Procuring Grid Flexibility

A global guide for decision makers to increase power system reliability and affordability in the context of rapid technological change

Report / August 2026

About the work

This report was developed by RMI as part of the Global BESS Consortium, in partnership with the Global Energy Alliance for People and Planet. The Consortium supports countries in accelerating battery energy storage system (BESS) deployment through targeted technical assistance, regulatory support, implementation guidance, peer learning, and knowledge exchange. It also provides participating organizations with access to global best practices, technical resources, and engagement with industry through private-sector platforms.

The recommendations presented in this report draw on RMI's experience supporting policymakers, regulators, utilities, and system operators across Asia, Africa, and Latin America to strengthen grid flexibility, enable energy storage deployment, and advance reliable, affordable, and resilient power systems. RMI and the Global Energy Alliance also continue to support governments in translating these concepts into implementation through BESS roadmaps, economic viability assessments, procurement and market design, regulatory reform, project deployment resources, and more.

Organizations interested in strengthening grid flexibility or advancing battery energy storage deployment are encouraged to connect with RMI and the Global Energy Alliance to discuss opportunities for collaboration, including participation in the Global BESS Consortium, the Regulatory Energy Transition Accelerator, and other complementary initiatives.

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About RMI

Rocky Mountain Institute (RMI) is an independent, nonpartisan nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to secure a prosperous, resilient, clean energy future for all. In collaboration with businesses, policymakers, funders, communities, and other partners, RMI drives investment to scale clean energy solutions, reduce energy waste, and boost access to affordable clean energy in ways that enhance security, strengthen the economy, and improve people's livelihoods. RMI is active in over 50 countries.

About Global Energy Alliance

Global Energy Alliance for People and Planet is a global nonprofit that builds public, private and philanthropic partnerships to accelerate clean energy and economic opportunity. Founded in 2021 by The Rockefeller Foundation, IKEA Foundation and Bezos Earth Fund, we build the technical, financial and institutional foundations that make clean energy investable and scalable across emerging economies. Our work is anchored in two mutually reinforcing global pillars that together address the market fragmentation that has historically slowed down progress on energy access and economic development. Grids of the Future strengthens energy supply through AI-enabled, renewables-ready power grids. Powering Opportunity builds demand, helping people harness clean energy to power businesses, create jobs and drive economic growth. Together, these pillars create a reinforcing cycle of abundant energy and economic opportunity. With 130 projects across Africa, Asia and Latin America and the Caribbean, we are on track to reach 91 million people with clean energy, create or improve more than 3 million jobs and prevent nearly 300 million tons of carbon emissions. For more information, please visit www.energyalliance.org and follow us on LinkedIn.

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About the cover

Overhead view of the BESS site at Kanengo — the first utility BESS project in Malawi, supported by the Global Energy Alliance.

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Glossary

Ancillary services — Services that support the secure and reliable operation of the power system by maintaining frequency, voltage, operating reserves, and system restoration following disturbances.

Battery energy storage system (BESS) — A system that chemically stores electrical energy for later use and can charge and discharge electricity to provide energy, capacity, and other reliability services.

Expected unserved energy — A resource adequacy metric representing the total expected amount of unserved energy in megawatt-hours (MWh) during a specified planning horizon.

Fast frequency response (FFR) — An ancillary service that automatically initiates and delivers a defined active power response within milliseconds after frequency crosses a defined threshold.

Grid-forming (GFM) — Technology, specifically inverters, that can replicate the function of synchronous generators by maintaining grid frequency and voltage autonomously. They can improve system stability in power systems with high penetrations of inverter-based resources, and — where designed to do so — provide black-start capabilities.

Grid reliability — The ability of the power system to continuously provide adequate, secure, and stable electricity supply both under normal operating conditions and amid credible disturbances.

Inverter-based resources (IBR) — Generation and storage resources that connect to the power system through power electronic inverters rather than synchronous machines. Examples include modern wind turbines, solar photovoltaic, and battery energy storage systems.

Loss-of-load expectation (LOLE) — A resource adequacy metric representing the expected number of times that system resources are insufficient to meet demand during a specified planning horizon.

Reliability services — Services procured to maintain reliable power system operations across dimensions including resource adequacy, system balancing, and system stability.

Revenue stacking — The ability of a single asset to provide and be compensated for multiple grid services or market products.

Introduction

Periods of technological change have repeatedly reshaped electricity systems, from the expansion of large-scale hydro and nuclear generation to the liberalization of electricity markets, and now the growth in renewable energy. Each transition has required regulators to adapt planning, operational, and procurement frameworks to maintain and improve the delivery of reliable and affordable electricity to support economic growth and prosperity.

Today's transition is once again reshaping the services required to cost-effectively maintain reliability. As power systems evolve, flexibility — the system's ability to respond to changes in electricity supply, demand, and grid availability — is becoming one of the defining challenges for maintaining reliable and affordable electricity. Declining renewable energy costs, growing electricity demand, advances in digital technologies, evolving operating conditions, and increasing focus on energy security are driving up the value of flexibility and creating new opportunities to improve reliability, affordability, and system resilience. Meeting these evolving reliability needs increasingly depends on procuring flexibility services based on power system requirements rather than the technologies that provide them.

Among the technologies emerging to provide this flexibility, battery energy storage systems (BESS) have become one of the most versatile and least-cost solutions. A single BESS asset can support resource adequacy, system balancing, and system stability, making it uniquely capable of responding to changing grid conditions across multiple timescales. This makes BESS a useful illustration of the broader shift toward procuring grid services based on measurable performance rather than technology type.

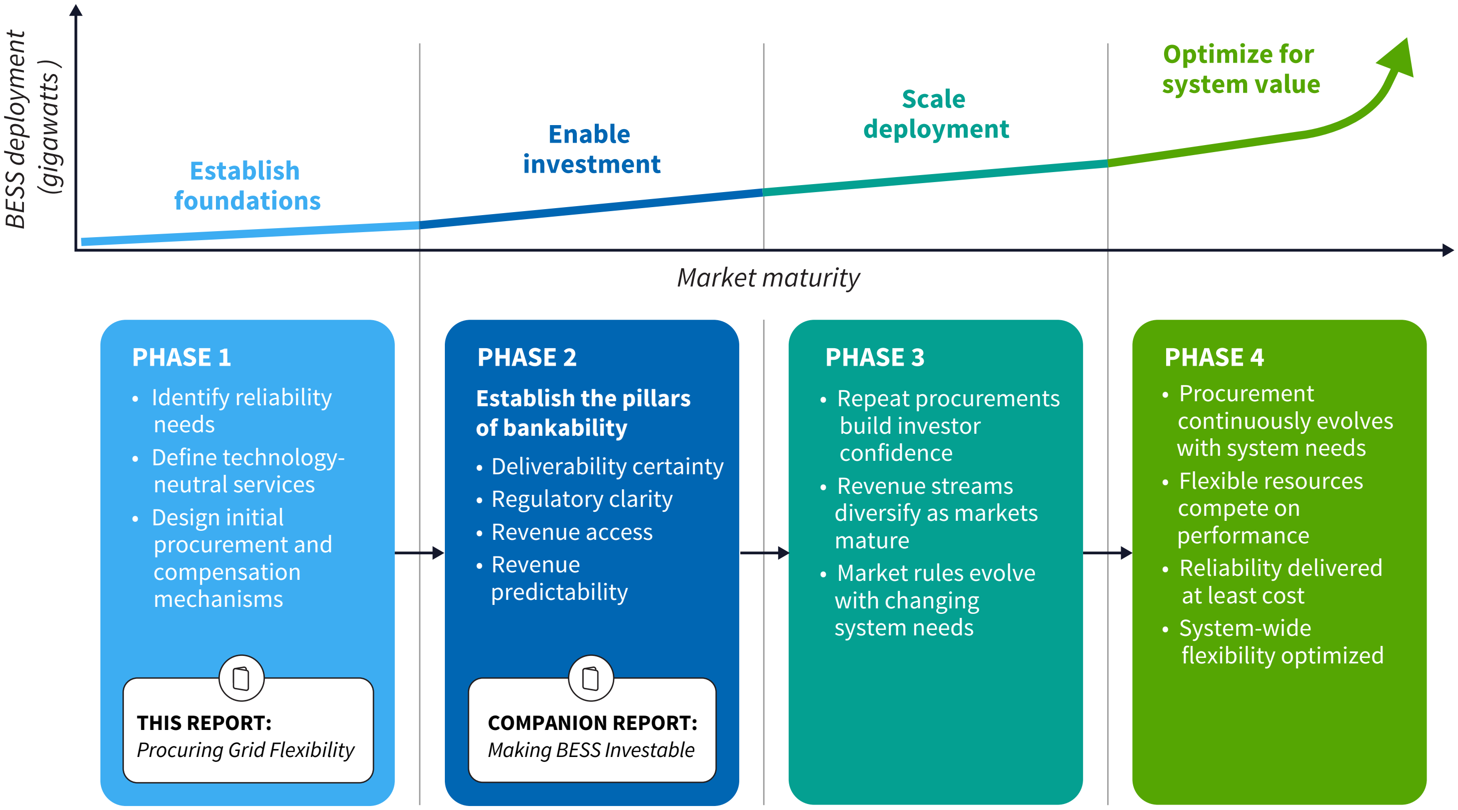
Although many jurisdictions are transitioning toward technology-neutral procurement based on performance, much of today's regulatory and market frameworks still reflect an electricity system dominated by conventional generation. These frameworks often recognize only a narrow set of reliability services and compensate technologies according to traditional roles rather than measurable performance. As a result, flexible resources such as BESS, long-duration energy storage, advanced inverter resources, and virtual power plants (VPPs) cannot always compete based on the full value they provide to the power system.

