Role of Grid Digitalization and Renewable Energy in Building Smart Grids

ADB Support to address Digitalization of Grids in Sri Lanka

Driving Power Sector Reforms for Enhanced Renewable Energy Growth and Sector Performance Workshop

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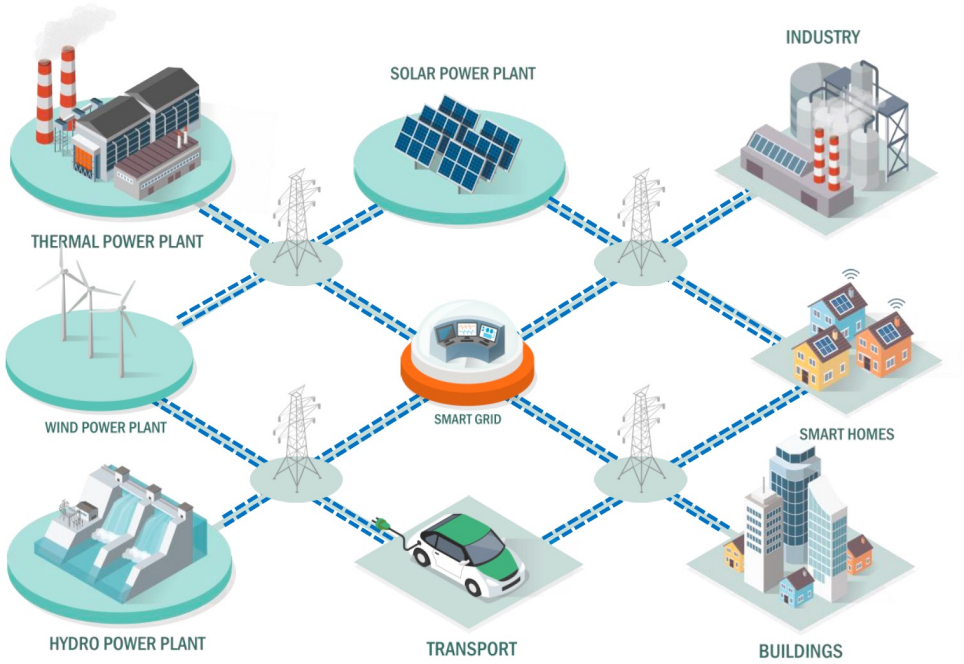
Colombo, January 30, 2025

Prof. José Aguado *is Full Professor and Head of the Department of Electrical Engineering at the University of Málaga, Spain.*

His expertise lies in the operation and planning of electric energy systems, renewable energy integration, energy storage and electric vehicles.

His consultancy expertise spans over 30 developing countries, including Sri Lanka and other nations in Asia and in the Pacific.

The 4 ‘Ds’ of Energy Transition: Opportunities for Sri Lanka



De-carbonization

70% RE share by 2030

Des-centralization

Highest Solar Roof-top penetration in the region (25%)

Digitalization

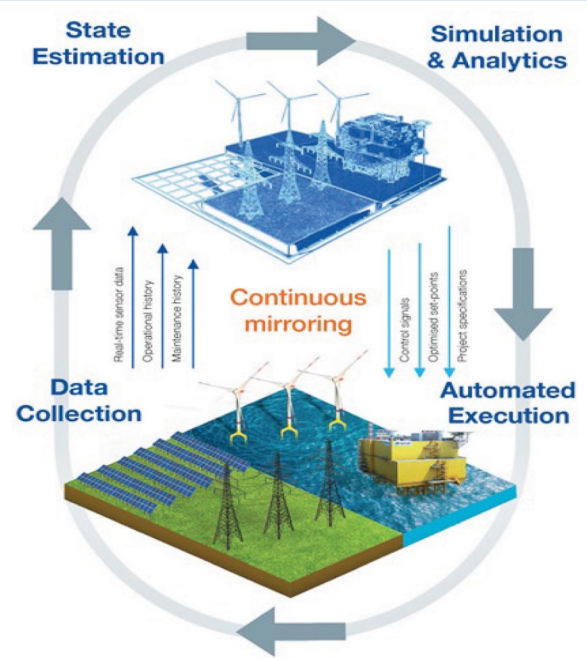
Increase the adoption of digital tools (AMI, Power Grid AI-DT, Smart Grid)

Democratization

Energy-share models to empower citizens

Grid Digitalization: From Smart meters to Power Grid Digital-Twins

Power Grid Digital Twin

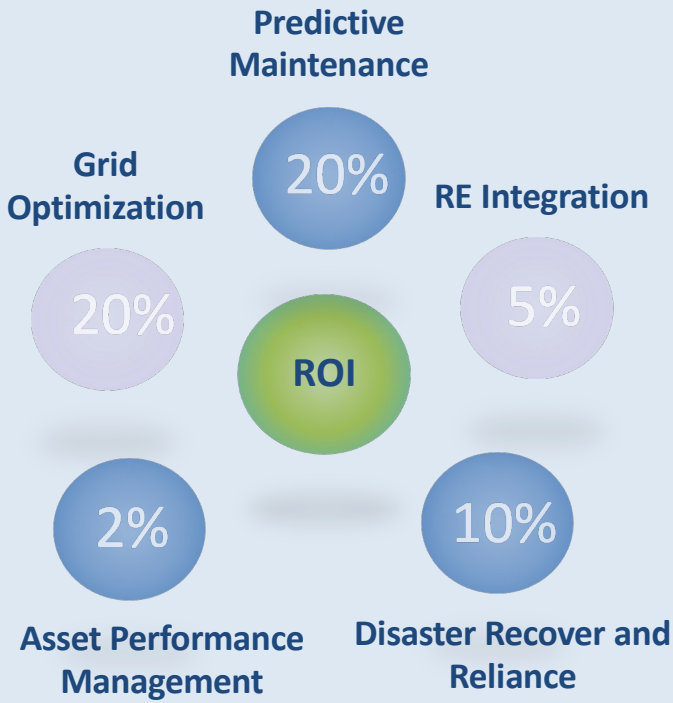


AI-Assisted Control Room

(CERCE, RE Control Room in Madrid)

- Co-piloted Real-time Operations
- Medium and Long-Term Decis.
- Control Room Training
- Forensic Analysis

Measurable ROIs



Grid Integration Challenges: Soft- and Hard- Tools

Front-Runners and Soft-Tools

Front-runners: Denmark, Ireland, South Australia and Spain are integrating up to 75% of VRE in their annual generation

Essential Soft Elements:

- Modernize System Operation
- Improved Strategic Planning
- Overhauling Regulatory Frameworks (markets, business models, etc.)

