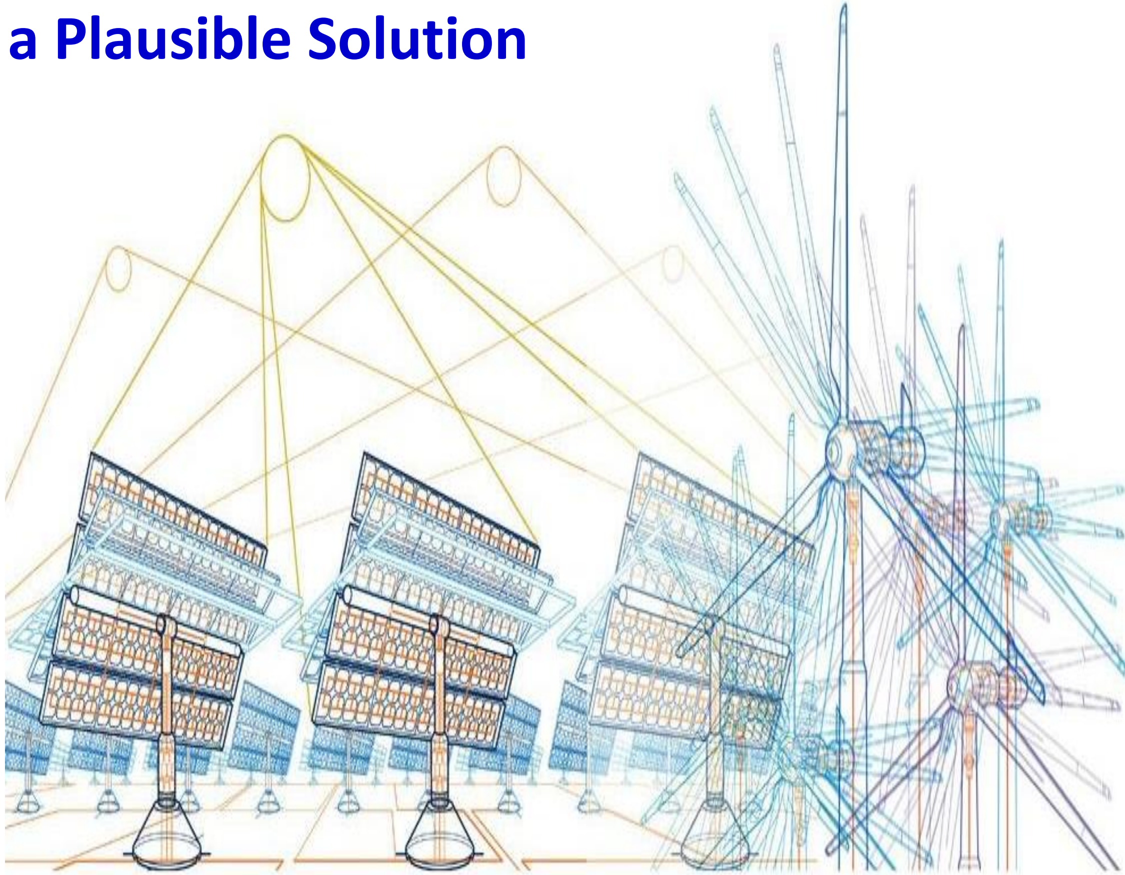
Variable Renewable Energy (VRE) Integration in Mauritius Power Grid

Battery Energy Storage System (BESS) a Plausible Solution



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OUTLINE

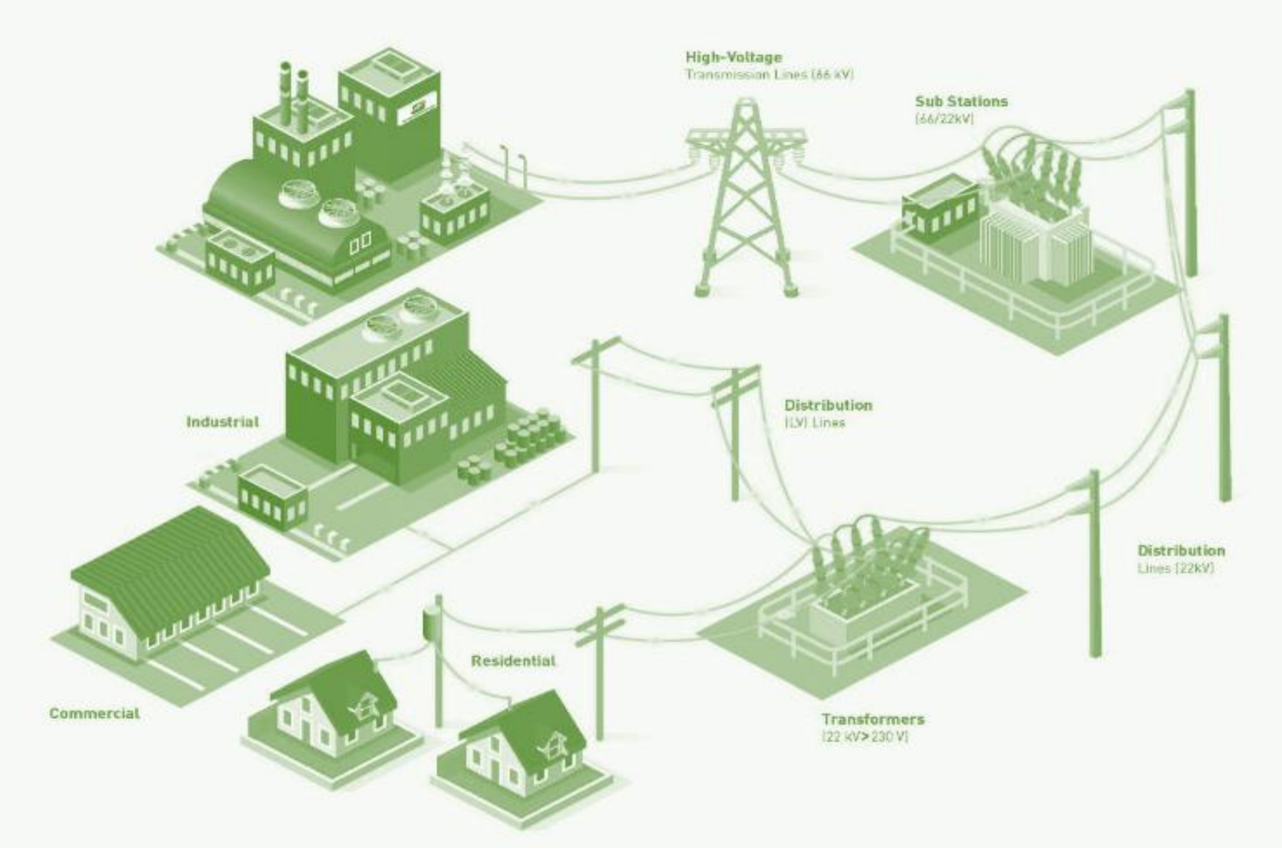
- Mauritian Power System
- Long Term Energy Strategy 2009-2025
- Challenges for VRE Integration
- Actions taken