Realizing this opportunity requires regulators, working alongside policymakers, system operators, and utilities, to establish procurement frameworks that deliver reliability services at least cost. Because the costs of these services are ultimately borne by consumers through electricity tariffs or public funding, regulators play a pivotal role in ensuring that procurement delivers measurable reliability improvements that justify their costs. Despite broad consensus on the need for greater system flexibility, regulators and policymakers face practical questions about where to start, which reforms to prioritize, and how to sequence implementation — particularly where detailed grid assessments are not yet available.

International experience shows that flexibility reforms are implemented progressively rather than through a single procurement or regulatory decision. Countries typically move through multiyear reforms, beginning with identifying reliability needs and establishing initial procurement methods, before strengthening the commercial conditions needed to support sustained investment and deployment (see Exhibit 1). Although presented sequentially, these reforms are often iterative in practice.

Exhibit 1 Phases of BESS market development

Market development follows a progression, with procurement and commercial reforms reinforcing one another as deployment expands.



PHASE 1

- Identify reliability needs
- Define technology-neutral services
- Design initial procurement and compensation mechanisms

THIS REPORT: *Procuring Grid Flexibility*

PHASE 2

Establish the pillars of bankability

- Deliverability certainty
- Regulatory clarity
- Revenue access
- Revenue predictability

COMPANION REPORT: *Making BESS Investable*

PHASE 3

- Repeat procurements build investor confidence
- Revenue streams diversify as markets mature
- Market rules evolve with changing system needs

PHASE 4

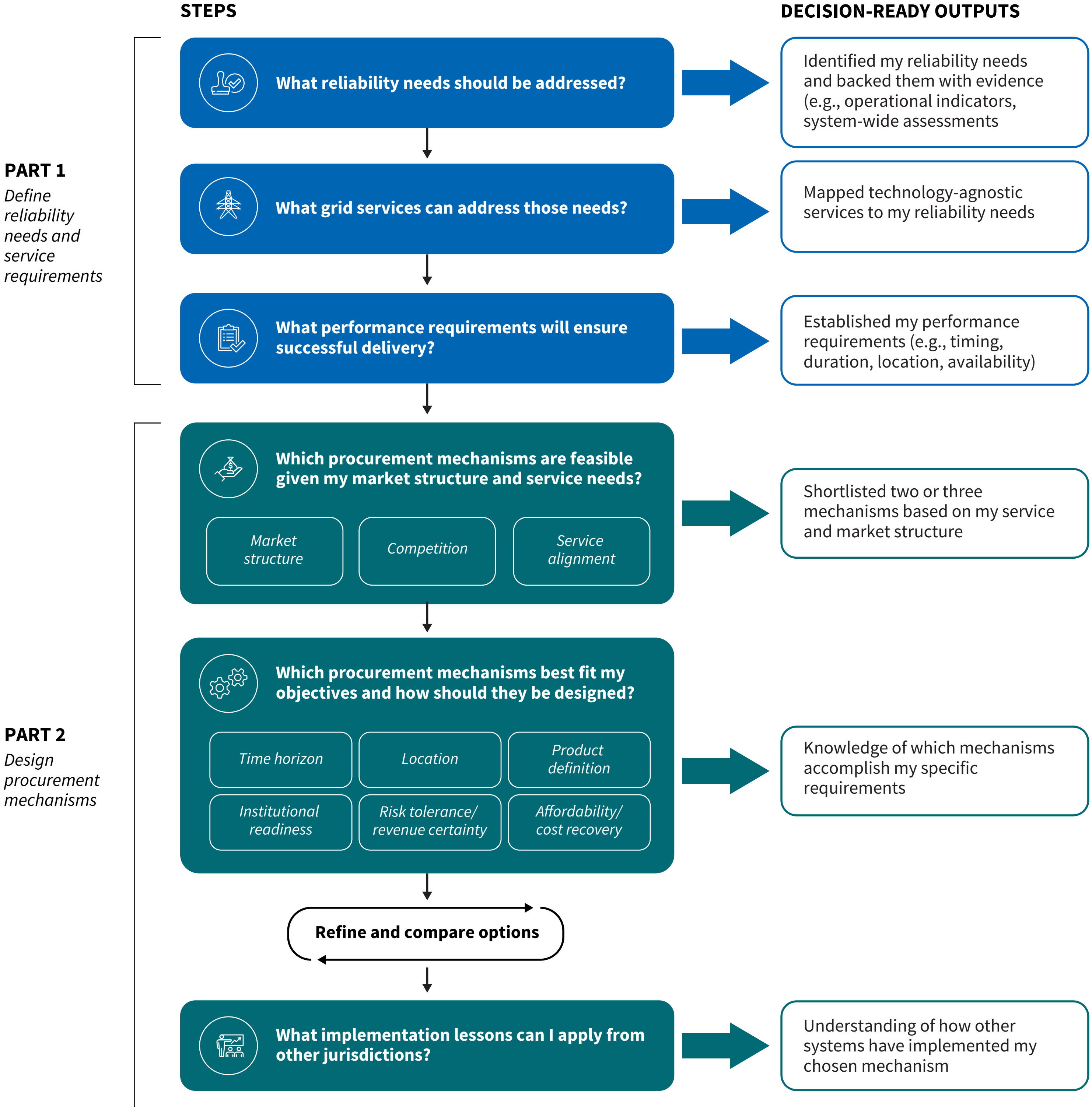
- Procurement continuously evolves with system needs
- Flexible resources compete on performance
- Reliability delivered at least cost
- System-wide flexibility optimized

RMI Graphic. Source: RMI; Clean Air Task Force

This report focuses on the first phase of that journey: establishing the technical and regulatory foundations for reliability service procurement through a framework that guides regulators in identifying reliability needs, defining grid services, establishing performance requirements, and designing procurement mechanisms suited to local market conditions (see Exhibit 2). The first three steps are technology agnostic, focused on the services needed by the system rather than any particular technology. Although considerations such as market structure, institutional arrangements, and the level of market competition influence how services are ultimately procured, they play a larger role in the design of procurement mechanisms than in identifying system needs or defining service requirements. The regulatory foundations are essential, yet many emerging economies also require early technical assistance, demonstration projects, and concessional financial support to build institutional capability and translate new procurement frameworks into investable projects.

Although the framework presented in this report is technology neutral, BESS is used throughout as the principal example because a single asset can provide resource adequacy, balancing, and stability services. Its versatility makes it a practical illustration of the procurement decisions that regulators increasingly face, but the underlying framework applies equally to other flexibility resources that are technically capable of delivering the required service.

