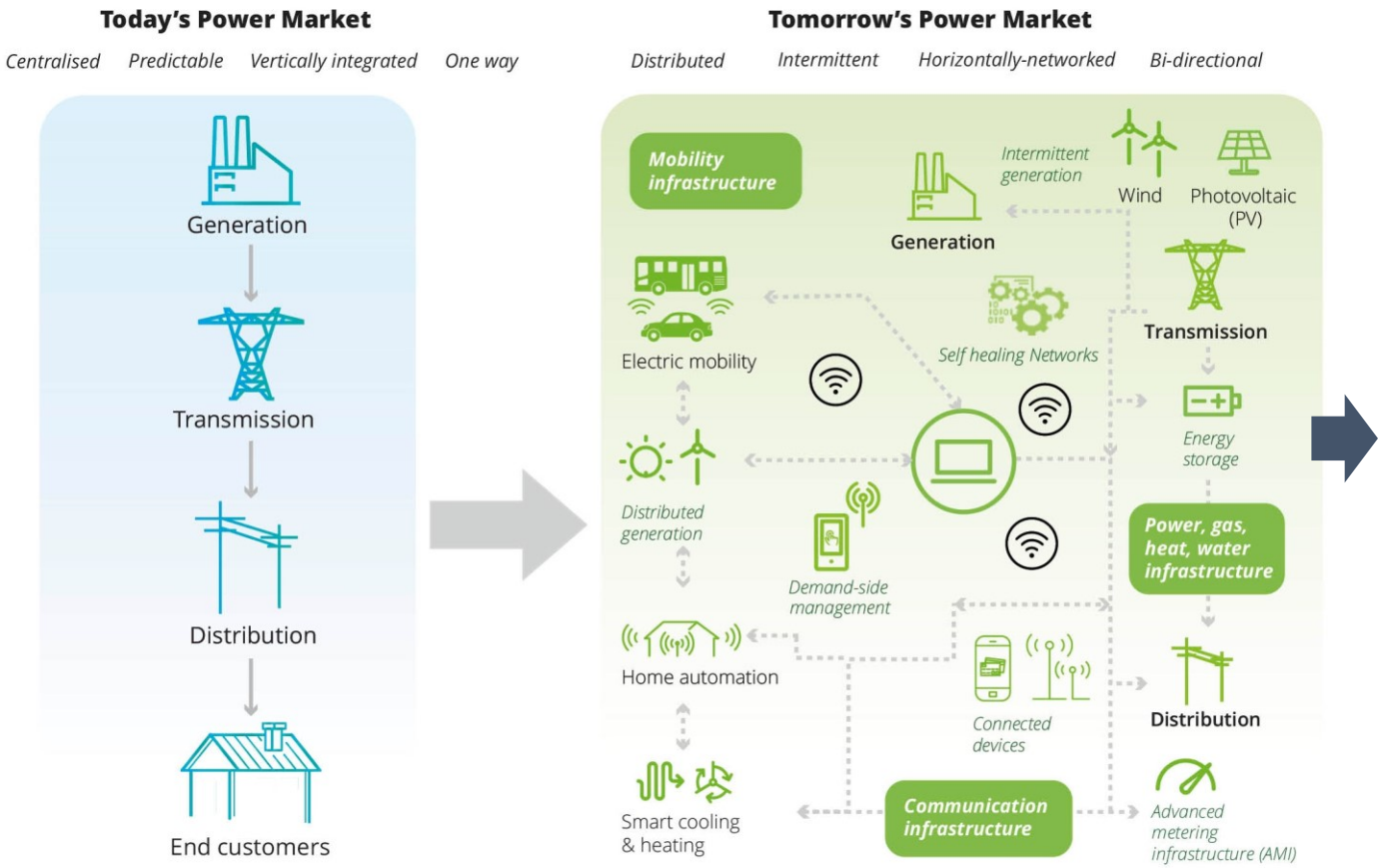
- schools, colleges, universities,
- military bases,
- airports,
- metro stations,
- data centers,
- hospitals,
- remote islands,
- municipalities,
- hotels,
- malls,
- farms,
- grocery stores,
- office buildings,
- housing societies,
- factories,
- Apartments and high rises, …

