PROGRAM SUMMARY REPORT JULY 2024

Accelerated Energy Storage Deployment in RELAC Countries

Renewables in Latin America and the Caribbean (RELAC)[1] is a regional initiative across Latin America and the Caribbean (LAC) created in 2019 within the framework of the United Nations Climate Action Summit, with the objective of reaching at least 70% of renewable energy installed capacity and 80% of the region's total electricity generation from renewables by 2030.[2]

16 countries are members (**Figure 1**), with others in discussions to join. RELAC provides:

1. Support for addressing technical and financial needs to increase renewable energy penetration
2. Matchmaking with financial resources to support capacity building needs and implementation of renewable energy expansion plans
3. Knowledge exchange via peer-learning and best practices in renewable energy integration to the electrical grid.

Background

Achieving 80% or more renewable energy generation by 2030 will require RELAC countries to manage many complex technical challenges. Effective integration and use of energy-storage technologies will be a key enabling factor for balancing increasing levels of variable renewable energy, providing ancillary services, and ensuring the stability, uptime, reliability, and resilience of the electric grid.

Figure 1. Map of RELAC countries. *Image by Nate Blair and Andrew Bilich, NREL.*

In the last decade, battery energy storage costs declined 88% —a greater decline than any other renewable energy technology over the same period—and those costs are projected to decline even further over the next few decades (**Figure 2**).[3] While the energy storage sector has made significant advances in markets like the United States and Europe, in RELAC countries, it is still nascent.

In fact, almost 93% of the over 15 GW of global cumulative energy storage capacity deployed from 2015 to 2021 was deployed in China, the United States, Europe, South Korea,

[1] See https://hubenergia.org/en/relac.
[2] Target was updated by member countries in November 2023.
[3] NREL "Energy Storage Futures Study" (2022); Available at: https://www.nrel.gov/docs/fy22osti/81779.pdf

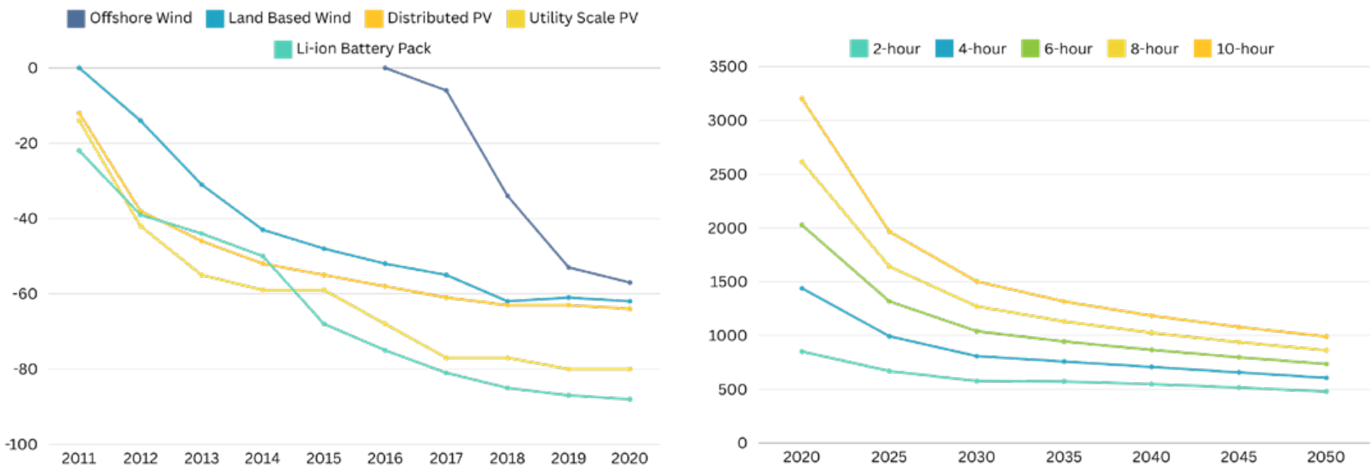

Figure 2. Decline in energy storage and renewable energy costs

and Japan, leaving just 1.1 GW in the rest of the world (including the RELAC countries).[4] A 2021 Inter-American Development Bank (IDB) report estimated that 111 MW of storage capacity is installed in LAC countries and an additional 87 MW is planned—far below the capacity needed to reach renewable energy goals.[5] This highlights a critical need to build technical capacity, awareness of new technologies, and state-of-the-art industry knowledge to foster an overall enabling environment for energy storage in LAC. These factors will accelerate optimal deployment and use of energy storage, maximizing the regional potential for renewable energy.

Program Overview

To address the regional need for energy storage planning and regulatory support, the National Renewable Energy Laboratory (NREL), in collaboration with the Global Climate Action Partnership (GCAP) and the Inter-American Development Bank (IDB), implemented a program to support the development of country-specific energy storage action plans for RELAC countries, driving investment and policy action that accelerates deployment of energy storage across the region.

The objectives of the program were to:

1. Enhance technical capacity for planning, deploying, integrating, and operating energy storage solutions for key stakeholders and decision makers in RELAC countries
2. Support planning for increased ambition in energy storage policymaking and planning across RELAC countries
3. Provide tailored technical assistance to help mobilize and accelerate the implementation of specific energy storage projects, initiatives, or regulations in RELAC countries
4. Build a network of energy storage stakeholders across RELAC to support peer-to-peer knowledge exchange and learn from regional successes
5. Create recorded materials that can be shared with others throughout the LAC region, helping to increase peer-learning and knowledge transfer.

To accomplish these objectives, the project implemented three interrelated components:

- **Energy storage workshop series:** Technical capacity-building workshop series focused on training key stakeholders and decision makers from RELAC countries on a broad spectrum of topics related to energy storage.
- **NREL site visit:** Site visit to the NREL campus to facilitate in-person regional dialogue, deepen engagement with NREL storage experts, deep dive into country-specific action plans, and provide awareness of NREL's other areas of renewable energy research and tools.
- **Country-level technical assistance for energy storage:** Direct technical assistance to strengthen and advance countries' energy storage action plans.

The specific approaches and impacts of each component are discussed below.

Workshop Series

Over the course of six months in 2023, RELAC conducted a series of seven technical workshops across a broad spectrum of topics related to energy storage. The seven technical workshops were attended by 96 stakeholders (mostly energy ministries, regulators, and other policymaker staff) across 14 RELAC countries (**Table 1**).