Measures to Integrate VRE

Enhance Power Plant Capability
- Retrofit conventional power plants
- Increase VRE technical requirements

Forecasting
- VRE generation
- Net Load
- Power Flows

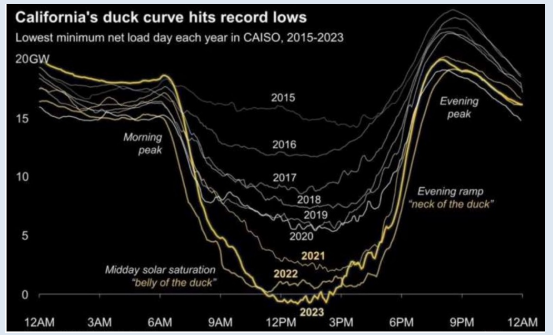
Demand Side Measures
- Industrial, Commercial, Residencial Response
- Steer location on new demand

Modify System Operation Rules
- Allow VRE Curtailment
- Balancing and Ancillary Service Market

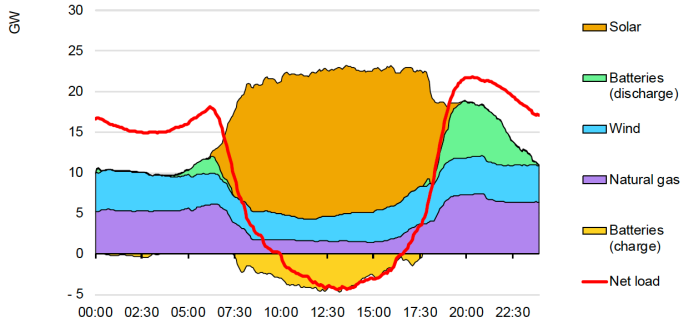
Enhance Grid Capacity and Use
- BESS, SYNCON, STATCOM
- Interconnection/Redundancy/mesh
- Balancing and Ancillary Service Market
- Steer Location of new VRE

Storage
- BESS
- Pumped Hydro, Long duration Storage

Solar Duck Curve and Beyond

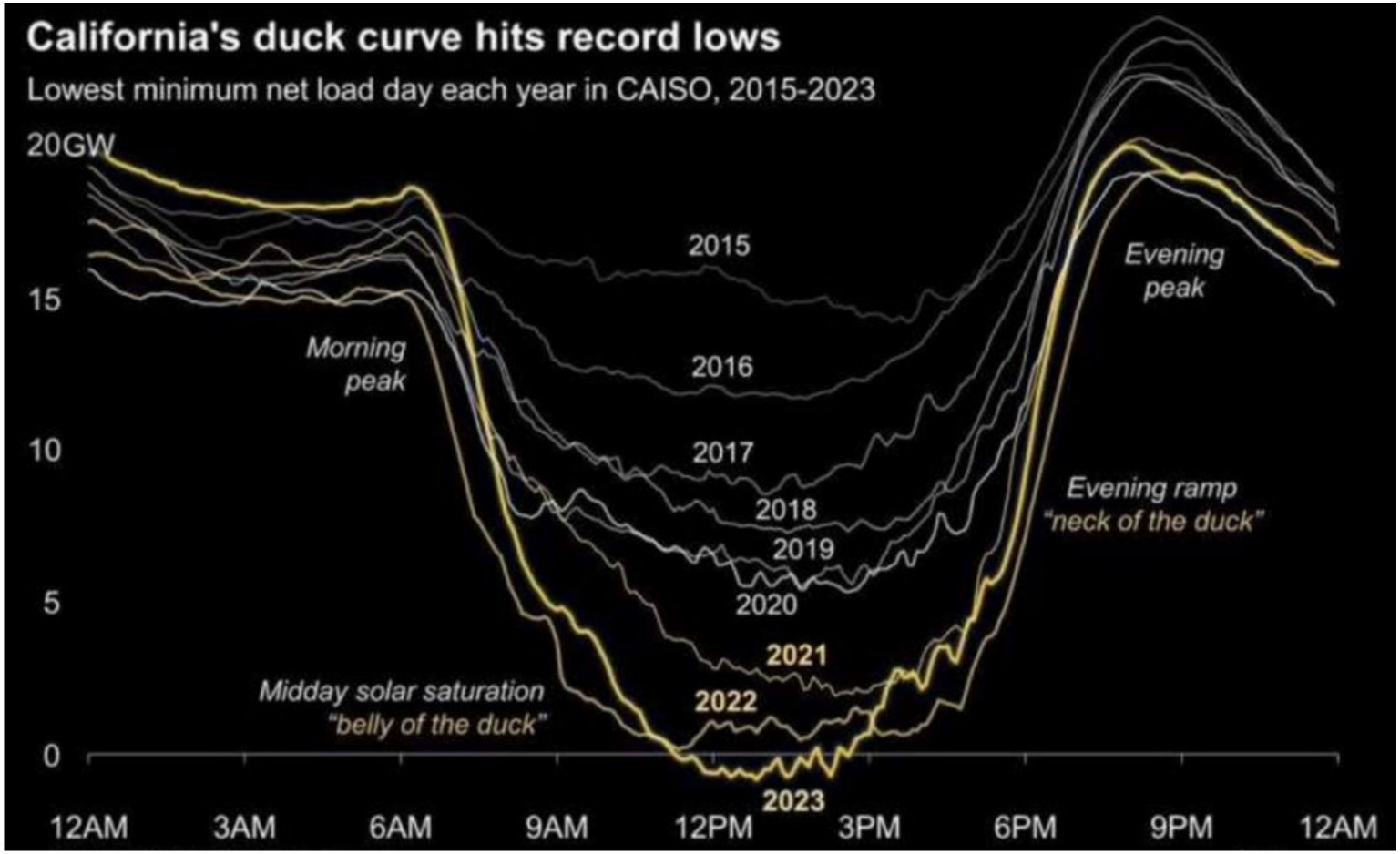


Generation profile in California (CAISO) for selected technologies, 30 April 2024



Challenges
- Behind the meter Visibility
- Grid Stability
- Price Volatility and negative prices