In order of Preference	Locations	Reasons
1.	Hospitals	Power failure may lead to failure in critical life support systems leading to fatalities.
2.	Military /Defense Facilities	More reliability in turn security.
3.	Commercial Centers like malls, shopping centers, business complexes.	Power failures may lead to financial losses & affect livelihoods.
4.	Campus(University, Colleges, Office complexes)	The campuses becomes self sufficient saving electricity bills as well as improves reliability.
5.	Housing Complexes	Independent power will help in reliability, saving,

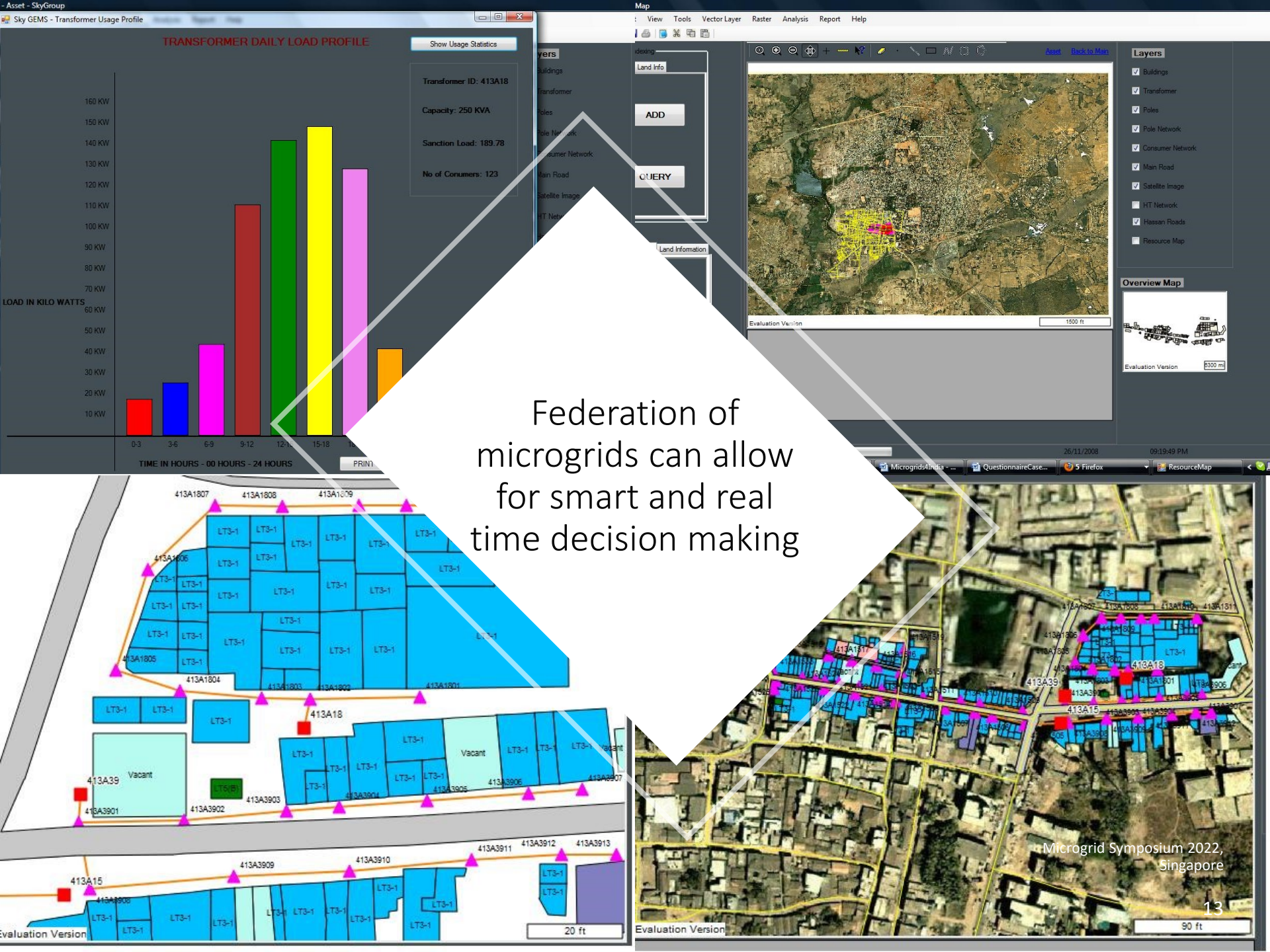
Last mile connectivity
Increased access
Possibility of clean green energy


