IRENA INNOVATION WEEK 2023

Grid Evolution: Transforming Energy Landscapes in Developing Countries and SIDS

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giz

26 September 2023 • 14:00 – 15:30 (CEST).

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IRENA INNOVATION WEEK 2023

Scene setting presentation

Simon Benmarraze
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IRENA Innovation and Technology Centre

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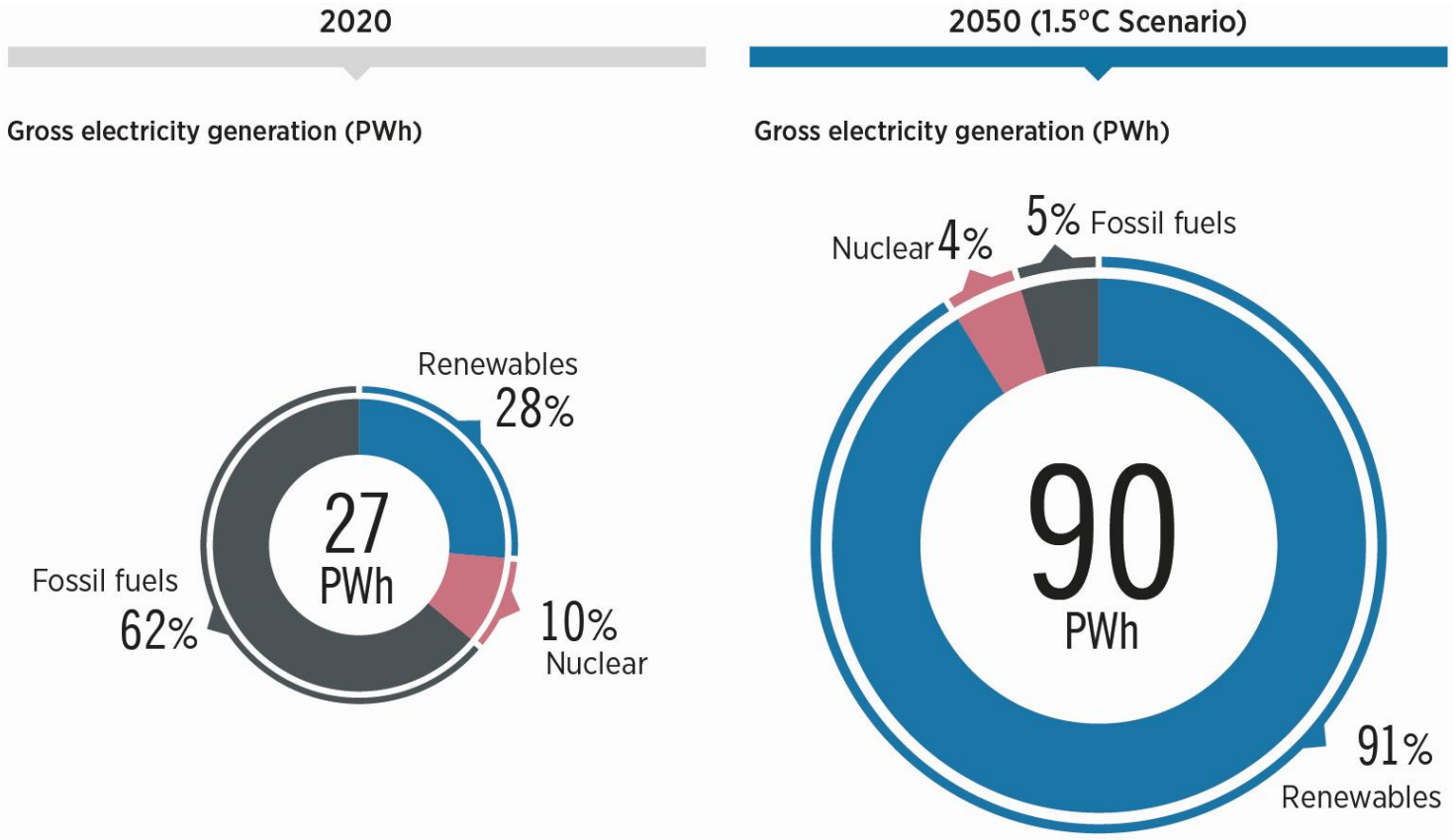
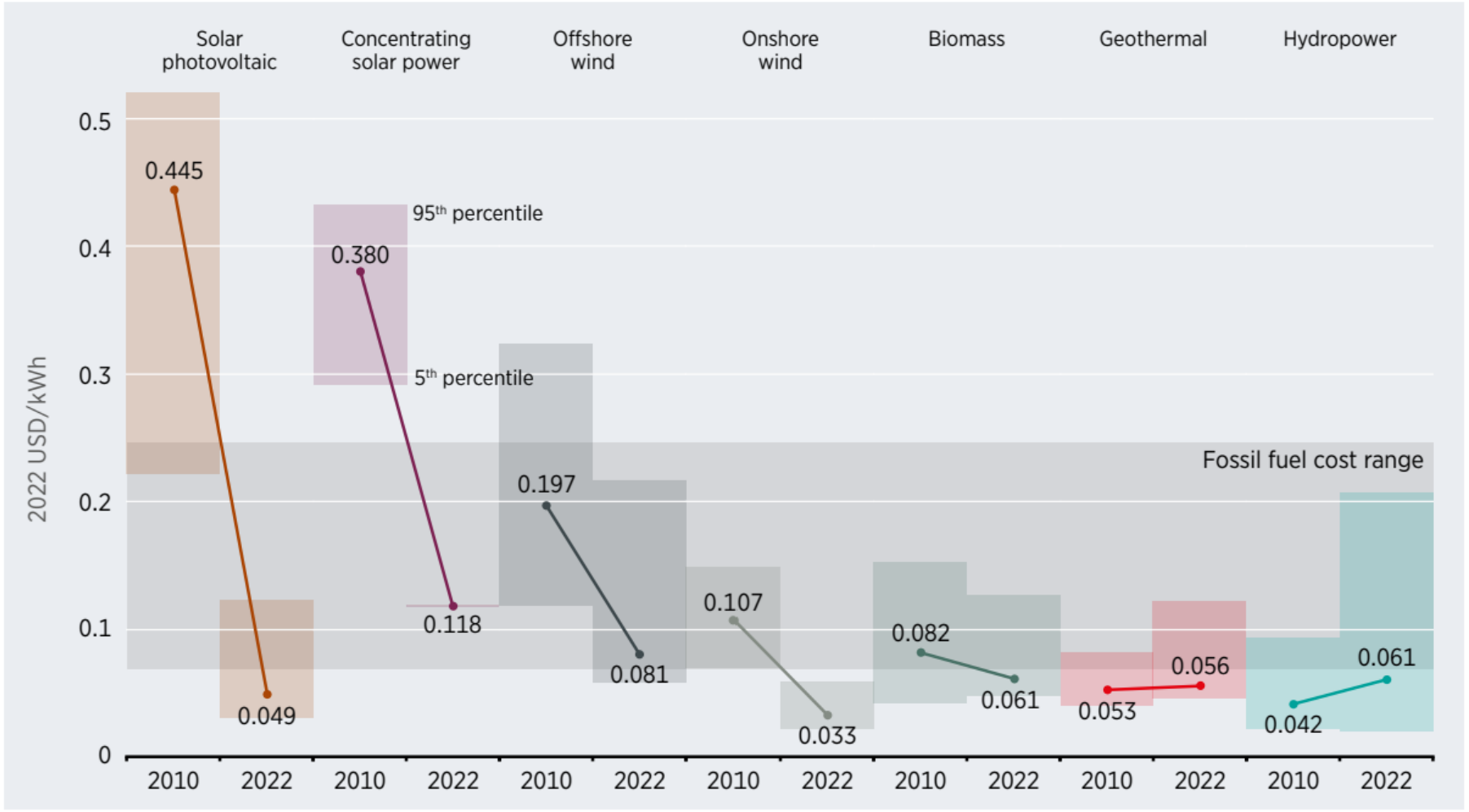
Power generation along with the share of RE in the electricity mix would need to more than triple by 2050



PWh = Petawatt hours

- Grid modernization crucial for Africa and SIDS, targeting 91% renewable electricity by 2050, up from 28% in 2020.
- Coal and oil phase-out by 2050, making renewables vital for energy stability.
- Emphasis on robust, adaptable grids to integrate variable renewable energy sources.

Renewables-based electricity is already the cheapest power option in most regions



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RENEWABLE POWER GENERATION COSTS IN 2022

Modernization of grid infrastructure is essential for the seamless integration of renewable energy sources.

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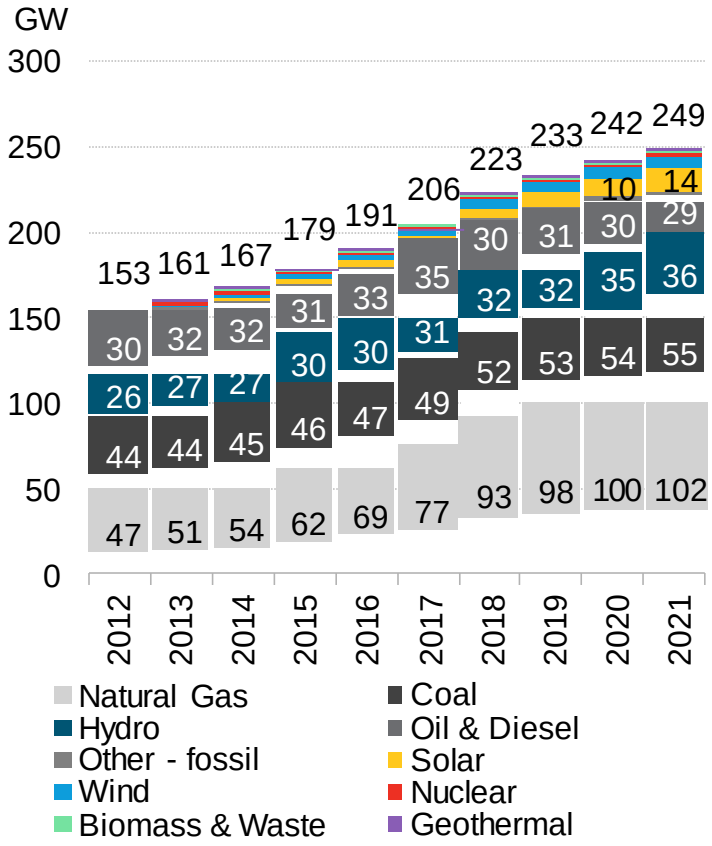
ONGOING TRANSFORMATIONS IN THE POWER SYSTEM

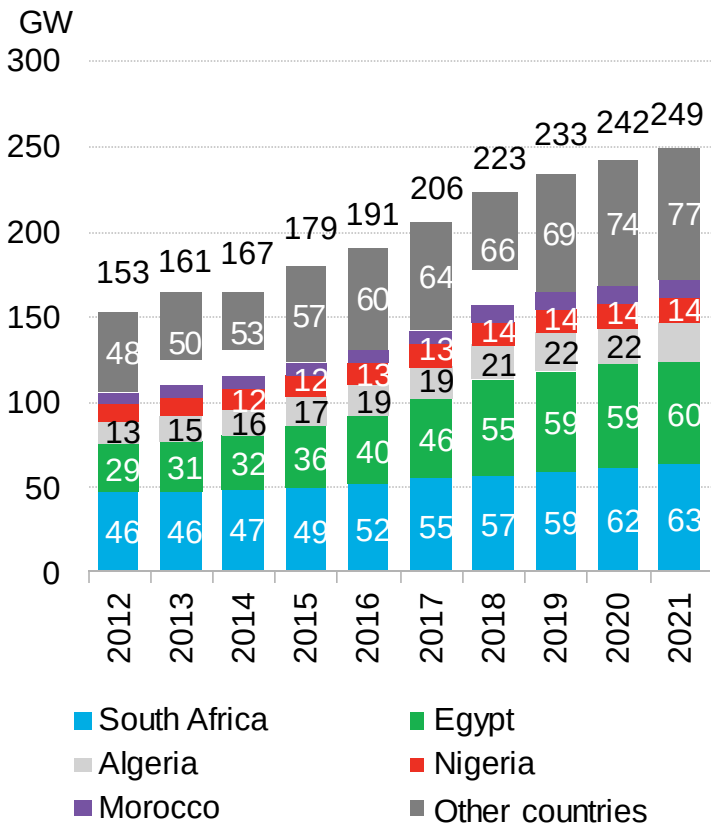
Previous state	New state
Regulated fuel influx	Variable Renewable Energy
Synchronous machines	Inverter-based resources
Large-scale power plants	Distributed generation
Flexible generation	Flexible generation, demand and storage
Process automation	Autonomous operation / Digital Smart Grid
Electric light and power	Electric light, power, heating and mobility
Consumers	Prosumers