1. Mauritian Power System

2. Long Term Energy Strategy

3. Challenges for VRE Integration

4 Actions taken

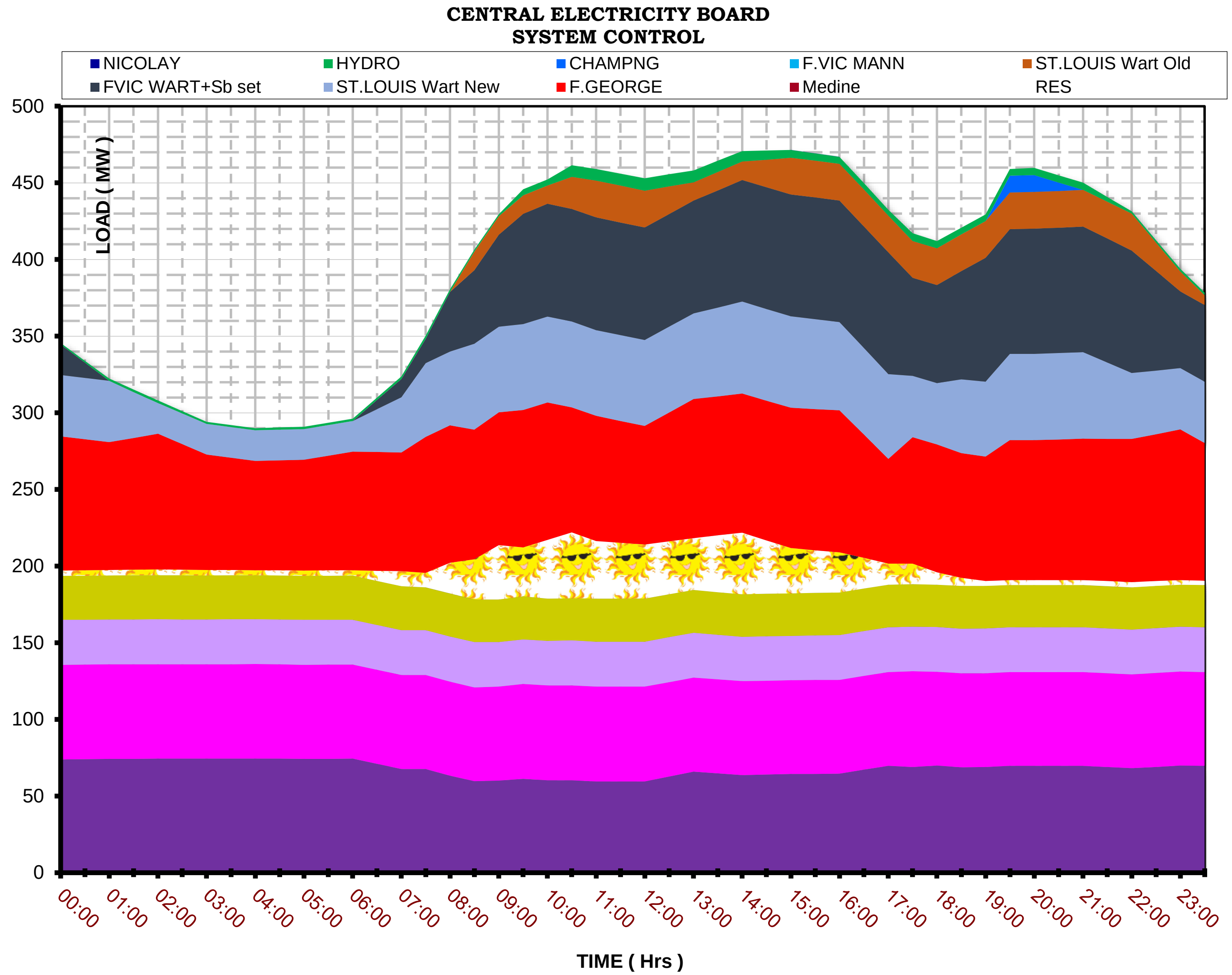


POWER GENERATION CAPACITIES – LOAD PROFILE

The CEB owns and operate some **480MW** of fuel oil thermal and **60MW** of hydro power capacity.

It also has IPP contracts for about **200MW** coal/bagasse for base load generation.

There are also some **107 MW** Solar PV, **3.3MW** Of Landfill Gas and **9.35 MW** of Wind.

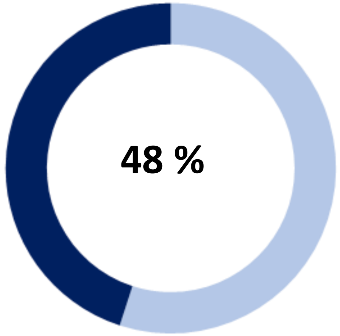


ELECTRICITY GENERATION AND DEMAND

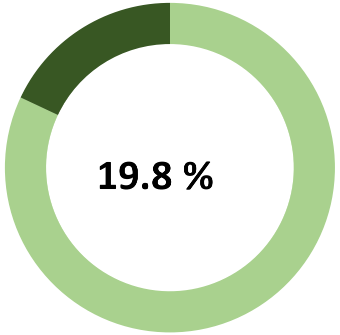
2937 GWH

ENERGY GENERATION IN 2019

Source	Share
HFO	44.81%
Coal	35.85%
Kerosene	0.1%
Hydro	3.36%
Bagasse	10.69%
Landfill Gas	0.68%
PV (5.53% in 2021)	**3.77%**
Wind	0.44%
Cane Trash	0.31%