Grid Integration Challenges: Soft- and Hard- Tools



Grid Integration Challenges: Soft- and Hard- Tools

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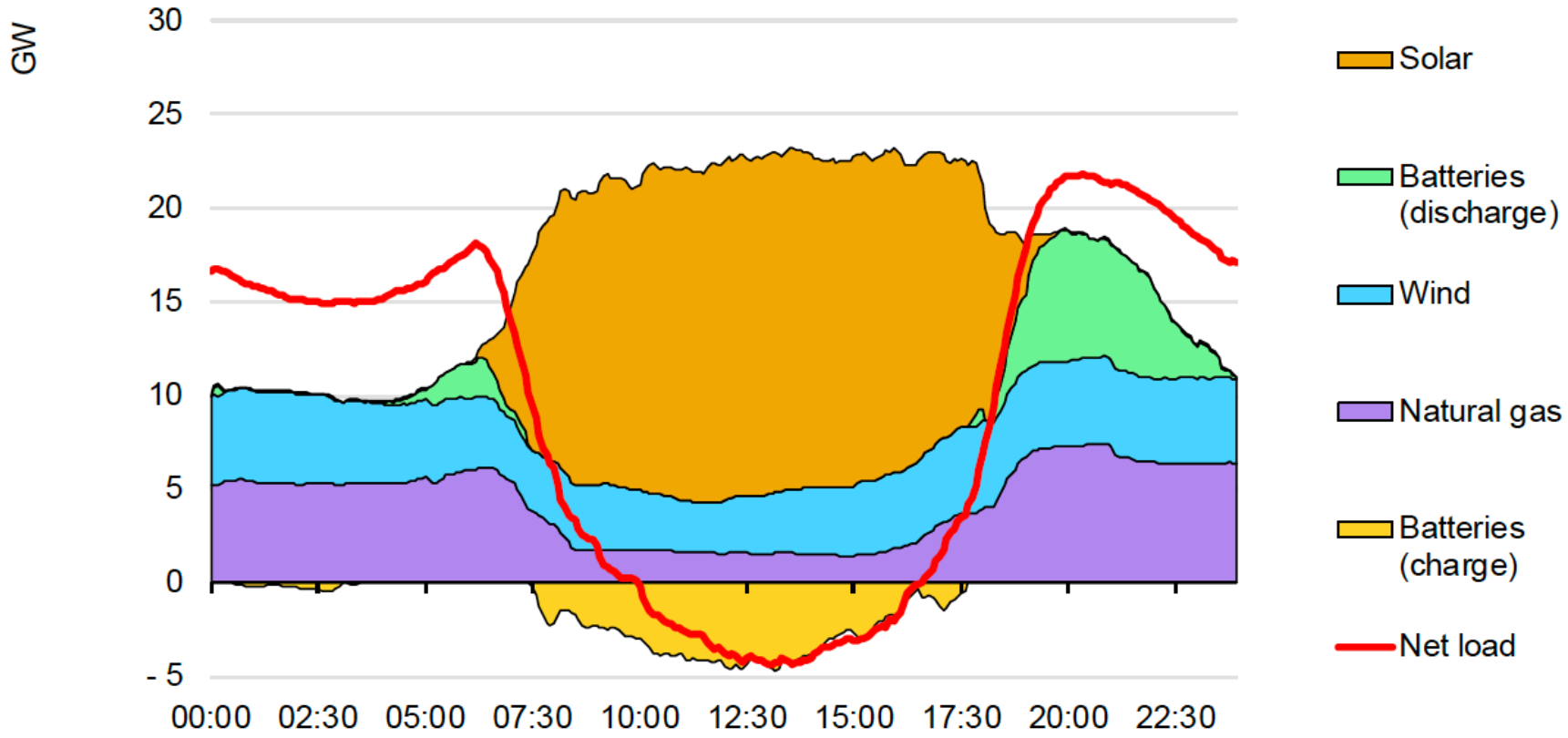
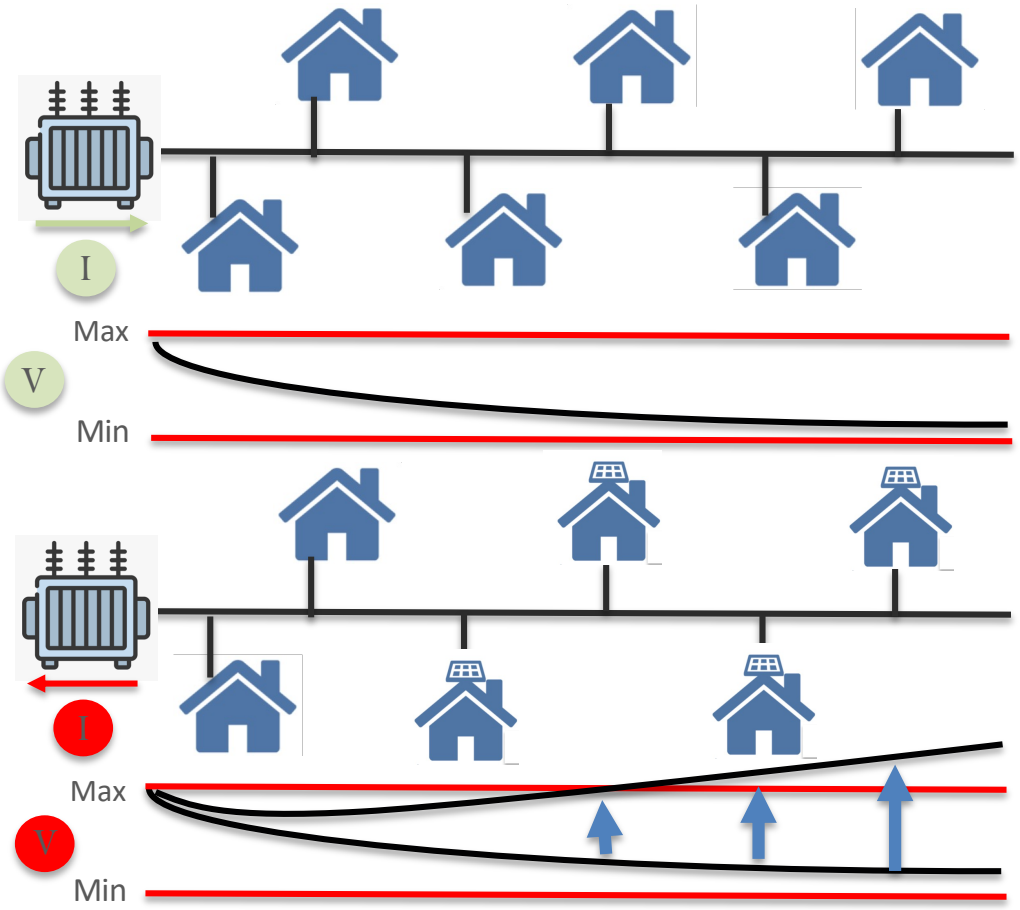


Distribution Grids with high RE penetration: Voltage Control

Distribution Feeders Voltage with hight PV



How is this solved today?