[4] International Energy Agency. 2022. "Annual grid-scale battery storage additions." Last modified August 30, 2022. https://www.iea.org/data-and-statistics/charts/annual-grid-scale-battery-storage-additions-2016-2021.

[5] Graham, Nate, Edwin Malagón, Lisa Viscidi, and Ariel Yépez. 2021. *State of Charge – Energy Storage in Latin America and the Caribbean*. Washington, D.C.: IDB. https://publications.iadb.org/publications/english/viewer/State-of-Charge-Energy-Storage-in-Latin-America-and-the-Caribbean.pdf.

Table 1. Overview of RELAC Energy Storage Workshops

Workshop	Summary
Workshop 1: Summary of Energy Storage Technical Applications and Planning *April 24, 2023*	Overview of energy storage technologies and concepts, NREL's storage and analysis tools and support capabilities, phases of storage deployment, the role of storage in the power system, and road maps for incorporating energy storage technologies to strengthen the penetration of renewables. (44 participants)
Workshop 2: Virtual Power Plants, Long-Term Storage, and Experiences of U.S. System Operator CAISO *May 16, 2023*	Overview of virtual power plants and long-term storage, including applications and requirements for an enabling regulatory environment and deep dive into how the California Independent System Operator (CAISO) uses energy storage technologies to improve power system flexibility in California. (43 participants)
Workshop 3: Deep Dive into Energy Storage Modeling Tools *June 6, 2023*	Deep dive into NREL's System Advisor Model[7] and how it can be used to model stand-alone and photovoltaic-coupled energy storage systems, as well as NREL's Storage Deployment Optimization Model (SDOM)[8] and how to model long-duration storage and storage optimization for power system planning. (42 participants)
Workshop 4: Economics with Storage Systems IDB Case Studies on Energy Storage Investments and Projects *June 27, 2023*	Overview of the economics of energy storage with a specific focus on financing battery storage resources. Case study of IDB energy storage investments—Bolivia's energy storage hybrid systems. (42 participants)
Workshop 5: Planning Regulatory Issues and Technical Standards *July 25, 2023*	Case study of providing ancillary energy services through battery storage in the Bahamas; overview of considerations of large-scale energy storage in the context of resource planning; case study of addressing regulatory issues for energy storage to solve network congestion in Colombia. (40 participants)
Workshop 6: Regulatory Frameworks and Ancillary Services *August 8, 2023*	Discussion of enabling environments for energy storage in RELAC countries, including a guided activity for attendees to evaluate their own countries using the energy storage readiness assessment.[9] Modeling ancillary services in energy storage using NREL's Sienna platform[10]; case study of the energy storage regulatory framework in Barbados (Fair Trading Commission–Barbados). (43 participants)
Workshop 7: Regulations, Policies, and Codes/Standards for the Management of End-of-Life Energy Storage *August 28, 2023*	Overview of the draft IDB tool for assessing regulatory frameworks for energy storage; deep dive into regulatory and policy considerations for reuse and end-of-life solar energy batteries in the United States; reuse, recycling, and safety of lithium-ion batteries. (59 participants)

Nearly all participants highlighted the high quality of the workshop series and said it focused on topics that were relevant and interesting to their work and country challenges. The majority of participants (>90%) also indicated an improved or greatly improved knowledge base and awareness across a variety of technical energy storage topics (**Figure 3**).[6] Ultimately, the webinars not only helped build this technical capacity and awareness, but also informed the development of the final country action plans and associated technical assistance support.

Site Visit

In October 2023, 24 participants from across 11 RELAC countries, as well as staff from IDB and the Global Energy Alliance for People and Planet (GEAPP), attended a 1-week intensive site visit to NREL's Colorado campus (**Figure 4**). The visit included tours of NREL facilities and research labs as well as technical presentations from NREL experts on a variety of topics both related to energy storage such as: storage regulation, regional cooperation, energy storage for transmission and ancillary services, long-duration storage, hydrogen, among others, as well as topics on the broader clean energy sector (e.g. wind/solar energy systems, electric vehicles charging and integration, smart buildings, grid insights and system operations, and agrivoltaics).

Additionally, countries had extended one-on-one technical sessions with NREL experts working to develop and refine their individual country energy storage action plans and scope/advance technical assistance projects (see technical assistance section below). By the end of the visit, all 11 countries had developed or refined specific action plans for energy storage, including priority action areas, that they then presented to their regional peers.

[6] Participation survey conducted in September 2023. 37 responses (39% response rate) mostly from participants who attended multiple workshops.
[7] See https://sam.nrel.gov/.
[8] See https://github.com/NREL/SDOM.
[9] See https://www.nrel.gov/docs/fy21osti/78197.pdf.
[10] See https://www.nrel.gov/analysis/sienna.html.