The Federation of Microgrids

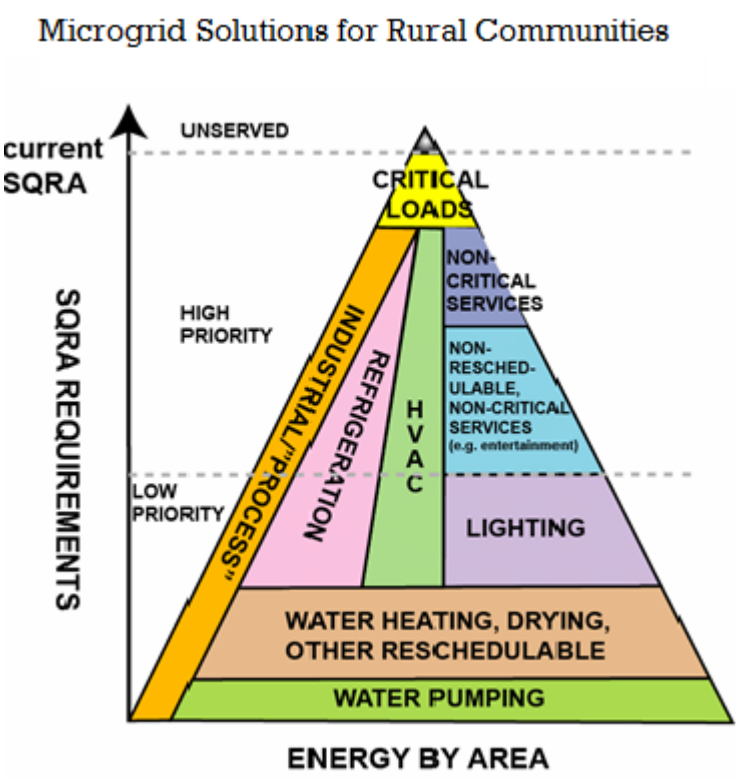
Energy 4.0



Microgrids are the future power system configuration that can provide clear economic and environmental benefits compared to expansion of our legacy modern power systems
And in HARMONY with the natural systems


Sky GEMS - Transformer Usage Profile
TRANSFORMER DAILY LOAD PROFILE
Show Usage Statistics
Transformer ID: 413A18
Capacity: 250 KVA
Sanction Load: 189.78
No of Conumers: 123
LOAD IN KILO WATTS
TIME IN HOURS - 00 HOURS - 24 HOURS
Map
Layers
Overview Map
Federation of microgrids can allow for smart and real time decision making
Microgrid Symposium 2022, Singapore
13

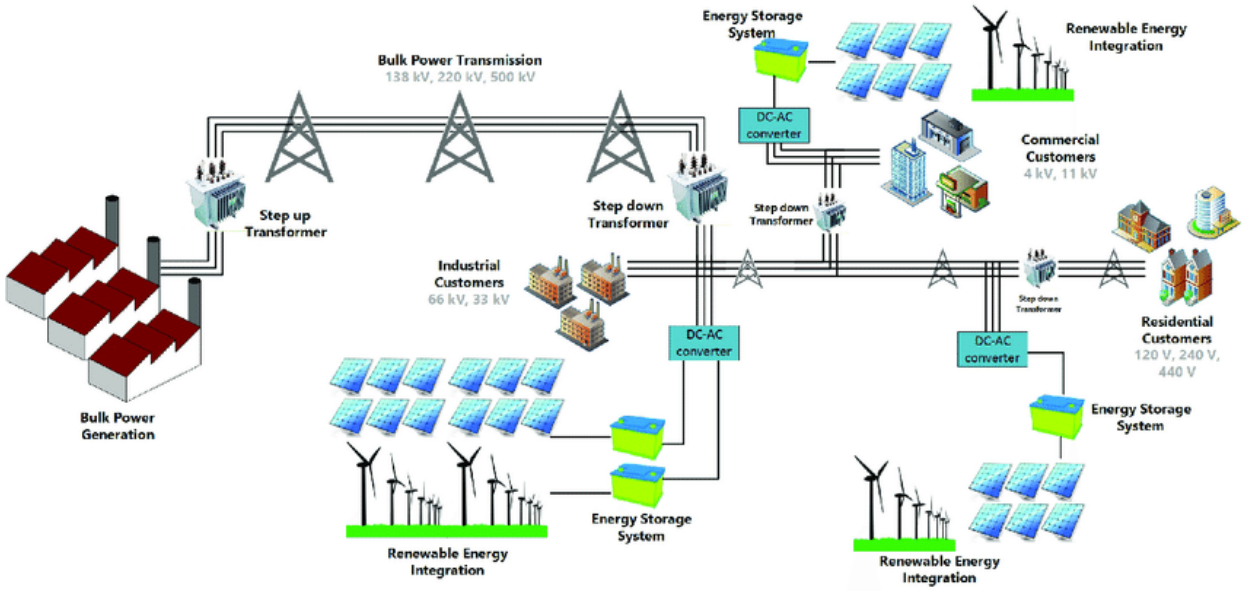
Grid Augmentable local Supply for microgrid operations