Exhibit 2 Framework to define reliability needs and services and to design procurement mechanisms



STEPS

DECISION-READY OUTPUTS

PART 1
Define reliability needs and service requirements

What reliability needs should be addressed? → Identified my reliability needs and backed them with evidence (e.g., operational indicators, system-wide assessments)

What grid services can address those needs? → Mapped technology-agnostic services to my reliability needs

What performance requirements will ensure successful delivery? → Established my performance requirements (e.g., timing, duration, location, availability)

PART 2
Design procurement mechanisms

Which procurement mechanisms are feasible given my market structure and service needs? → Shortlisted two or three mechanisms based on my service and market structure

- *Market structure*
- *Competition*
- *Service alignment*

Which procurement mechanisms best fit my objectives and how should they be designed? → Knowledge of which mechanisms accomplish my specific requirements

- *Time horizon*
- *Location*
- *Product definition*
- *Institutional readiness*
- *Risk tolerance/ revenue certainty*
- *Affordability/ cost recovery*

Refine and compare options

What implementation lessons can I apply from other jurisdictions? → Understanding of how other systems have implemented my chosen mechanism

RMI Graphic. Source: RMI; Clean Air Task Force

The framework draws on RMI's practical implementation experience, developed in partnership with the Global Energy Alliance for People and Planet (GEA), supporting policymakers, regulators, utilities, and system operators across Africa, Asia, and Latin America and the Caribbean. It also builds on a growing body of work by organizations including the International Energy Agency (IEA), Regulatory Assistance Project (RAP), National Laboratory of the Rockies (NLR), Agora, and Energy Systems Integration Group (ESIG) on electricity market design, ancillary services, and storage regulation.[1]

This report is written primarily for energy regulators responsible for establishing the regulatory and market frameworks that enable reliability services. Because system operators and planners typically identify reliability needs, define technical requirements, and procure or dispatch many of these services, the framework emphasizes collaboration across institutions, while recognizing that responsibilities vary by jurisdiction and market structure.

Many emerging economies are already establishing regulatory, technical, and institutional foundations to procure flexibility services and enable BESS deployment (see Exhibit 3). Although many of these reforms are still being implemented, they already provide valuable lessons for countries beginning a similar transition.

Exhibit 3

Examples of countries establishing the foundations to procure and deploy BESS

Country	BESS deployment
Colombia Operational BESS: <0.1 gigawatt (GW)	In 2026, Comisión de Regulación de Energía y Gas approved BESS participation in the secondary frequency regulation market, creating new revenue opportunities. This improves project economics, but additional revenue streams to provide long-term revenue certainty may be required to support bankable BESS deployment.
Vietnam Operational BESS: <0.1 GW	Regulators established a BESS pricing framework and pilot projects to build operational experience to address peak shaving and congestion with utility Vietnam Electricity (EVN) driving an initial 300+ MW deployment. The country's Power Development Plan targets >10 GW of BESS by 2030; however, Vietnam is currently focused on defining services, compensation, and procurement frameworks.
Indonesia Operational BESS: <0.1 GW	PLN, the state-owned electric utility company, has included 4 GW of BESS in its plans to support system stability and reduce reliance on diesel. Indonesia is developing national BESS standards, policy frameworks, and a deployment roadmap to guide market development.
Nigeria Operational BESS: <0.1 GW	Nigeria is strengthening the regulatory and institutional foundations for BESS deployment through electricity market reforms, including establishing the Nigerian Independent System Operator, introducing mandatory primary frequency response requirements through the Free Governor Control Order, and evaluating priority transmission-scale BESS applications through the Transmission Company of Nigeria (TCN)/African Development Bank feasibility study. These initiatives help identify priority reliability needs and inform future procurement pathways for grid-scale BESS.

Note: operational BESS figures as of August 2026.

RMI Graphic. Source: Nishimura, et al.; Energy Transition Partnership; TCN; Nigerian Electricity Regulatory Commission; The Electricity Journal; EVN

These examples reinforce that there is no single pathway to enabling flexibility. Rather than prescribing a single procurement model, this report provides:

- Context on drivers behind the urgency to increase system flexibility while ensuring reliability
- A summary of processes to define reliability needs and services to meet them
- A decision support framework that helps regulators understand which procurement mechanisms best address different grid needs, and the implementation decisions and trade-offs associated with each approach
- A means of identifying additional technical analysis, stakeholder engagement, and peer learning to support country-specific implementation

Building on these regulatory and procurement foundations to enable flexibility, the companion report, *Making BESS Investable*, focuses on Phase 2 of the framework in Exhibit 1: creating the market, regulatory, and commercial conditions needed to translate these foundations into bankable projects and sustained deployment. Together, the two reports provide complementary guidance on the technical, regulatory, and commercial reforms needed to enable flexibility at scale.

Context

Power system flexibility is essential for reliability and affordability

Power system flexibility is a grid's responsiveness to changes in electricity supply, demand, and network conditions.[2]

Flexibility is not an objective, but rather a capability of infrastructure that supports reliability and affordability as system conditions change across multiple timescales. Building on services-based reliability frameworks developed by Agora and Telos Energy, this report shows how flexibility capabilities are translated into reliability services that support resource adequacy, system balancing, and system stability, and how those services can be procured and compensated.[3]

Grid reliability needs are evolving

The grid reliability framework developed by Telos (now part of PowerGEM) outlines three components of grid reliability services based on timescale.[4]

1. **Resource adequacy:** In the long term, ensuring that sufficient supply is available to meet demand years into the future
2. **System balancing:** Ensuring hourly and daily matching of supply and demand
3. **System stability:** Maintaining the system within windows of safe tolerance in the sub-second-to-seconds time frame, despite disturbances

Reliability needs within each category are changing as increasingly variable and correlated supply and demand, changing weather patterns, and the growing share of inverter-based resources reshape power system operation. These shifts require regulators and system operators to reevaluate the resources and planning processes that are used to maintain grid reliability. Although stakeholders define each individual service somewhat differently, the general categories of services include fast frequency response (including synthetic inertia), primary frequency response, regulation, non-spin replacement reserves, capacity, grid strength, and voltage regulation.[5]

Exhibit 4 illustrates how these power system trends are changing reliability needs and the resulting implications for resource and planning requirements.[i]

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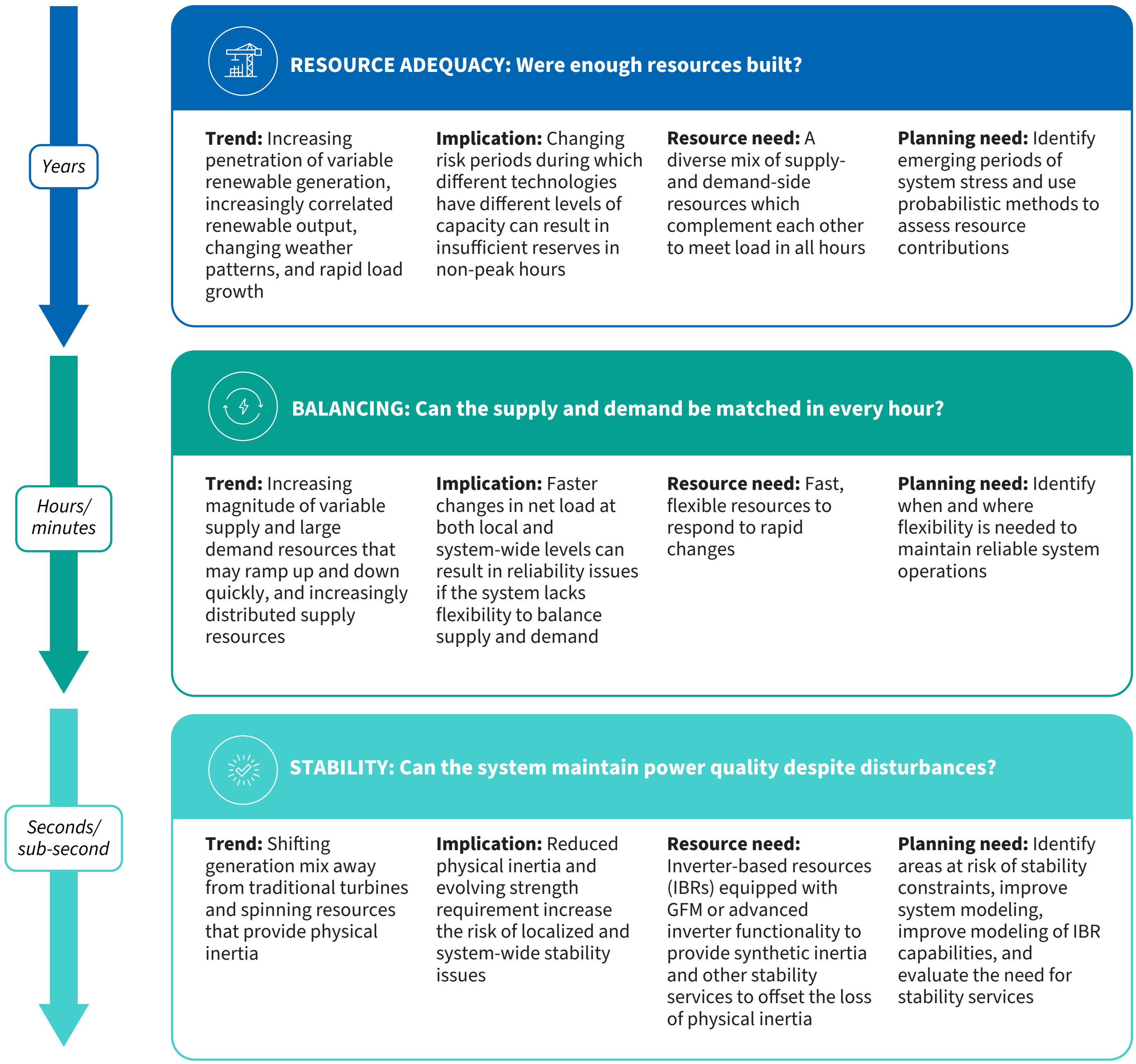
[i] RMI often uses the National Laboratory of the Rockies' reliability framework of resource adequacy, operational reliability, and resilience for other work given its value in communicating reliability outcomes. This report uses Telos' reliability framework given its greater focus on categorizing the services required to deliver reliability outcomes, which directly informs how they are procured.