Fossil fuels predominate in Africa but are concentrated in five countries

Africa installed capacity by technology



Africa installed capacity by market



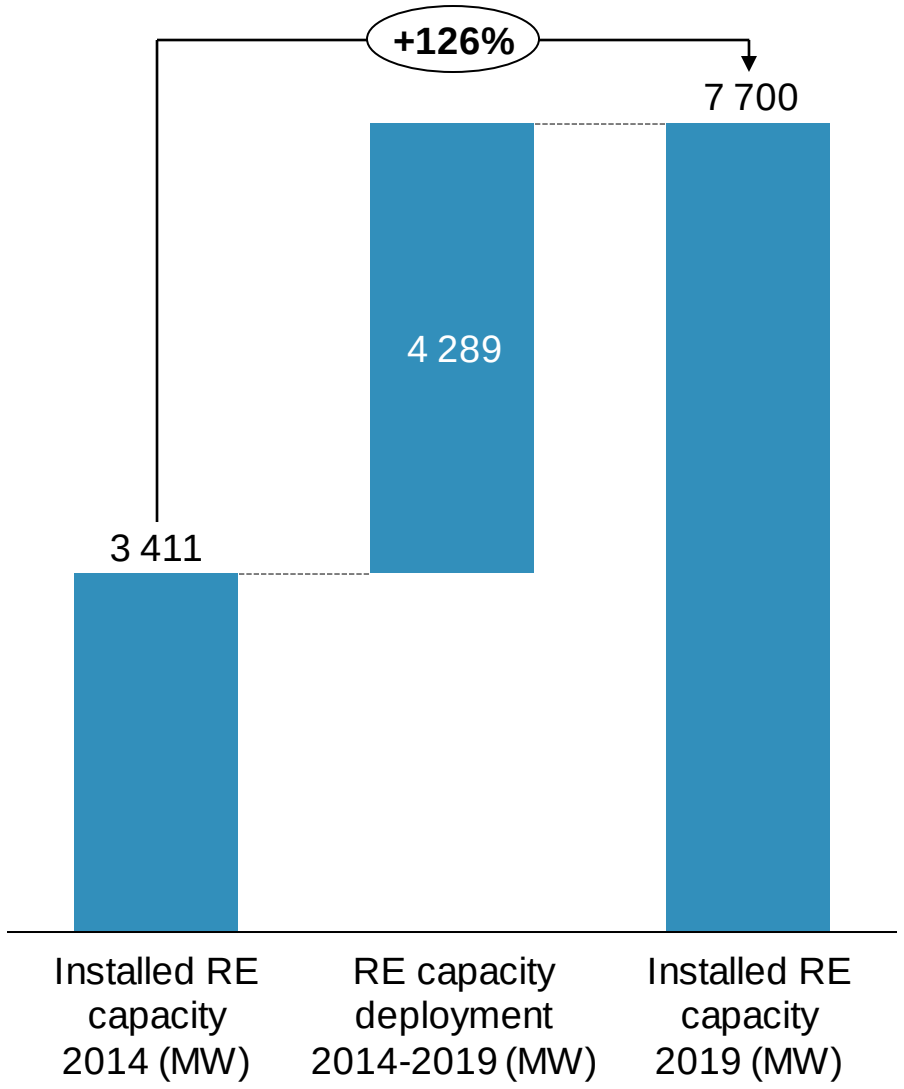
Fossil fuels, led by natural gas at 41% and coal at 22%, are the mainstays of Africa's energy sector. Renewables have risen to 23% of total capacity, with solar growing from 0.3GW to 14GW and wind from 1.2GW to 8GW since 2012.

Five countries—South Africa, Egypt, Algeria, Nigeria, and Morocco—hold 69% of Africa's 172GW energy capacity and lead in electrification rates.

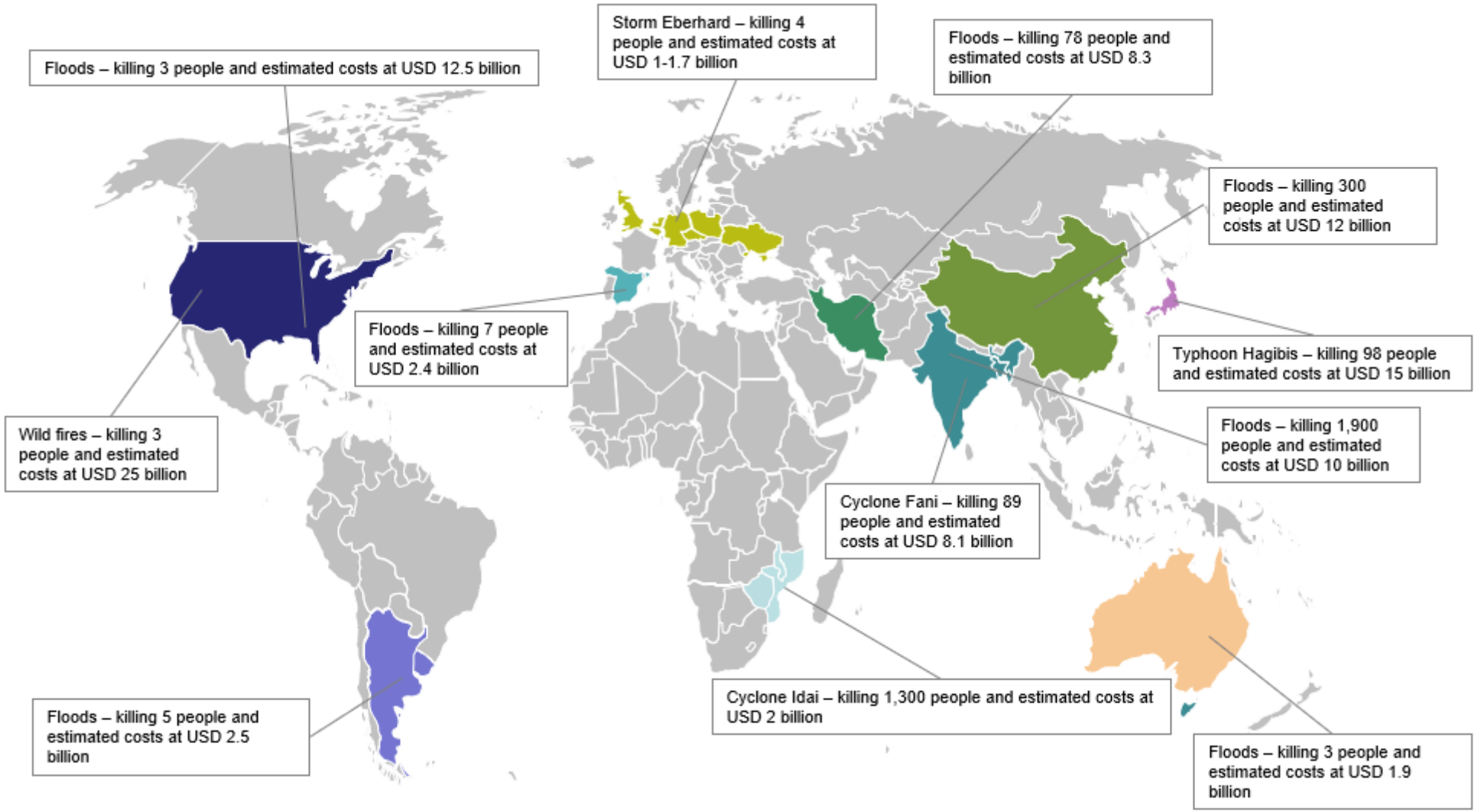
Solar could be a game-changer for Sub-Saharan Africa, where 75% lack reliable electricity. Projections show solar reaching 55GW by 2030 and 400GW by 2050, contingent on addressing financial and regulatory hurdles.

SIDS faces many challenges in scaling up renewable energy

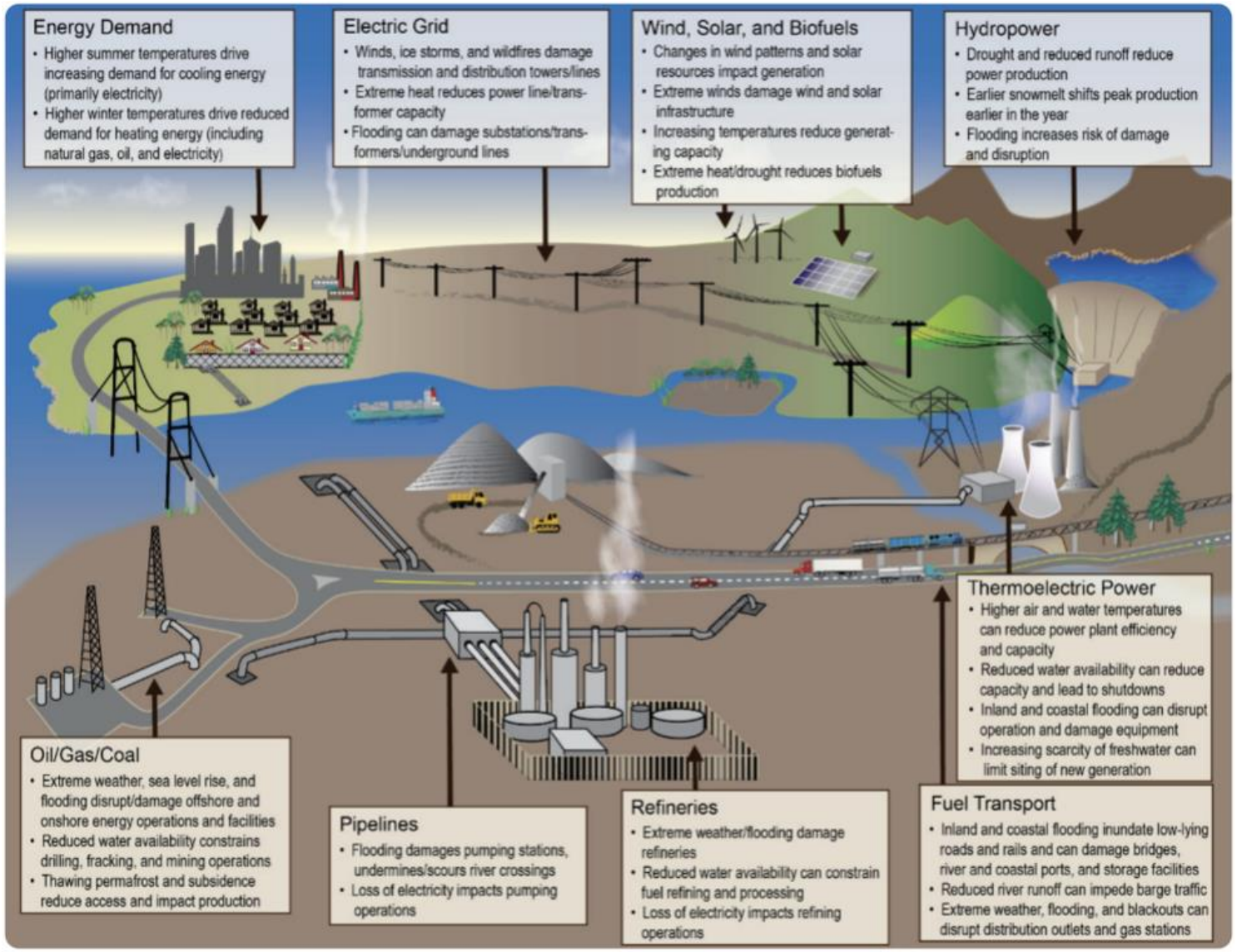
- Particularly vulnerable to the impacts of climate change, such as climate variability, sea-level rise and natural disasters
- Financial constraints for technology development, implementation, and operation and management for commercial use of renewable energy resources.
- Lack of local expertise in renewable energy
- Dependent on the development and commercialization of “island-proof” technologies.



15 of the Most Devastating Weather Event Resulted in Estimated Costs Exceeding USD 135 Billion



Power system resilience is closely related to coping with the effects of climate change and adapting to it than to eliminating climatic events.

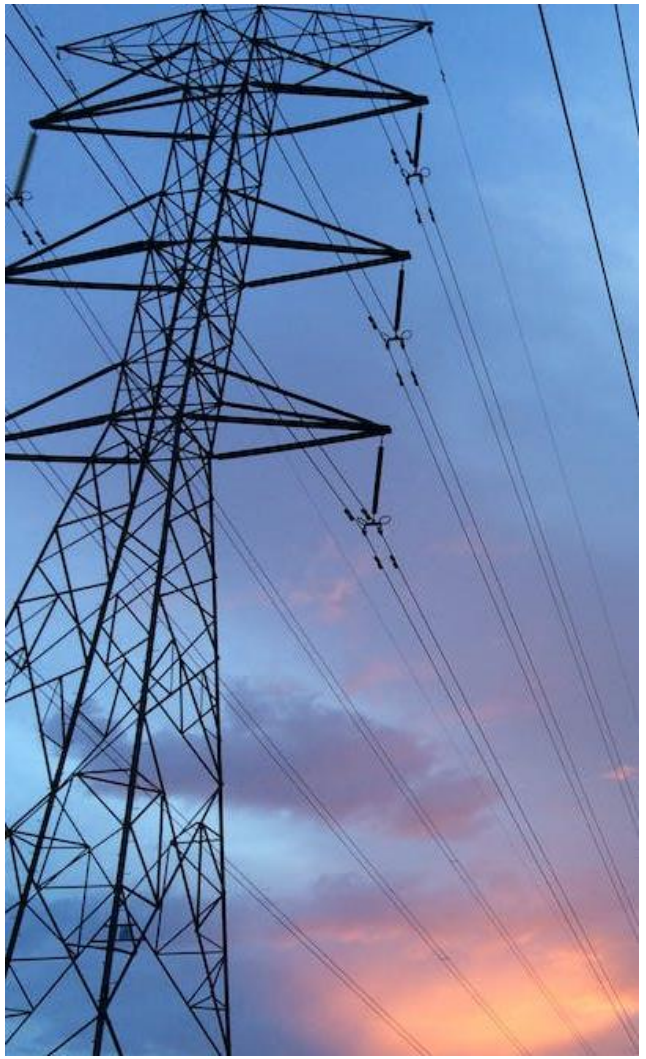


- **Grid Impact:** Transmission & Distribution Systems Stand as the Most Vulnerable and Frequently Targeted Components in the Electricity Infrastructure.