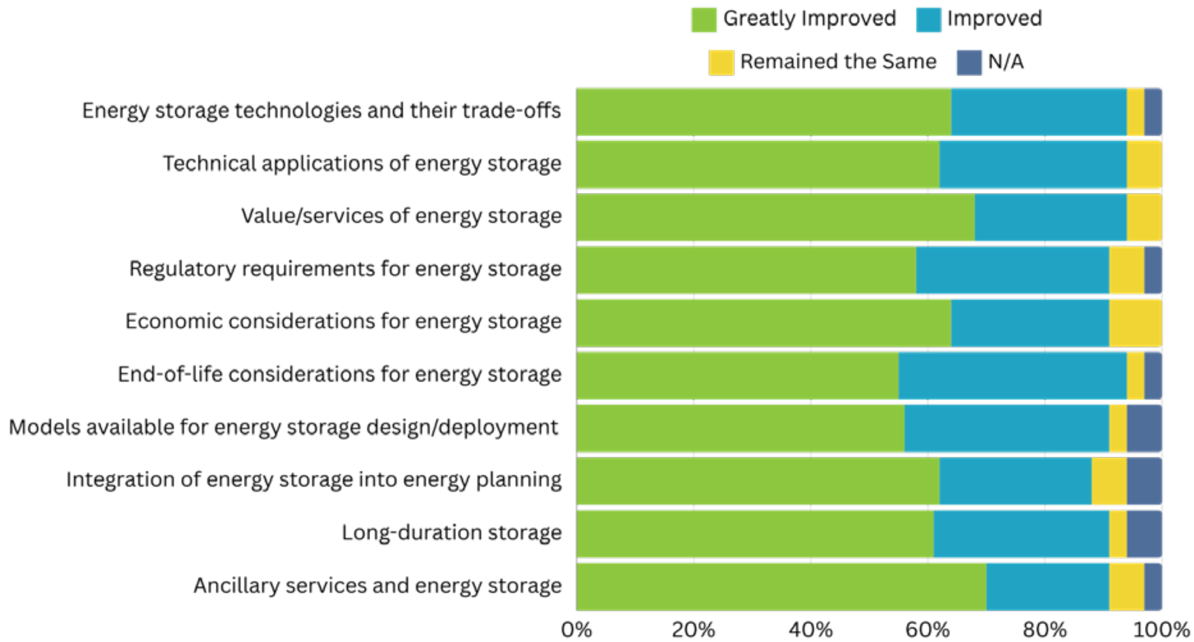

Figure 3. Change in energy storage knowledge/awareness. *Image by Andrew Bilich, NREL.*

These action plans highlighted several common focus areas across the countries, including amending grid codes to better support energy storage, techno-economic assessments and modeling energy storage integration into national grids, capacity building for evaluating energy storage in national energy planning, and support for procurement and request-for-proposal processes for energy storage. Individual country action plans are summarized in **Table 2**.

Overall, participants highlighted the presentations on energy storage and NREL research, one-on-one support from NREL experts, and tours of NREL facilities as the most valuable elements of the NREL visit. Among other benefits, participants highlighted that the visit helped them identify new energy storage concepts, ideas, and opportunities to incorporate into action plans; build an understanding of their country's gaps and needs for energy storage; understand new tools; develop new contacts; receive support for modeling or pilots; and broaden/clarify the scope of collaboration with NREL and the broader RELAC network.[11]

Technical Assistance

NREL also provided technical assistance support to the RELAC countries that participated in the energy storage program. Generally, the technical assistance focused on direct energy storage modeling and analysis support (including capacity building for modeling platforms) or regulatory enabling conditions for energy storage, as detailed below.

Energy Storage Potential Estimates

NREL used SDOM,[12] an open-source modeling tool for assessing the operation and deployment of energy storage, to develop initial modeling for Uruguay, Peru, and El Salvador to assess different scenarios for energy storage that support renewables integration, reduce curtailment, and increase grid stability through 2050. The modeled scenarios were developed using key inputs from the individual ministries of energy in the respective countries.

For this initial analysis, imports/exports were ignored to enable a streamlined assessment of renewable energy and storage potential, leaving all other things equal. Increased generation of renewables can potentially enable greater export to neighboring grids, but as those grids are also developing more renewables, there is increased opportunity

Figure 4. RELAC participants for NREL site visit

[11] A summary video from the visit can be found at: https://www.youtube.com/watch?v=BEzB6ieWcyg.
[12] See https://github.com/NREL/SDOM.

Table 2. Country Energy Storage Action Plans

Country	Summary of Priority Action Items for Energy Storage
Barbados	• Amend the grid code to better support energy storage, ensuring key communication standards and requirements for grid modernization • Evaluate existing energy storage projects to assess net benefits of energy storage and highlight opportunities to improve the regulatory framework for future projects • Support the development of an energy storage procurement process.
Bolivia	• Develop a proposal for integrating energy storage into Bolivia's regulatory framework • Build awareness and outreach to energy sector stakeholders on the value of energy storage, particularly for providing ancillary services.
Chile	• Model and assess potential energy storage configurations identified in Chile's long-term energy planning scenarios, leveraging the SDOM platform • Build technical capacity for modeling energy storage technologies • Develop a learning network to share best practices for energy storage regulation.
Costa Rica	• Develop a simulation model representing demand, generation, and transmission capacity to evaluate the potential of energy storage to address grid challenges and renewable integration.
Dominican Republic	• Analyze baseline situation for the integration of energy storage into the electricity grid, including ancillary services, system anomalies, load shedding, and regulations • Support modeling and planning of potential energy storage projects to address system challenges • Refine existing regulatory framework to better enable energy storage.
Ecuador	• Update grid codes at the national level and for the Galapagos to allow for the technical/economic participation of energy storage • Model for an energy storage pilot project to support renewable energy integration and increased transmission capacity between Ecuador and Peru.
El Salvador	• Build technical capacity for modeling and planning energy storage • Evaluate and adapt regulatory frameworks, particularly the General Electricity Law, to help promote the participation of energy storage activities • Update wholesale market operating regulations as well as the national grid code to allow for interconnection, participation, and remuneration of energy storage and other technologies • Integrate energy storage into long-horizon energy planning processes, starting with analysis of potential storage needs and capacity across El Salvador, particularly for reducing curtailment.
Guatemala	• Build capacity to integrate energy storage, particularly battery storage, into national energy planning to inform the next generation of Guatemala's Renewable Expansion Plan • Support public tender design considering the possible integration of energy storage.
Honduras	• Complete a request-for-proposals project for a technical consultancy to review the existing regulatory framework and develop regulations for energy storage • Technical capacity building and modeling support (e.g., using the REopt® tool[13]) for expanding mini-grids as part of the National Rural Electrification Plan.
Peru	• Techno-economic assessment and scenario analysis to evaluate the feasibility of integrating energy storage systems in the national electricity grid • Adapt National Grid Codes and develop a proposal for a regulatory framework or modification of existing regulations to make the implementation of storage systems feasible • Build technical capacity related to regulating and operating energy storage technologies.
Uruguay	• Support integration of renewables and grid stability with modeling and scenario analysis of energy storage potential, particularly for load centers and balancing hydropower fluctuations • Explore potential for long-term storage, particularly hydrogen and pumped hydro • Update energy regulation to allow energy storage to participate in markets and grid services • Align potential storage incentives and policies with Uruguay's Green Hydrogen Road Map.

[13] See https://reopt.nrel.gov/tool.

