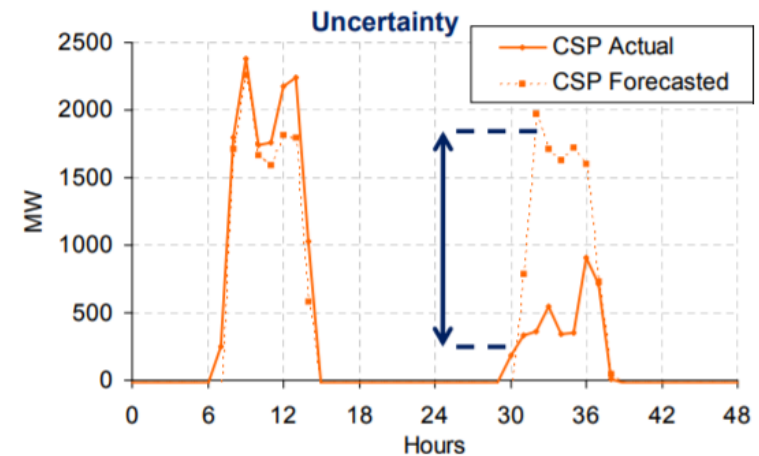
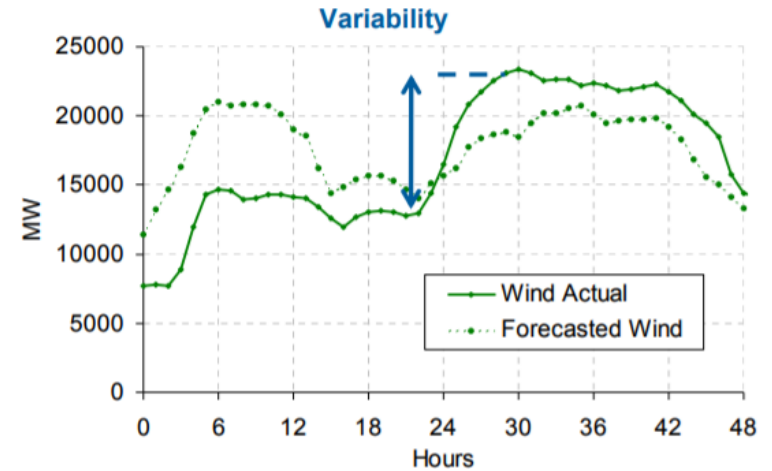


Variable Renewable Energy Integration in Central America

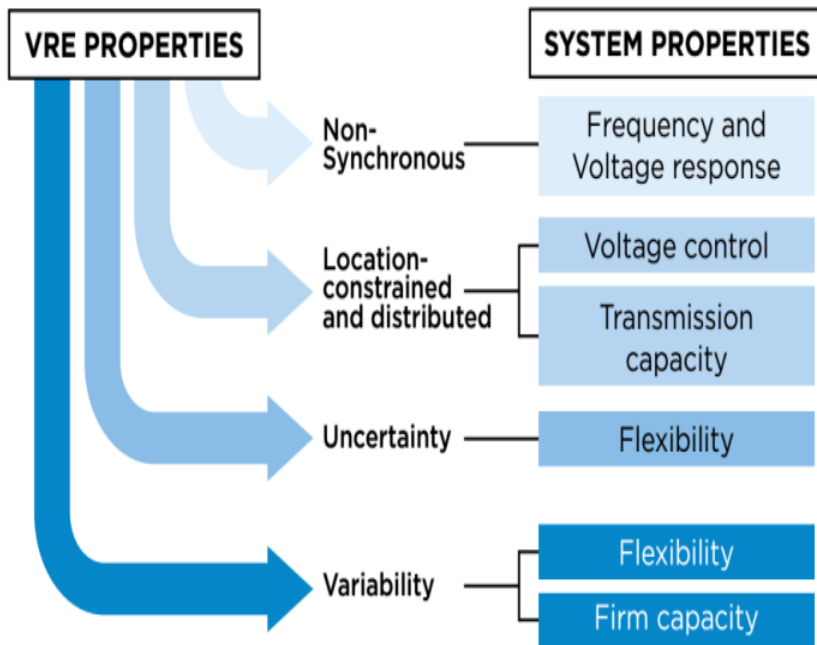
Important Characteristics of VRE That Matter

- **Variability**
 - The expected change of power output, due to the variability in the available primary resource (radiation or wind speed) occurring over time.
- **Uncertainty**
 - Inability to perfectly forecast the output from renewable energy resources.
- **Location constrained**
 - Availability of renewable energy resources are not uniform across all geographical locations.
- **Non-synchronous technologies**
 - VRE interface with grid using power electronics, which decouples the power source from grid dynamics.



Source: NREL

How VREs impact the system?