Exhibit 4 Grid service categories: Key trends, resource needs, and planning implications



RESOURCE ADEQUACY: Were enough resources built?

Trend: Increasing penetration of variable renewable generation, increasingly correlated renewable output, changing weather patterns, and rapid load growth

Implication: Changing risk periods during which different technologies have different levels of capacity can result in insufficient reserves in non-peak hours

Resource need: A diverse mix of supply- and demand-side resources which complement each other to meet load in all hours

Planning need: Identify emerging periods of system stress and use probabilistic methods to assess resource contributions

BALANCING: Can the supply and demand be matched in every hour?

Trend: Increasing magnitude of variable supply and large demand resources that may ramp up and down quickly, and increasingly distributed supply resources

Implication: Faster changes in net load at both local and system-wide levels can result in reliability issues if the system lacks flexibility to balance supply and demand

Resource need: Fast, flexible resources to respond to rapid changes

Planning need: Identify when and where flexibility is needed to maintain reliable system operations

STABILITY: Can the system maintain power quality despite disturbances?

Trend: Shifting generation mix away from traditional turbines and spinning resources that provide physical inertia

Implication: Reduced physical inertia and evolving strength requirement increase the risk of localized and system-wide stability issues

Resource need: Inverter-based resources (IBRs) equipped with GFM or advanced inverter functionality to provide synthetic inertia and other stability services to offset the loss of physical inertia

Planning need: Identify areas at risk of stability constraints, improve system modeling, improve modeling of IBR capabilities, and evaluate the need for stability services

RMI Graphic. Source: ESIG; RMI

Multiple technologies can provide grid flexibility through technology-neutral procurement

Planners and operators require a range of resources that can provide flexibility services across multiple timescales and locations. A growing set of proven technologies that can provide these services includes lithium-ion battery storage (referred to as BESS throughout this report), demand response, and emerging long-duration energy storage. Distributed energy resources, including behind-the-meter batteries and demand-side resources, can also be aggregated (e.g., into VPPs) to provide grid services and support system reliability. Although not discussed further in this report, transmission expanding and grid-enhancing technologies (GETs) can also increase system flexibility.[ii]

Exhibit 5 compares a non-exhaustive subset of mature flexibility technologies, illustrating how they differ in the reliability of services they provide, operational characteristics, siting constraints, and cost.

The value of flexibility resources is highly location dependent. Pumped-hydro storage requires rainfall and ample water resources to provide reliable grid services. Solar and wind also depend on the availability of renewable resources. By contrast, BESS has relatively fewer geographic constraints and can be sited near system needs. System planners should therefore consider both where flexibility is needed on the grid and where different technologies can be practically deployed.

Technology-neutral procurement is increasingly being adopted to procure grid flexibility by defining the required grid service and requirement, rather than prescribing the technology that it provides. By specifying performance requirements such as location, duration, response speed, or operational flexibility, regulators can allow any technically capable resource to provide the service.

Considering that no single technology can serve reliability across all time horizons and locations,[6] this approach allows system operators to procure the resource best suited to each application. In doing so, technology-neutral procurement can bolster competition, encourage innovation, and improve the cost-effectiveness of flexibility procurement while maintaining reliability.[7]

[ii] ESIG provides practical guidance on the deployment of GETs, including utility implementation, planning considerations, operational integration, and regulatory actions drawn from real-world examples.

Exhibit 5 Common flexibility solutions differ in the reliability needs they address, their operational characteristics, and cost

	BESS (Lithium-ion+)	**Pumped-hydro storage**	**Gas peaker**	**Demand response**	**Synchronous condenser**	**Solar or wind (advanced inverters)**
Reliability needs served						
Services by need	Resource adequacy, balancing, stability	Resource adequacy, balancing	Resource adequacy, balancing	Resource adequacy, balancing	Stability	Stability
Performance						
Response speed	Milliseconds	Minutes	10–30 minutes	Seconds–hours	Instantaneous	Milliseconds
Duration	1–8+ hours	8–12+ hours	Unlimited (fuel)	Hours (event-based)	Continuous	Weather-dependent
Siting flexibility	High	Low — geography constrained	Moderate	High — distributed	Moderate	Moderate
Cost						
Annualized cost US$/kW-year	$130–$210/ kW-y; four-hour system; excluding charging	$140–$210/ kW-y; high site variability	$120–$150/ kW-y; excluding fuel	$40–$180/ kW-y; incentive + aggregation costs	See note	$100-$160/ kW-y *GFM adds negligible incremental cost
Cost trend	↓ Rapidly falling	→ Stable	↑ Rising	↓ Falling as capacity expands	→ Stable	**PV**: ↓ Falling **Wind**: → Mixed (supply chain dependent)

Note: Technologies are compared under a common cold-start assumption to illustrate their relative capability to provide different reliability services. Warm-start gas turbines can respond within seconds to 10 minutes, while demand response ranges from seconds (crypto mines, HVAC systems) to hours (heavy manufacturing). Pumped-hydro storage and gas peakers can also provide stability services when already synchronized with the grid. BESS values reflect four-hour lithium-ion storage. Resource adequacy refers to dispatchability and responsiveness to variations in net peak load; solar and wind are excluded from this comparison. Cost ranges reflect experience in advanced markets and will vary with local financing and currency conditions. Synchronous condenser costs (typically US$15–$40 million for utility-scale deployments) are not directly comparable on a $/kW-y basis.

RMI Graphic. Source: Agora; Electric Power Research Institute; NLR; Lazard; American Council for an Energy-Efficient Economy; US Energy Information Administration; RMI