- Solar (PV + Thermal)
- Wind (micro wind turbines)
- Hydel (micro and mini hydel)
- Biogas/ Biomass based systems
- Municipal waste-based systems
- CHP Systems
- Natural Gas based systems (potential gas grid)
- Fuel Cells
- Biodiesel based systems (as a hybrid to diesel generators, which are highly prevalent)

Source: Berkeley Labs

Federation of Microgrids



- Microgrids enable a **network of networks architecture** that ensure
  - Autonomy
  - Stability
  - Compatibility
  - Flexibility
  - Scalability
  - Efficiency
  - Economics
  - Peer-to-Peer Interactions

Microgrids enable **seamless integration** of new supply systems designed for the edge or using biomimicry, through appropriate use of **ENERGY SERVICE PROVIDERS**

MicroGrid Economics

Main Issues

- Optimal technology investment
  - Optimal mix of renewables
- Utilization of some unique aspects
  - Local control of power quality and reliability
  - Societal perspective
- Relationship with distribution system

Emerging Issues

- Joint optimization of demand and Supply
- Joint optimization of heat and electric supply
- Focus on quality & reliability
- Metering arrangements
- Connection charges
- Tariff mechanisms

Federation of Microgrids

Multi-level control (federal structure)

Allow for plug and play operations

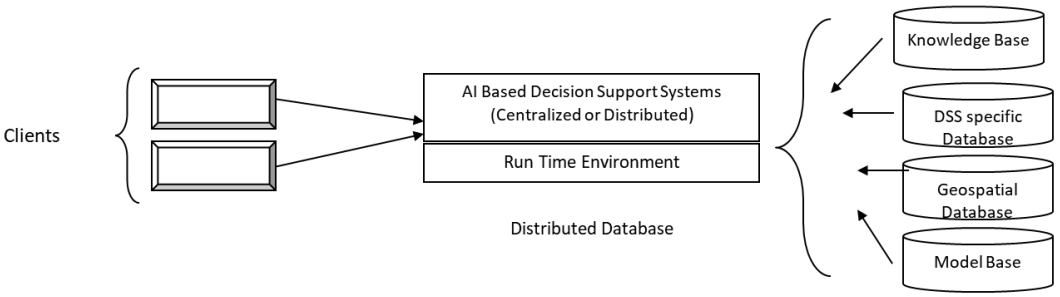
Ensure Local & Grid Level Resource Optimization