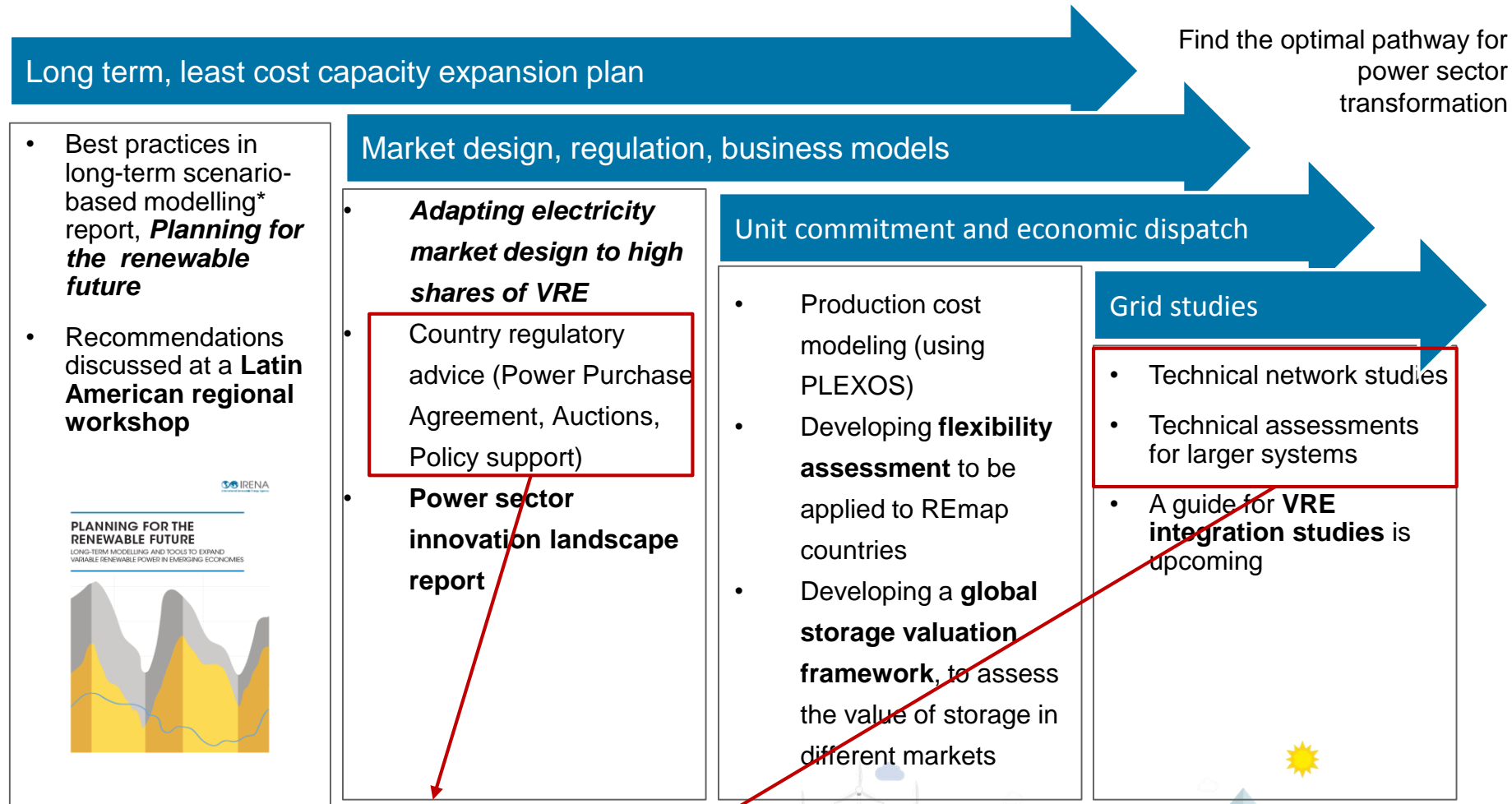
VRE = Variable Renewable Energy generation like solar PV or Wind Power

- Historically power systems were mostly based on conventional synchronous generators.
- Together with the network infrastructures, they provided all the services required to operate the system at given reliability and power quality levels.
- Solar and wind have different technical characteristics than conventional generators and can therefore bring new challenges when they are integrated in the electricity supply mix
- The system should have sufficient **'flexible' resource** in order to integrate VREs
- **Flexibility** of the power system refers to the ability of generators in the system to effectively balance the variations that in occur in demand and generation.

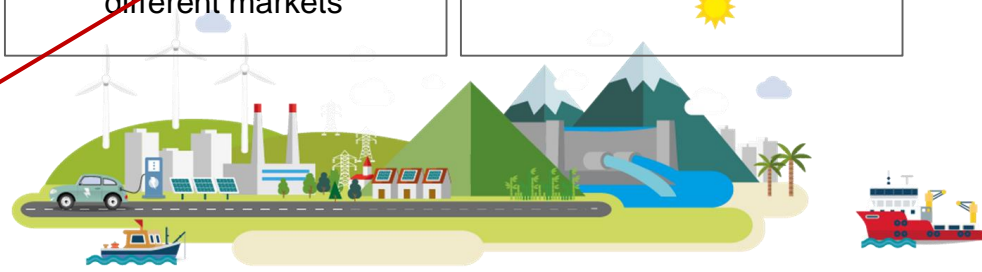
How can VRE Integration Studies help?