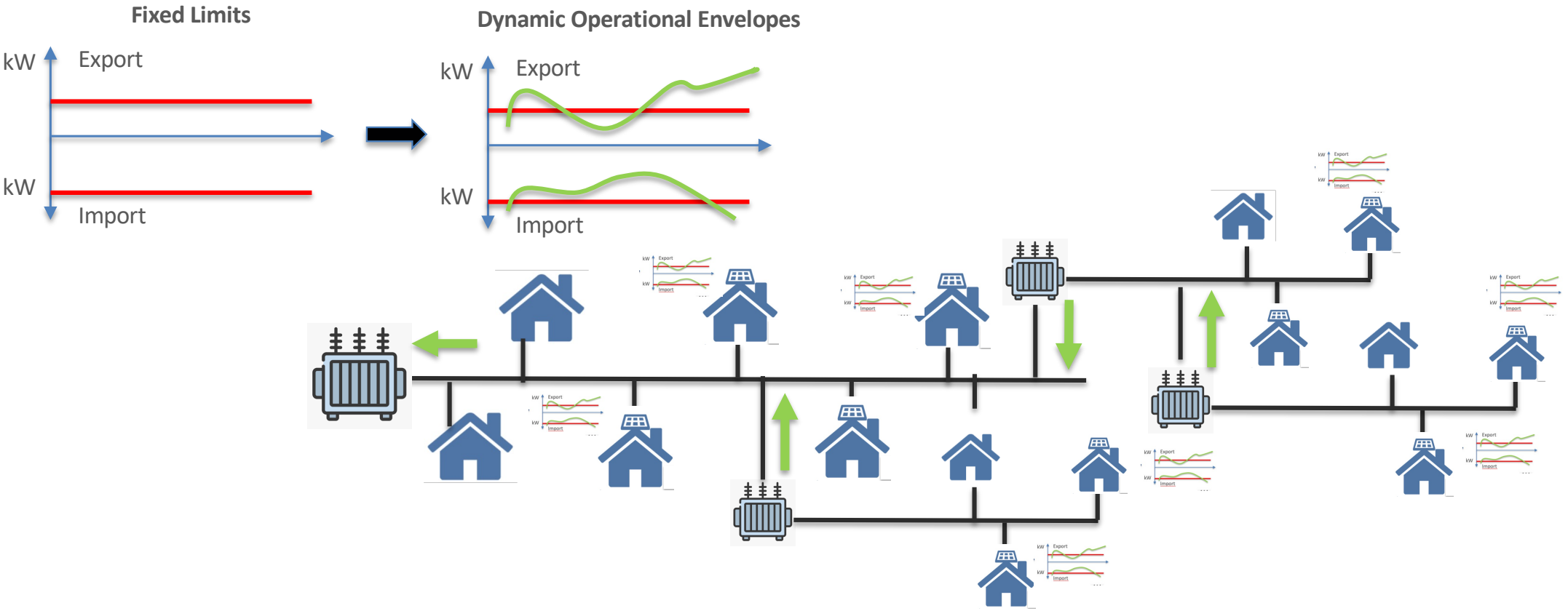
Enhanced Grid Codes (home/community BESS)

Using PV Smart Inverter functions

Voltage Regulating Devices

Fixed Export Limits

Distribution Grids with high RE penetration: Operational Envelopes



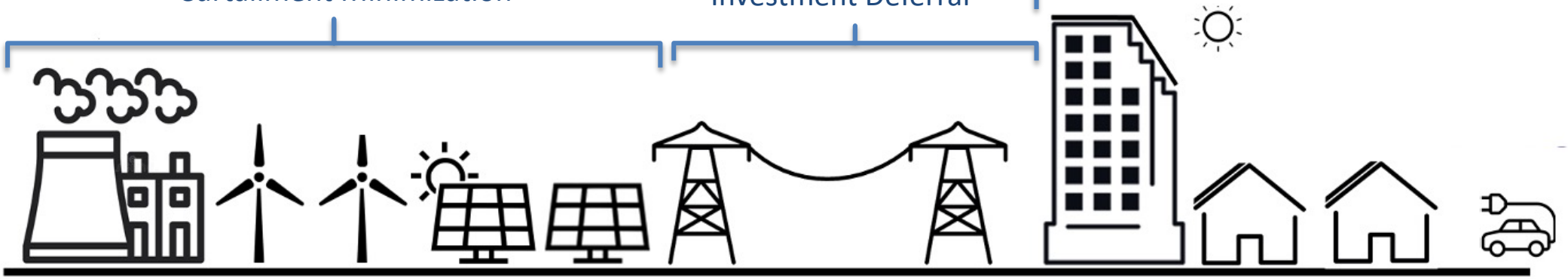
Calculation of Meter-Level Limits → Broadcast to Aggregators → Aggregator provides strategy → DER use optimal capacity Bottom-up Service

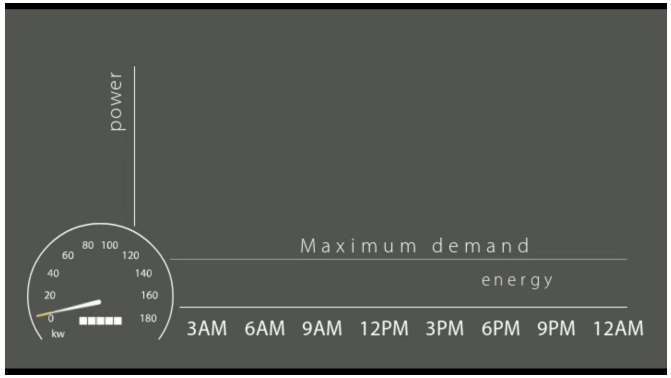
Battery Energy Storage Systems

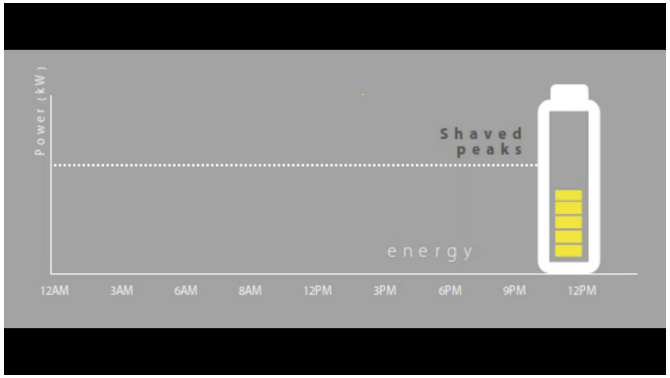
Arbitrage
Capacity Firming
Curtailment Minimization