Achieve Multiple levels of SQRA

Cost effective

Improve Efficiency and Control of Operations

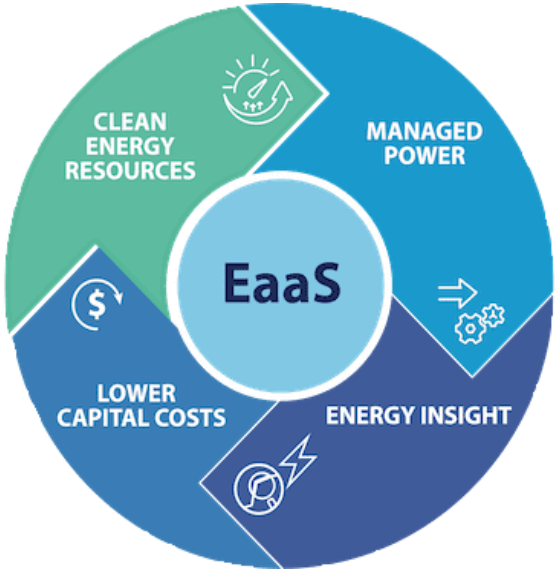
Enable Better Demand Response



Types of Decision Support

- Demand in the region/ location
- Optimal supply mix (past, present, future)
- Technology availability
- Alternate options for demand/ supply
- Types of consumers and usage patterns
- Typical consumer equipment/ appliances used
- Typical consumer energy costs and breakup…
- Scenarios (Demand) –
  - different equipment – HH with equip 1,2,3… - profile…
  - comparison
  - Extrapolation
- Scenarios (Supply)
  - Profiles
  - Comparison
  - Extrapolation
- "Input/ Out" scenarios
- Supply Chain Management
- Scenarios for improving the efficiency of SCM (Enabling Green supply chains)
- Best technology mix for given "capital"
- Meso level decisions
  - Niches…
  - Innovation…
  - R&D …

Microgrids can provide Energy as a Service



Energy as a Service Market to Garner Astounding CAGR of +44% by 2027 and grow to US$20 billion