- **Resilience Enhancement Measures:** Divided into Short-Term Operational Actions, such as network reconfiguration and demand side management, and Long-Term Planning Strategies like infrastructure hardening for improved resilience.

Infrastructure measures to deal with the energy crisis and accelerate the transition

- **Adopt integrated planning to modernize grids,** emphasizing local solutions like microgrids, to improve energy access, particularly in off-grid communities in Africa and SIDS.
- **Offer incentives for underfunded yet crucial grid projects**, such as T&D, rural electrification and renewable mini-grids, to expand energy access in remote and off-grid regions.
- **Streamline permits for key grid infrastructure projects**, ensuring rigorous environmental and social assessments to maintain local well-being and foster public acceptance.
- **Include climate resilience measures** in all planning and development stages to better prepare for extreme weather and changing environmental conditions.
- **Boost public funding for essential, climate-resilient infrastructure**, focusing on areas with unique logistical and environmental challenges.



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Keynote

Reji Kumar Pillai
President India Smart Grid Forum (ISGF)

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India’s Tryst with Electrification

1898: 130 kW Sidrapong hydroelectric power station in Darjeeling

CESC LIMITED

- 1899: 1 MW thermal plant in Kolkata
- 1902: Electric Trams in Kolkata

India’s Installed Capacity

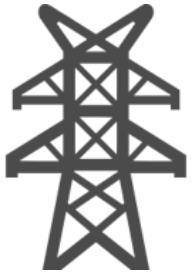
Generation Capacity
1947: 1.36 GW
2023: **424 GW** (>300X in 75 Yrs!)

Per Capita Consumption
1947: 16.3 kWh
2022: 1400 kWh

Installed Power Generation Capacity (Source-wise) in GW							
Thermal (Coal, Gas and Diesel)	Hydro	Solar	Wind	Nuclear	Other	Total Non-Fossil	Grand Total
238.44	**46.85**	**71.61**	**44.08**	**7.48**	**15.82**	**185.84**	**424.28**
56.19	11.04	16.88	10.39	1.77	3.73	**43.8**	100%

One Nation – One Grid (1/2)

India has the **3rd largest power system** in the world



Modern Transmission System

- 800 kV & 500 kV HVDC lines
- 765 kV & 400 kV AC lines
- Modern Control Centers

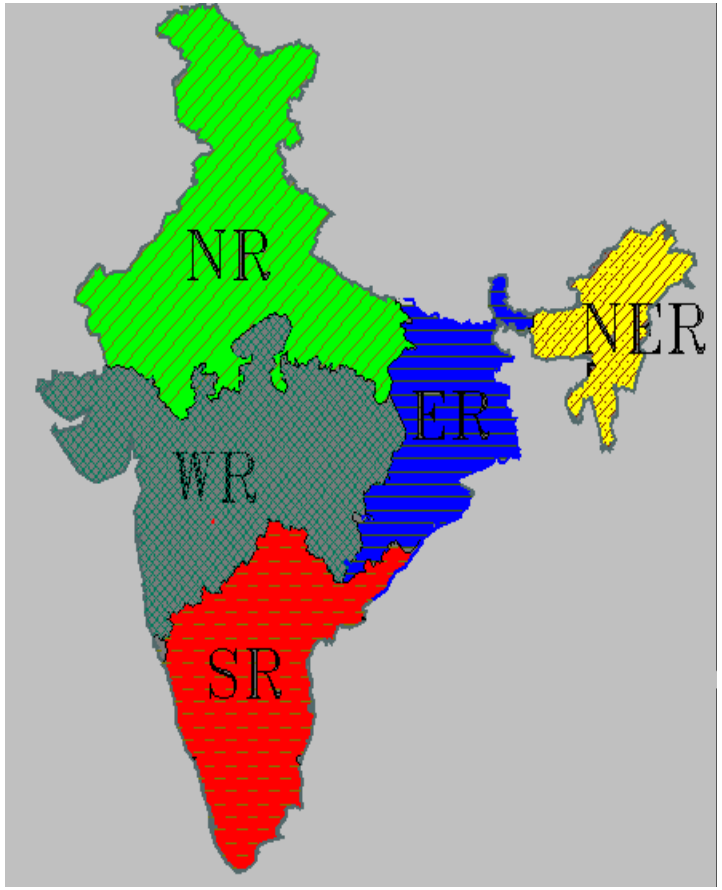
424 GW, 300 million customers
One Grid covering >3 million Sqkm operating in one frequency

Electrification

- 619,000 villages and 99.9% households electrified
- 27 million households electrified in 18 months (Nov 2017 to March 2019) through a focused mission

One Nation – One Grid (2/2)

- Indian Power System is operated as **5 regional grids** with separate control centers – Regional Load Dispatch Centers (RLDCs)
- National Control Centre (NLDC) integrates all 5 Regions (RLDC)
- Independent System Operator (GRID CONTROLLER OF INDIA LTD) manages the RLDCs and NLDCs
- All states have State Load Dispatch Centers (SLDCs) managed by respective state transmission companies
- 1124 PMUs installed 7 years ago on the EHV grid
- All regions are interconnected and operates in **ONE FREQUENCY**
- 11 Renewable Energy Management Centers (REMCs) with Advanced Tools for Weather and RE Generation Forecasting – 7 being added
- Matured power markets with 3 functional power exchanges
- Renewable Purchase Obligations (RPO) for Utilities
- Real-Time Market operational since June 2020
- Green Term Ahead Market (GTAM) launched in 2021
- Green Energy Open Access Rules in 2022 (open access for customers with >100kW demand)
- Carbon Market will be launched by end of 2023
- Power Trading with Nepal, Bhutan and Bangladesh



Grid Modernization Initiatives in India

- **India is the only country amongst major economies that achieved the target under Paris Climate Agreement of 40% power generation capacity from non-fossil fuels by 2030 in 2022 – 8 years ahead!**
- **New Target: 500 GW Renewable Energy (RE) capacity by 2030**
- **Smart Grid Initiatives in India**
  - ***Smart Grid Vision and Roadmap in 2013*** *(formulated by ISGF, adopted by Ministry of Power)*
  - ***14 Smart Grid Pilot Projects*** *allotted in 2013 – 50% project cost by Govt of India*
  - *National Standards for Smart Meters (IS:16444/IS:15959) in 2015/2017*
  - *EVSE Standards: IS 17017 series; 12 standards issued, rest under progress*
- **Net Metering:** All States and Union Territories issued net metering policies between 2013 and 2016
- **Energy Storage Systems Roadmap for India prepared by ISGF in 2019 -** cumulative capacity estimated by **2032 is 2416 GWh of which 209 GWh is for grid support**
- **250 Million Smart Meters presently under rollout on fast track on innovative business model – 15% capex by Govt of India as grant; rest as monthly fee (Opex): $xx per meter per month for 93 months**
- **Open Access for RE for all customers with demand >100 kW**
- **Time of Day or variable tariff for all customers from April 2025 – upto 20% rebate during high solar hours; and up to 20% surcharge during peak hours**

Major Success Stories

Solar and Wind

- Projects allotted through transparent auctions brought prices to **3 US Cents per kWh** which is cheaper than power from new coal plants
- Last 4 years added more RE capacity than coal and gas

Unnat Jyoti by Affordable LEDs for All (UJALA)

- LED Bulbs: 368 Million (Till Feb 2023)
- Savings: 47.8 Billion kWh (BU) (>US $ 2.5 billion) per year
- Carbon Reduction: 3.85 MTOE CO_2 per year

Other Energy Efficiency Programs

- Star labelling - 10 mandatory and 13 voluntary labeled appliances
- Total electricity savings in 2017-18: 86 BU (7.14% of total consumption)-US$ 7.5 bn/year
- Total reduction in CO_2 emissions of around 108 MTOE annually

APDRP, R-APDRP, IPDS and UDAY

- T&D loss reduction by over 50% in last 15 years (>36% to below 18%)

SAUBHAGYA

- 27 million households in the remotest parts electrified in 17 months – a World Record!

KUSUM (Under progress now)

- 10,000 megawatts (MW) of decentralized ground mounted grid-connected RE units
- 1.75 million standalone solar powered agriculture pumps
- 1 million grid-connected solar powered agriculture pumps

Projected Growth of Indian Power System

IEA Projections of Indian Power System (Capacities in GW)		
	2030	**2040**
Solar	207	622
Wind	119	219
Other RE	19	28
Other Sources	444	597
Battery Storage	34	118
Total	823	1584
Flexibility Requirement	-	**±85% (50% ramp-up and 35% backdown**

Need to build demand-side flexibility, power plant flexibility, energy storage systems, grid flexibility; policy, market and regulatory solutions for short-term to medium-term

India's Approach on RE Integration

A. What we have done/are doing

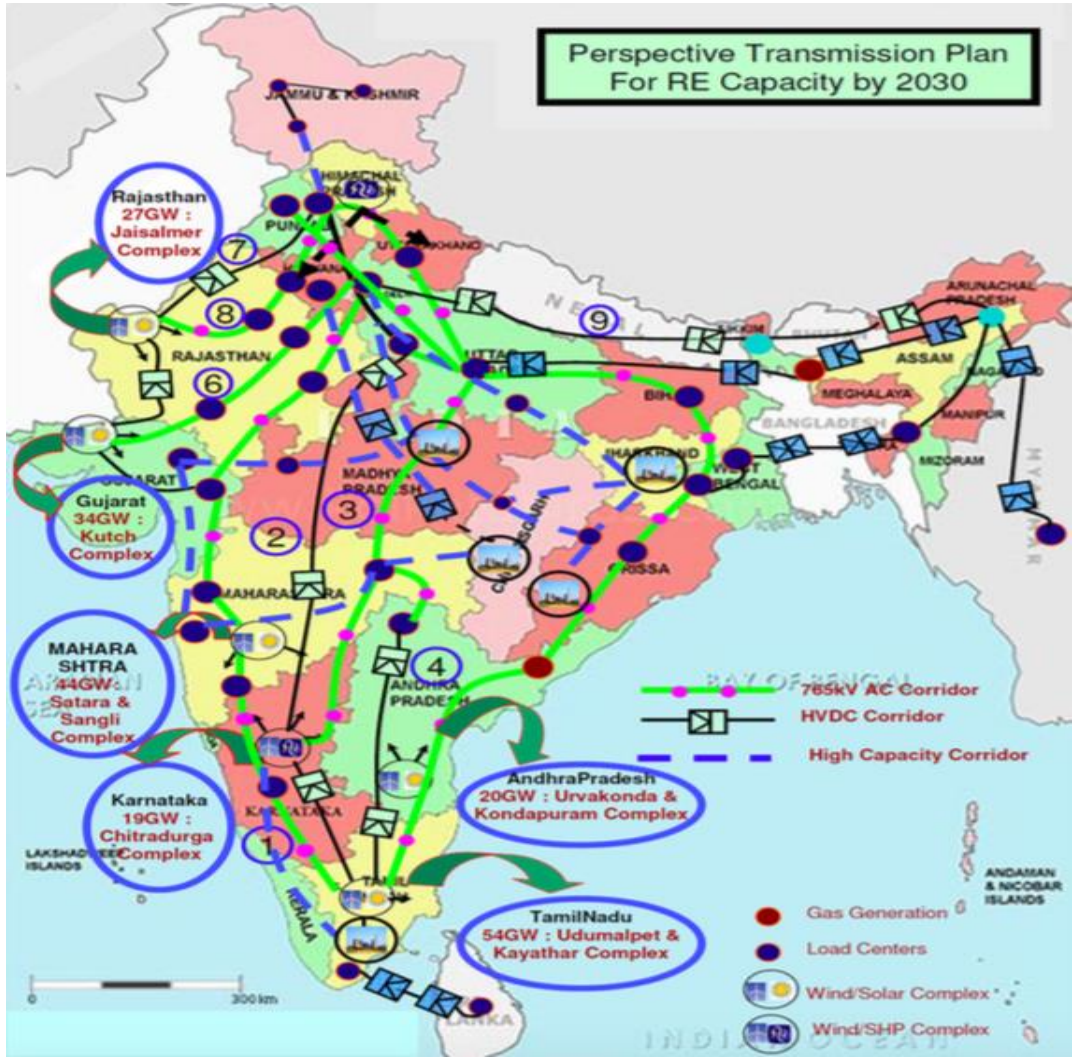
- Green Corridors
- Renewable Energy Monitoring Centers (REMC)
- Round The Clock (RTC) RE Power - Energy Storage Systems (ESS) with Solar and Wind Farms to supply 24x7 RE
- Smart Grids
- Solarization of Irrigation Pump (IP) sets with BESS

B. What ISGF is advocating - Flexibility in Demand and Generation

- Distributed ESS - Replacement of Diesel Generating Sets with Battery Energy Storage Systems (BESS), District Cooling Systems etc
- Demand Response and Ancillary Services
- Time of Use (TOU) or Real-time Tariffs
- National Solar Rooftop Registry
- Smart Inverters – IEEE 1547: 2018
- Electric Vehicles (EV) - Grid Integration
- Grid Interactive Buildings and Campuses – Smart Microgrids
- Peer to Peer (P2P) Transactions of Green Energy
- Redesign of the Grid