CEB Share in Energy Generation



Renewable Energy Share in 2021

507 MW

PEAK DEMAND

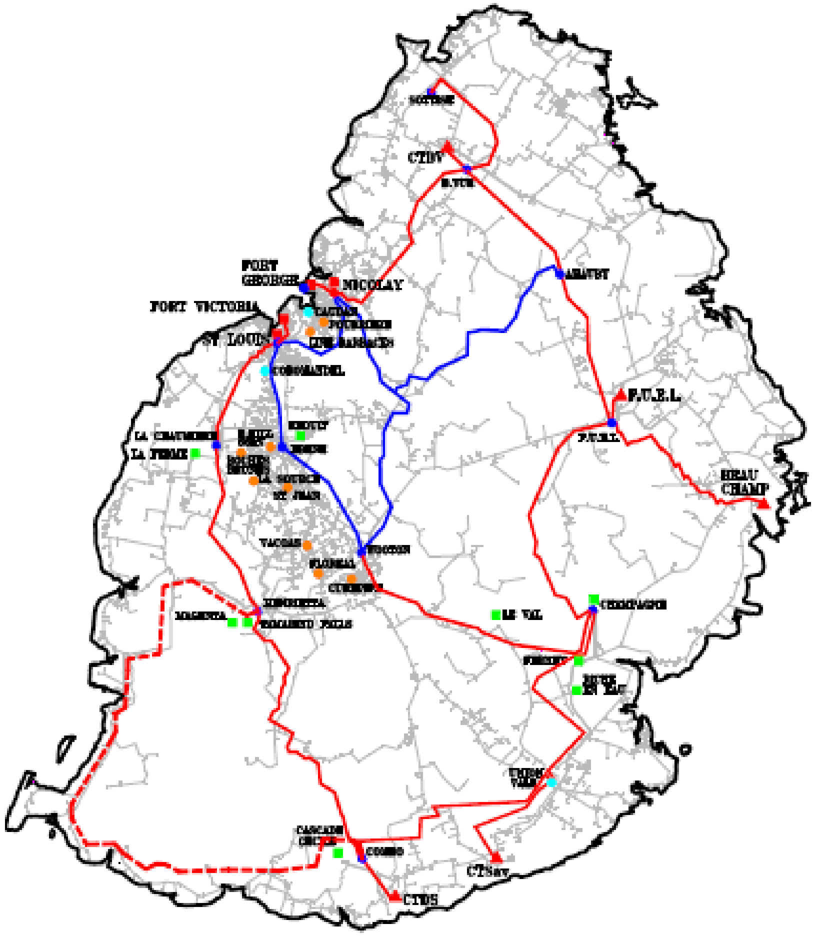
1.3 M

POPULATION

App. 2000 km^2

AREA

TRANSMISSION NETWORK



The transmission network, operates at 66 kV, transporting power in bulk from the main sources of generation to **eighteen** 66kV-22kV substations scattered over the island.

Part of the transmission network has been built to operate at **132kV when the need arises.**

Transmission network is designed to **N-1 security criteria** *(Lines and Substation Power Transformers)*

300 km of Overhead line (*Combination of concrete Poles and Towers*) and **26 km** of underground Cables

DISTRBUTION NETWORK

- The CEB's distribution system supplies electricity at lower voltages from its substations to around **490,000** customers' premises through around 22kV-415V distribution transformers.

- The distribution feeders, operates in **radial configuration**, are extended outwards from their respective substations to supply customers within a delimited service area.

- Distribution Lines : **9147 km** Overhead Line and **973 km** Underground Cable.