Issues that need to be addressed

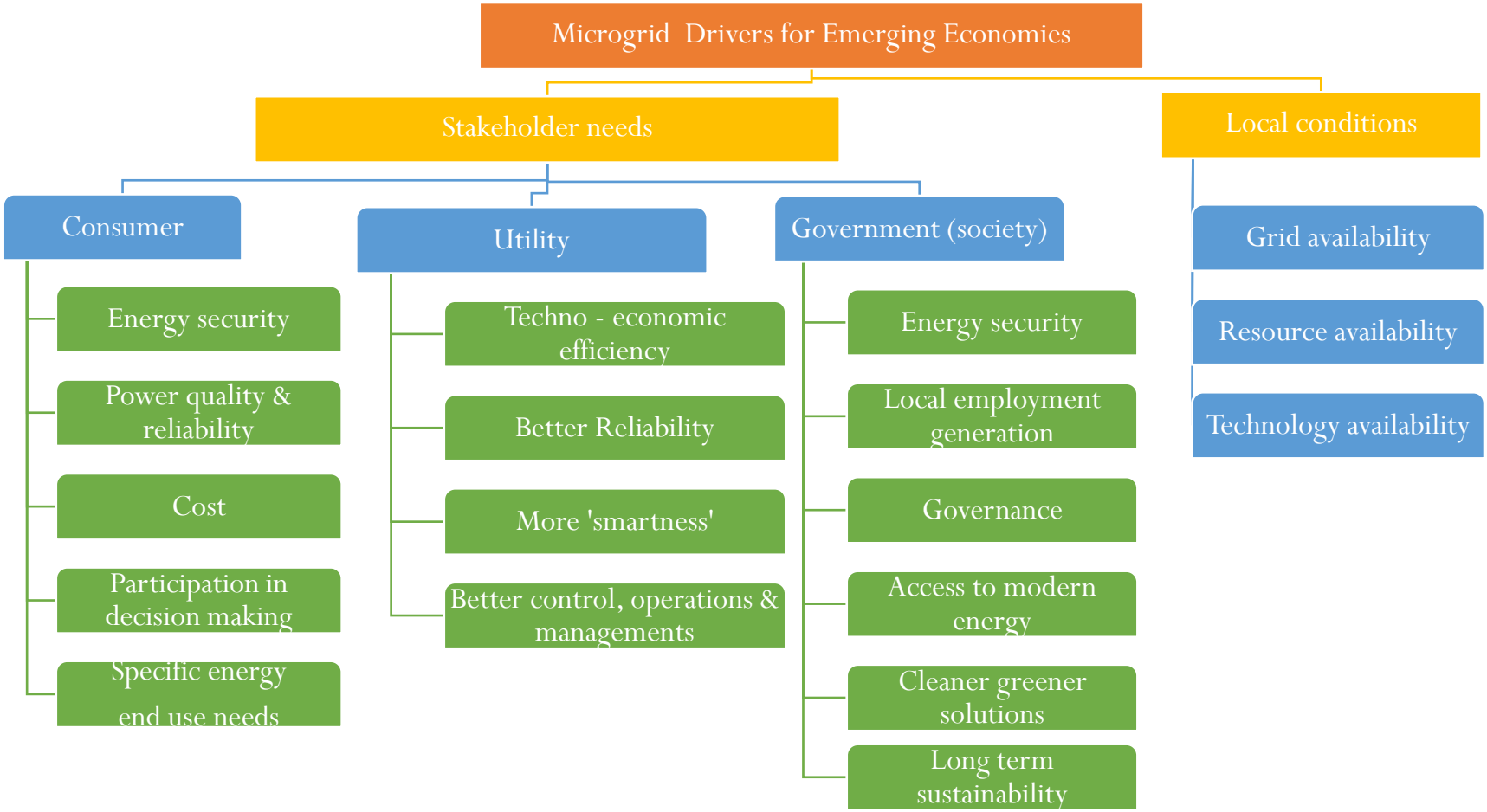
Technical

- Impacts of voltage, frequency, power quality
- Protection schemes and modifications
- Monitoring, information exchange and control
- Understanding load requirements of the customer/s
- Knowing the characteristics of the DG/DERs
- Identifying steady state and transient conditions
- Reserve margins, load shedding, demand response