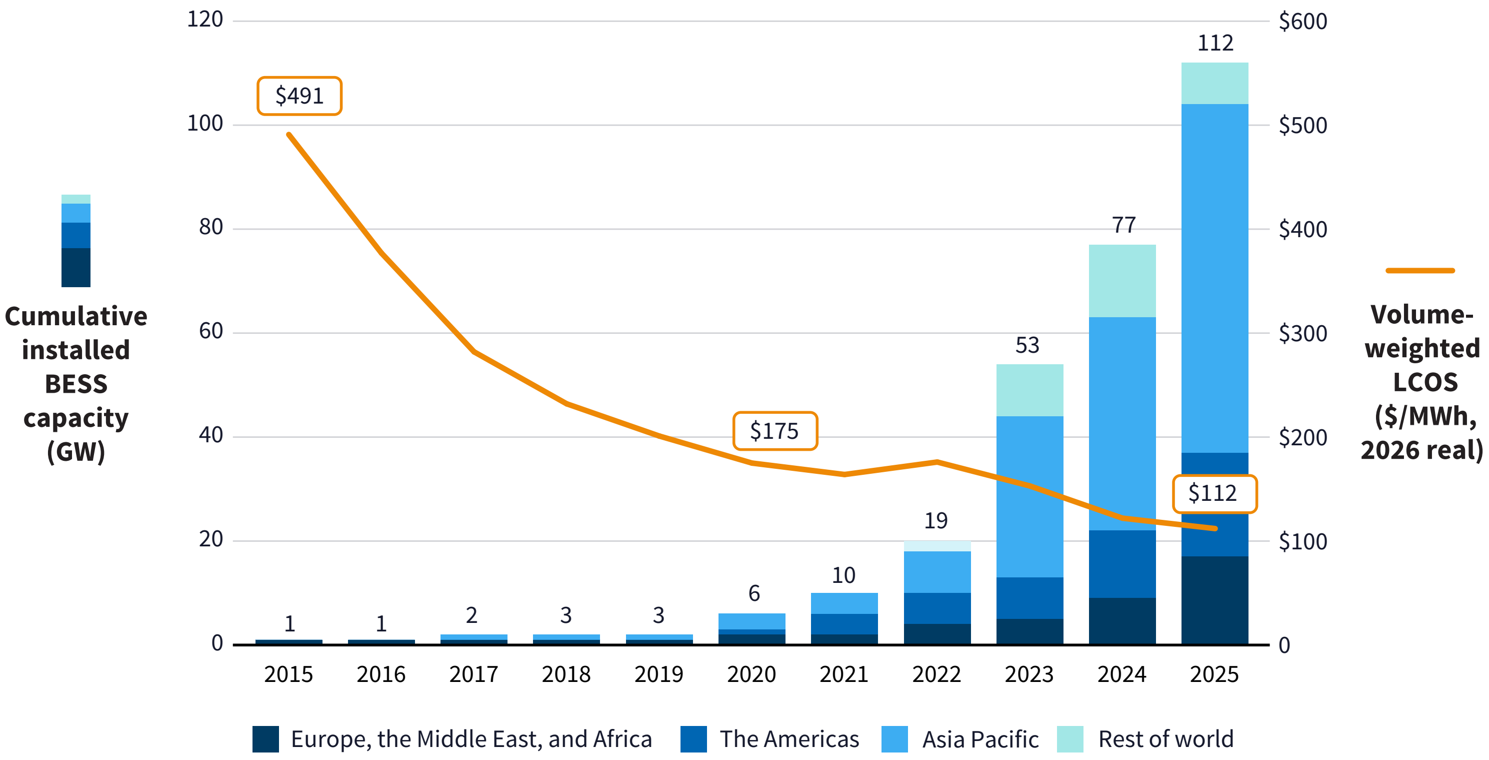
BESS as a multiservice flexibility resource

Among inverter-based resources, which respond much faster than conventional thermal generation, BESS is especially well suited to provide stability services, delivering fast, accurate, and bidirectional active power on demand, and it supports resource adequacy by delivering energy during critical net-load periods.

Whereas variable renewable resources are limited to providing power when their resource is available, BESS can store low-cost energy from those resources and dispatch it when needed. BESS does this by decoupling energy production from service delivery and providing reliability services independent of weather conditions. When strategically deployed, BESS can also help relieve network constraints, improve utilization of transmission infrastructure, and in some cases defer or reduce the need for network upgrades. These capabilities can be optimized through adequate performance requirements that are discussed in the section ***What performance requirements will ensure successful delivery?*** (page 23).

Battery deployment has accelerated in recent years, driven by declining costs and its ability to provide multiple high-value grid services (see Exhibit 6). In 2025, 33 GW of batteries were developed outside of the United States and China, a doubling since 2023 and a tenfold increase from 2021.

Exhibit 6 Comparing global BESS capacity additions against levelized costs



Note: Projections expect 116 GW of additional BESS by 2030, a doubling of current capacity. LCOS = Levelized cost of storage.

Source: BloombergNEF

Part I: Define Reliability Needs and Service Requirements

Over time, regulators should work closely with system operators and utilities to ensure that procurement decisions are grounded in a clear understanding of the reliability services the system needs. This process should be supported by appropriate operational information, analytical studies, and planning processes to identify reliability needs. The goal is not perfect foresight, but procurement frameworks anchored in reliability requirements and performance requirements rather than specific technologies. This approach also allows procurement to reflect local system conditions and resource availability and enables least-cost system reliability outcomes as system needs evolve.

In practice, many regulators and utilities must make procurement decisions before they have the data, analytical results, or institutional capacity to fully understand reliability needs. This section outlines a practical approach for building that evidence base and using it to inform procurement decisions over time. By taking a service- and reliability-centric approach, regulators, in partnership with system operators and planners, face three fundamental questions:

- What reliability needs should be addressed?
- What grid services can address those needs?
- What performance requirements are needed to deliver those services?

Answering these questions establishes the technical foundation for procurement by ensuring that the services being procured and the associated performance requirements are clearly defined before procurement mechanisms are designed.

What reliability needs should be addressed?

A range of assessments and studies determine when, where, and what services are needed to maintain reliability. Policymakers, system operators, and regulators are relying on one of three approaches to understanding their system reliability needs (see Exhibit 7).

Exhibit 7 **Key assessment approaches for determining system needs**

Assessment approach	Objective	Examples
Operational indicators and market signals	Provide an early indication of reliability issues and help prioritize where more detailed assessment or regulatory action may be needed. When comprehensive reliability studies are not yet feasible, regulators can work with system operators to interpret observable indicators using the operational data and available monitoring systems. This approach is well suited to jurisdictions with analytical constraints or incomplete operational data.	**The Philippines:** Department of Energy, Energy Regulatory Commission, and Independent Market Operator of the Philippines Wholesale Electricity Spot market are using operational indicators to identify emerging reliability challenges, including operating margin, reserve sufficiency, renewable curtailment, and congestion. These indicators are being used to prioritize flexibility needs and regulatory reforms while National Grid Corporation of the Philippines develops more comprehensive grid integration studies on grid-supportive inverter technologies. **Vietnam:** Vietnam Electricity has relied on frequency and voltage operational indicators to identify emerging reliability needs and prioritize procuring services to support accelerated rates of renewable energy connecting to the grid. These indicators include grid congestion, curtailment of wind and solar, and lack of ancillary services to manage frequency and voltage.
Targeted reliability and/or issue-based assessments	Investigate a specific reliability challenge in greater depth to determine its causes, quantify its impact and identify potential solutions. These assessments focus on specific issues such as frequency control, voltage stability, resource adequacy, and network constraints. They can be implemented more quickly and with fewer resources than comprehensive system-wide assessments, making them well-suited to near-term or location-specific issues.	**Ireland:** Eirgrid's DS3 program published specific studies that focused on frequency and inertia and initiated new products through these targeted assessments to secure the system's operational reliability. **Taiwan:** Through Taiwan Power Research Institute, Taipower undertook targeted technical research on declining system inertia, frequency regulation, and energy storage applications as renewable penetration increased. This study was published in parallel to the design and launch of a bilateral regulation reserve service called Dynamic Regulation (dReg). Following dReg, e-dReg was launched, which allowed BESS to stack peak shaving services onto existing regulation reserve services.
System-wide assessments	Provide a comprehensive understanding of current and future system reliability needs to inform long-term planning, procurement, and market design. These assessments integrate resource adequacy, stability, balancing, and network constraints but require extensive operational data, advanced analytical capabilities, and coordination across multiple institutions.	**Australia:** The Australian Energy Market Operator (AEMO) and National Electricity Market (NEM) work together to use findings from complementary studies like the *Transition Plan for System Security* and *Integrated System Plan* to determine system needs based on operational requirements for resource adequacy and capability, frequency and inertia, voltage management, and system restoration and flexibility. This whole-system approach is used to design and upgrade services (e.g., fast frequency) at lowest cost and minimize risk while supporting the transition to net zero. **Great Britain:** National Energy System Operator uses a suite of complementary studies, including *Operability Strategy Report*, *Frequency Risk and Control Report*, and *Future Energy Scenarios*, to assess resource adequacy, transmission needs, and stability across the system. Together, these studies identify emerging reliability risks and inform decisions on the procurement and evolution of services such as inertia and frequency response.

RMI Graphic. Source: Philippines DOE; ReGlobal (for Vietnam); EirGrid; Taipower; AEMO; NESO; RMI

Regardless of the approach used, regulators should work closely with system operators and planners to ensure that assessments are regularly shared, reviewed, and incorporated into procurement decision-making forums.

The ***Appendix: System Need Assessment Approach — Strengths and Limitations*** provides additional guidance on operational indicators, monitoring tools, and the principal reliability study types that support each stage of the progression.