ELECTRIFICATION	SAIDI	SAIFI
100%	**2.79**	**1.72**

CEB Website http://ceb.mu for more information

1. Mauritian Power System

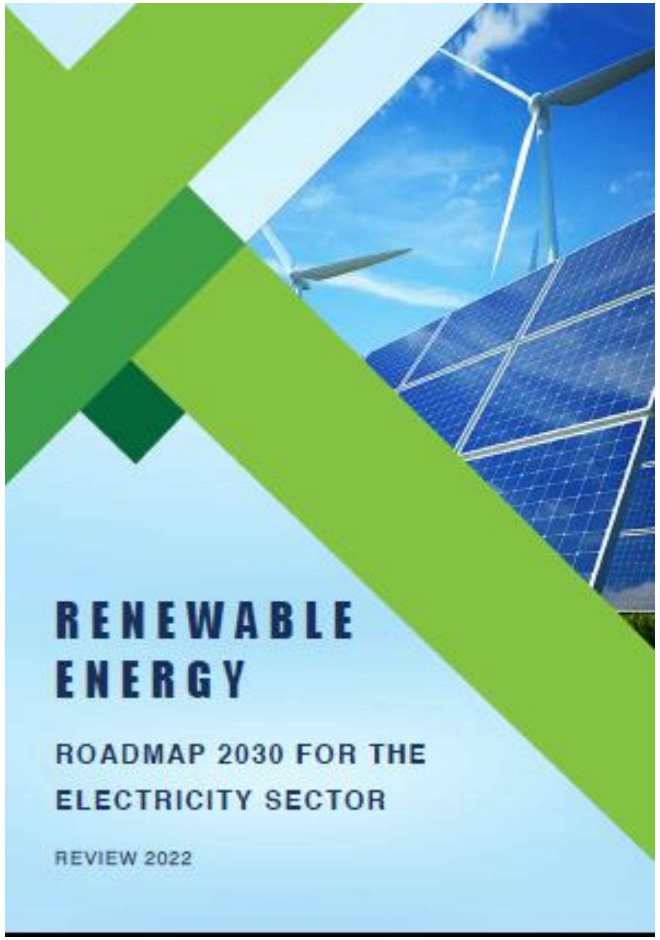
2. Renewable Energy Roadmap 2030

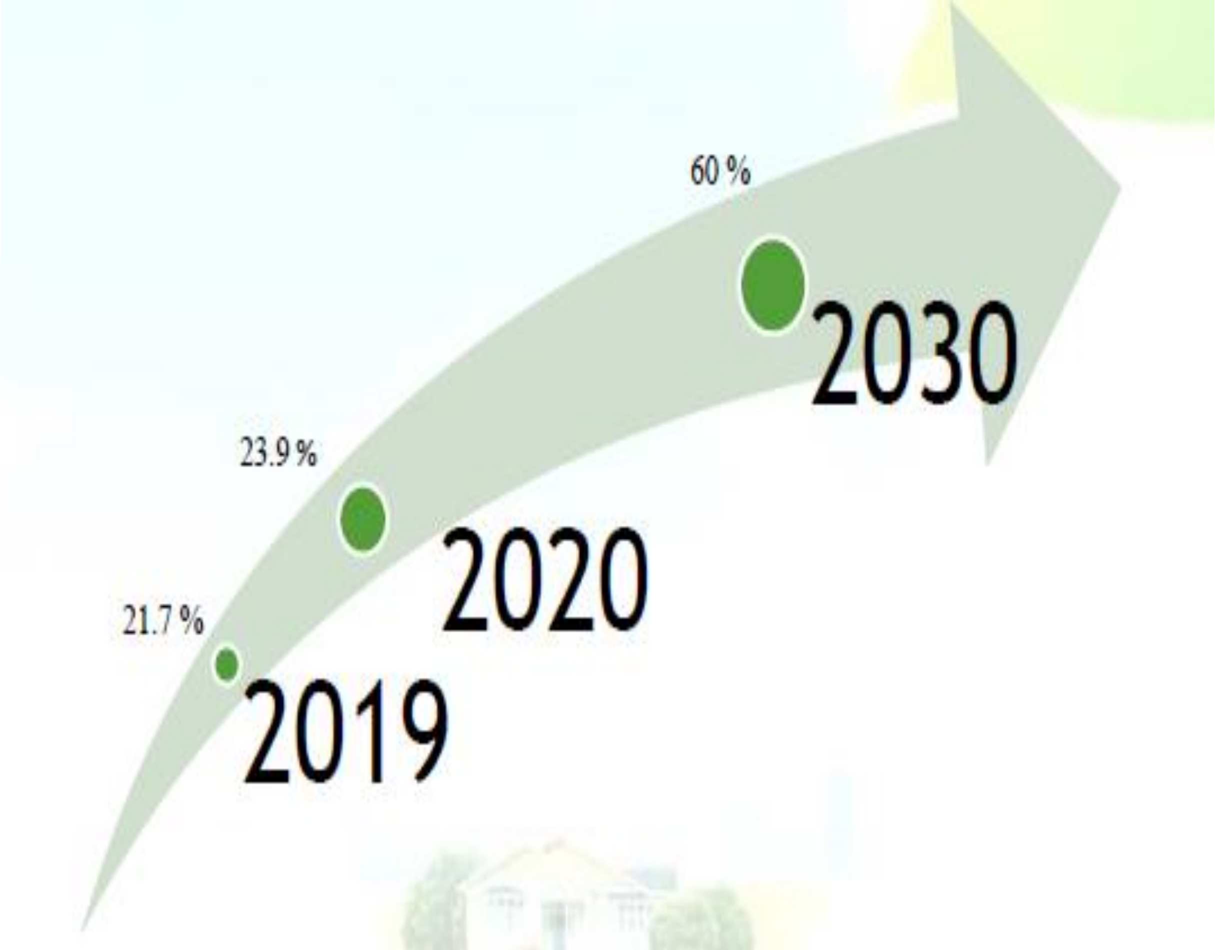
3. Challenges for VRE Integration

4 Actions taken

RENEWABLE ENERGY ROADMAP 2030

- Launched on 13 May 2022





RE ROADMAP 2030

RE POWER EXPANSION STRATEGY

	Year 2030			
	Actual	Low Case	Base Case	High Case
PEAK				
Nicolay Power Station (GWh)	5	11.4	13.86	16.35
Hydro (GWh)	25	25	25	25
Total (Energy Generation) (GWh)	30	36.4	38.86	41.35
Maximum energy for peak (GWh)	30	36.4	38.86	41.35
SEMI-BASE				
Solar (GWh)	160	591	591	606
REHF Solar+Battery storage (GWh)	0	300	300	300
Total Energy generated by RE (GWh)	160	891	891	906
Fort Victoria (GWh)	383	190.63	193.6	225
St Louis (GWh)	468	155.97	236.6	275
Total (Energy Generation) (GWh)	1010	1237.6	1321.2	1405.9
Max Energy for Semi-Base (GWh)	1010	1237.6	1321.24	1405.9
BASE				
Hydro (GWh)	68	68	68	68
Biomass-Bagasse (GWh)	430	0	0	0
Biomass-Cane Trash (GWh)	8	0.0	0	0
REHF (Solar+Wind+battery storage) (GWh)	0	350	350	350
Small Scale REHF (GWh)	0	140	140	140
Large Scale REHF-Biomass (GWh)	0	685	685	685
Onshore Wind (GWh)	15	15	15	15
Offshore Wind (GWh)	0	150	150	150
Marine Renewables (tidal/wave energy) (GWh)	0	50	50	50
Landfill gas (GWh)	23	23	23	23
WtE (GWh)	0	75	75	75
Total Energy generated by RE (GWh)	544	1556	1556	1556
Coal (GWh)	800	0	0	0
Fort George/CCGT (GWh)	587	810	969.9	1132
Total (Energy Generation) (GWh)	1932	2366	2525.9	2687.8
Max Energy for Base (GWh)	1932	2366	2525.9	2687.75
Total Energy demand forecast (GWh)	2971	3640	3886	4135
% Renewables	24.5	67.9	63.6	60.1
% Non-renewables	75.5	32.1	36.4	39.9

1. Mauritian Power System

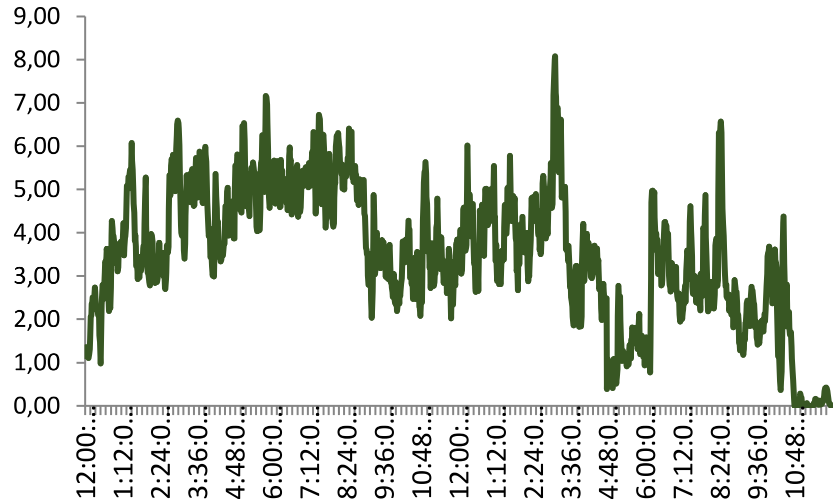
2. Long Term Energy Strategy

3. Challenges of VRE Integration

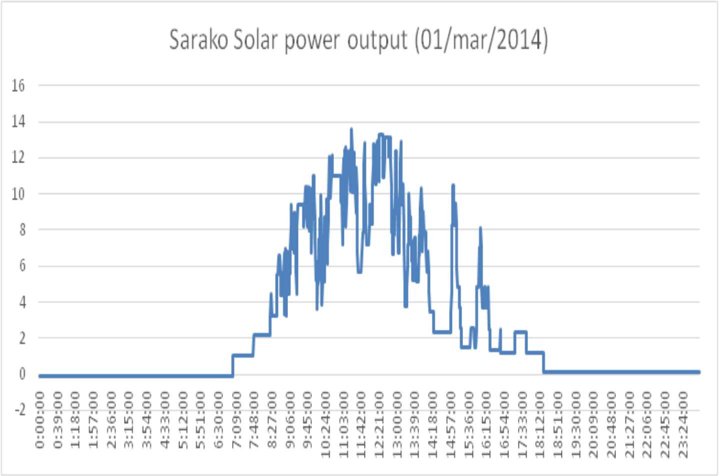
4 Actions taken

Small Islanded power systems

- Low inertia
- Highly sensitive to network disturbance (Load and Generation)
- High risk of frequency instability due to volatile power output of non-dispatchable renewable energy systems, mainly wind and solar.