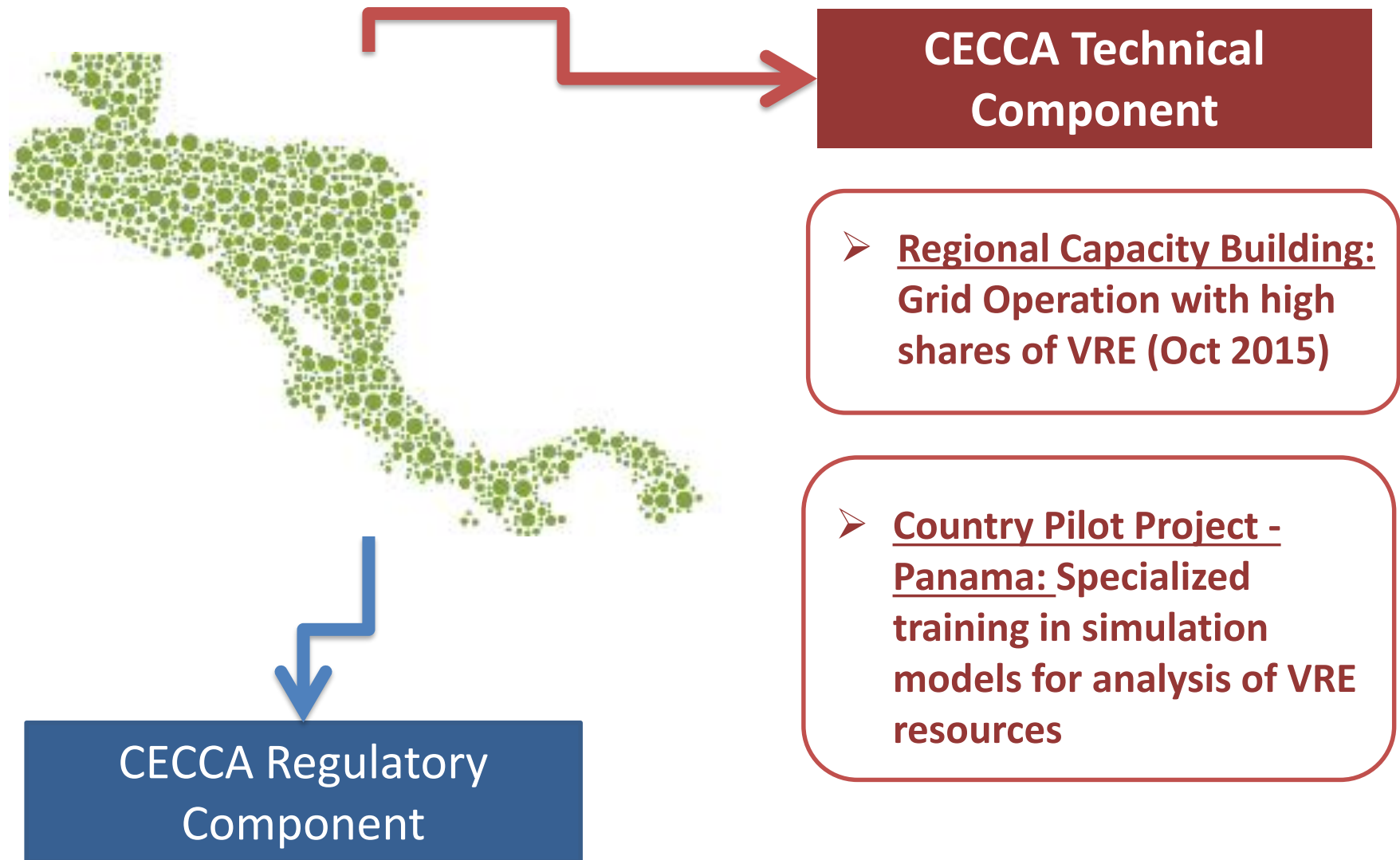
- VRE Integration Studies helps in addressing some of the most important questions in deploying VRE:
 - How much VRE can be safely deployed in the grid?
 - What are the technical impacts of deploying significant amounts of VRE?
 - How does VRE impact energy markets and power system economics?
 - What strategies are the most effective in integrating renewables?
- The scope of VRE Integration Studies varies:
 - Power System Economics, Regulatory Frameworks, RE Policies
 - Market Design, Generator Dispatch, Grid Balancing
 - Network Studies: Transmission & Distribution system studies
- It is very important to clearly define the scope and expectations of grid integration studies.

VRE Integration work at IRENA – in the context of the CECCA initiative



Past and Ongoing Activities under the CECCA initiative





Capacity Building for System Operators of Central America

- Training course in operation of electricity systems with high shares of variable renewable energy, Madrid, 5-9 October 2015
- Conducted by experts from REE. REE is the Transmission System Operator (TSO) of the Spanish electricity system.
- Course focused on best practices, strategies and the use of tools in the system operator control room regarding the operation of power systems with medium to high penetrations of VRE.

Best Practices in VRE Integration

- Generation predictability and variability,
- Fault Behavior,
- Dispatchability
- VRE curtailment

Visibility, situational awareness and controllability of VRE generation

- Decision support systems
- PMUs
- Control center structure and telemetry,
- Voltage control
- Balancing services

Forecasting VRE

- Probabilistic reserve planning

Implementation of the Technical Component

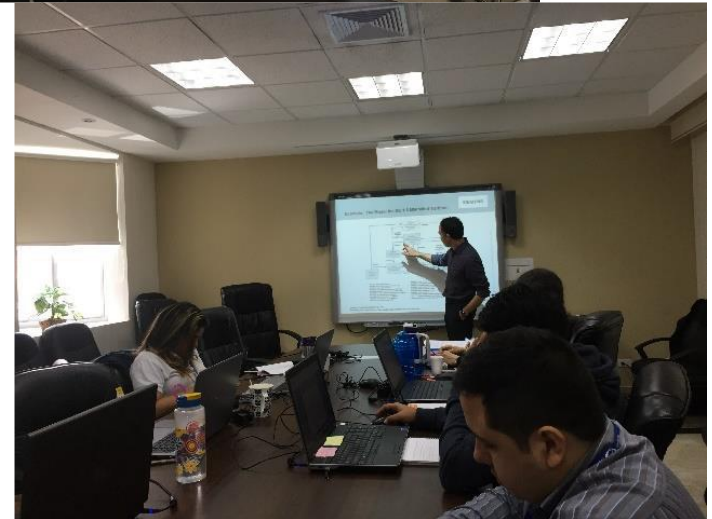
Panama Pilot Project



- Areas identified in the Gap Analysis:
 - **Specialized training to CND analysts** in using simulation models for analysis of VRE resources
 - **VRE generation forecast systems** and improvements to the operational and planning process
 - **Quantitative evaluation of system flexibility**