Taking action as data and analytical capability mature

The objective is not to gain perfect information, but to build sufficient confidence to support timely decision-making. When comprehensive assessments are not yet feasible, operational indicators and targeted assessment approaches provide a practical starting point while data quality and institutional capacity advance. If they clearly point to emerging reliability challenges, regulators may need to act while analytical capability continues to mature. In these circumstances, targeted technology-specific procurements can address urgent system needs while building operational experience with emerging technologies such as BESS. India and South Africa did not wait for comprehensive system need studies. Their approaches allowed the system operator or market to define the operational need that BESS was to address.

India: Colocated storage mandate

India is scaling solar-plus-BESS resources across multiple states to better manage evening peak demand using batteries to deploy energy stored from daytime solar generation.[8] Guidance from the Ministry of Power for Renewable Energy Implementing Agencies and state utilities mandates that future solar tenders incorporate two-hour colocated energy storage systems.[9]

South Africa: Battery procurement program

South Africa also adopted technology-specific procurement to rapidly deploy BESS in response to acute reliability challenges. Rather than procuring a technology-agnostic reliability service, the Battery Energy Storage Independent Power Producer Procurement Programme (BESIPPPP) specifically targeted battery storage to address capacity shortfalls, relieve transmission constraints, and provide a portfolio of reliability services, including energy shifting and ancillary services (see Exhibits 11 and 23). Run under the IPP Office, BESIPPPP is overseen by the Department of Electricity and Energy, National Treasury, and the Development Bank of Southern Africa.

Regardless of the assessment approach or stage of market development, regulators should ensure that the reliability assessment and operational indicators support transparent, timely, and evidence-based decision-making. Assessment processes and outcomes should:

- Be shared with policymakers and regulators in time to inform procurement decisions, even if detailed operational data cannot be publicly disclosed
- Be transparent in assumptions, methodologies, and key findings so stakeholders can understand, evaluate, and apply the results

- Engage stakeholders to validate assumptions, build confidence in results, and improve analytical approaches, reducing the risk that important operational knowledge or institutional perspectives are overlooked

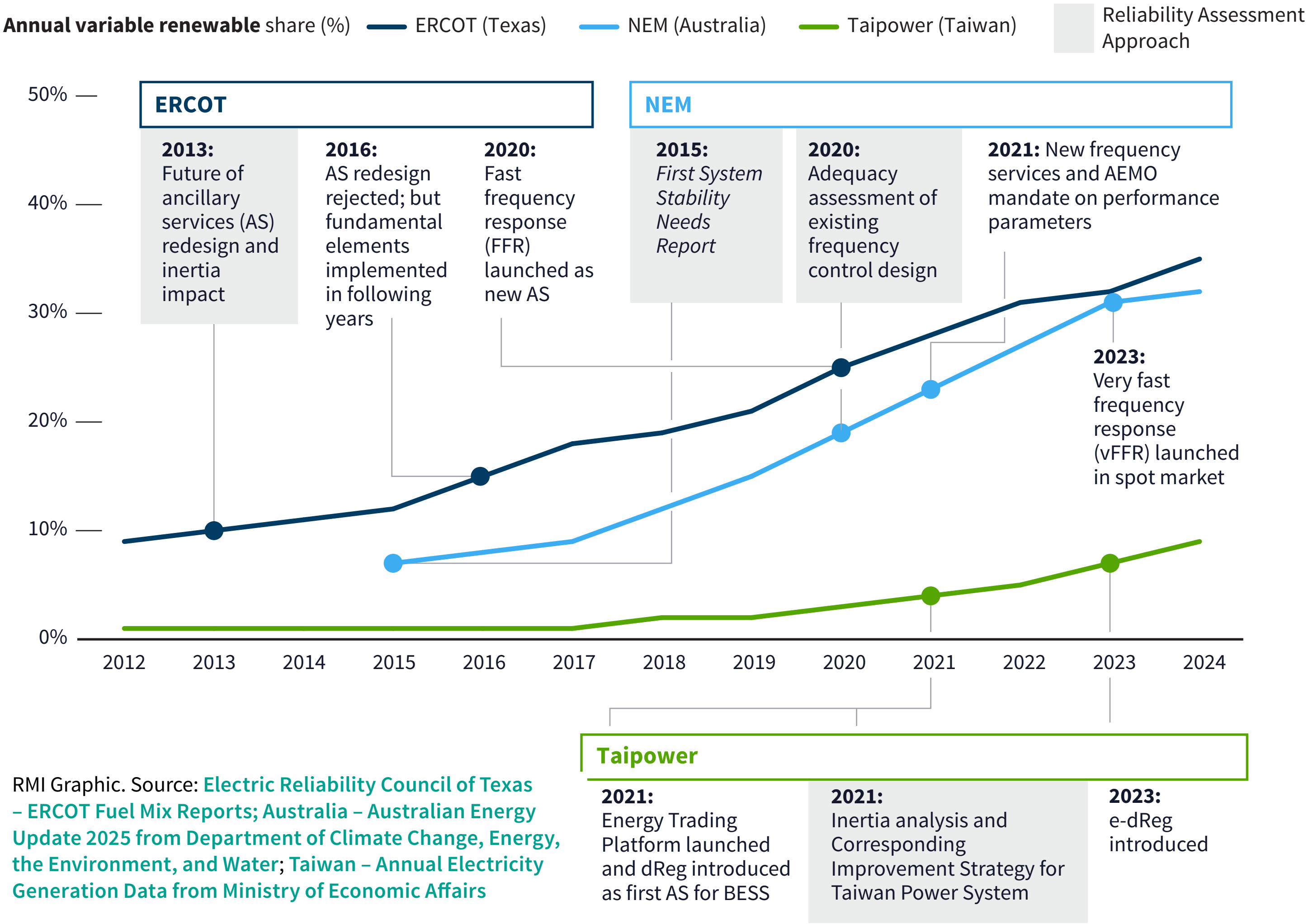
- Be updated regularly to reflect evolving demand, generation, network conditions, and operational requirements

- Draw on third-party modeling firms, technical experts, and independent research institutions where these capabilities are not available in-house

Reliability assessment is an iterative process that evolves as power systems, analytical capability, and institutional capacity mature. Countries typically begin with operational indicators and targeted assessments before progressing to more comprehensive system-wide studies, refining procurement decisions as new information becomes available.

Exhibit 8 illustrates how several markets initiated different reliability studies well in advance of launching new reliability and fast frequency response (FFR) products, often at relatively early stages of renewable transition.

Exhibit 8 How example countries have evolved reliability studies and services as variable renewable energy penetration increases



ERCOT

2013: Future of ancillary services (AS) redesign and inertia impact

2016: AS redesign rejected; but fundamental elements implemented in following years

2020: Fast frequency response (FFR) launched as new AS

NEM

2015: *First System Stability Needs Report*

2020: Adequacy assessment of existing frequency control design

2021: New frequency services and AEMO mandate on performance parameters

2023: Very fast frequency response (vFFR) launched in spot market

Taipower

2021: Energy Trading Platform launched and dReg introduced as first AS for BESS

2021: Inertia analysis and Corresponding Improvement Strategy for Taiwan Power System

2023: e-dReg introduced

RMI Graphic. Source: Electric Reliability Council of Texas – ERCOT Fuel Mix Reports; Australia – Australian Energy Update 2025 from Department of Climate Change, Energy, the Environment, and Water; Taiwan – Annual Electricity Generation Data from Ministry of Economic Affairs

What grid services can address identified needs?

Once system needs are identified, regulators should work with system operators and planners to determine how those needs should be expressed as procurable services. Together, these decisions determine which services can be procured and how those services are compensated. Well-designed service definitions help:

- Anchor procurement in measurable outcomes
- Preserve technology agnosticism
- Enable competition among multiple resource types
- Reduce regulatory and investor uncertainty
- Provide credible investment signals

The services that are ultimately prioritized will vary across power systems depending on their reliability needs and stage of evolution. Systems facing supply shortages may initially prioritize capacity, operating reserves, and frequency response, while transmission-constrained systems may prioritize voltage support or other locational services. Systems experiencing increasing variability in supply and demand may place greater emphasis on balancing services, while those with higher penetrations of inverter-based resources may prioritize services such as FFR, grid strength, and voltage regulation. There is no fixed sequence: Service priorities should be informed by system-specific reliability assessments and evolve as power systems change.