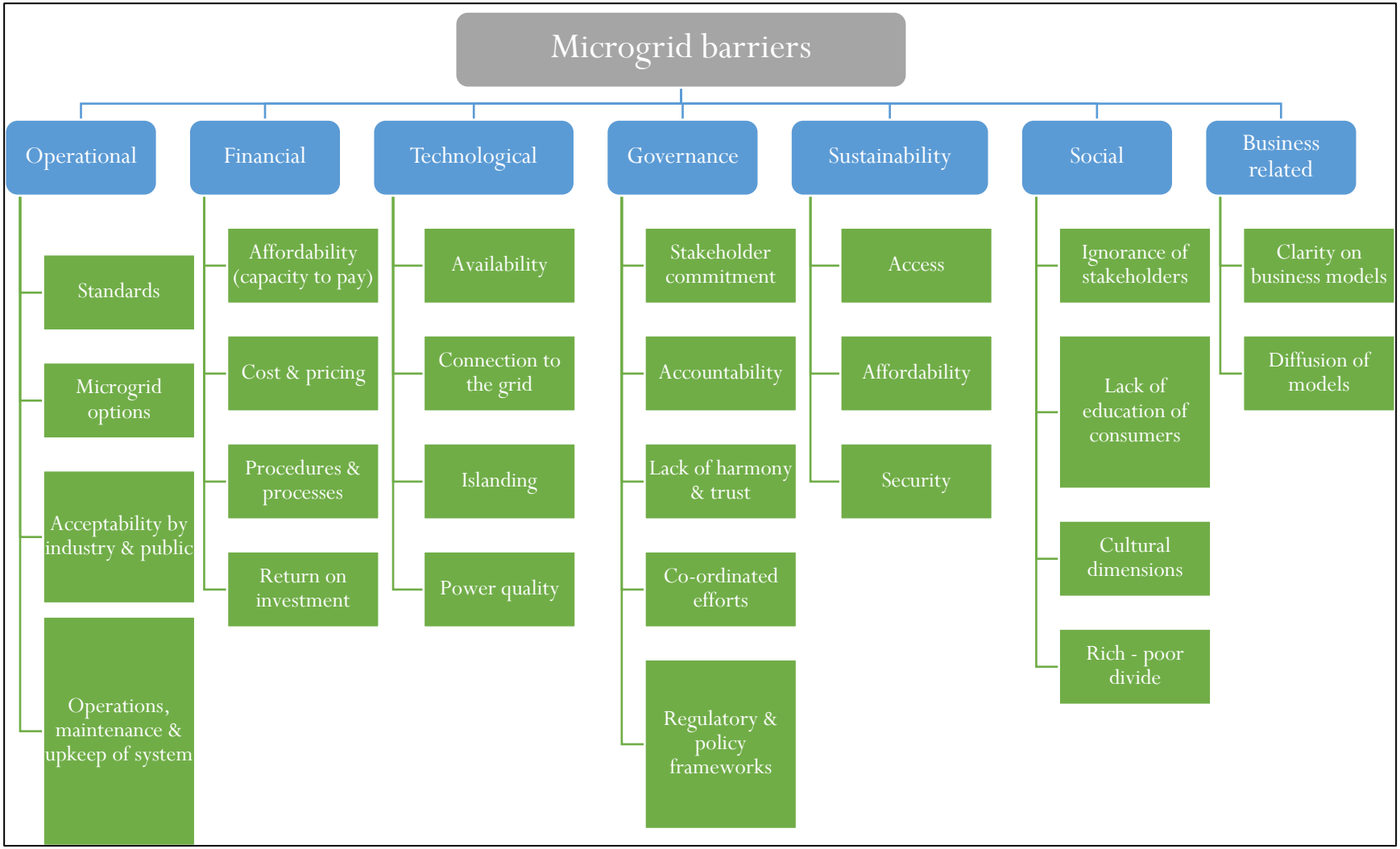
Commercial

- 'Right sizing' & Design
- Cost – fixed and variable, tariff setting
- Grid interactivity
- Microgrid/s interactivity
- Right business models
- Regulatory aspects
- Institutional frameworks
- 'Energy as a Service'

Microgrid Drivers for Emerging Economies



Microgrid barriers for Emerging Economies



Microgrids CAN Impact Lives!!!

For millions of Indians, microgrids may be the only option to have access to modern energy and for improving their lives

Thank You

innomantra
TRANSFORMING IMAGINATION

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Energy based Startups in India

Name of Startup	Brief Description	Website URL
Amberroot Systems	Power back-up solution for solar PV (homes and small offices)	www.amberroot.com/
Aspiration Energy	Solar industrial heating solution with pay-as-you save model	www.aspirationenergy.com/
Green Power Systems	Mid-scale biowaste to energy (biogas) reactors for urban applications	www.greenpowersystems.co.in/
Nessa Illumination Technologies	Solar & LED streetlighting solution with pay-as-you-save model	www.nessa.in/
ReMaterials	Alternative & superior roofing material/tiles made from waste materials	www.re-materials.com/
Science for Society	Solar drying solutions	
SecureT Solutions	Security as a service, with energy mgmt. built in	www.securet.in/
Southern Biocoal	Bio-Coal: a coal substitute from biomass through proprietary process	https://southernbiocoal.wordpress.com/
Abhinav Gupta, Priyans Murarka	Advanced home energy management and automation systems	

Energy based Startups in India

Name of Startup	Brief Description	Website URL
GramPower	Micro-grid solution for rural electrification	http://www.grampower.com/
Green Brick Eco Solns.	Bio-gas capture and storage for cooking applications	http://gbes.in/
Nuru Energy	Solar based LED-lighting solution	http://nuruenergy.com/
Fourth Partner Energy	Solar EPC startup focused on commercial and industrial segment	http://www.fourthpartner.co/
Revive eWaste Mgmnt. Co.	E-waste management startup	http://www.revive-ewaste.com/
REConnect Energy Solns.	Renewable energy forecasting and services startup	http://www.reconnectenergy.com/

Energy based Startups in India

Name of Startup	Brief description	Website URL
Ezysolare	Online tool to facilitate solar decision-making for end users, system integrators and financiers by providing end-to-end support in the form of independent assessments, engineering and design of plants and procurement of equipments.	http://www.ezysolare.com/
Solarwaale	An online marketplace for solar installations by bringing together customers, developers/installers, ensuring quality and timeliness of execution through online project management support to customers.	http://www.solarwaale.com/
Sunkalp Energy	Develop a low-cost and scalable model to be able to target the small-ticket but high volume residential solar market through in-house mobile application for fast rooftop assessment, easy to assemble assisted-DIY solar kits and consumer financing options.	http://sunkalp.com/
Glowship	Marketplace platform for energy & environment related products, solutions and services, offering a simplified and customized buying experience pertaining to the areas of renewable energy, energy efficiency, home automation, etc. and enabling buyers to make a purchase from verified sellers/service providers	http://www.glowship.com/
RenXSol EcoTech	A Solutions provider in the field of solar thermal fluid heating working on adapting concentrated solar thermal to the specific needs of process industries, steam generation and drying.	http://www.renxsol.com/
Promethean Energy	Overall focus on developing a range of products targeting energy efficiency in industries; currently working on a waste heat recovery product to be retro-fitted on refrigeration cycles.	http://www.prometheanenergy.in/