Capacity Building for Grid Integration - Panama

- **Title:** Modelling of Renewable Energy and Application on Power System Studies
- **Target Audience:** Power System Operators and Planners from Panama
- **Focus:** Network analysis software (PSSE) to assess the impacts of the integration of high shares of VRE
- Topics Covered in the training
 - Wind Farm modeling
 - PV Types and modeling
 - Load flow analysis
 - Stability Studies (transient, voltage management, etc.)
 - Interconnection requirements: codes, requirements and studies



Integration studies in association with energy authorities and network operators supporting evaluation of impacts and Operation & Expansion planning of the grid

Concluded Grid Studies

- Palau
- Samoa
- Antigua and Barbuda
- Cook Islands

Ongoing/Planned 2018

- Vanuatu
- Fiji
- Dominican Republic
- Cuba

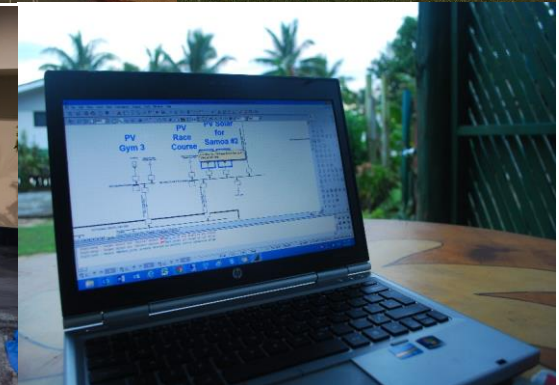


Exchange of Experience and Capacity Building

- Technical workshops and webinars with partners in the Caribbean, Pacific, Panama technical guides and global access to software tools

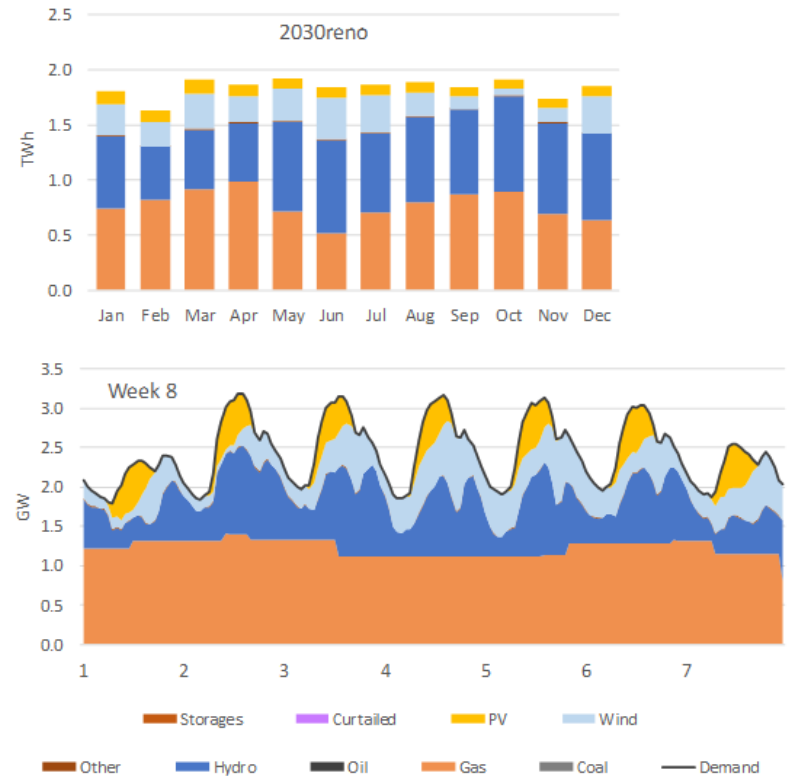
Capacity Building in Grid Integration

- ✓ Webinars and technical workshops in partnerships with regional organizations in Panama, Pacific Power Association and CARILEC
- ✓ Global access and support in use of stability analysis software DigSilent, PowerFactory and PSSE
- ✓ Guides on grid stability and technical assessments for grid integration planning



Flexibility Analysis of the Power System

- An electric power system is flexible if it can:
 - Maintain the balance between generation and demand at all times
 - Dispatch all (or most) of the existing VRE on the system, avoiding curtailment
- IRENA FlexTool is used to analyze the flexibility of the system.
- IRENA FlexTool
 - Dispatch + Capacity Expansion
 - Some Solutions:
 - Interconnection
 - Demand side management
 - Storage (hydro, batteries)
 - Electric Vehicles
 - Power-to-X



- Which aspects of flexibility to consider?
 - Ramp rates, Minimum load levels, Start-up times, Storage, Interconnectors, Demand response