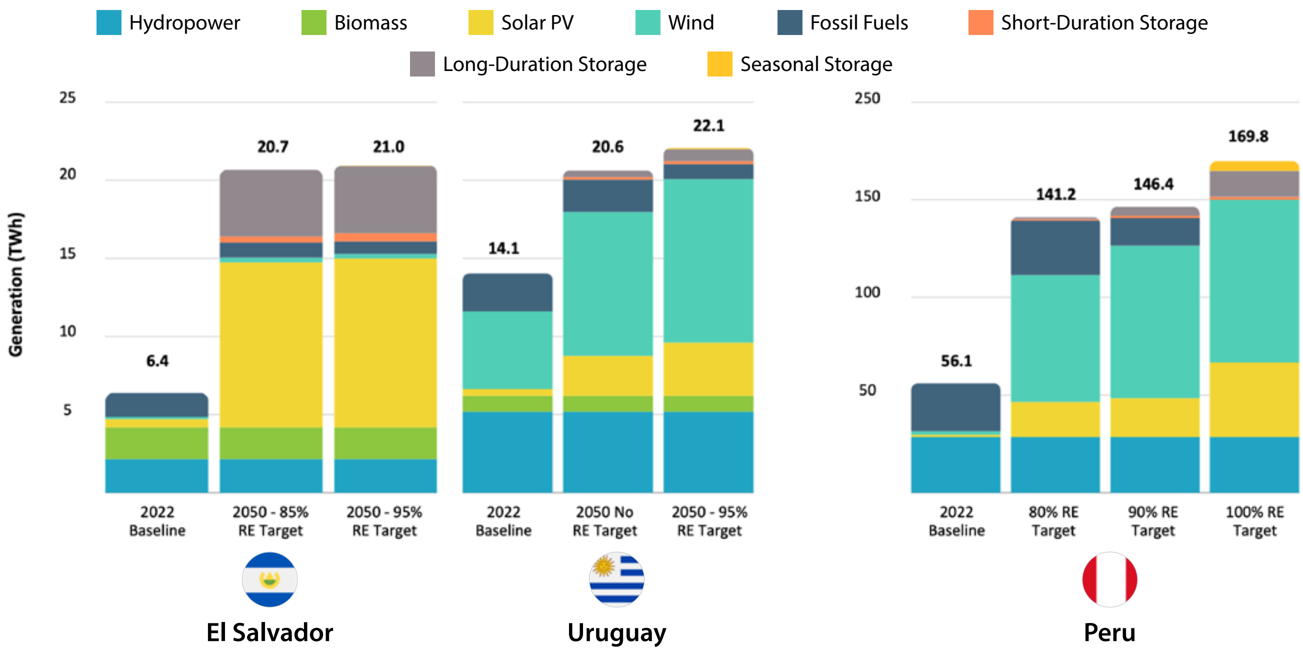

Figure 5. Generation to grid by resource, scenario, and country. **Note:** RE = renewable energy; PV = photovoltaics

Image by Omar Jose Guerra Fernandez and Andrew Bilich, NREL

for imports of progressively lower-cost renewables, especially during periods of seasonal excess. These dynamics are complex and will require more in-depth scenario testing and regional modeling. Also, SDOM considers no transmission constraints (copperplate power grid), so transmission constraints could increase the need for energy storage technologies.

Based on these country-level inputs and constraints, SDOM models varying generation mixes and capacity expansion rates under different renewable energy targets through 2050 (**Figure 5**) and considers the potential for the following types of energy storage:

- **Short duration:** Storage technologies with high energy-related costs but the lowest power-related costs that typically provide energy storage in the range of 1-10 hours. This technology is based on lithium-ion battery projections, but it could also represent alternative battery types that could achieve optimum cost and performance values.
- **Long duration:** Storage technologies with low power and energy costs that typically provide energy storage for between 10–100 hours. Two generic options are considered: (1) technologies with lower power and energy costs and lower round-trip efficiencies (e.g., adiabatic compress air energy storage or pumped thermal storage); and (2) technologies with higher capacity and energy costs but also higher efficiencies (e.g., pumped hydropower storage or longer duration batteries such as flow batteries)
- **Seasonal:** Storage technologies with higher power-related costs, very low energy-related costs, and low round-trip efficiencies (e.g., hydrogen or similar type of technology), that typically provide energy storage of 100 hours or more.

In the highest renewable energy scenarios as defined by each respective country (Peru: 100%, Uruguay: 95%, El Salvador: 95%), substantial storage capacity is needed to support renewable energy deployment, especially when moving to 100% renewable energy scenarios in which seasonal storage becomes even more critical (e.g., Peru in Figure 6). Both types of energy storage and their utilization patterns depend significantly on the resource mix, and particularly the amount of solar and wind generation. In general, short-duration storage is utilized for intra-day shifting of surplus variable renewables, long-duration storage follows a similar pattern but is utilized for both intra-day and inter-day shifting of surplus variable renewables and does not fully discharge every day like the short-duration technologies. Seasonal storage allows for shifting renewable surplus from one season to another. In solar-dominated systems like El Salvador, more short-duration storage is needed, and that storage dispatch tends to follow a pattern of solar charging in the afternoon and discharging late at night or in the early morning. For wind-dominated systems like Uruguay, the storage requirements are more random, following the variability of wind (**Figure 6**).

Across all countries, storage deployment helps alleviate the potential curtailment of variable renewable energy, but in the high-variable renewable energy integration scenarios (e.g., over 95%), curtailment estimates were still in the 7%–14% of total variable renewable energy generation range.