One useful approach, developed by engineering consultancy Telos Energy (recently acquired by PowerGEM), categorizes grid services according to the function they perform rather than the technologies that provide them.[10] Broadly, reliability services fall into three functional categories:

- Balancing supply and demand, and maintaining frequency across operational timescales
- Maintaining voltage stability and grid strength following disturbances
- Restoring the system following major outages

This framework includes services such as:

- FFR (including synthetic inertia)
- Primary frequency response
- Regulation
- Non-spin replacement reserves
- Capacity
- Grid strength
- Voltage regulation[iii]

[iii] In the Telos framework, these services are further categorized as active and reactive power services. Active power services primarily support balancing and frequency response, while reactive power services provide voltage support.

Black start is treated separately in this report because it is a dedicated system restoration service, rather than an ongoing balancing, stability, or voltage support service.

Exhibit 9 illustrates how common reliability changes can be translated into the grid services most likely to address them.

Exhibit 9

Examples that illustrate how observable reliability challenges can be addressed by specific grid services

Grid signal	Relevant services
• Frequent or sustained voltage deviations beyond acceptable limits, or unstable voltage fluctuations • Low or exhausted margins of reactive reserves or voltage stability • High reactive power imports	• Voltage support
• High rate of change of frequency • Short time available to clear a fault prior to instability	• Synthetic inertia and FFR • Primary frequency response • Grid strength or inertia
• Lack of or limited system restoration ability post-outage	• Black start*
• Rapid load growth • Increasing balancing complexity • Exceeding, or nearly exceeding, loss-of-load expectation (LOLE) targets	• Regulation • Non-spin replacement reserves • Capacity

*Procurement of black start services should be coordinated with the system operator's restoration strategy, including restoration paths, system topology, and technical performance requirements.

RMI Graphic. Source: RMI

What performance requirements will ensure successful delivery?

Setting performance requirements is one of the most important parts of the procurement process because it determines which resources are eligible to participate and how effectively they address the underlying reliability need. In many jurisdictions, system operators develop these requirements based on system needs, while regulators review and approve them to ensure that they are measurable, aligned with policy objectives, and supported by adequate compliance arrangements.

Collectively, performance requirements translate broad service definitions into measurable technical obligations that can be monitored, verified, and compensated. This is distinct from determining how much of a service the system must procure to meet system needs (i.e., resource adequacy).

Performance requirements should clearly specify the following characteristics of service delivery:

- **Service obligation:** How much of the service (e.g., MW, megavolt-amperes reactive) must each provider be capable of delivering when dispatched or otherwise required under its contract or market obligation?
- **Response time:** Given a specific service, how fast must assets react to events (within 50 milliseconds, or five minutes, etc.)?
- **Duration:** How long must the asset continue to provide a service (e.g., four- or eight-hour windows)?
- **Location:** Based on system needs assessments, what geographical extent (nodes, zones) must the asset provide the service to when needed?
- **Availability:** How much energy are providers required to hold at all times (no matter when the energy is called upon to deploy)? If stacking is allowed, how much availability is held for each service the asset is used for? Maintaining state of charge is a key factor in maintaining required availability.

South Africa's BESIPPPP illustrates how performance requirements can be translated into specifications for grid-scale BESS to support system reliability, reduce constraints on renewable integration, and increase usable grid capacity in constrained supply areas (see Exhibit 10).

Exhibit 10

South Africa BESIPPPP performance requirements

Performance requirement	South Africa BESIPPPP
Service obligation	Minimum 123 MW to maximum 124 MW per window
Response time	Varies depending on service
Duration	Four-hour windows
Location	Each round of bidding was site-specific, with one preferred bidder per specified grid site/substation: • Bid number 1: mainly focused on the Northern Cape province and related constrained areas • Bid number 2: targeted North West province, Gauteng province, and Free State supply areas • Bid number 3: focused on five Free State sites
Availability	Minimum availability of 95% over 8,760 hours/contract year

RMI Graphic. Source: IPPP Programme, Department of Electricity and Energy (DEE)

Whereas reliability assessments identify the services the system requires, performance requirements define the technical capabilities that providers must demonstrate to deliver them. They establish a measurable basis for ongoing testing, monitoring, and verification. Performance requirements alone, however, do not ensure delivery. Periodic review of provider performance and procurement outcomes enables regulators and system operators to refine service definitions and performance standards. Procurement mechanisms, contractual obligations, and compliance arrangements ensure that resources are operational and delivered when the system needs them.

Part II: Design Procurement Mechanisms

Three-step framework for mechanism design

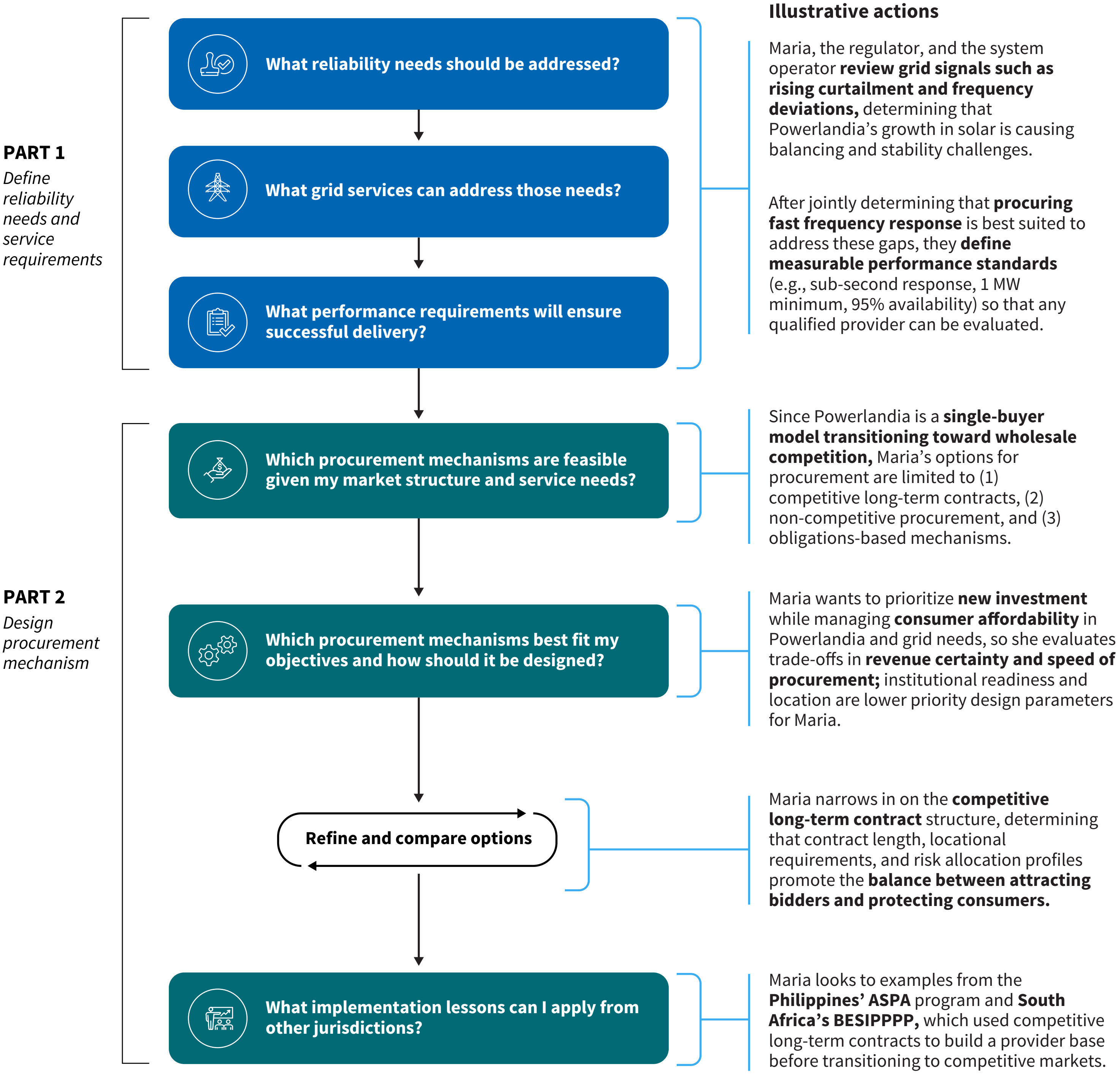
Once regulators have worked with system operators to determine system needs and translate those needs into procurable services, they use that evidence to establish procurement frameworks and prioritize reforms that deliver reliability at least cost to customers. In many jurisdictions, system operators and central buyers administer procurement but regulators establish the framework, approve the procurement approaches, and oversee outcomes. Establishing new service definitions, performance requirements, and procurement mechanisms is typically an iterative, multiyear process. International experience suggests that these reforms commonly take two to seven years from initial assessment through implementation, underscoring the importance of beginning reliability assessments before constraints become acute.