Green Energy Corridors

- Green Energy Corridor is a comprehensive scheme for evacuation and integration of RE from large wind and solar farms in 8 RE rich states - Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh and Madhya Pradesh
- The first phase of the project includes about approx. 9400 ckm transmission lines and substations of total capacity of approx. 19000 MVA (32.5 GW of RE Plants)
- The funding mechanism consists of Viability Gap Funding (VGF) of 40% of the project cost from Government of India
- Second Phase is presently under implementation



Renewable Energy Management Centers (REMC)

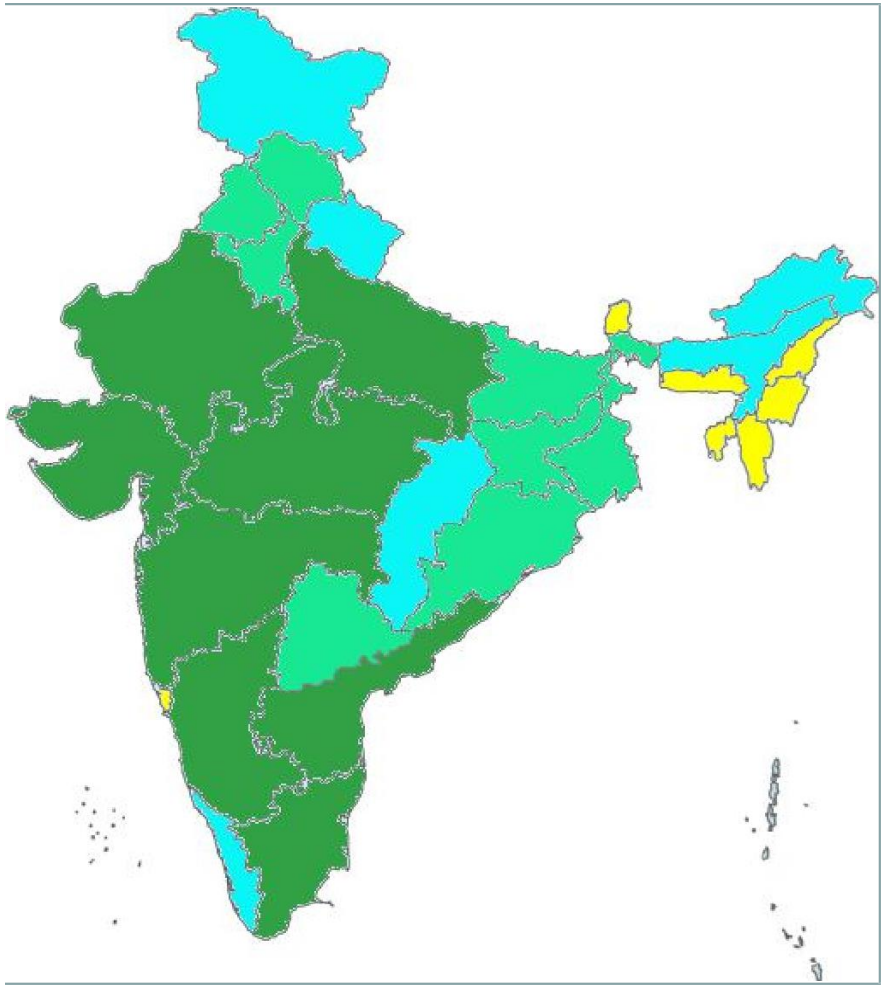
Objectives and Benefits

- State of the Art modelling tools for accurate RE generation forecasts integrated with weather forecasting inputs
- RE scheduling with secure interfaces for Grid Operators, Regulators and RE Generators; maximize RE utilization and help utilities meet Renewable energy Purchase Obligations (RPO)
- System-wide visibility and improved operational coordination; visualization and evaluation of RE forecast performance

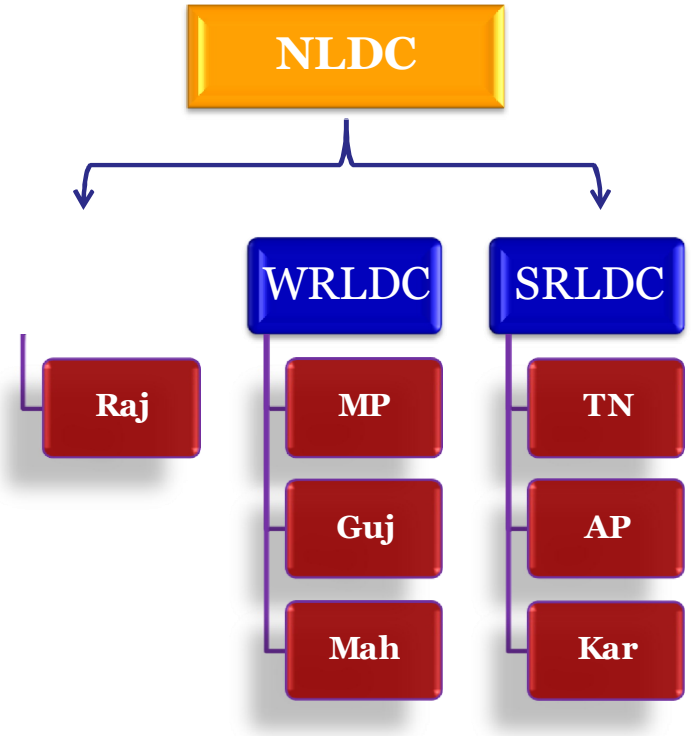
Architecture

- 4 Regional REMCs (Northern, Southern, Western and Eastern) and a National REMC – these are integrated with the Regional Load Dispatch Centers (RLDCs) and the National Load Dispatch Centre (NLDC)
- Supports Grid Operators to ensure coordination with conventional resources to achieve lower operational costs
- Manage reliability challenges through curtailment and modification of RE schedules during constrained conditions

REMC – Phase 1



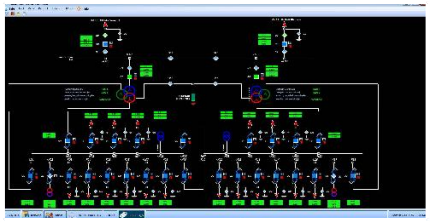
Phase 2: REMCs in 6 States and one Region under implementation



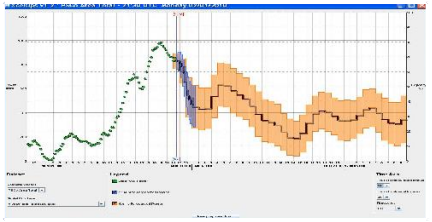
Phase 1: REMCs in 7 States, 3 Regions and National Level (11 REMCs) for US$ 62 Million – completed

REMC Scope and Main Modules

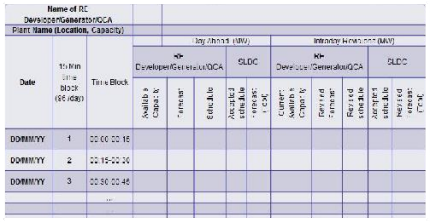
- Forecasting of RE generation on very short term (15 mins), day-ahead, intra-day and week-ahead basis
- Real time tracking of generation from RE sources and its geo-spatial visualization
- Scheduling solutions for private RE project developers
- Close coordination with respective SLDCs for RE generation and control for smooth grid operation
- Single source information repository and coordination point for RE penetration (static /dynamic data)