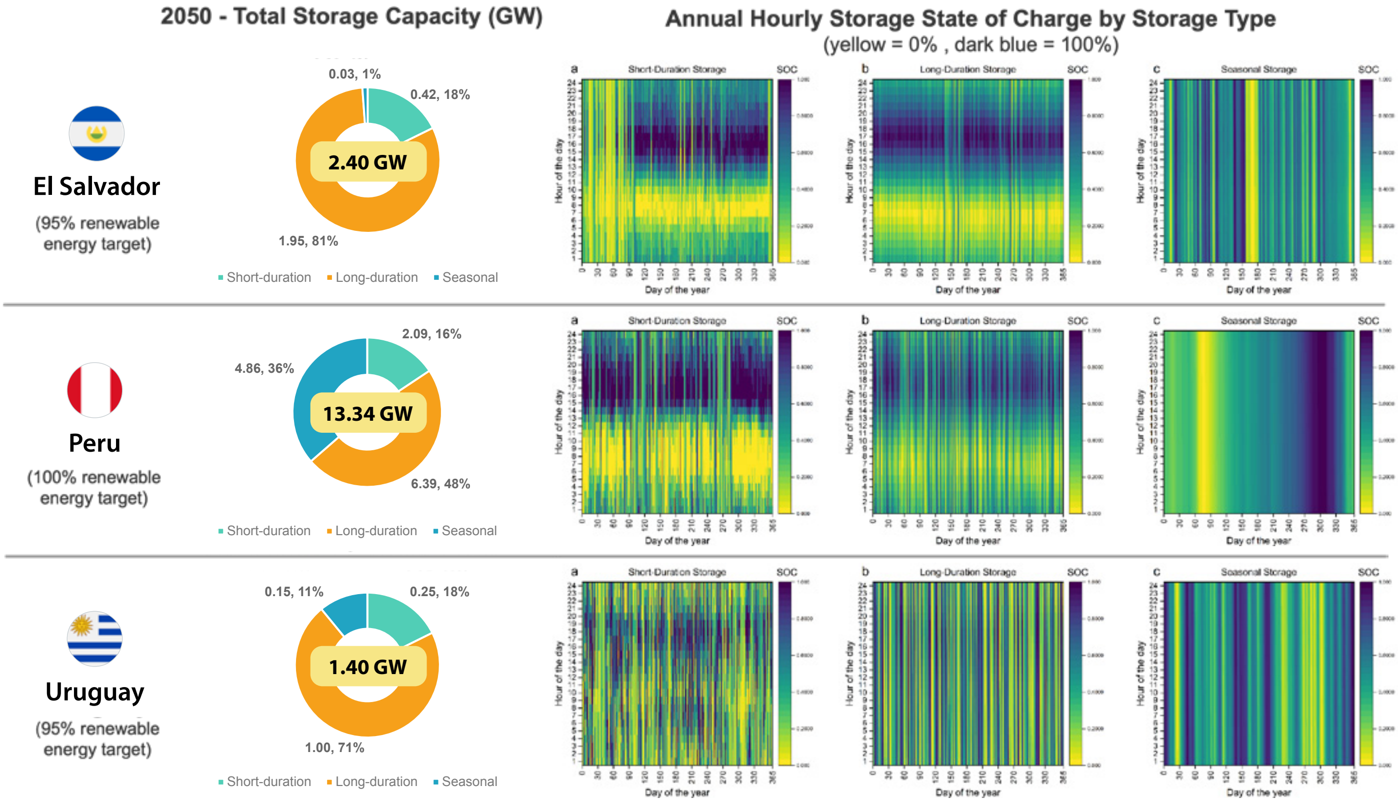

Figure 6. SDOM-estimated storage capacity and annual hourly state of charge for different types of deployed energy storage (high renewables scenarios) *Image by Omar Jose Guerra Fernandez and Andrew Bilich, NREL*

NREL developed more in-depth analyses and reports for each country, but the initial SDOM estimates highlight a key potential need for energy storage to support energy transitions for RELAC countries. To fully enable energy storage deployment, the countries will need to develop and refine their existing policy and regulatory frameworks to allow for energy storage (see Regulatory Frameworks for Energy Storage section below for RELAC support examples).

Further, the initial SDOM modeling can inform other, more-detailed power system models (e.g., NREL's open-source Sienna[14] model for power system opportunities and NREL's System Advisor Model for techno-economic analysis of specific projects) to assess how and where to deploy specific energy storage projects based on the needs/constraints of the country-specific electricity systems, as well as the technical specifications and economic viability of those energy storage projects (see the Energy Storage Integration Modeling section for examples).

Energy Storage Integration Modeling

To further assess the integration of energy storage, NREL developed a simplified modeling framework using its open-source Sienna platform, a modular framework for dynamic power system modeling. NREL used the Sienna\Data and Sienna\Ops software packages to develop the dataset and conduct the power simulations (**Figure 7**).

NREL used Sienna for energy storage modeling (and associated capacity building) in three countries:

- **Costa Rica:** National framework for evaluating energy storage deployment for renewables optimization
- **Ecuador:** Deployment of energy storage at the interconnection between Peru and Ecuador to bring the current transmission capacity of around 40 MW, closer to its originally rated transmission capacity of 100 MW
- **Honduras:** Deployment of up to 50 MW of energy storage to improve grid reliability, renewables integration, and regional energy planning.

While the modeling support for Ecuador and Honduras is ongoing, the analysis and training for Costa Rica has been completed, as detailed below.

In their initial draft action plan, the Instituto Costarricense de Electricidad (ICE) highlighted several priority areas for energy storage in Costa Rica, including modeling and planning for energy storage resources, particularly to understand when and where to deploy energy storage in the Costa Rican grid to support integrating renewable energy and improving grid

[14] See https://www.nrel.gov/analysis/sienna.html.