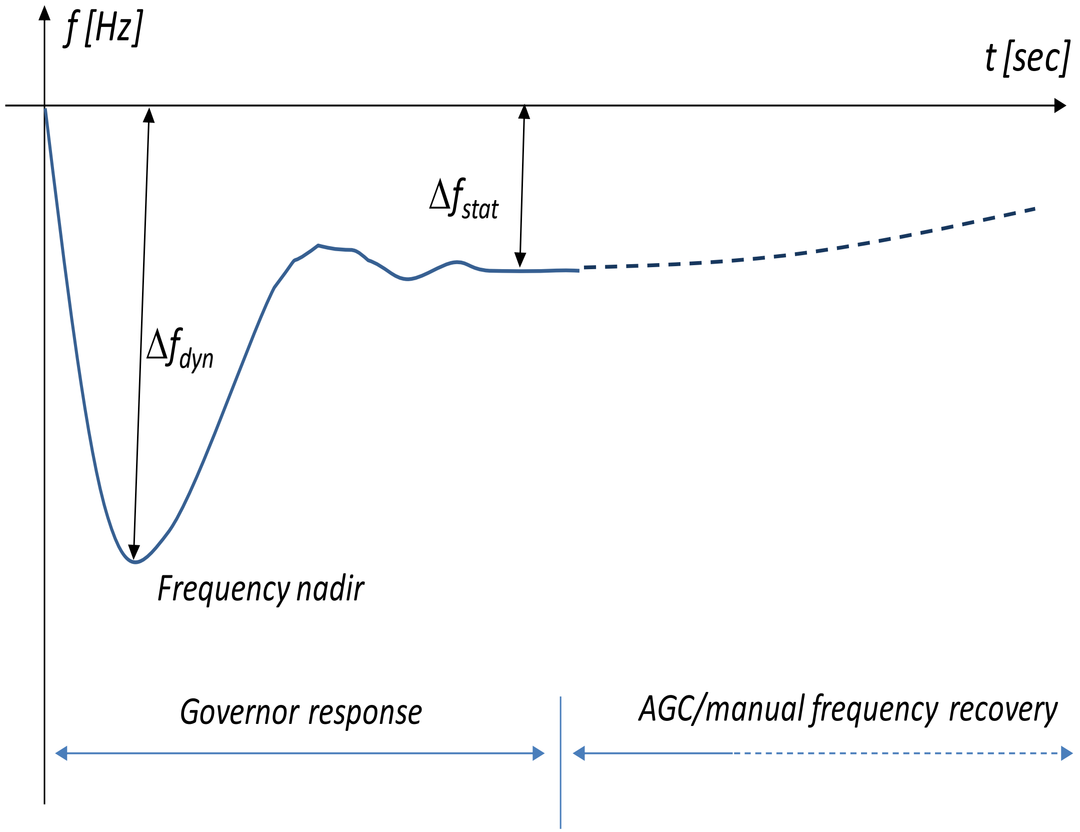


CEB has to maintain system frequency within ±1.5% of the nominal value of 50Hz,



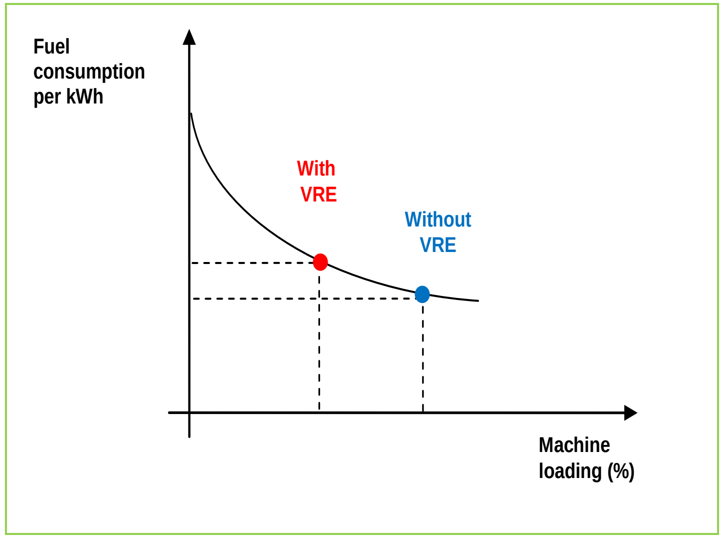
VRE Integration and System Inertia

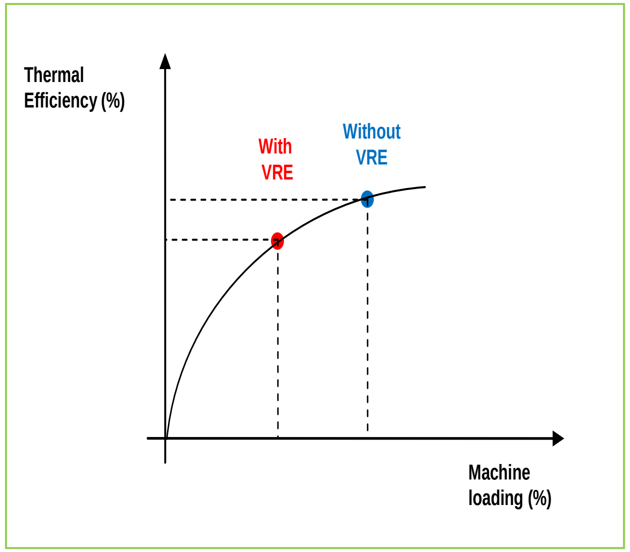
- VRE farms do not contribute to the system inertia
- VRE displace conventional generating units leading to a **reduction in inertia**



Down Reserve and Efficiency

- The integration of VRES causes conventional generating units to reduce their power output close to the minimum permissible value
- It is required to ensure that sufficient down regulation is available to maintain the frequency within the regulatory and planning (50.5 Hz) limits.
- Negative impact on thermal efficiency and fuel consumptions





FAST RESPONSE POWER SYSTEM

1. Mauritian Power System

2. Long Term Energy Strategy

3. Challenges for VRE Integration

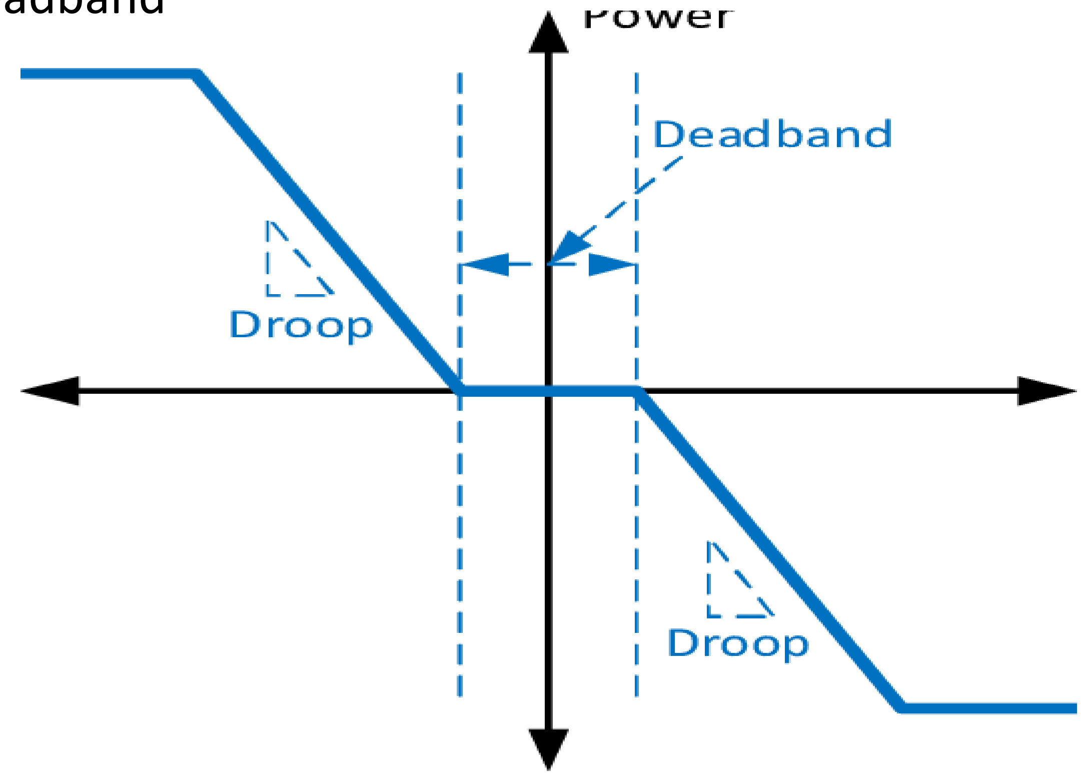
4 Actions taken

Droop Control

- CEB units switch to frequency control when the frequency goes outside a frequency band - ± 0.5Hz