SCADA

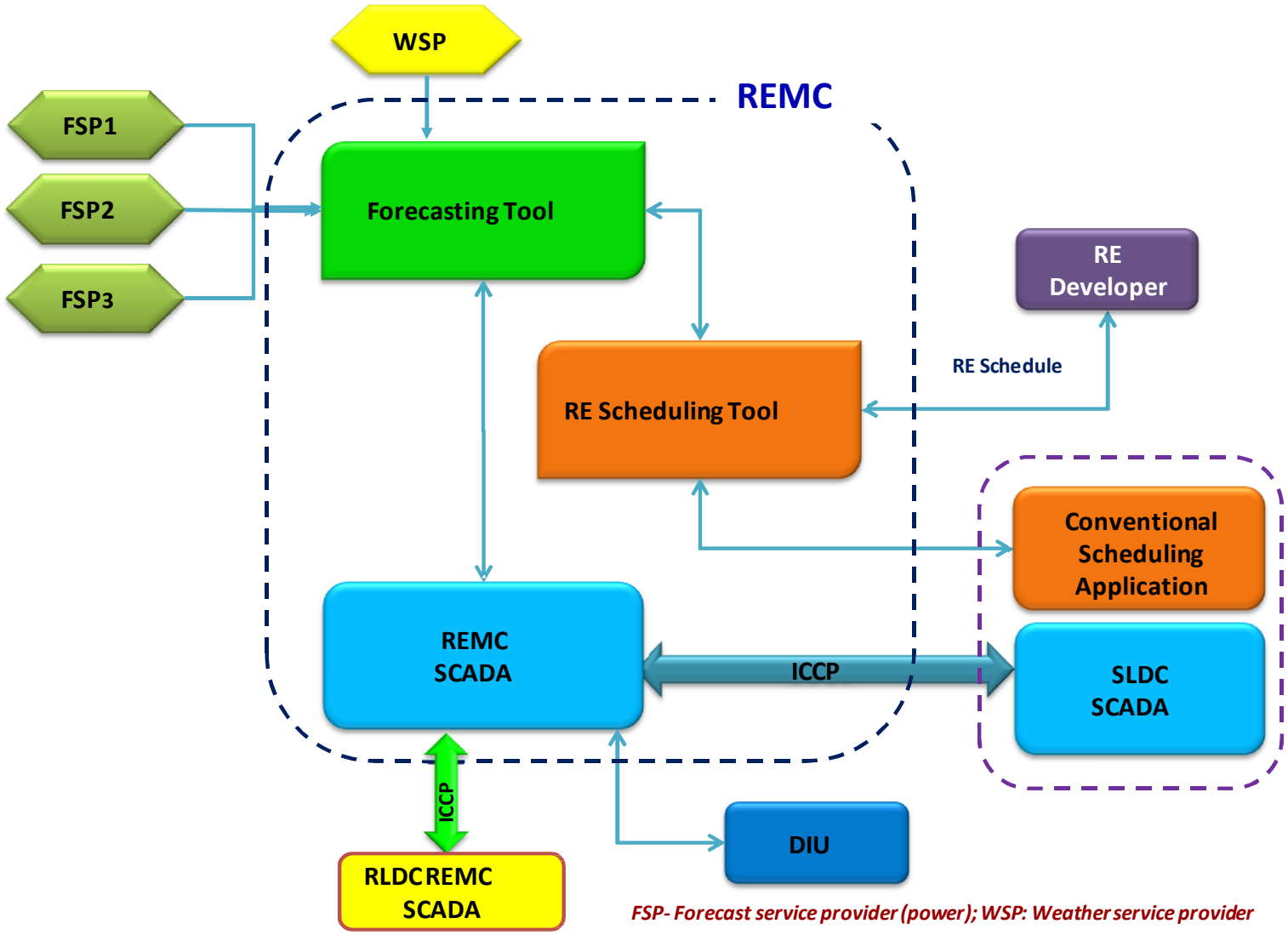


Forecasting Tool



Scheduling Tool

REMC Architecture



FSP- Forecast service provider (power); WSP: Weather service provider

Features of RE Forecasting Tool

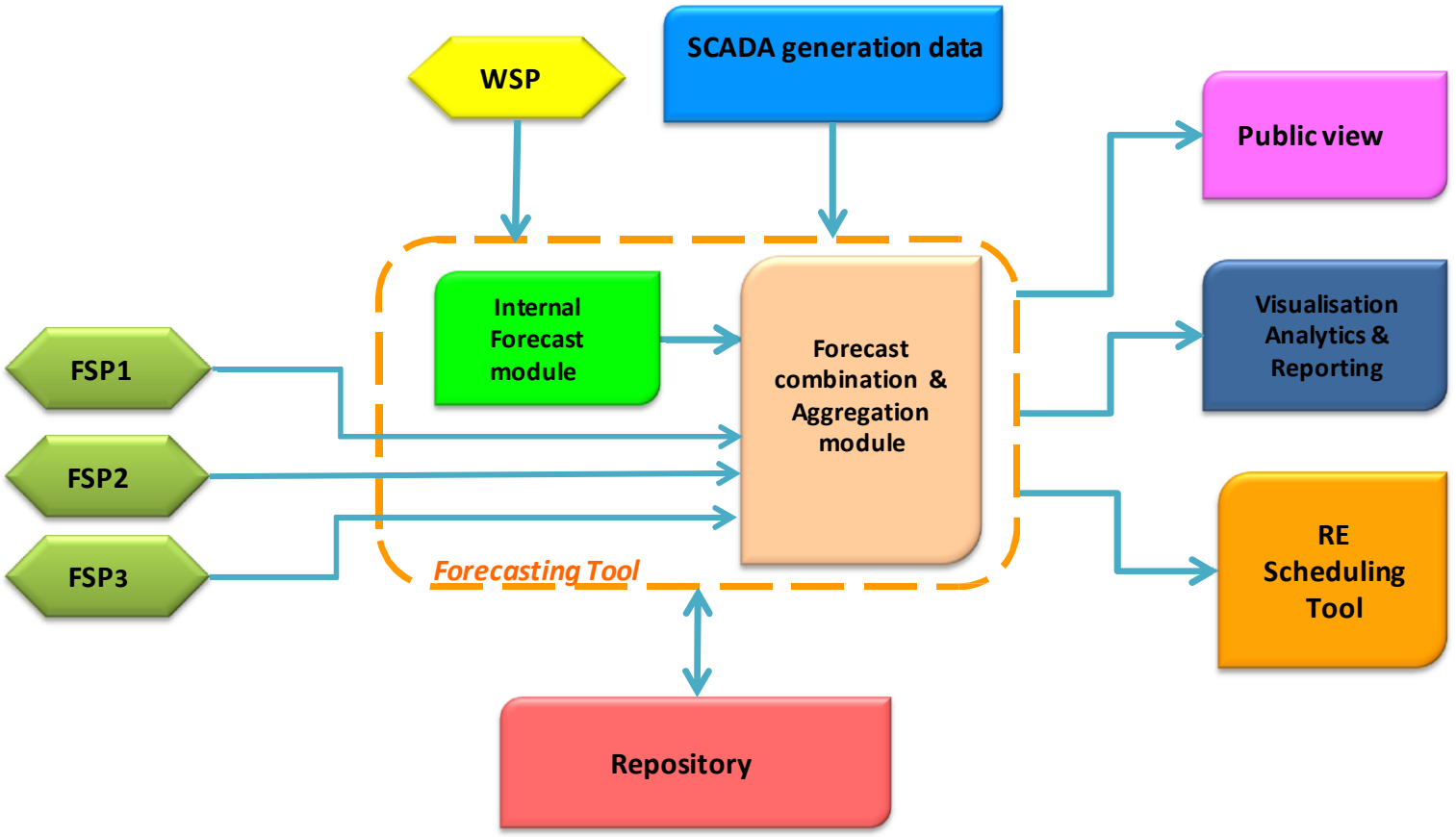
Data Exchange

- Share Static, Historical and Real Time SCADA data with Forecast Service Providers (FSPs)
- Collect Power forecast from different FSPs as well as Internal Fx tool
- Transfer of power forecasts to scheduling Tool
- Historical data from repository

Analytics Module

- Accuracy Analysis of power forecasts which has implication on payments terms – performance-based payments
- Performance based retentions terms for FSPs (after two years)

RE Forecasting Tool



Round The Clock RE Power

- **Round The Clock (RTC) Power from RE Plants**

- RE Developers to Setup ESS to Supply 24x7 RE Power to Buyers
- Solar Energy Corporation of India awarded several such projects in last 2 years
- Project Developers are setting up pumped-hydro storage or BESS
- First project expected to be completed in 2024

Distributed Energy Storage Systems

- **Distributed Energy Storage Systems (ESS)**
  1. **Diesel Generator (DG) set replacement with BESS**
  2. **District Cooling Systems (DCS) with Thermal Energy Storage**

- **Replacement of DG sets with BESS** is the fastest and cheapest route to build flexibility for the Indian grid
  - Over 80 GW of large-size DG sets in India
  - Diesel at INR 95/liter, DG set will cost >INR 30/kWh
  - Power from BESS will be INR 15.40/kWh
  - Ban DG sets for standby power in new buildings
- More than half the electricity consumption in a building is for space cooling
  - Instead of each building having their centralized air-conditioning plant (or room-ACs)
  - **District Cooling Systems (DCS)** are successfully implemented around the world (including GIFT City in Gujarat, India)
- *ISGF White Paper on DG Replacement with Lithium-Ion Batteries in Commercial Buildings – www.indiasmartgrid.org*
- *ISGF White Paper on Sustainable Air Conditioning with District Cooling Systems - – www.indiasmartgrid.org*

Ancillary Services and Demand Response

Demand Response and Ancillary Services

- Ancillary Services Regulations at transmission levels is in place – need to bring it to distribution grid
- Business models for Demand Response need to be worked out

Time of Use (TOU) Tariff

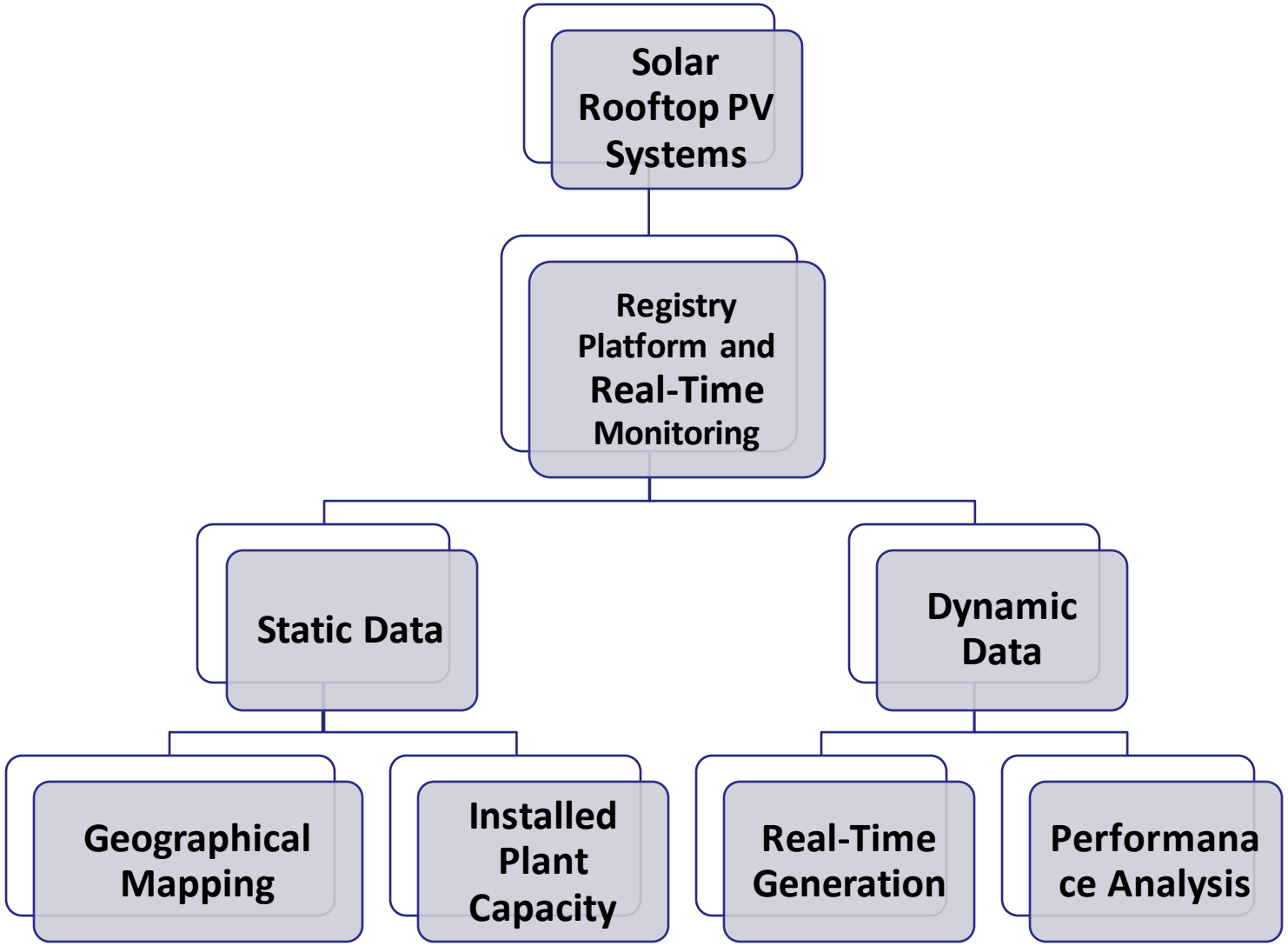
Time of Use (TOU) Tariff for Electricity

Time of Use (ToU) Tariffs are real-time pricing for electricity based on supply-demand scenario in real-time

- Price signals are communicated to the participating customers in advance about the Rebate or Surcharge in different time-blocks on the following day so that customers can adjust their interruptible loads accordingly
- *ISGF prepared TOU Tariff Framework for Gujarat in 2020 – www.indiasmartgrid.org*
- *ISGF conducted a Pilot Demonstration Project in Lucknow with 50 customers (22 MW load) during 2022 - 2023*

Rooftop Solar Registry

National Rooftop Solar Registry – required for forecasting, scheduling and dispatch of Rooftop Solar Generation



Smart Inverters

Smart Inverters – IEEE 1547:2018 compliant

- Mandating Smart Inverters for all DERs
- IEEE 1547:2018 standard compliant smart inverters have following functionalities:
  - Remote Monitoring and Control
  - Voltage Ride-Through and Dynamic Voltage Support
  - Frequency Ride-Through and Frequency Support
  - Start-Up Ramp Rate

Bureau of Indian Standards to adapt IEEE 1547-2018 soon

EV- Grid Integration

- **EV-Grid integration - Vehicle-to-Grid (V2G) technologies**
- **Virtual Power Plants (VPPs)**
- **Promotion of RE for EV charging**

EV-Grid Integration

- Both EVs and Rooftop PV (RTPV) are connected to the low-voltage (LV) grid
- **V2G:** Grid connected EVs can mitigate the variability of RTPV generation during the day as well as store surplus generation in the EV batteries and pump back to the grid during peak hours
- **VPP:** Large number of EVs connected to the grid can be aggregated as virtual power plants (VPP)
- **Promotion of RE for EV Charging** through innovative business models to decarbonize the transport sector

Grid Interactive Buildings/ Campuses/Smart Appliances

Grid Interactive Buildings and Campuses - Smart Microgrids Smart Appliances

- **Smart "grid-connected" microgrids:** Large building and campuses to be made **Grid-interactive** with islanding features to provide flexibility to the main grid
  - Buildings and Campuses with RTPV, BESS (instead of DG sets for standby power), and EVs with V2G capability
  - Microgrids can buy (green) electricity from the grid at the cheapest rates and store it in the BESS and EVs and use it during peak hours or even sell it back to the grid at higher prices
  - **Smart Appliances:** All electrical equipment and appliances should be made smart and grid interactive; Ban production and sale of inefficient equipment and appliances in a phased manner

Dynamic RE Markets and P2P Trading of Green Energy

- **Peer-to-Peer (P2P) Trading on Blockchain Platforms**
- **Dynamic RE Markets**

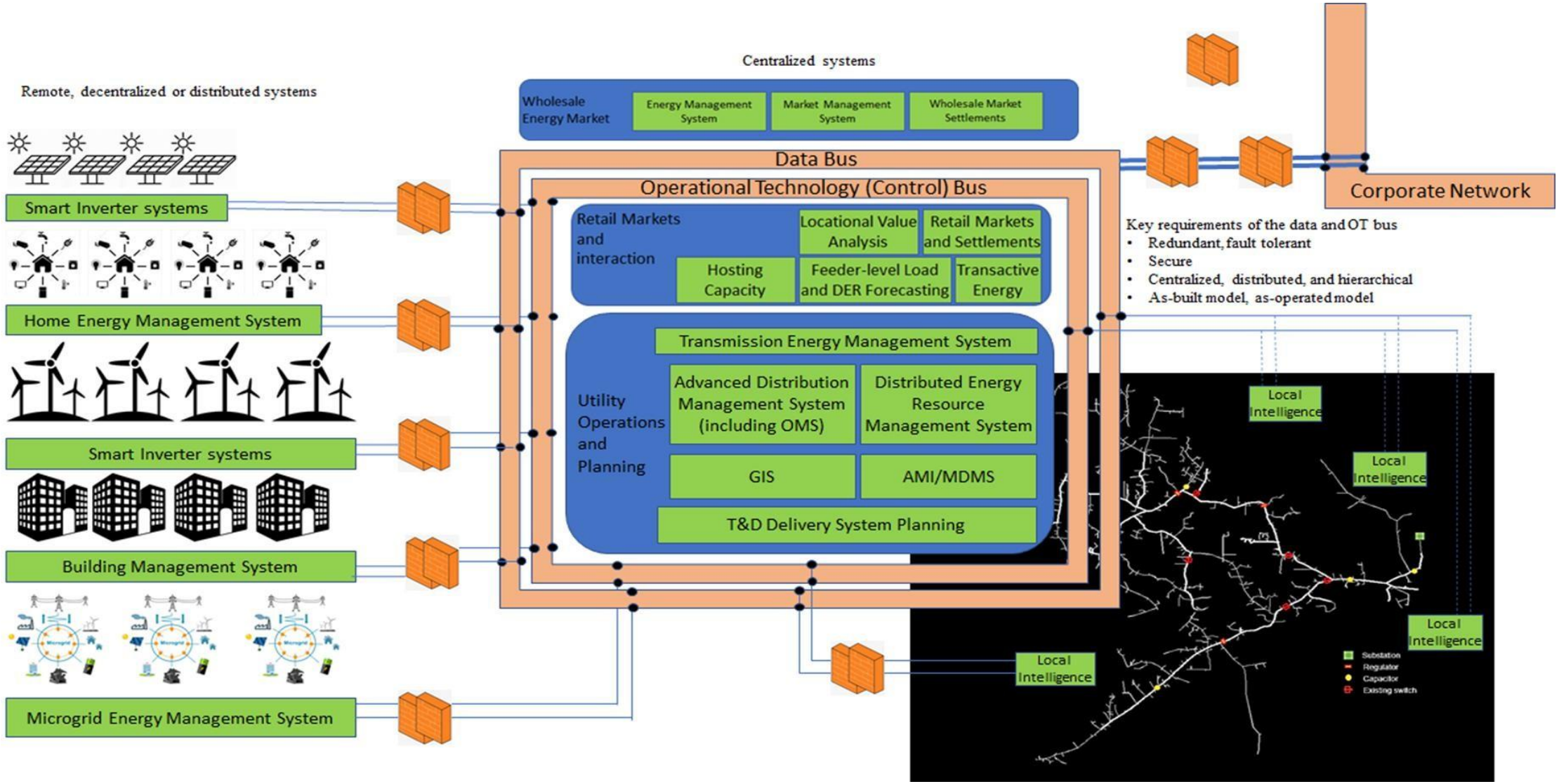
- **Peer-to-Peer (P2P) Trading:** Prosumers with RTPV systems can sell their surplus electricity to others who wish to buy GREEN ELECTRICITY – this can be done efficiently on blockchain platforms
- Promotion of Dynamic RE Markets - where those obligated to offset Scope 2 Emissions can buy green energy
  - *ISGF implemented 3 pilot projects (Lucknow, Delhi and Kolkata) on P2P trading of solar energy on blockchain*