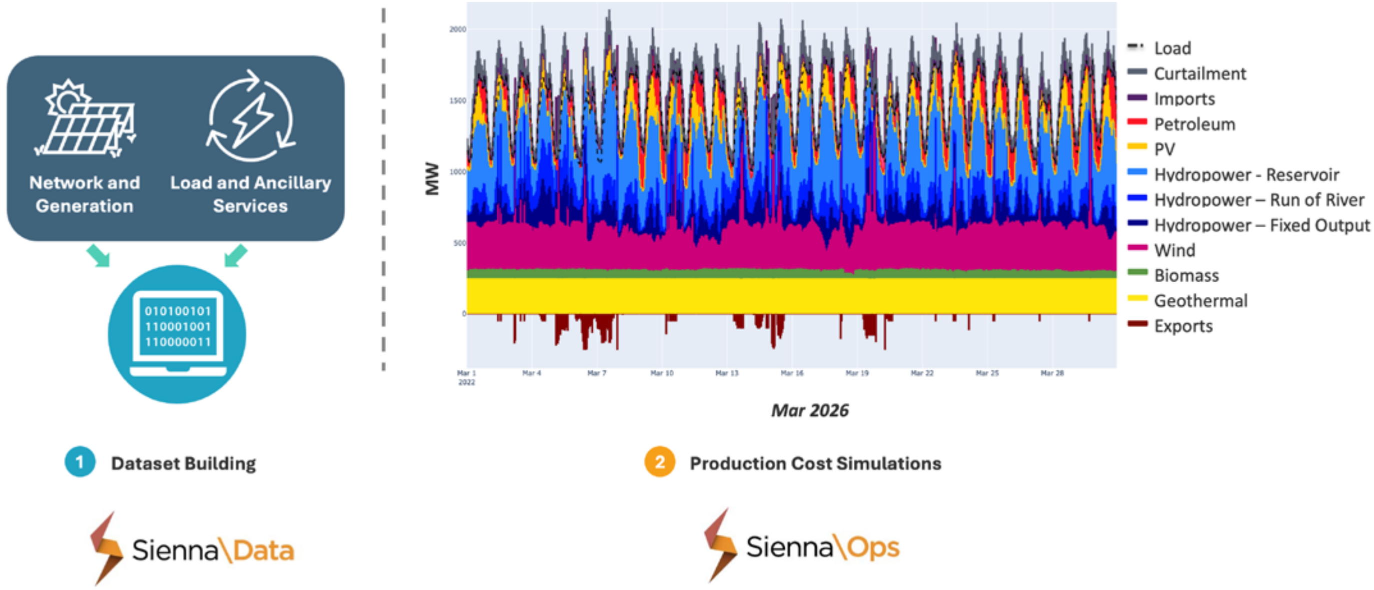

Figure 7. Example Sienna process flow *Image by Omar Guerra and Andrew Bilich, NREL*

operations. Using Sienna, NREL worked with ICE'S Operations Division and Planning Division to support better system modeling for the integration of renewable energy and storage in line with their 2023 capacity expansion plan[15] which highlighted a need to significantly expand renewable energy capacity (460 MW of wind and solar between 2024-2027, an additional 525 MW between 2028 and 2032, and 650 MW between 2033 and 2035) as well as energy storage (at least 30 MW of energy storage by 2028 and over 120 MW by 2033) to support integration.

An initial comparison, for example, utilized a 2022 baseline for generation patterns and buildout of the network in line with the capacity expansion plan for 2026 to evaluate the optimal placement of 200 MW of 2-hr storage within the Costa Rican grid for reducing the total amount of fossil fuels burned during March (the highest load month). Four 2026 scenarios were developed: (1) No storage; (2) 200 MW deployed close to generation in the North; (3) 200 MW deployed in the central part of the country close to load; and (4) 100 MW each in the North and Central areas of the grid.

This initial modeling highlighted that deploying storage could reduce petroleum consumption in the highest load month by 15%–20% (2.96–3.89 million liters of fuel savings[16]), with the highest savings coming when storage was deployed in the Central region close to load (**Figure 7**).

With the training on the Sienna model, ICE can now construct and evaluate additional scenarios for storage deployment, comparing metrics like energy costs, fuel consumption, renewable curtailment and integration, etc.

This process helped convene stakeholders from across the different generation planning, transmission planning, and operation planning units, which historically have operated separately. However, using a consistent modeling approach and leveraging open-source Sienna tools to break down software-related barriers across the different government agencies allowed different stakeholders to physically be on the same page, using the same model and dataset to better understand future scenarios and their dynamic interplays. This convening and aligning element in many ways was as impactful as the scenario modeling itself.

Capacity Building for National Mini-Grid Modeling

To support Honduras' mini-grid planning under the National Rural Electrification Plan, NREL conducted a series of technical capacity-building workshops with the Secretary of Energy and other energy sector stakeholders in Honduras focused on using NREL's open-source REopt tool[17] to design and conduct techno-economic assessments of potential distributed solar + storage mini-grid systems. In total, 30+ stakeholders from across the Secretary of Energy, Electricity Regulatory Commission, National University of Honduras, and other organizations were trained on both REopt's online interface[18] and the back-end Julia code set.[19]

[15] See https://www.grupoice.com/wps/wcm/connect/741c8397-09f0-4109-a444-bed598cb7440/PEG+2022-2040+versi%C3%B3n+final.pdf?MOD=AJPERES&CVID=oLtHPgv.
[16] The actual macro-economic impact of these savings will depend on a variety of factors like subsidies, customer tariffs, etc. that ICE and other stakeholders will be evaluating in other scenario modeling going forward.
[17] See https://reopt.nrel.gov/tool.
[18] See https://reopt.nrel.gov/tool.
[19] See https://github.com/NREL/REopt_API.