Frequency Control & Stability
Voltage Control
Investment Deferral

Peak Shaving
Time-of-Use energy cost management
Continuity of energy supply

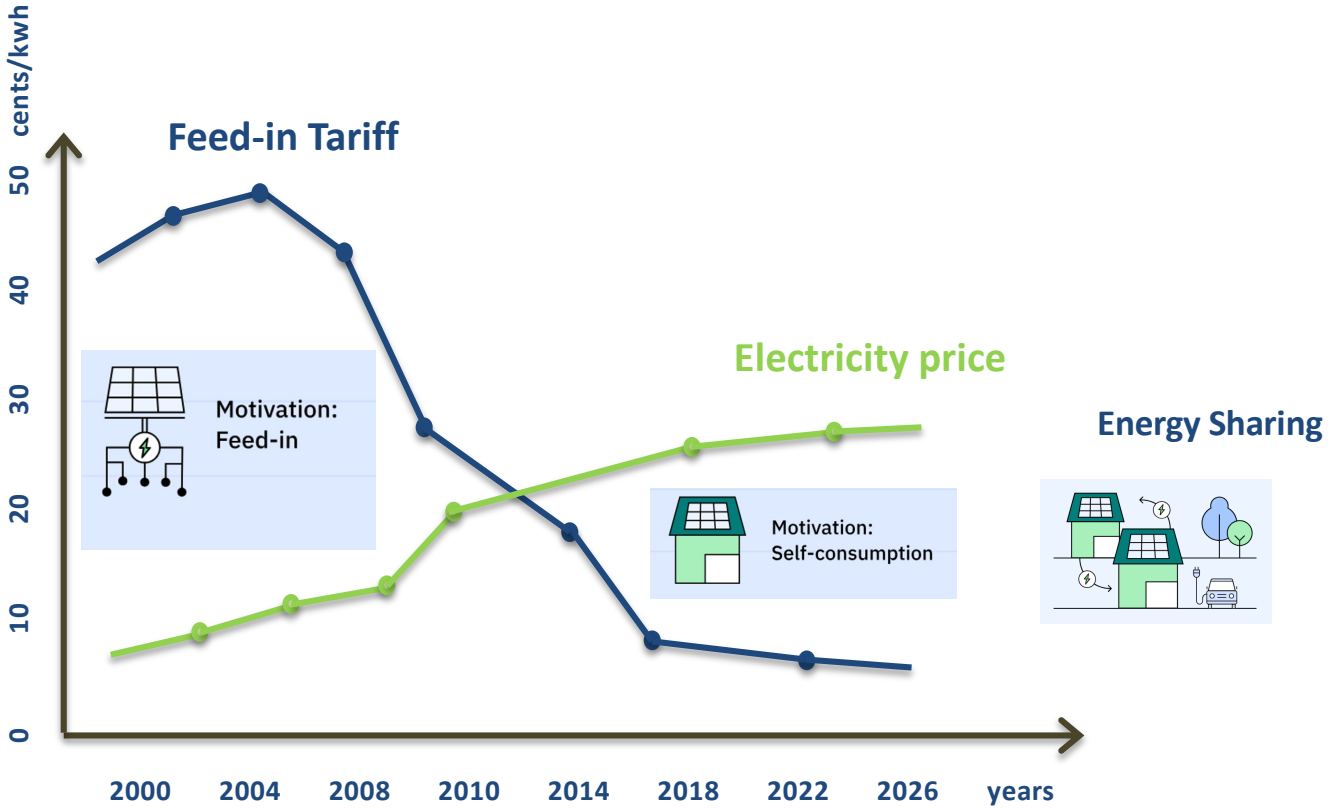






New Business Models for Digital and Clean Energy Systems in SRL

From Feed-in to Self-Consumption to Energy Sharing



Emerging Business Models

- Aggregation
- Virtual Net Metering
- Community Solar
- Energy as a Service
- Virtual Power Plants
- Green Bonds

ADB Support to address Digitalization of Grids in Sri Lanka

In Sri Lanka, ADB is leading a holistic effort to digitalise, increase RE share, enhance technology, processes and institutions in order to enable a clean and secure electricity system for the future

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Principal Energy Specialist.
Energy Sector Office
Sectors Group
Asian Development Bank

Key Transformations in Power System

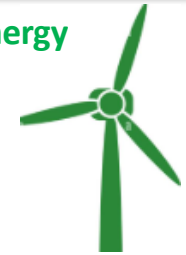
Generation	*Regulated Generation Plants*	*Variable RE Generation (VRE)*
	Synchronous Generators	*Inverter Based Systems (IBS)*
	Dispatchable Energy	*Non-Dispatchable Energy*
Networks	*Centralized Generation Plants*	*Distributed Generation*
	Directional Power Flows	*Bi-directional Power Flows*
	Passive Distribution Networks	***Active Distribution Networks****
	Centralized Energy Storage	***Distributed Energy Storage****
Business Models	*Ownership Models*	***Market / Service Oriented Models****
Utilization	*Consumers*	*Prosumers*
	Electric Light and Power	*Electric Light, Power and **E-mobility***

Digital framework an essential requirement.