Flexibility Assessment: Panama Case Study

– Preliminary Results

Conclusion:

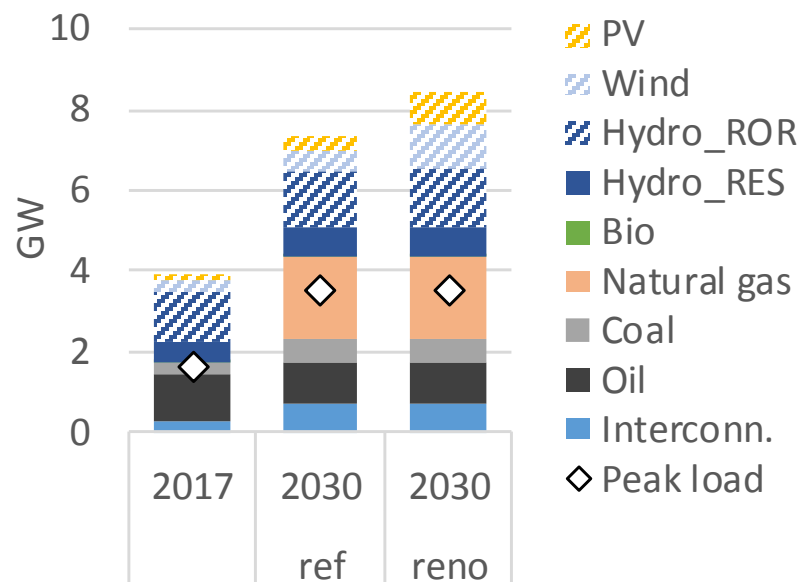
No flexibility issues identified in 2030 reference or 2030 renewable scenarios.

Opportunities:

Annual operation costs of renewable scenario are 20% lower than in the reference scenario.

Risks:

New thermal generation capacity replaces the old thermal generation in the plans. The new capacity has still low full load hours. This might create challenges for economical operations of both new and old thermal capacity.

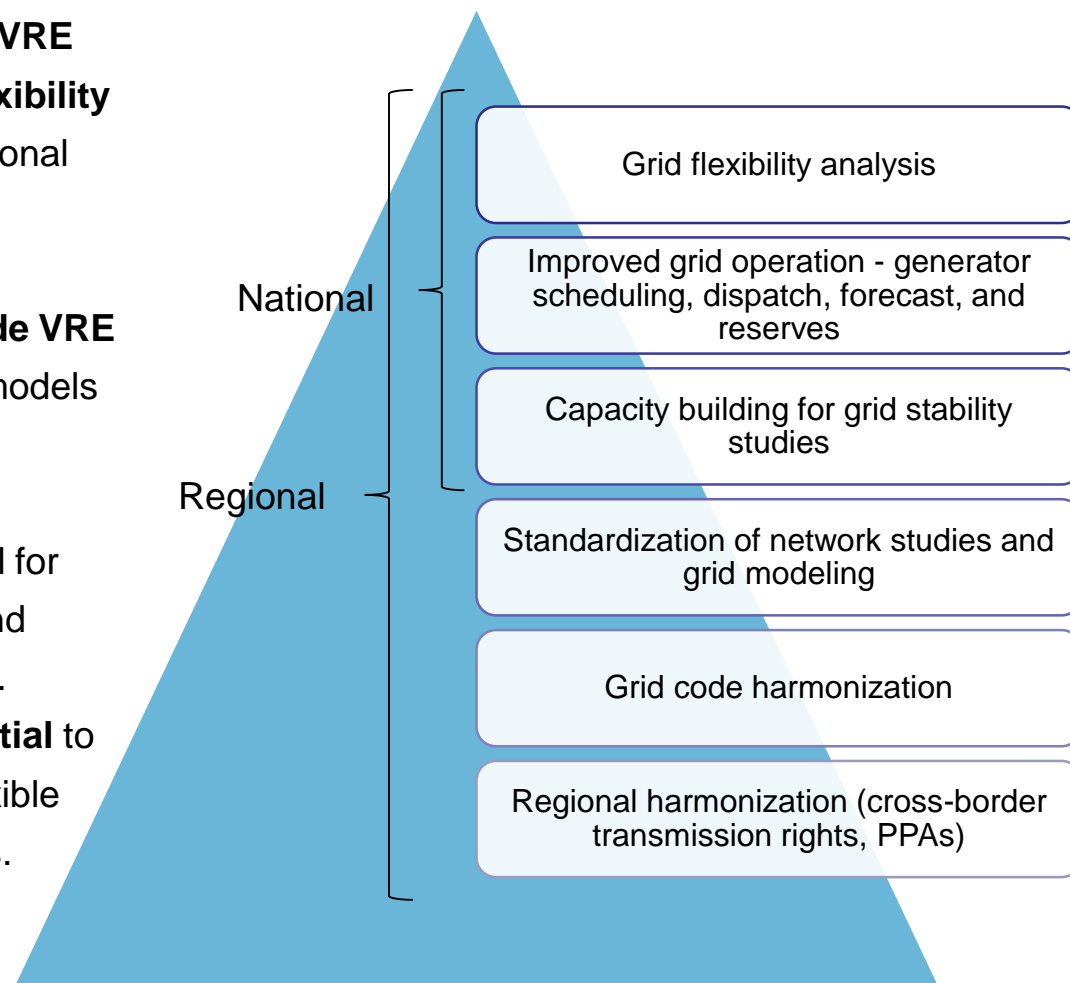


Sensitivity analysis - studied cost-effectiveness of additional solar PV.