Redesign of the Grid

Comprehensive planning and re-design of the electrical network for the evolving "green grid of the 21st century"

- **Comprehensive planning and re-design of the electrical network** – both transmission and distribution grids
  - Present architecture of transmission and distribution grids is based on the concepts of: ***"one-way flow of electricity"*** and ***"electricity cannot be stored"***
- **Why planning and re-design?**
  - Distributed Energy Resources (DER) that are intermittent and connected to the low-voltage grid
  - Bi-directional energy flows - Prosumers
  - Transfer of RE power to major load centers
  - Energy storage systems (ESS)
  - EV-Grid Integration

A Logical Architectural Construct of the Future Grid



India Brings Volumes to the Benefit of Whole World!

- **Mobile Phone:** in 1995 – US$ 1000; today smart phones available at <US$50
- **Solar PV:** In 2011 – US$ 0.40/kWh; today it is US$0.03/kWh
- **LED Lamps:** 2014 – US$5 for a 7W lamp; today <US$1 for a 9W lamp
- **Smart Meters:** 2015 - >US$100/meter; today US$ 50/meter – we are yet to start roll outs!
- Volumes offered by a market of >1.4 billion people brings benefits to rest of the 7 billion in the world!

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Thank you!

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Keynote

Chavan Dabeedin
Head of Production, Central Electricity Board, Mauritius

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Outline of Presentation

1) Mauritian Power System

2) RE Targets for Mauritius

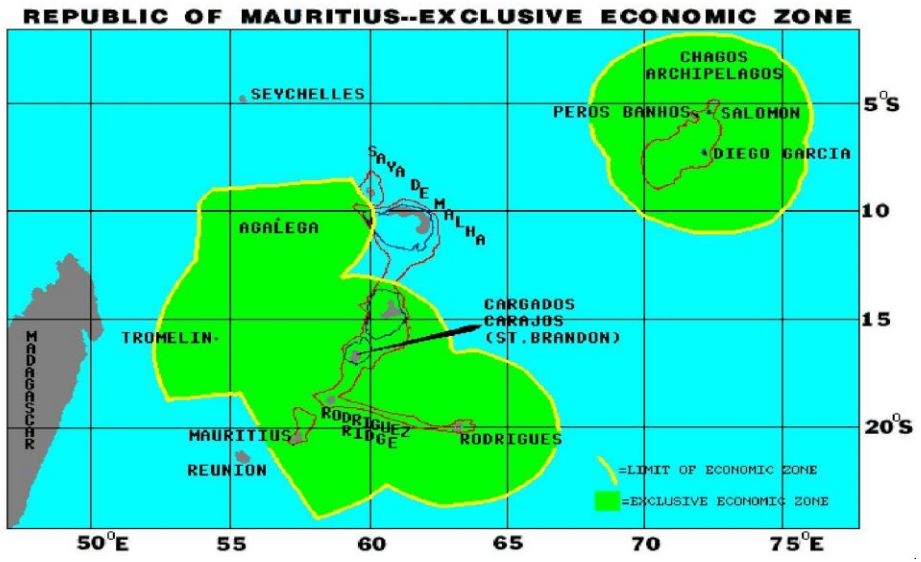
3) Technical Challenges

4) Grid Reinforcement and Smart Grid Support for RE

5) Regulatory Innovation

6) Opportunities

Mauritius Facts and Figures



Independence: since 1968

Population: 1.3 Million

Area: 2040 km2

Maritime Zone (EEZ): 2.3 million km2

GDP per Capita: 14 000 USD

Life Expectancy: 75.51 years

Electricity: 100 % electrification since 1982

Economy: Manufacturing, textiles, Financial services, Banking offshore and on shore, BPO, Tourism/hotel/food, Construction and real state, trade and repairs, seafood hub, sugar/ethanol/liquor ….

Politics: Parliamentary democracy, Westminster system

Mauritian Power System

- Fundamentally robust and resilient and continues to be upgraded to accommodate future load growth.

- The CEB owns and operate some **410MW** of Heavy fuel oil thermal, **70 MW** Gas Turbine and **60MW** of hydro power capacity. It also has IPP contract for about **230MW** coal/bagasse for base load generation, **123 MW** Solar PV, **3.3MW** Of Landfill Gas and **9.35 MW** of Wind

PEAK DEMAND 10 DEC 2019

507 MW

NETWORK LOSSES

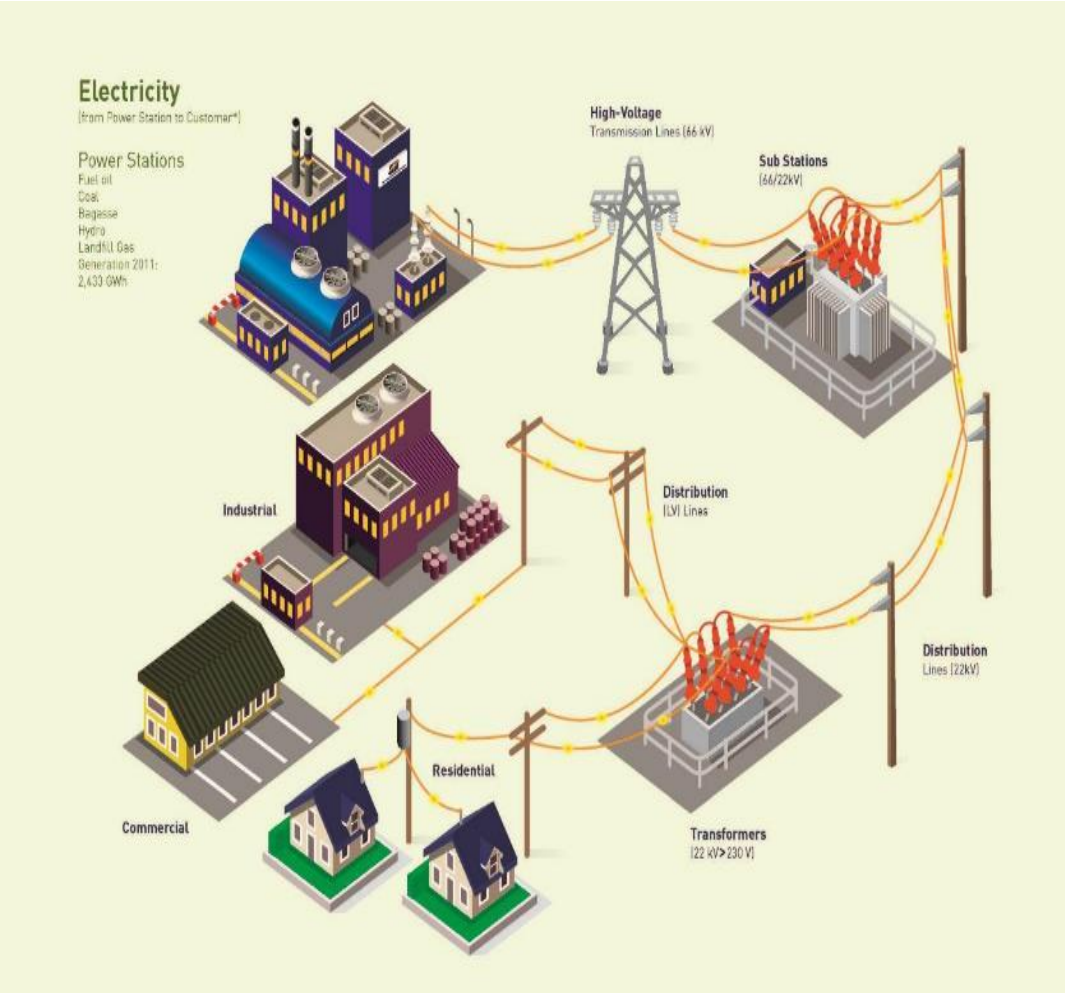
7%

ENERGY GENERATION

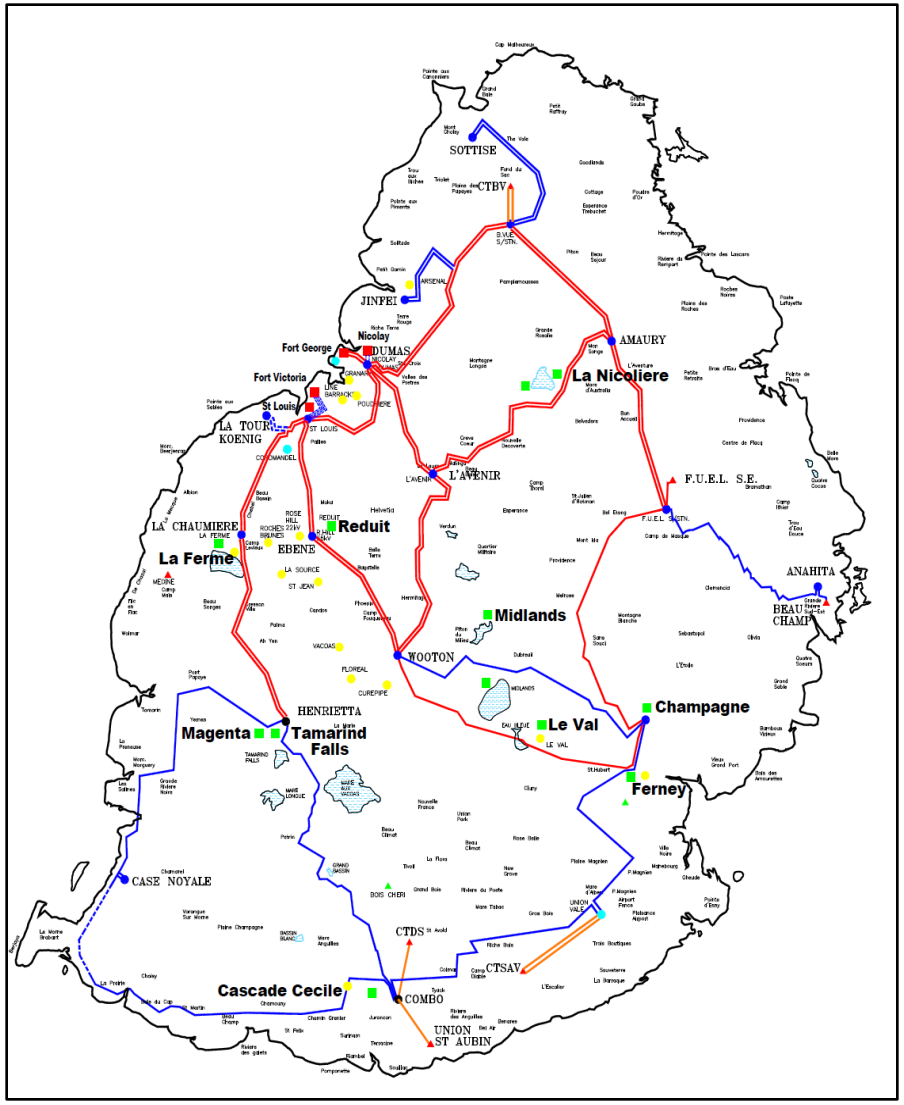
2859 GWH

% RE 2022

19.2%



Mauritius Transmission and Distribution Network



TRANSMISSION NETWORK

- The transmission network, operates at 66 kV, transporting power in bulk from the main sources of generation to **eighteen** 66 kV-to-22 kV 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**
- **300 km** of Overhead line (*Combination of concrete Poles and Towers*) and **26km** of underground Cables

DISTRIBUTION NETWORK

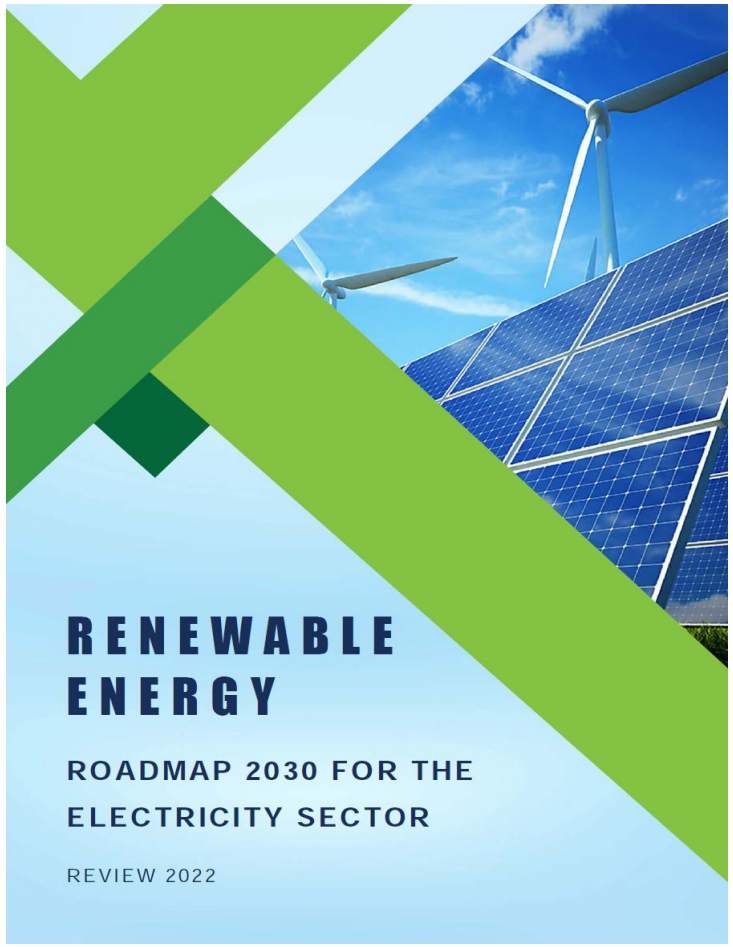
- The distribution system supplies electricity at lower voltages from its substations to around **500,000** customers' premises through around 22 kV-to-415 V distribution transformers.
- Distribution Lines : **9147 km** Overhead Line and **973 km** Underground Cable.