- Switch to droop Control with the removal of the deadband

- Droop of 4%

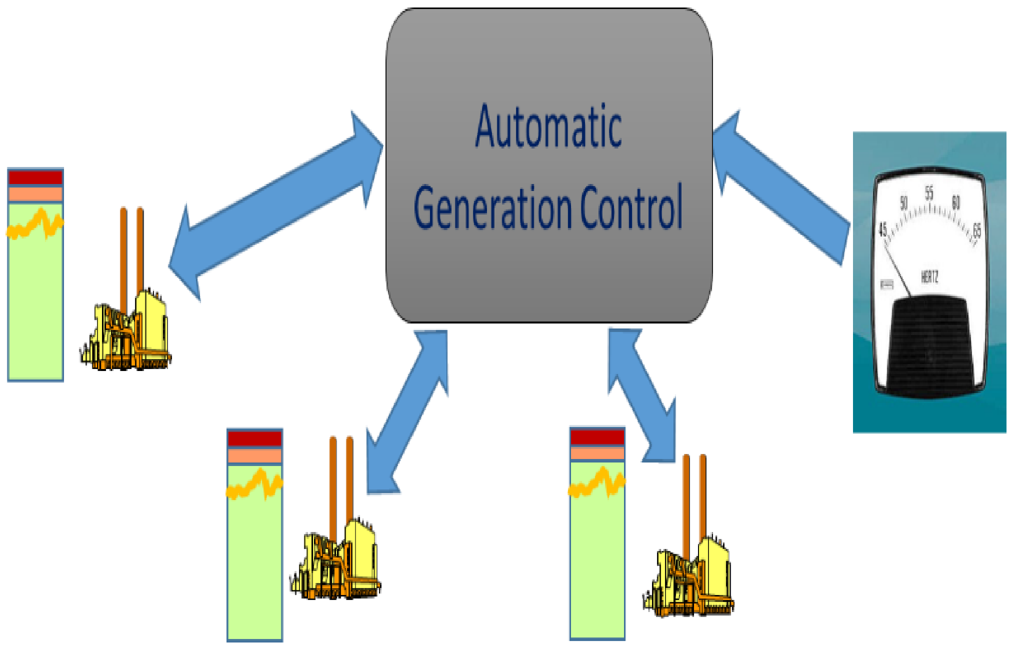


Automatic Generation Control (1/2)

An Automatic Generation Control send signals to one or more generating units to either raise or lower their corresponding generating outputs to restore the frequency of a network to nominal frequency of 50Hz following a disturbance.

Rapid Secondary response through AGC as compare to System Operators calling power plant to raise or lower their respective generation output which generally is a lengthy process.

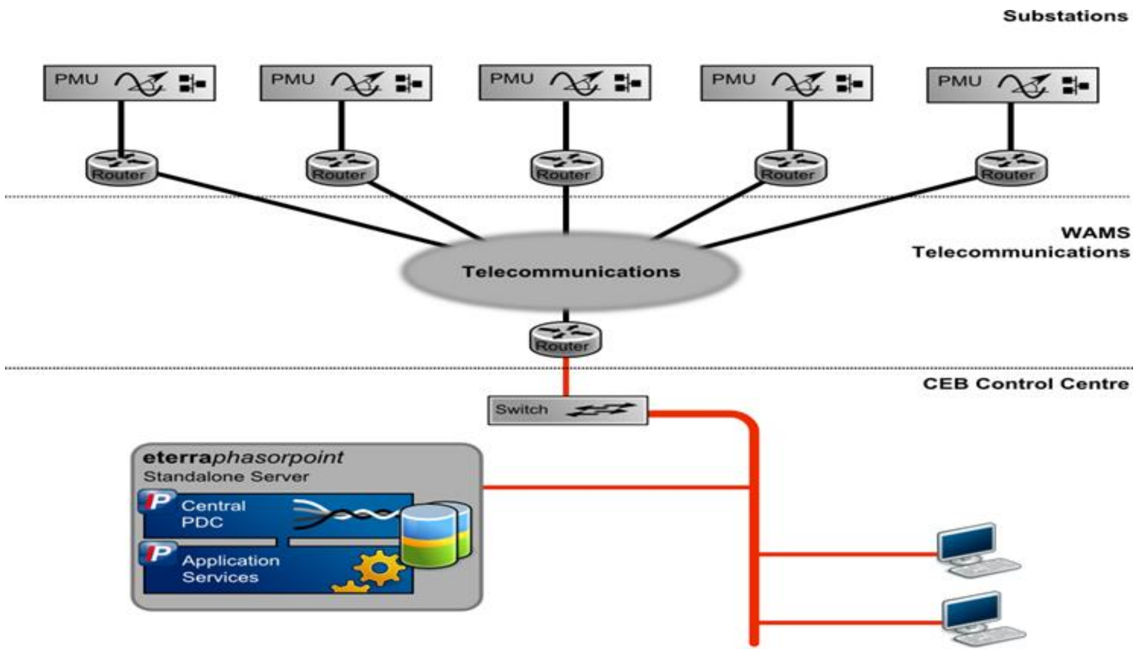
With the variable RE generation, manual frequency recovery is risky for a network.



WIDE AREA MONITORING SYSTEM (1/2)

Wide area monitoring system (WAMS) is based on data acquisition using Phasor Measurement Units (PMU) installed at selected locations in a power system, in view of detecting grid instabilities. It can be regarded as a grid instabilities forecasting system

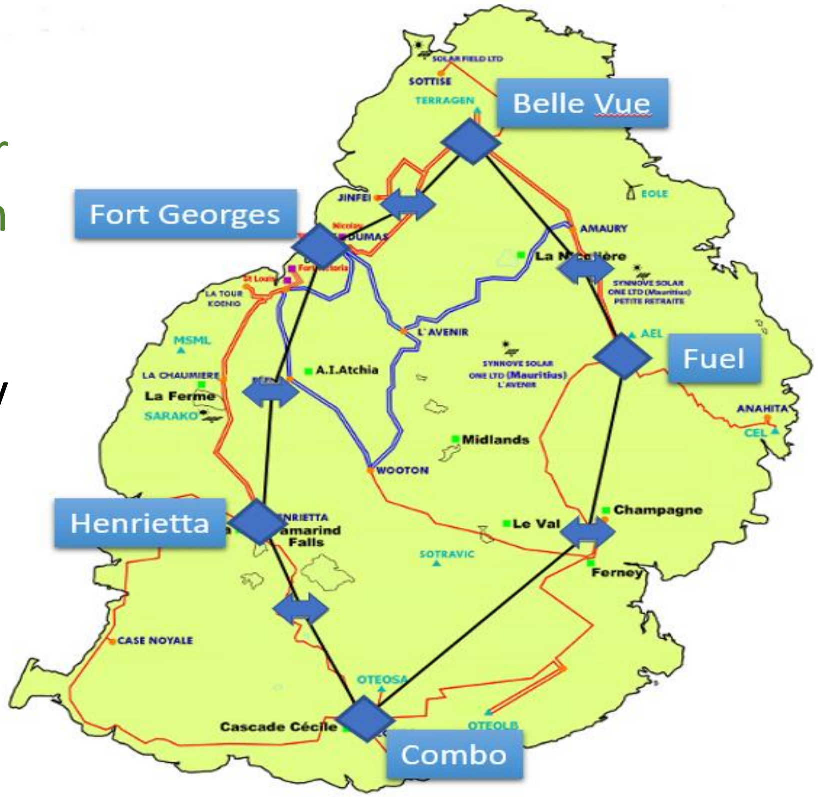
The WAMS can be set to control generating units in the event of anticipated grid instabilities.