* Presently not available in Sri Lanka

Digitalization and Green Energy Transition: Challenges & Strategies

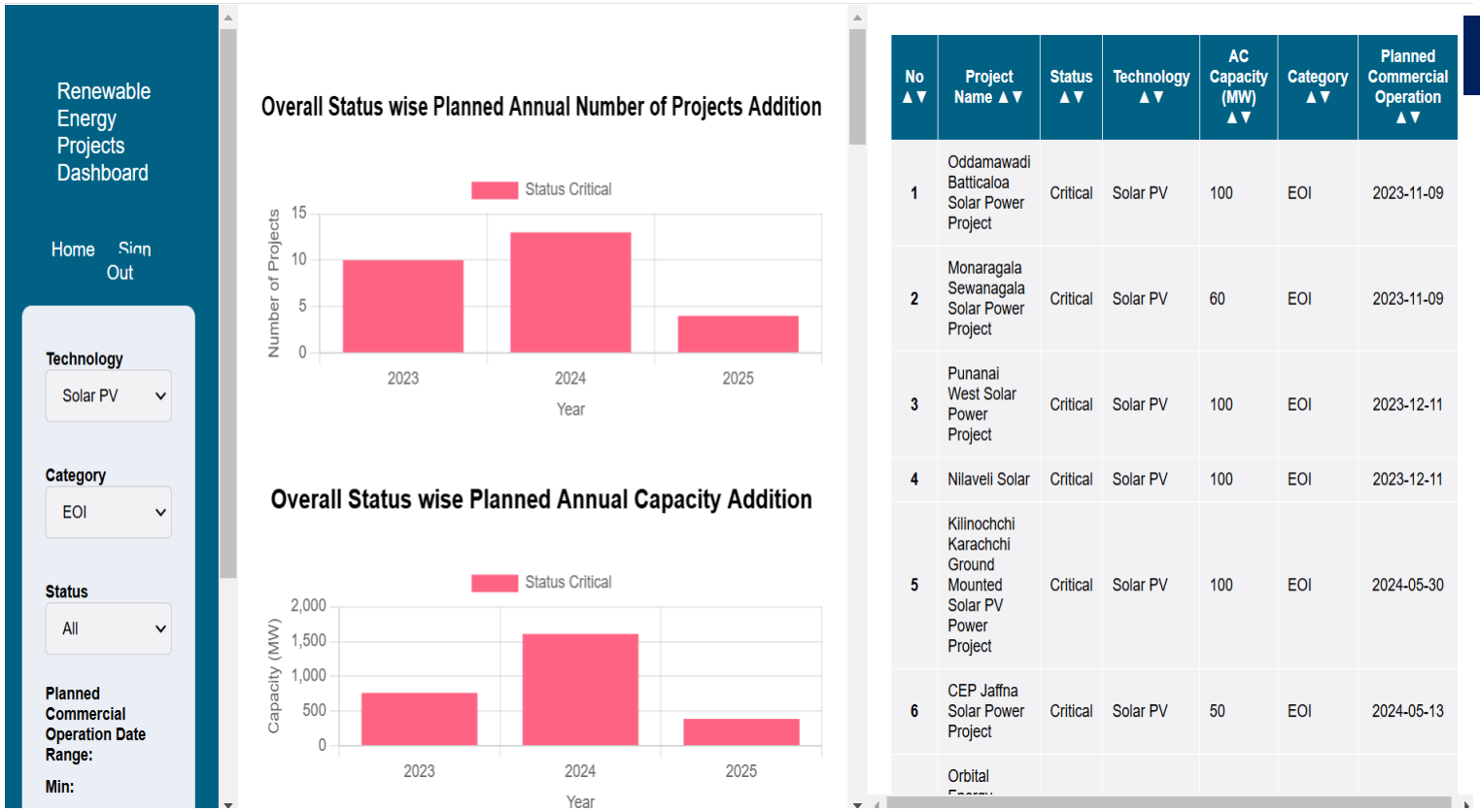
Renewable Energy Sources



	Key Challenges	System Impact	Solutions
RE Grid Integration	Intermittency Uncertainty Inverter Characteristics Network Flexibility	Reliability Issues Stability Issues Bi-directional power flows in distribution networks Voltage and Frequency Regulation System strength and inertia	Short Term, Medium / Long Term Strategies No quick fix Develop a time-based approach for systematic implementation
Transparency and Competition	Limited transparency in Investments Limited Competition Static Energy Markets	High RE Prices Reduced RE deployment	Access to RE project info to stakeholders Establish Competitive Energy Markets / Business Models

Digitalization and Green Transition: Critical for Competitive Market & RE

Immediate Interventions: Transparency in Investments and its Monitoring



No ▲▼	Project Name ▲▼	Status ▲▼	Technology ▲▼	AC Capacity (MW) ▲▼	Category ▲▼	Planned Commercial Operation ▲▼
1	Oddamawadi Batticaloa Solar Power Project	Critical	Solar PV	100	EOI	2023-11-09
2	Monaragala Sewanagala Solar Power Project	Critical	Solar PV	60	EOI	2023-11-09
3	Punanai West Solar Power Project	Critical	Solar PV	100	EOI	2023-12-11
4	Nilaveli Solar	Critical	Solar PV	100	EOI	2023-12-11
5	Kilinochchi Karachchi Ground Mounted Solar PV Power Project	Critical	Solar PV	100	EOI	2024-05-30
6	CEP Jaffna Solar Power Project	Critical	Solar PV	50	EOI	2024-05-13
	Orbital					

Renewable Energy Dashboard

- Online Monitoring Tool
- Provide Access to relevant stakeholders

ADB Support:

- RED is ready for Monitoring
- Installed in SLSEA server
- Request MOE Support in Publishing

Digitalization and Green Transition: Critical for Competitive Market & RE

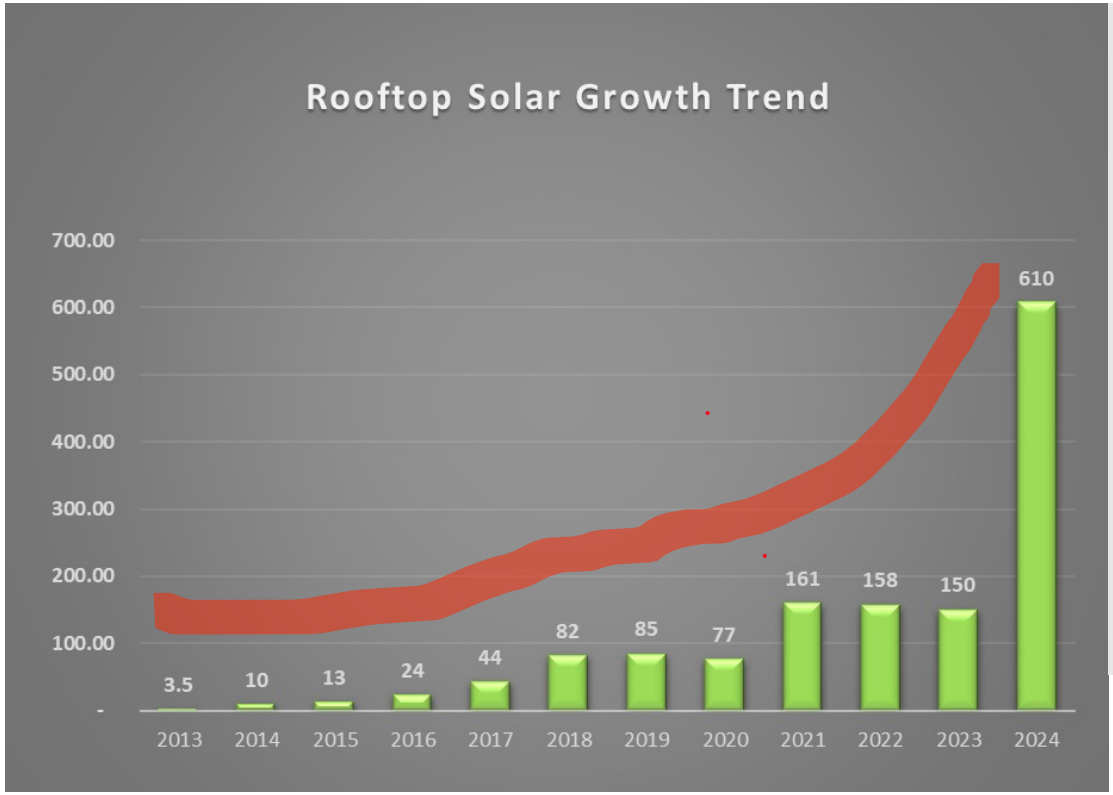
Immediate Interventions: Digitalization framework

- Develop Policy and Roadmap
- Create Clear Guidelines for future entities
- Follow international Best Practices

ADB Support:

- Draft framework being prepared working with various stakeholders
- **Urgent action required to implement the immediate Interventions**