2.79
SAIDI

1.72
SAIFI

RE Targets

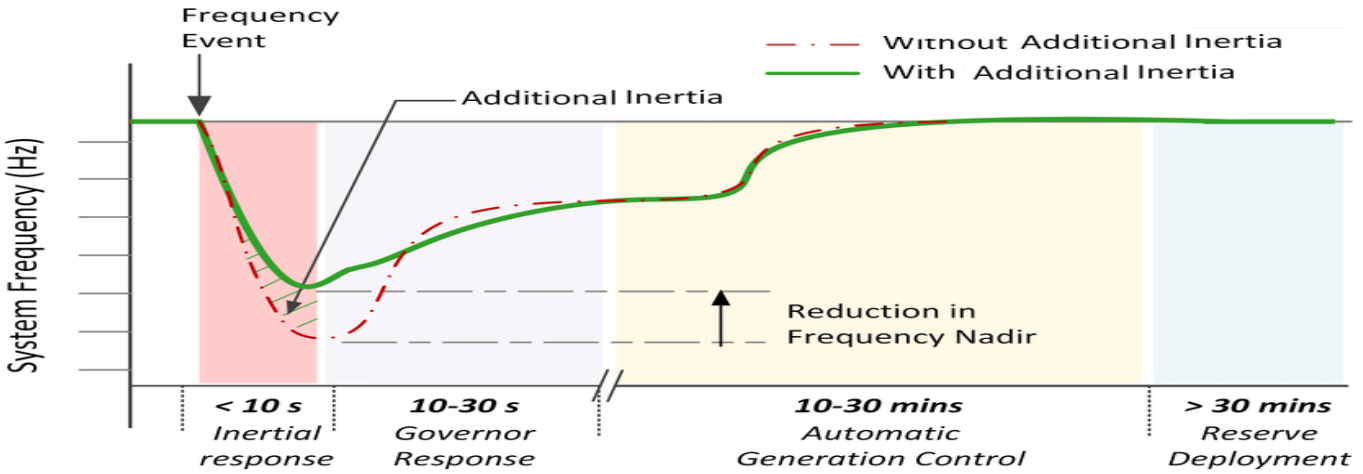
The RE target for 2030 has been reviewed upward in the revised RE Roadmap 2030 launched in May 2022. The new target is **60% by 2030.**

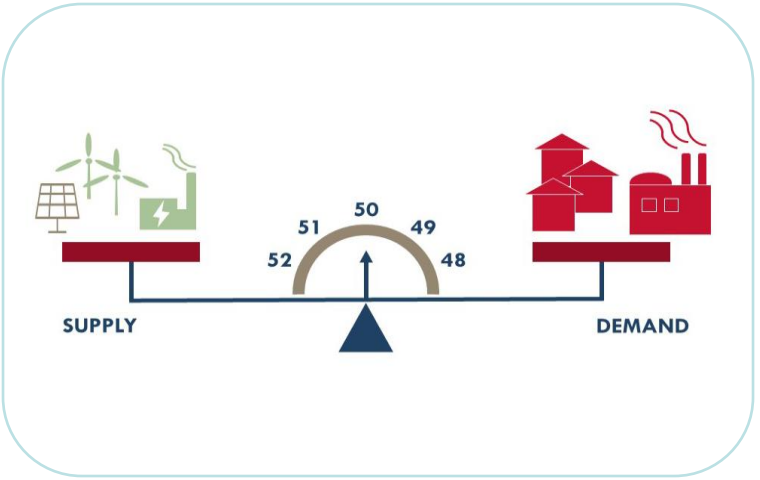


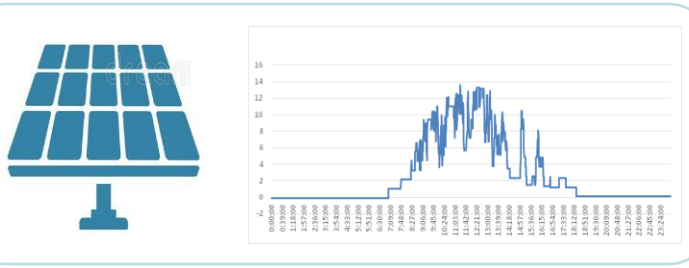
	Power Plants/Projects/Schemes	2022 GWh	2022 MW	2023 GWh	2023 MW	2024 GWh	2024 MW	2025 GWh	2025 MW	2026 GWh	2026 MW	2027 GWh	2027 MW	2028 GWh	2028 MW	2029 GWh	2029 MW	2030 GWh	2030 MW
In Operation	Hydro Generation	93	60	93	60	93	60	93	60	93	60	93	60	93	60	93	60	93	60
	PV Farms - Henrietta	5	3.1	16	10	16	10	16	10	16	10	16	10	16	10	16	10	16	10
	SSDG - Feed in Tariff	2.5	3	2.5	3	2.5	3	2.5	3	2.5	3	2.5	3	2.5	3	2.5	3	2.5	3
	SSDG -Net Metering Schemes	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5
	MSDG - Net Metering	10	7	10	7	10	7	10	7	10	7	10	7	10	7	10	7	10	7
	Subtotal	**118**	78.1	**128.5**	85	**128.5**	85	**129**	85	**129**	85	**129**	85	**129**	85	**129**	85	**129**	85
SSDG Schemes Currently under Implementation	Home Solar Project	3	2	6	4	8	5.3	10	7	12	8	15	10	15	10	15	10	15	10
	Green Energy Scheme for SMEs	4	2.7	6	4	6	4	6	4	6	4	6	4	6	4	6	4	6	4
	SSDG Net-Billing Schemes	1	0.6	5	3.1	8	5	8	5	8	5	8	5	8	5	8	5	8	5
	Religious Bodies	1	0.5	3	2	4.5	3	6	4	6	4	6	4	6	4	6	4	6	4
	Non-Governmental Institution (NGOs) - 2 MW	1	0.5	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2
	Electric Vehicle (EV) Scheme (10 MW)	1	0.7	2	1.3	4.0	2.7	6	4	10	7	15	10	15	10	15	10	15	10
	SSDG Gross Metering Scheme (10 MW)	5	3.3	10	6.7	15	10	15	10	15	10	15	10	15	10	15	10	15	10
	Subtotal	**16**	10.3	**35**	23.1	**48.5**	32	**54**	36	**60**	40	**68**	45	**68**	45	**68**	45	**68**	45
MSDG Schemes Currently under Implementation	MSDG -Gross Metering	10	6.7	20	13.3	30	20	40	27	50	33	60	40	63	42	63	42	63	42
	MSDG Smart City Scheme	5	3.3	10	6.7	15	10	18	12	22	15	25	17	30	20	30	20	30	20
	MSDG Public Sector Entities Scheme	1.5	1	4.5	3.1	9	6.1	15	10	18	12	22	15	22	15	22	15	22	15
	Greenfield RE Public Sector Entity	0	0	0	0	45	30	60	40	90	60	125	83	135	90	135	90	135	90
	MSDG Educational Institutions	1	1	3	2	6	4	9	6	9	6	9	6	9	6	9	6	9	6
	Subtotal	**17.5**	11.7	**37.5**	25.1	**105**	70.1	**142**	95	**189**	126	**241**	161	**259**	173	**259**	173	**259**	173
IPP RE Projects in Operation	IPP Bagasse Generated [4]	350	129	350	129	350	129	350	129	350	129	100	37	0	0	0	0	0	0
	Cane Trash	8		8		8		13		13		0		0		0		0	
	Landfill Gas (Mare Chicose)	23	3	23	3	23	3	23	3	23	3	23	3	23	3	23	3	23	3
	EOLE Wind Farm	15	9	15	9	15	9	15	9	15	9	15	9	15	9	15	9	15	9
	Saraiko PV Farm	22	15.7	22	15.7	21	15	21	15	21	15	21	15	21	15	21	15	21	15
	RFP Solar PV 5 x 2 MW (2012)	9	6	9	6	9	6	9	6	9	6	9	6	9	6	9	6	9	6
	RFP Solar PV 10-15 MW (2016)	78	41	78	41	78	41	78	41	78	41	78	41	78	41	78	41	78	41
	RFP Solar PV 1-9 MW (2016)	25	14	25	14	25	14	25	14	25	14	25	14	25	14	25	14	25	14
Ongoing RE Project	RFP Solar PV 3 x10 MW (2021)	0	0	0	0	35	20	35	20	35	20	35	20	35	20	35	20	35	20
Planned New RE Projects	REHF Solar PV + Battery Energy Storage	0	0	0	0	150	50	300	100	300	100	300	100	300	100	300	100	300	100
	REHF Solar PV + Wind + Battery Energy storage	0	0	0	0	0	0	0	0	0	0	0	0	175	50	350	100	350	100
	Small Scale REHF	0	0	0	0	70	20	140	40	140	40	140	40	140	40	140	40	140	40
	Large Scale REHF Biomass	0	0	0	0	0	0	0	0	0	0	400	58	685	100	685	100	685	100
	Floating PV	0	0	2	2	3	2	3	2	32	17	32	17	60	32	60	32	60	32
	Offshore Wind Farm	0	0	0	0	0	0	0	0	60	20	60	20	60	20	150	50	150	50
	Renewable Energy from Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	10	75	10
	Marine Renewables (Wave and/or Tidal)	0	0	0	0	0	0	0	0	25	10	25	10	25	10	50	20	50	20
	Subtotal	**530**	**218**	**532**	**220**	**787**	**309**	**1012**	**379**	**1126**	**424**	**1263**	**390**	**1651**	**460**	**2016**	**560**	**2016**	**560**
Total		**681**	**318**	**733**	**353**	**1069**	**496**	**1337**	**594**	**1504**	**675**	**1701**	**681**	**2107**	**763**	**2472**	**863**	**2472**	**863**
Total Forecasted Annual Energy Generation (Base Case)		3102		3240		3369		3548		3621		3687		3754		3820		3886	
Total Expected Annual RE Generation		681		733		1069		1337		1504		1701		2107		2472		2472	
Share of RE Generation		**21.9%**		**22.6%**		**31.7%**		**37.7%**		**41.5%**		**46.1%**		**56.1%**		**64.7%**		**63.6%**	
	New Schemes																		
	On-going RE Projects - Only 2x10 MW Solar PV shall be commissioned																		
	Planned new RE Projects																		

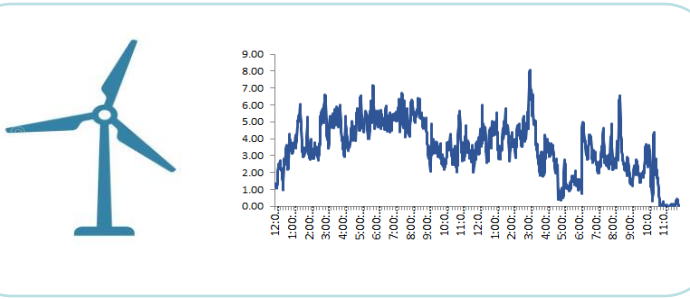
Technical Challenges

- 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.
- VRE farms do not contribute to the system inertia
- VRE displace conventional generating units leading to a **reduction in inertia, thus affecting the stability of a grid.**