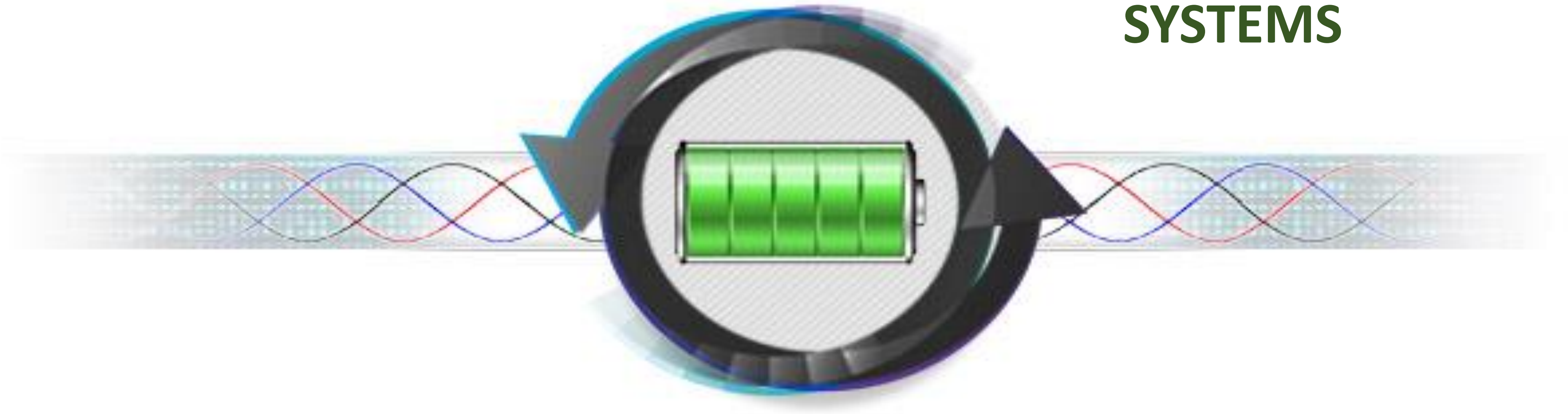
Current, voltage and frequency measurements are taken by the PMU and stored in a data concentrator. The measured quantities include both magnitudes and phase angles, and are time-synchronised via Global Positioning System (GPS) receivers with an accuracy in microsecond.

WIDE AREA MONITORING SYSTEM (2/2)

- The CEB has already deployed five PMUs in five substations.
  - Monitor the stability of the network
  - Have precise data to tune dynamic models of the CEB power systems for dynamic studies and subsequently decision talking
- Feasibility of deploying additional PMUs by using existing 66kV protection relays is in progress.



ENERGY STORAGE SYSTEMS



TYPES OF ENERGY STORAGE SYSTEM

ELECTROCHEMICAL
- Lead Acid
- Lithium Ion
- Other accumulator eg NaS
- Flow Batteries

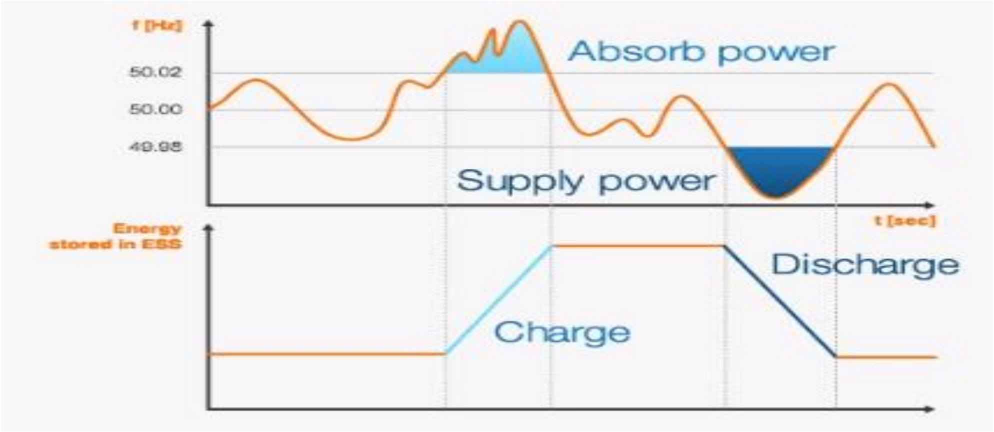
CHEMICAL
- Hydrogen Cell
- Fuel Cell

ELECTRICAL
- Super Capacitors
- Super Conducting Magnets

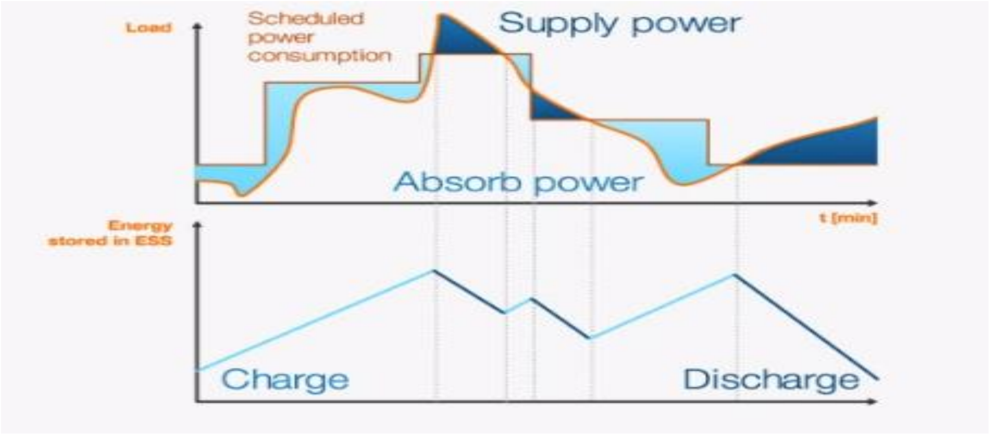
MECHANICAL
- Flywheel
- Pump Storage
- Compressed Air