FlexTool finds that it is economically-optimal to invest in additional 1.5-2GW of solar PV

VRE Grid Integration – The way forward

- Technical and economic **impacts of VRE integration** including **generation flexibility have to be analyzed** at both the regional and national level
- **Grid stability studies should include VRE** and must use standardized generic models for network simulation
- **Regional harmonization** is essential for effective integration of renewables and stable operation of the power system.
 - **Regional integration is essential** to mitigate impacts by sharing flexible generation assets and reserves.





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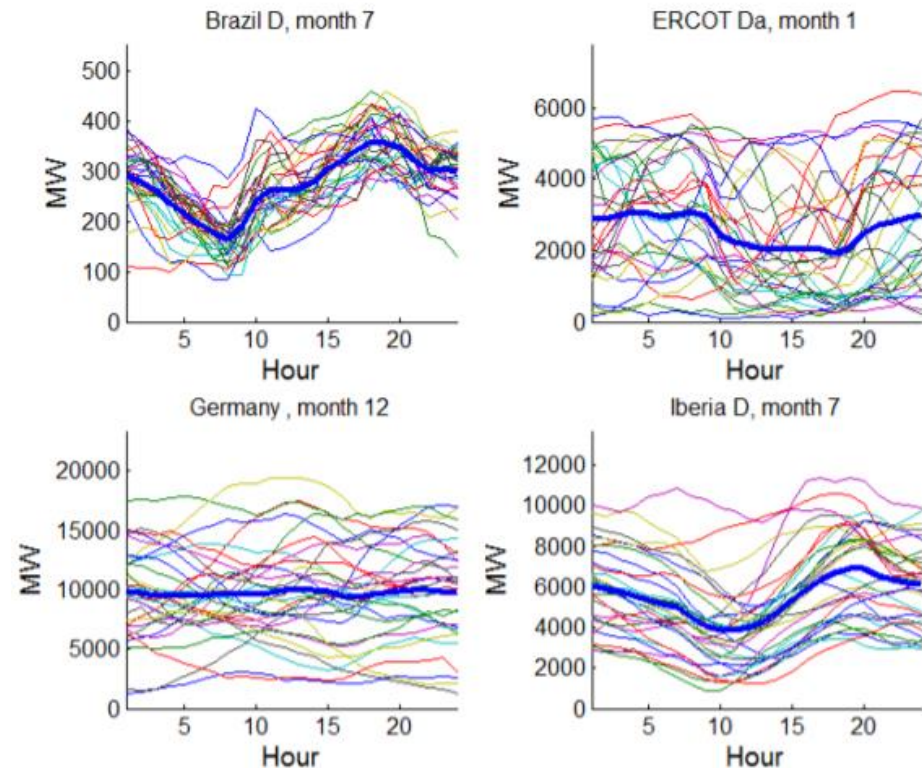


www.youtube.com/user/irenaorg

BACKUP SLIDES

Variability: Output of VRE plants depends on the availability of the resource

- The output from VRE plants depends on the resource availability, which is impacted by weather patterns and is constantly changing.
- The variability affects the minute to minute operation of the power system.
- Energy planners have always had to deal with variability and uncertainty to some extent, but the challenges that variable renewable energy (VRE) poses to the power sector are in many ways distinct.
- It requires grid operator to perform more complicated voltage and frequency regulation. The higher the VRE penetration is, the more complicated (sometimes impossible) to manage.

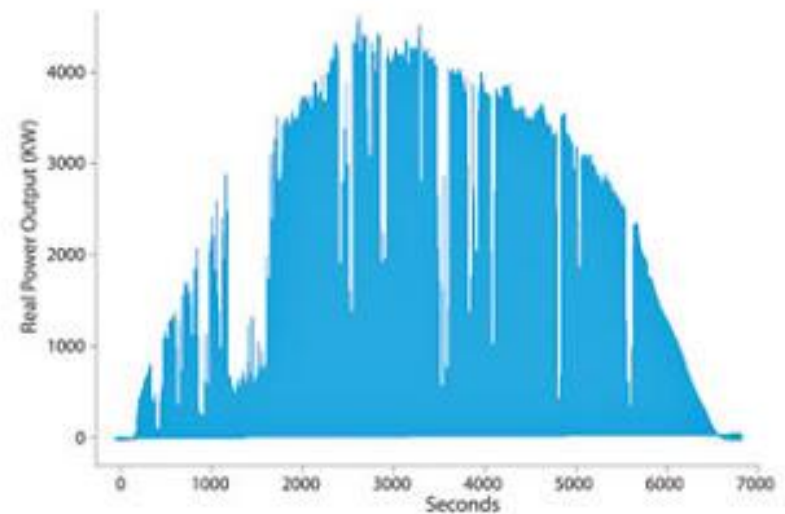


Source: [iea.org - https://www.iea.org/media/training/presentations/latinamerica2014/7B_8B_9B_Grid_Integration.pdf](https://www.iea.org/media/training/presentations/latinamerica2014/7B_8B_9B_Grid_Integration.pdf)

Uncertainty: Output from VRE plants are difficult to forecast

- Output from VRE are very difficult to forecast with perfect accuracy.
- The difficulty in forecast creates uncertainty in managing the power systems and scheduling generators.
- The system needs sufficient resources in the system that are flexible enough to manage the uncertainties created in the system.