Grid Reinforcement - Modernization of Substations

OUTDOOR AIR INSULATED SWITCHGEAR SUBSTATION

INDOOR GAS INSULATED SWITCHGEAR SUBSTATION

Benefits

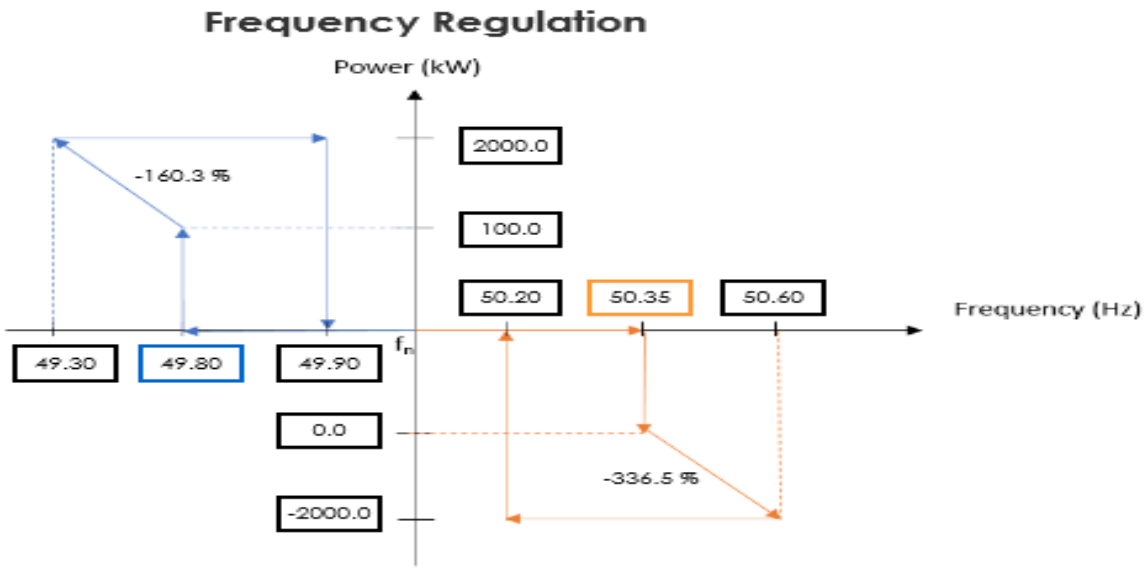
1. Compact design and less space requirements.
2. Increase the capacity of the grid to integrate utility scale Renewable Energy Generation
3. High reliability and high degree of safety
4. Economic efficiency, long service life, little maintenance requirements, and low life cycle costs
5. IEC 61850 – Smart Grid Application

Grid Reinforcement - Increase Response Time

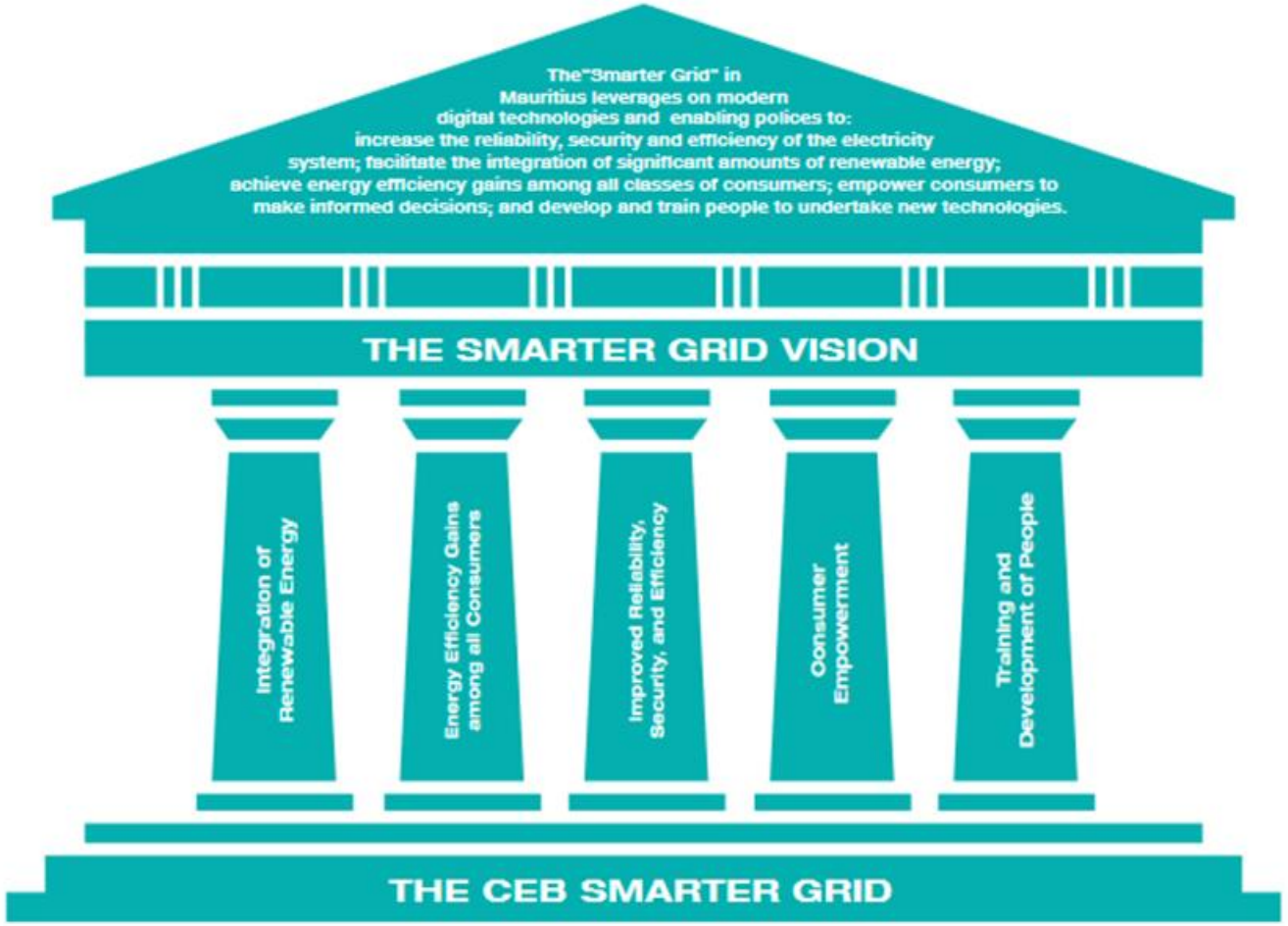
Increase the response of our power system to frequency excursion

- 18 MW Battery Energy Storage System for primary frequency control – ***Commissioned in 2021***
- 20 MW Battery Energy Storage System for primary frequency control and peak shaving –***Implementation Stage***
- Operating CEB's generating unit on droop control – ***Already Implemented***
- Deployment of ***SMART GRID*** Technologies–

  In progress



Smart Grid Technologies in Mauritius

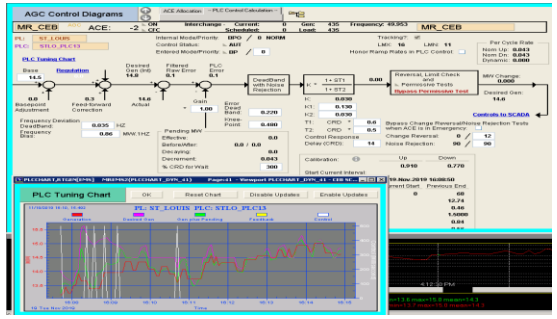


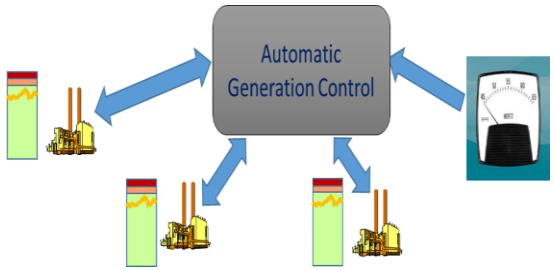
SMART GRID TECHNOLOGIES

- Automatic Generation Control
- Wide Area Monitoring System
- Advanced Metering Infrastructure with smart meters
- Advanced Distribution Management System

Smart Grid Technologies in Mauritius

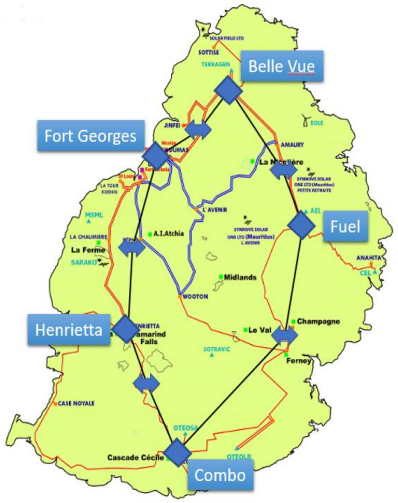
Automatic Generation Control – secondary frequency control
An Automatic Generation Control send signals to one or more generating units to either raise or lower their corresponding generating outputs to restore the frequency of a network to nominal frequency of 50Hz following a disturbance.



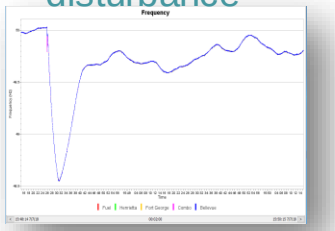


Wide Area Monitoring System (WAMS)
WAMS is based on data acquisition using Phasor Measurement Units (PMU) installed at selected locations in a power system, in view of detecting grid instabilities. It can be regarded as a grid instabilities forecasting system

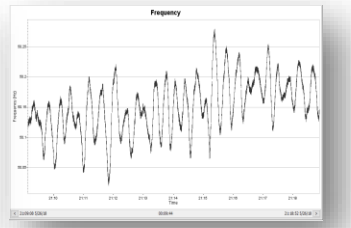
The WAMS can be set to control generating units in the event of anticipated grid instabilities.



Frequency disturbance

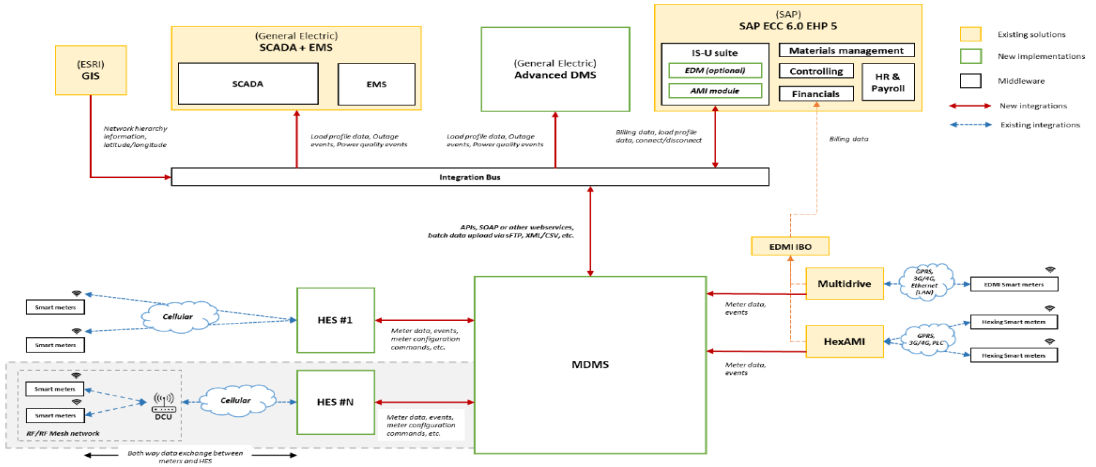


Frequency oscillations



Smart Grid Technologies in Mauritius

Advanced Metering Infrastructure with smart meters
It is the whole infrastructure from Smart Meters to two way-communication network to control center equipment and all the applications that enable the gathering and transfer of information in near real-time. AMI is the backbone of smart grid.



Advanced Distribution Management System (ADMS)
ADMS is a collection of applications designed to monitor & control the entire distribution network efficiently and reliably. It acts as a decision support system to assist the System Operator and field operating personnel with the monitoring and control of the electric distribution system.

ADMSs access real-time data and provide all information on a single console at the control center in an integrated manner

Regulatory Innovations

- Technical Requirements for the interconnection of distributed generation to the low voltage and medium voltage network (SSDG and MSDG Grid Codes)
- Democratize access to the electricity grid –Customers becoming Producers of Electricity under RE Schemes launched by the Utility
- Simplified the administrative procedures for becoming a prosumer on the grid. – *Require only a Connection Agreements with the Utility as compared to the past whereby signature of the President is required (Proclamation)*

Opportunities

Green Energy Industry has become an economic pillar of activity of the island.

- Implementation of innovative technologies under the National Scheme for Emerging/Innovative Renewable Energy Technologies of MARENA.
- Contribute to our objective to achieve our target of 60% by participating to call for proposals for RE projects and technologies to increase the grid absorption capacities for variable renewable energy.
- Market for providing RE solutions to potential prosumers.

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Thank you!

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Panel discussion

Moderator

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Policy Advisor for Energy Transition, GIZ

Kaleb Udui, Jr.
Minister of Finance, Palau

Chavan DABEEDIN
Head of Production, Central Electricity Board, Mauritius

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Kader DIOP
Senior Advisor to the Director-General, National Agency for Renewable Energy (ANER), Senegal

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President India Smart Grid Forum (ISGF), India

Claire Nicolas
Senior Energy Economist, World Bank

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Closing Remarks

Simon Benmarraze
Team Lead, Technology and Infrastructure
IRENA Innovation and Technology Centre

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Thank you!

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