Application of Energy Storage System

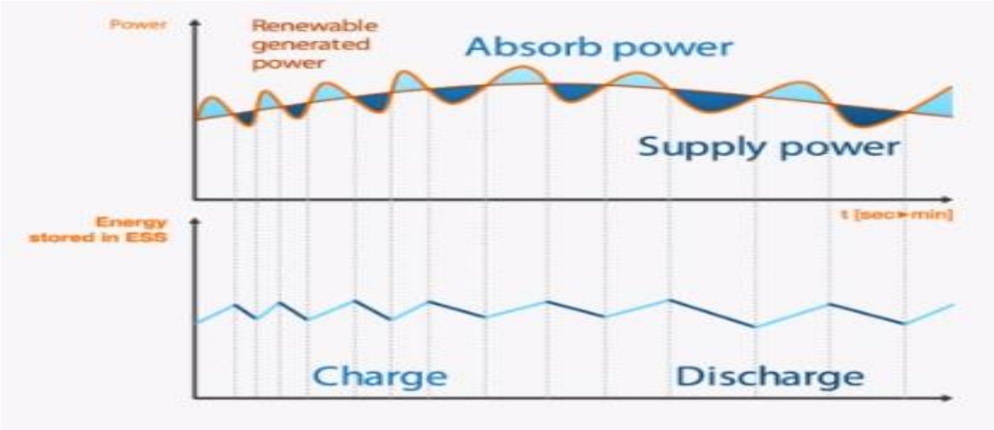
Frequency Control



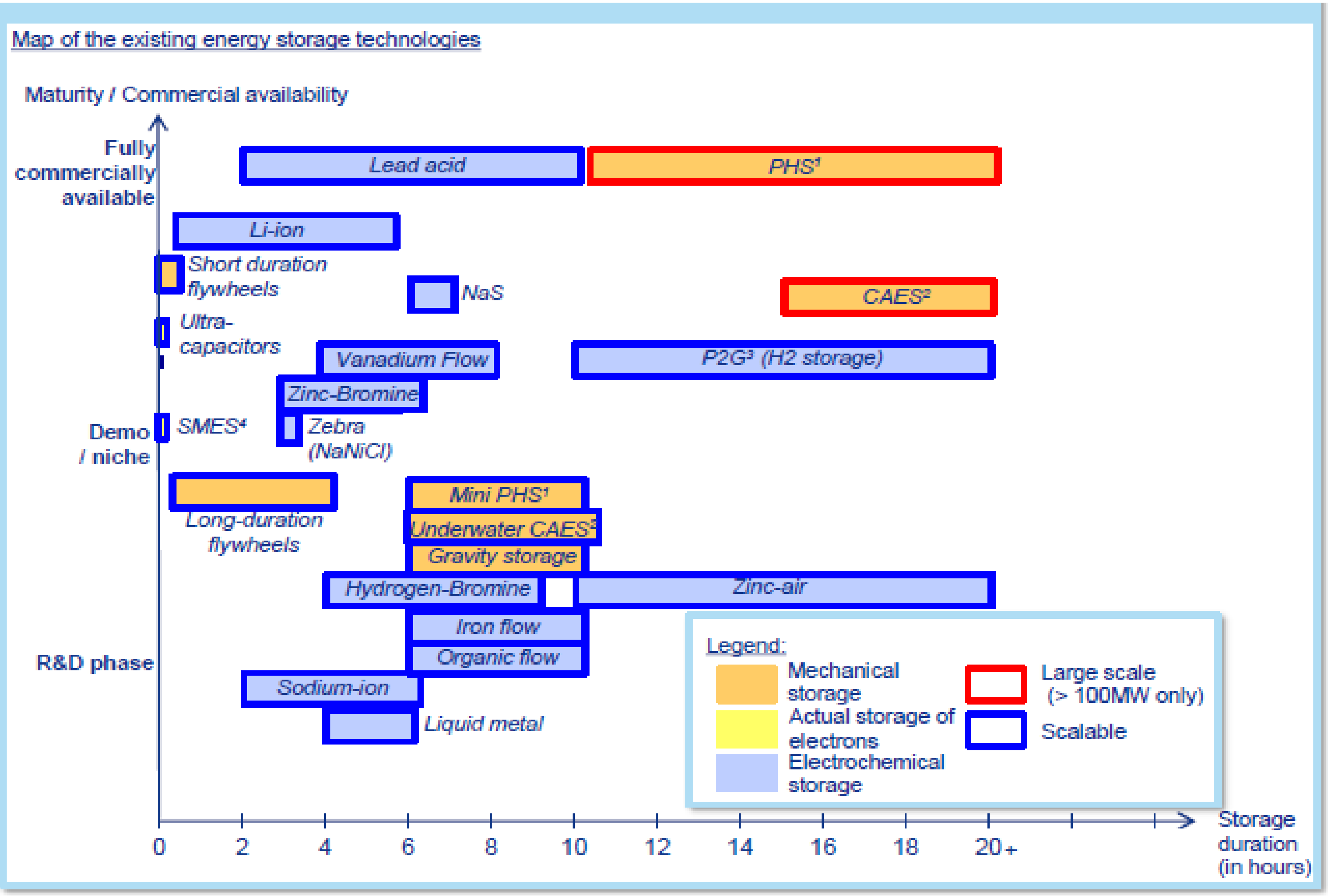
Peak Shaving



Capacity Firming



Maturity and Storage Duration



Note: 1. Pumped Hydro Storage, 2. Compressed Air Energy Storage 3. Power-to-gas 4. Superconducting Magnetic Energy Storage

ENERGY STORAGE SYSTEM ARE NUMEROUS BUT ONLY A HANDFUL ARE COMMERCIALLY MATURE

Mauritius Battery Energy Storage System Project

- ❑ **Why BESS? GCF FP 033 | USD 28 M GRANT**
- ❑ **Which type? LI-ION**
- ❑ **18 MW / 9 MWh | 185 MW VRES**
- ❑ **Initially for FREQUENCY REGULATION**

- Support the integration of Variable Renewable Energy
- Sustain the Stability of the Network
- Maintain the reliability of the Mauritian Grid

Peak Shaving BESS

- ❑ PV Capacity Credit in Daytime
- ❑ BESS for Evening Peak Shaving
- ❑ Installation of a 20 MW BESS

GCF SUPPORTED GRID ENHANCEMENT AND PV DEPLOYMENT

- **The 18 MW BESS Implementation**
- **Investment of around USD 12 M**

PHASE 1 – 4MW

Amaury Substation
Henrietta Substation

Completed in August 2018

PHASE 2 – 14MW

La Tour Koenig Substation
Anahita Substation
Jin Fei Substation
Wooton Substation

Tender launched in January 2019
Expected Completion – Mid 2020
Completed in 2021

2 MW Battery Energy Storage System At Amaury Substation

- 15 MINS Rated Power at 50% DOD
- 20ms Response Time

ADDITIONAL MEASURES

- Geographical dispersion of VRE sources so that fluctuating climatic conditions do not impact significantly on VRE outputs;
- Implementation of power output Forecasting (day ahead and hour ahead) in new upcoming PV farms;
- Curtailment of VRE under emergency conditions for new PV Farms;

For more details (conception, feasibility, planning, procurement, resources mobilization and deployment, testing & commissioning and outcomes) including technical visit on the Mauritius BESS project send email to ceb@intent.mu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