Generation Scenario in SL : Critical Need for Digitalization



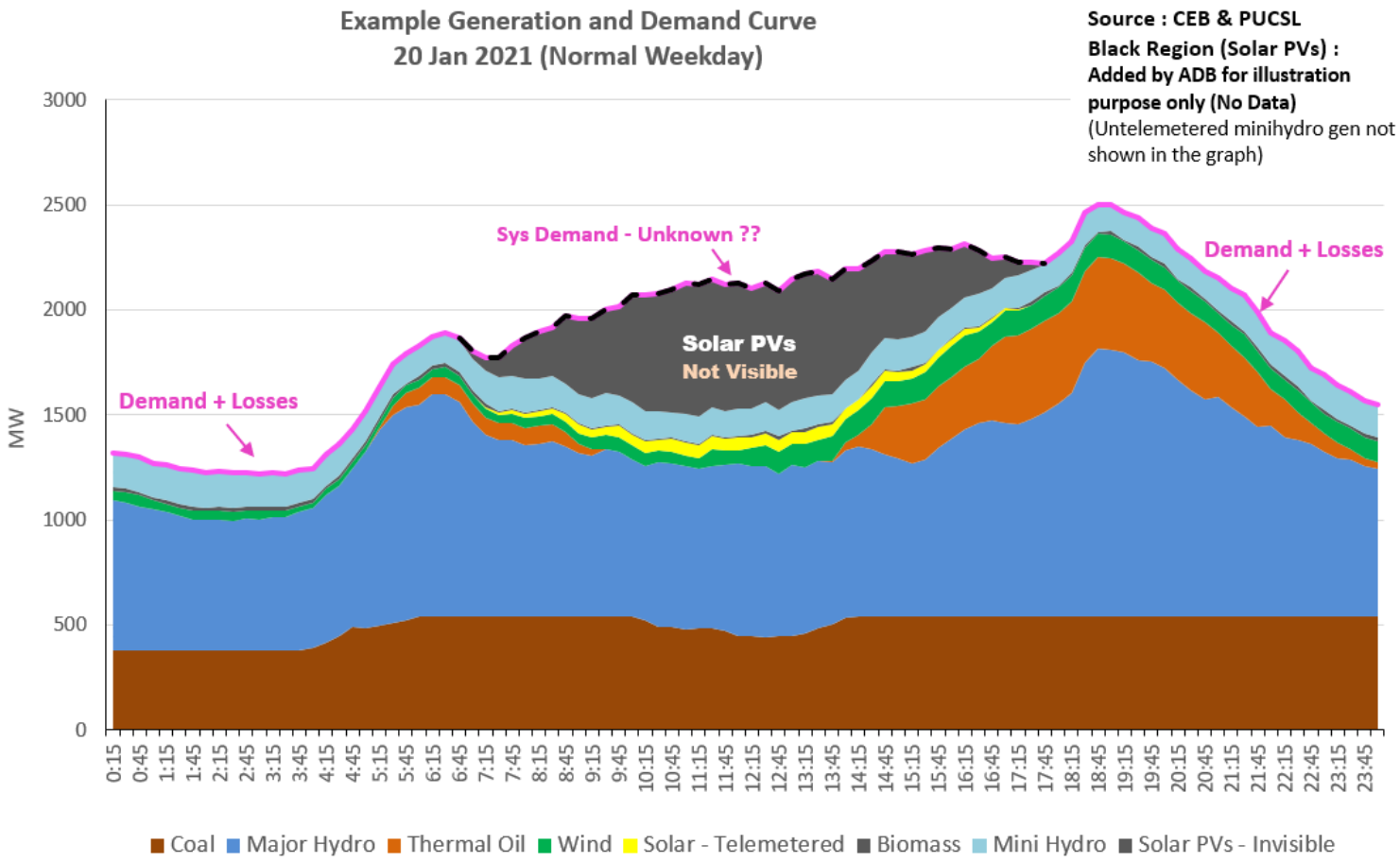
GENERATION STATISTICS

Ownership & Type of Power Station		No. of Power Stations			Installed Capacity (MW)		
		2022	2023	% Change	2022	2023	% Change
CEB :	Total	30	30	-	3,071	3,218	4.8%
	Major Hydro	18	18	-	1,413	1,413	-
	Thermal (Oil)	10	10	-	654	801	22.5%
	Thermal (Coal)	1	1	-	900	900	-
	NCRE (Wind)	1	1	-	104	104	-
IPP :	Total	321	334	4.0%	1,013	1,163	14.8%
	Thermal (Oil)	1	3	200.0%	270	387	43.2%
	NCRE (Mini Hydro)	211	212	0.5%	414	419	1.3%
	NCRE (Wind)	17	19	11.8%	148	163	10.1%
	NCRE (Other)	14	14		50	54	7.9%
	NCRE (Grid Connected Solar)	78	86	10.3%	130	139	6.9%
Total		351	364	3.7%	4,084	4,381	7.3%

2024 Rooftop Capacity : 600 MW
Total rooftop Capacity : 1,420 MW

Rooftop solar installed capacity is about 25% of the installed capacity

Generation and Demand Curve: Critical Need for Digitalization

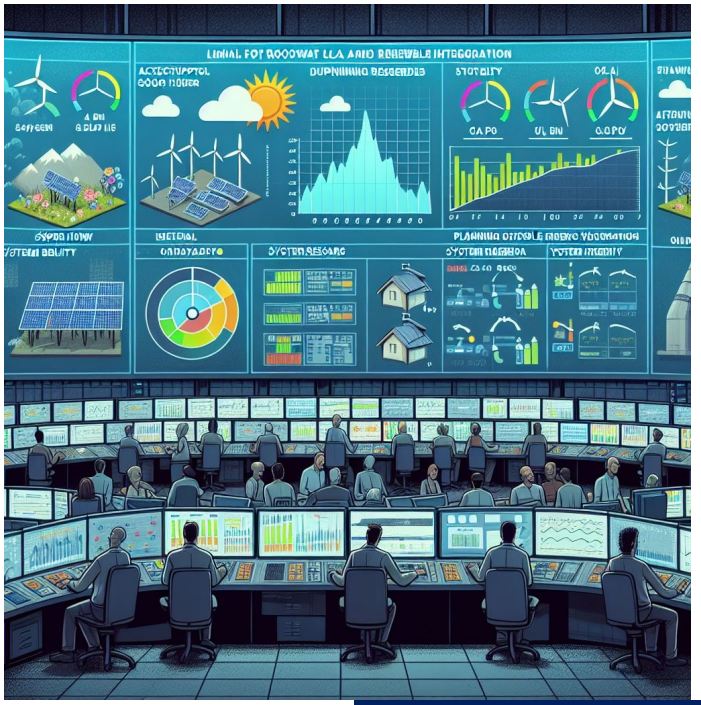


- **<u>Over 50% of day-time demand will be met through distributed RE</u>**
- **No Visibility**
- **Limited predictability**
- **Limited Control**
- **Reduced system strength and inertia**
- **Constraints on economic dispatch and maintaining system stability**