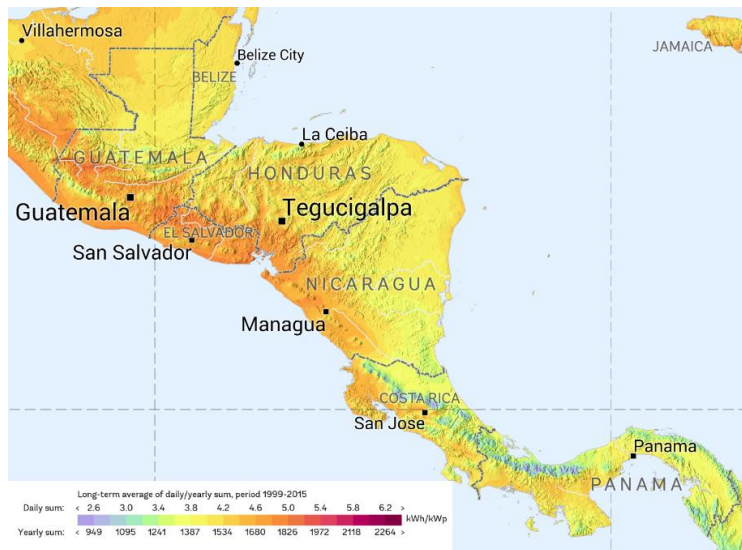
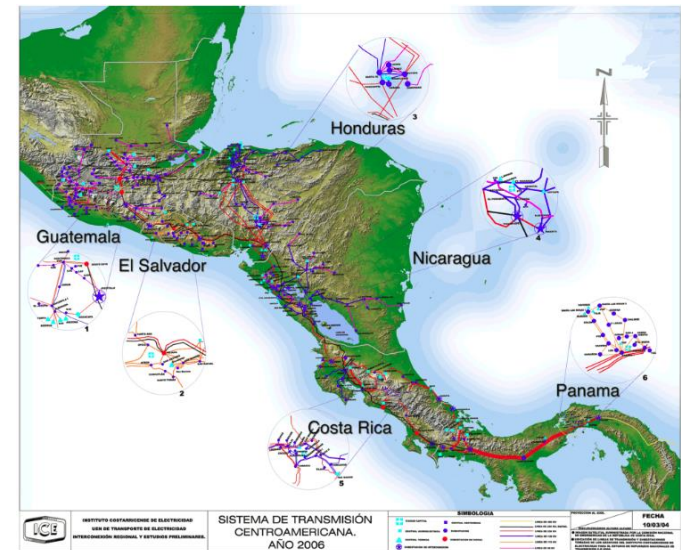
Real power output of a 4 MW PV power plant



SOURCE - EPRI

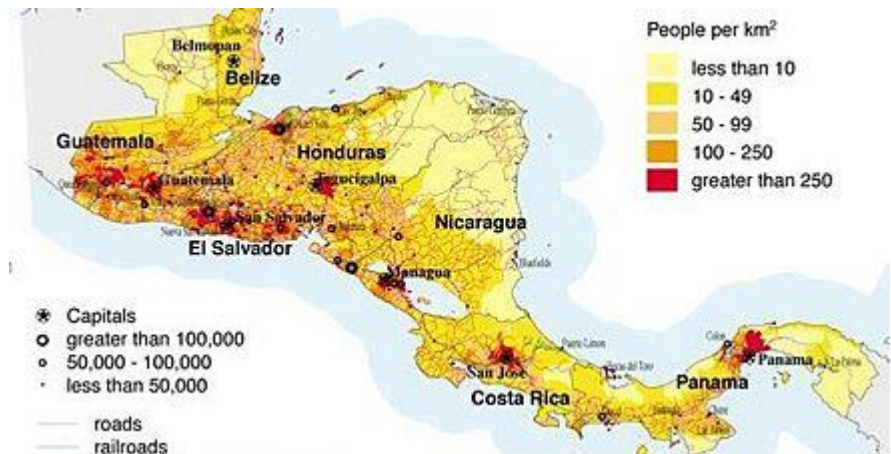
Location Constrained

- VRE generators can be constrained by the availability of renewable energy resources and might require significant network extensions or lead to network congestions.
- The modularity of VRE technologies also means that they can be deployed at very small scales in distribution grids, which were historically not designed to accommodate power generation.