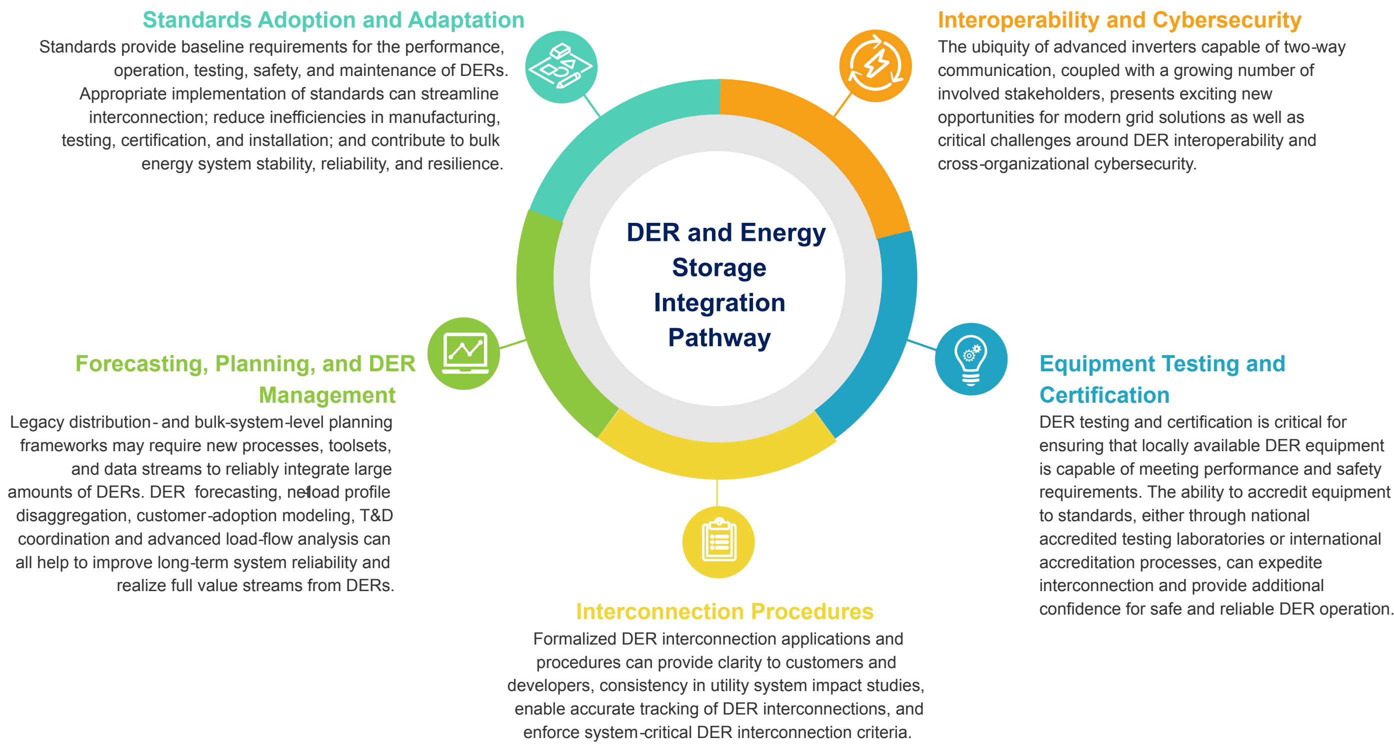

Figure 8. Overview of DER integration pathways. **Note:** T&D = transmission and distribution
Image by Killian McKenna, Erik Pohl, and Andrew Bilich, NREL

Regulatory Frameworks for Energy Storage

Given the strong interest in regulatory support identified through the workshop series, NREL hosted an additional regulatory workshop that helped participants evaluate the regulatory framework for their country, deep-diving into six areas of the energy storage readiness assessment.[20] The workshop was attended by 33 stakeholders from Honduras, Dominican Republic, Haiti, Ecuador, El Salvador, Peru, Chile, and Uruguay.

RELAC worked with countries to scope technical assistance support for the development/refinement of regulatory frameworks for energy storage based on the energy storage action plans. RELAC was then able to catalyze support from the Clean Energy Ministerial's Clean Energy Solutions Center (6 countries) and the U.S. Agency for International Development USAID (Haiti) to implement the technical assistance.

One example of broad regulatory support includes technical assistance for refining national grid codes in El Salvador, Peru, and Ecuador, as well as subnational grid codes in the Galapagos to support integration and operation of energy storage and other distributed energy resources (DERs). This work focused on comparing existing regulatory frameworks[21, 22, 23] and building capacity for the ministries of energy to adapt and enhance their standards in alignment with best practice standards like Institute of Electrical and Electronics Engineers (IEEE) 2800-2022 and IEEE 1547-2018 (**Figure 8, Figure 9**).[24, 25, 26]

These comparisons help to illustrate key technical aspects of their grid codes that could be clarified to better support integration of distributed energy resources, particularly energy storage. The three countries had different starting points for grid codes, but generally one key area for focus across all three grid codes was improving provisions for voltage support and voltage control functions. It is important to note that **Figure 9** in particular represents a high-level preliminary comparison

[20] See https://www.nrel.gov/docs/fy21osti/78197.pdf.
[21] El Salvador grid code documents: El Salvador General Superintendence of Electricity and Telecommunications AGREEMENT No. 294-E-2011; AGREEMENT No. 30-E-2011.
[22] Peru grid code documents: COES Proposal Network Design Code August 2020; Unidad de Transacciones Transmission System and Wholesale Market Operation Regulations Based on Production Cost D.O. Number 138 Volume 392.
[23] Government of Ecuador Board of Directors of the Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources RESOLUTION NO. ARCERNNR-XX/2023 – Proyecto de Regulacion CodCx; Codigo de Operacion.
[24] Patel, Manish. 2022. "IEEE Std 2800™-2022 Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems EPRI-NAGF-NATF-NERC Joint Webinar." May 03, 2022. https://www.nerc.com/comm/RSTC/IRPS/IEEE_2800-2022_EPRI-NAGF-NATF-NERC_May_3-2022_Joint_Webinar.pdf.
[25] IEEE. 2022. "2800-2022 - IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems." IEEE Std 2800-2022. Feb. 2022. doi: 10.1109/IEEESTD.2022.9762253.
[26] IEEE. 2018. "1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces." IEEE Std 1547-2018. Apr. 2018. https://ieeexplore.ieee.org/document/8332112.

Key Grid Functionality	IEEE 2800–2022	IEEE 1547–2018	Peru	El Salvador	Ecuador
Reference Point of Applicability	POM	POC/PCC	PCC	O	O
Adjustability in Ranges of Settings	✓	✓	-	-	-
Prioritization of Functions	✓	✓	-	-	-
Ramp Rate Control	-	✓	✓	-	✓
Communication Interface	✓	✓	✓	✓	✓
Disable Permit Service	✓	✓	-	O	-
Limit Active Power	✓	✓	✓	✓	✓
Monitor Key Data	✓	✓	✓	✓	✓
Remote Configurability	✓	✓	✓	O	✓
Set Active Power	✓	✓	-	✓	-
Scheduling Power Values	✓	-	O	✓	-
Constant Power Factor	✓	✓	✓	✓	✓
Volt-VAR	✓	✓	O	-	✓
Autonomously Adjustable Voltage	-	✓	-	-	-
VARs at night	✓	-	-	-	O
Constant Reactive Power	✓	✓	✓	✓	O
Volt-Watt	✓	✓	O	-	O
Dynamic Voltage Support Balanced	✓	O	✓	-	✓
Dynamic Voltage Support Unbalanced	✓	O	-	-	✓
Frequency Ride-Through	✓	✓	✓	-	✓
ROCOF Ride-Through	✓	✓	-	-	✓
Voltage Ride Through	✓	✓	✓	-	✓
Transient Overvoltage ride-Through	✓	✓	-	-	-
Consecutive Voltage Dip Ride-Through	✓	✓	-	-	-
Restore Output After Voltage Ride-Through	✓	✓	O	-	O
Voltage Phase-Angle Jump ride-Through	✓	✓	-	-	✓
Frequency Droop/Frequency Watt	✓	✓	✓	✓	✓
Underfrequency FFR	✓	-	O	-	O
Over frequency FFR	✓	-	O	-	O
Return to Service	✓	✓	-	-	✓
Black Start	✓	O	-	✓	✓
Abnormal Frequency Trip	✓	✓	O	O	✓
ROCOF Protection	✓	-	-	-	✓
Abnormal Voltage Trip	✓	✓	O	✓	✓
AC Overcurrent Protection	✓	O	✓	O	✓
Unintentional Islanding Detection and Trip	✓	✓	-	-	O
Interconnection System Protection	✓	O	✓	O	✓
Limitation of DC Current Injection	-	✓	-	-	-
Limitation of Voltage Fluctuations	✓	✓	✓	✓	✓
Limitation of Current Distortion	✓	✓	✓	✓	✓
Limitation Voltage Distortion	✓	✓	✓	✓	✓
Limitation of Transient Overvoltage	✓	✓	✓	-	-