Challenges in Power System Operation : Need for Digitalization

Limited Visibility
Limited predictability
Limited Control

VS

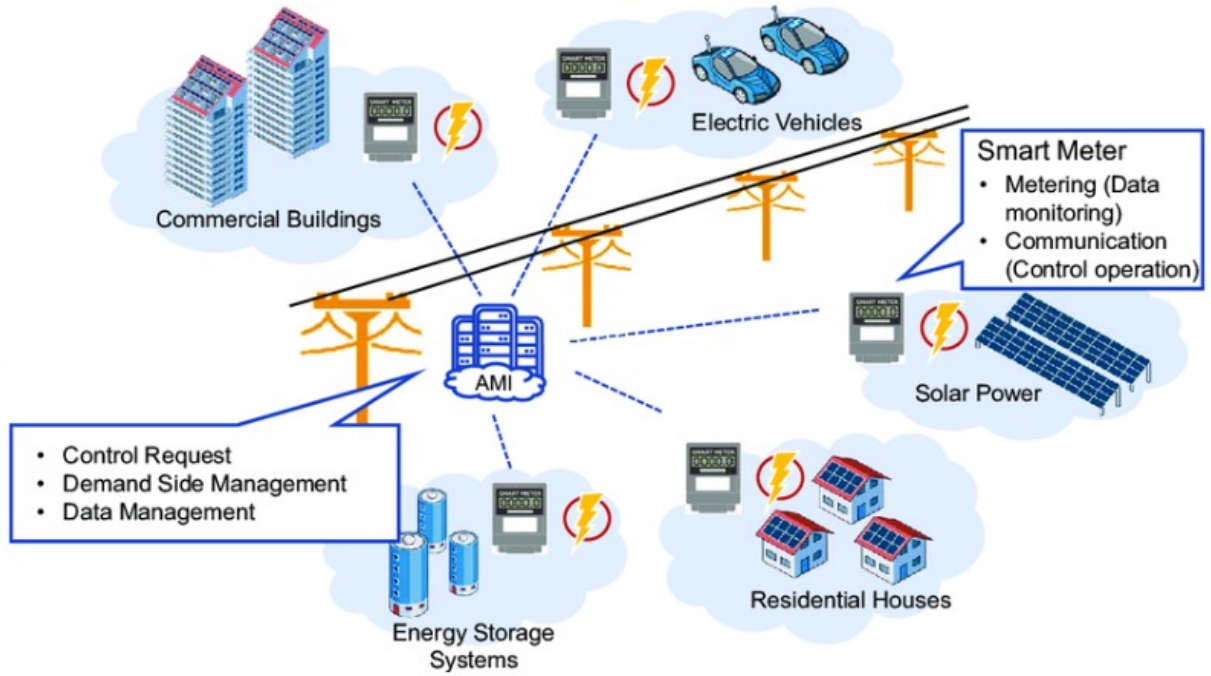


Power Grid Digital-Twins

Full Visibility
High predictability (AI driven)
Flexibility and Control

Digitalization and Green Transition: Critical for Competitive Market & RE

Immediate Interventions: Automatic Metering Infrastructure (AMI)



Smart metering configuration and functionalities.

- Smart Metering ++
- Key and first step of Digitalization
- Progressing Slow

ADB Support:

- Roadmap for AMI implementation (Draft Prepared)
- Urgent action is required to implementation

Digitalization and Green Transition: Critical for Competitive Market & RE

1 Immediate Intervention: Voltage Response Settings for PV Inverters

- Current Situation : Over voltage Tripping in LV networks with high rooftop solar penetration
- Reduced PV Utilization and hosting capacity

ADB Support:

- Committee has been formulated to recommend Voltage Response settings within the current statutory limit (230+/-6%)
- Urgent action is required for its implementation (new installations and Old ones)

2 Next step: Increase Statutory Voltage limit to 230+/-10%

- Current Situation : This is being followed in countries Like Australia and Germany complying with international standards.
- Further consultations with Sri Lanka Standards Institution and other stakeholders are required
- Committee shall continue to work towards it.

NSO Modernization and Digitalization:

Immediate to medium Term Interventions:

1 Renewable Energy Center (REC) for NSO Operations

- Immediate: Prepare technical specifications covering modern technologies and international best practices including AI-DT (digital Twinning)
- Medium: Investment to support development of REC

2 Battery Energy Storage Solutions (BESS)

- Immediate: Prepare technical specifications and bid documents for Grid Scale BESS
- Identify BESS requirements in distribution system to manage power quality issues and improve hosting capacity
- Medium: Investment to support deployment of BESS

ADB Recently approved Loan has allocation to support both development of renewable energy Center and Grid scale BESS

ADB's Support on Futuristic Digitalization and Distributed Generation

Digital Microgrid Pilot with Universities

Project : AI-Powered Microgrids to Enable a Futuristic and Reliable Distributed Renewable Energy System

Implementing agencies : LECO

Design Team: UoJ, UoM, UoP, UoR

Key Outputs :

Develop, Establish and Pilot Test ; (a) Digitilization-framework for microgrids (b) AI-based network management platform (c) Lifeline power market through Microgrid (d) Enhancing PV hosting capacity through BESS and Voltage Regulating Equipment

Status : In Progress

Network Upgrading to facilitate RE, Grid Scale BESS, RE Control Centre and Virtual Net Metering

Project : Power System Strengthening and Renewable Energy Integration Project

Implementing agencies : CEB, LECO

Key Outputs :

(a) Tx and Dx grid development and modernization to facilitate RE integration **(b) Implement Grid-scale battery energy storage system (50 MWh)(c) Establish Renewable Energy Control center**

Status : In Progress

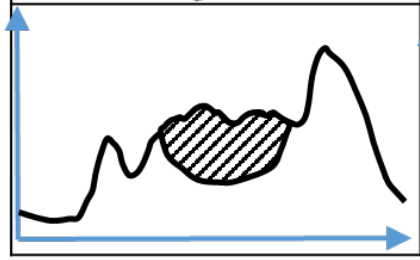
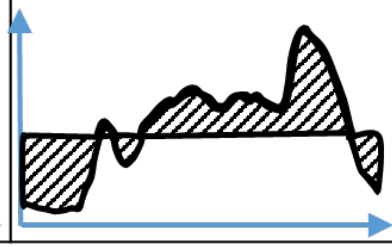
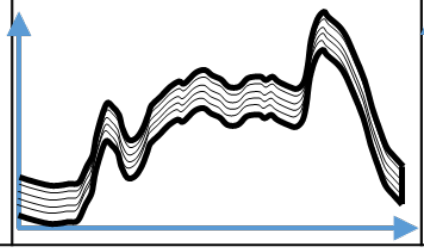
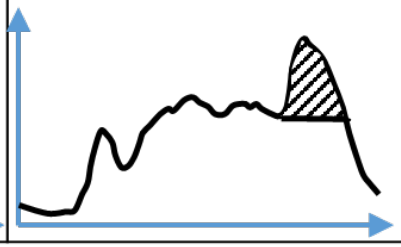
Project : Virtual Net Metering Project (concessional loan and grant funding)

Key Outputs : **(a) Virtual Net-Metering System** to develop a utility-driven aggregator rooftop PV business model **(b) Establish Social Compensation Electricity Pool** through VNM

Status : Being Processed (Support from EU and JFJCM)

Digitalization : Critical for future Distributed Generation

The Outcomes of DIGITALIZATION is Critical for Distributed Generation:

Distributed Generation	Distributed Storage	Demand Reduction	Demand Response
			
			

Thank You