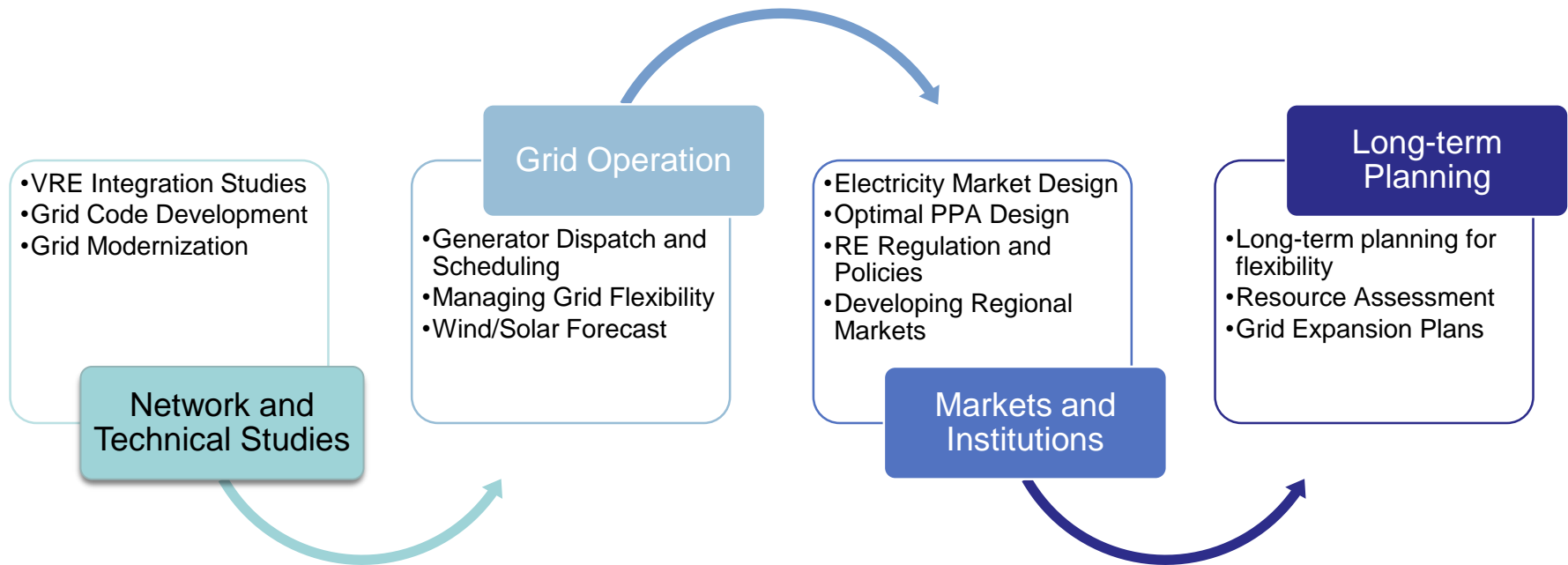
Solar Resource
(Source: Global Solar Atlas)

Population
(Source: World Population Review)



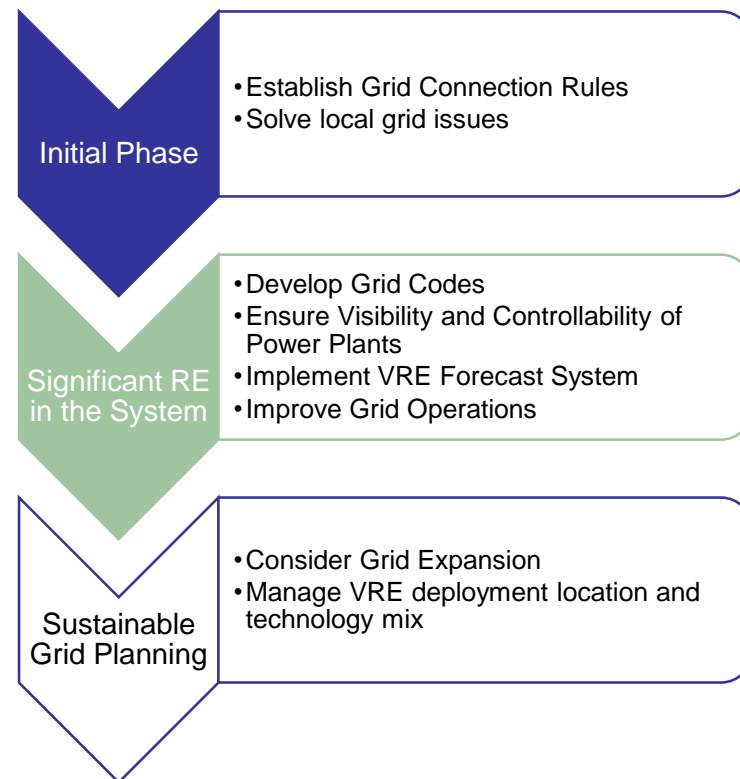
Transmission network
(Source: USAID)

What Have to be Done to Deal with VRE Impacts?



Different phases of RES integration

	Initial Phase	Significant RE in the system
Characterization from a system perspective	VRE capacity is not relevant at the all-system Level	Flexibility becomes relevant with greater swings in the supply demand balance
Impacts on the existing generator fleet	No noticeable difference between load and net Load	Greater variability of net load. Major differences in operating patterns;
Impacts on the grid	Local grid condition near points of connection, if any	Significant changes in power flow patterns across the grid; increased two-way flows between HV and LV grids
Main Challenges	Local conditions in the grid	Availability of flexible resources



- **Grid reinforcement**
 - **Reinforcement and Expansion of the transmission grid** to optimally utilize geographically diverse resources.
 - **Stronger regional interconnection** is crucial to mitigate impacts by sharing flexible generation assets and reserves.
- **Grid Modernization**
 - **Advanced SCADA** - the grid control systems have to be modernized to enable the real time monitoring and control of VRE from dispatch center.
 - **Better telemetry for real-time Communication network** has to be deployed.
 - **Smart Grid deployment** to support distributed generation, demand response and energy storage

Grid Integration Case Study: Antigua and Barbuda

- Study identified the technical limits to the variable renewable energy shares with the current infrastructure and operational practices of the power utility
- The results of the study demonstrated that the implementation 9 MW of solar PV, planned by the government for the following years, is feasible from the prospective of the grid operation and reliability
- The results helped to dispel the doubts of the power utility (APUA) to move forward with the planned PV projects.
- In 2016 the first 3 MW of PV power were commissioned.