✓ = Description of functionality partially or fully exists in standard
O = Functionality requirements unclear
\- = No clear description of functionality in standard
NOTE: This table represents a high-level preliminary review of these standards and translated country-specific grid codes. As such, this table may not be fully comprehensive of the functionalities listed in each document. The documents reviewed included requirements for transmission interconnections, distribution interconnections, or both.

Figure 9. Comparison of grid-support functions for energy storage in Peru, El Salvador, and Ecuador with IEEE standards
Image by Killian McKenna, Erik Pohl, and Andrew Bilich, NREL

of IEEE standards and translated country-specific grid codes at specific times (see documents reviewed in footnotes). As such, the information may not be fully comprehensive of the functionalities listed in each document. Furthermore, the evaluations provided in this figure do not provide an indication of strength or efficacy of the country grid codes themselves, but rather an indication of whether different functionalities highlighted in the IEEE standards were present with clear requirements in the country grid codes.

Some highlights from additional regulatory workstreams include:

- Accompaniment of Honduras in a request-for-proposals process to review and develop an energy storage framework for the Electricity Regulatory Commission
- Technical advisory support for the Ministry of Energy and Mines and Superintendencia de Electricidad in the Dominican Republic in a request-for-proposals process to elaborate technical requirements and compensation mechanisms for battery energy storage systems (BESS)
- Technical review of proposals for regulatory enabling conditions for energy storage in generation, transmission, and distribution networks in Panama
- Technical advisory support for regulatory questions related to feed-in tariffs, renewable energy integration, and energy storage in Guatemala
- Technical advisory support for Barbados regulator, energy ministry, and utilities for competitive procurement processes for energy storage
- Four-part technical training[27] for resilient energy planning and assessment for the Autorité nationale de régulation du secteur énergétique, Ministère des Travaux Publics, Transports et Communications, Technical Execution Unit of the Ministry of Economy and Finance, and Electricité d'Haïti in Haiti.

Additionally, and aligned with this energy storage-focused program, IDB, with the technical support of the Ibero-American Association of Energy Regulators, released *Regulatory Frameworks for the Incorporation of Energy Storage in Power Systems: International Experiences in Regulatory Models*,[28] a report that presents a synthesis of international experiences with BESS regulation in markets with high storage penetration to identify key regulatory elements that might favor the speedy adoption of energy storage systems in LAC countries.

[27] See https://www.youtube.com/playlist?list=PLmIn8Hncs7bFypKnZplxLROne0-qj-RdD.
[28] See https://publications.iadb.org/es/incorporacion-de-almacenamiento-de-energia-en-los-sistemas-electricos-experiencias-internacionales.

Mobilization of Other Support

RELAC used the workshops, technical assistance, and elaboration of the country energy storage action plans as a foundation for catalyzing additional funding and technical assistance support for the RELAC countries.

For example, as highlighted previously, RELAC helped leverage existing support to open and develop new opportunities from funds and programs, including technical assistance support for regulatory frameworks for energy storage through the Clean Energy Ministerial's Clean Energy Solutions Center.[29] RELAC also enabled additional technical support for Haiti's resilient energy training through a project with the U.S. Agency for International Development, as well as for electrification planning in Honduras through a program with the U.S. Embassy.

On a larger scale, GEAPP has worked to launch the BESS Consortium, a collaboration between investors, Alliance partners, and countries to catalyze BESS deployment in a set of "first-mover" countries and utilities in low- and middle-income countries. RELAC worked directly with GEAPP to scope expanded technical assistance for four RELAC countries[30]: Dominican Republic, Honduras, Barbados, and Uruguay, which will focus on accelerating implementation of concrete energy storage pilots and projects that can serve as replicable examples and successes in the region.

The ongoing technical assistance under RELAC is focused on refining the initial country-specific action plans to align with GEAPP/BESS Consortium objectives, identifying and technically evaluating potential pilot or large-scale projects for energy storage, supporting expanded modeling and analysis of system needs for energy storage, and building technical capacity for the country stakeholders. Ultimately, this support will help the target countries scope and develop specific projects/collaboration with GEAPP/BESS Consortium partners.

Discussion and Next Steps

IDB and NREL remain committed to helping RELAC countries integrate energy storage solutions, both on and off the grid. Future support will include at a minimum: (1) developing regulatory frameworks to streamline adoption; (2) conducting feasibility studies for integrating energy storage into the electric grid; and (3) providing or mobilizing financing for projects, whether at grid scale or off-grid.

In addition to NREL support on the country action plans, IDB is also supporting studies to: (1) incorporate storage in the long-term planning of Ecuador's electricity system; (2) identify and prioritize energy storage projects in Colombia; and (3) evaluate the feasibility of including energy storage in La Paz's teleferic system.

Both NREL and IDB will continue to provide support to RELAC countries not only on energy storage, but also for other key areas, challenges, and enabling conditions related to achieving the RELAC initiative's ambitious renewable energy targets. For example, RELAC's follow-on technical series is focused on system operators, grid-enhancing technologies, and renewable energy integration.

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[29] See https://www.cleanenergyministerial.org/initiatives-campaigns/clean-energy-solutions-center/.
[30] Target countries were established by GEAPP and the BESS initiative separately from the RELAC work.

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