The procurement mechanisms used depend on factors such as market structure, competition levels, the location, the nature of the system needs, and the urgency of the reliability challenge. Because no single mechanism is appropriate in every circumstance, the three-step decision-making framework below provides a structured approach to selecting and designing compensation mechanisms that reflect local system conditions.

Exhibit 11 walks through a real-world example of Maria, a regulator in Powerlandia, a single-buyer model electricity system transitioning to a wholesale market. This example shows how the framework can be applied.

The framework is applicable across competitive, vertically integrated, and transitioning systems, but the procurement mechanisms and responsible institutions differ.

Exhibit 11 **Illustrative application of the framework by a regulator**



PART 1
Define reliability needs and service requirements

What reliability needs should be addressed?

What grid services can address those needs?

What performance requirements will ensure successful delivery?

Illustrative actions

Maria, the regulator, and the system operator **review grid signals such as rising curtailment and frequency deviations,** determining that Powerlandia's growth in solar is causing balancing and stability challenges.

After jointly determining that **procuring fast frequency response** is best suited to address these gaps, they **define measurable performance standards** (e.g., sub-second response, 1 MW minimum, 95% availability) so that any qualified provider can be evaluated.

PART 2
Design procurement mechanism

Which procurement mechanisms are feasible given my market structure and service needs?

Since Powerlandia is a **single-buyer model transitioning toward wholesale competition,** Maria's options for procurement are limited to (1) competitive long-term contracts, (2) non-competitive procurement, and (3) obligations-based mechanisms.

Which procurement mechanisms best fit my objectives and how should it be designed?

Maria wants to prioritize **new investment** while managing **consumer affordability** in Powerlandia and grid needs, so she evaluates trade-offs in **revenue certainty and speed of procurement;** institutional readiness and location are lower priority design parameters for Maria.

Refine and compare options

Maria narrows in on the **competitive long-term contract** structure, determining that contract length, locational requirements, and risk allocation profiles promote the **balance between attracting bidders and protecting consumers.**

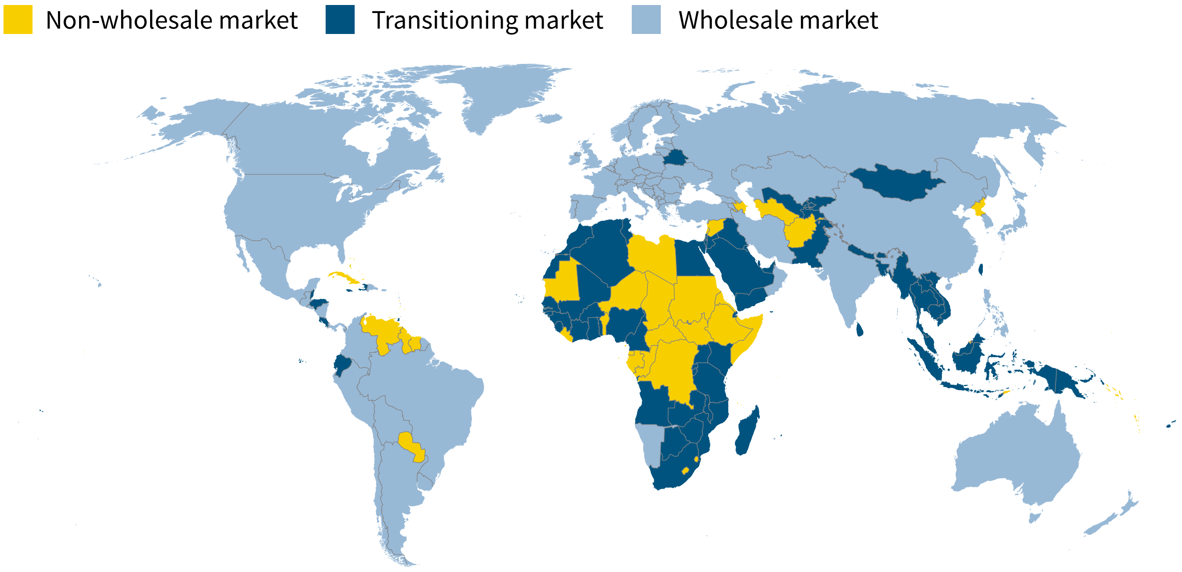
What implementation lessons can I apply from other jurisdictions?

Maria looks to examples from the **Philippines' ASPA** program and **South Africa's BESIPPPP,** which used competitive long-term contracts to build a provider base before transitioning to competitive markets.

RMI Graphic. Source: RMI; Clean Air Task Force

Exhibit 12 indicates the countries that are wholesale competitive markets, transitioning markets, and vertically integrated non-wholesale markets, highlighting the broad applicability of the decision-making framework outlined in this report.

Exhibit 12 Global electricity market structures



Note: Non-wholesale electricity market: Electricity is bought and sold under a vertically integrated utility or centralized state provider. Transitioning market: Countries moving toward competition including single-buyer models where independent generators sell to one buyer. Wholesale market: Generators/buyers trade directly or via a market operator.

RMI Graphic. Source: World Bank

There are four primary mechanisms, listed below, through which regulators enable the procurement of reliability services. These mechanisms are not mutually exclusive. In practice, regulators often combine and sequence multiple mechanisms to address different reliability needs, support different stages of market development, or manage implementation risks.

1. **Competitive markets:** Provide a standing day-ahead and/or real-time market for buyers and sellers to determine prices through competitive bidding.[11]

2. **Competitive long-term contracts:** Allow multiple providers to provide a defined service over a set time frame (one year or more) at best value through a competitive bidding process.[12]

3. **Non-competitive long-term procurement:** Secures reliability services outside competitive markets through bilateral contracts, standard offer programs, administratively determined tariffs, or regulated utility investment where compensation is established through regulatory or contractual arrangements rather than competitive price discovery.[13]

4. **Obligations and compliance based:** Services are secured through regulatory obligations (e.g., regulation or grid codes) to establish baseline reliability requirements. Obligations can apply to specific services while allowing the same asset to provide additional services through other procurement mechanisms. Compensation varies by jurisdiction and may be absent, provided through cost recovery, or administratively priced.[14]

To decide which of the four procurement mechanisms a decision maker can deploy, the following three-step process helps translate a grid service need into a procurement mechanism decision:

- **Step 1: Short-list feasible procurement mechanisms.** What two or three procurement options are most feasible in my system from a market structure and services point of view?
- **Step 2: Evaluate trade-offs and select the best-fit mechanism.** Which mechanism best meets these requirements, and what are the trade-offs with the various design choices?
- **Step 3: Adapt implementation lessons from international benchmarking.** How has this been implemented elsewhere and what design lessons can I apply?

Completing this process leads the decision maker to a short list of procurement options, clarity on trade-offs between them, and a set of relevant international experiences to draw from.

Designing procurement mechanisms requires balancing multiple considerations

The following tables are intended to guide, rather than prescribe, procurement decisions. In practice, regulators and system operators should use them together to iteratively evaluate system needs, market structure, competition, and implementation priorities so they can select the procurement mechanism best suited to their context.

Step 1

Short-list feasible procurement mechanisms

What procurement options are feasible in my system from a market structure and services point of view?

First, identify the procurement mechanisms that best align with the service being procured. Although most services can be procured through multiple mechanisms, international experience shows that certain services are better suited to specific approaches because of their technical, commercial, or locational characteristics.

Service applicability

Most reliability services can be procured through multiple mechanisms. However, international experience shows that service characteristics — such as location specificity, the need for competing providers, and ease of measurement and verification — often make some procurement mechanisms more suitable than others. Exhibit 13 summarizes the procurement approaches most commonly used for each reliability service.

Aside from the specific service that is being procured, market structure, competition levels, and existing contractual or regulatory arrangements may determine which procurement mechanisms are feasible. Regulators should use the structure outlined in Exhibit 14 to identify which procurement mechanisms are realistic given their market structure, institutional arrangements, and level of competition.

Exhibit 13 Mapping grid services to procurement mechanisms

LIMITED: Limited market procurement examples

SOME: Some market procurement examples; moderate alignment with service needs

EXTENSIVE: Extensive market procurement examples; strong alignment with service needs

Service	Competitive markets	Competitive contracts	Non-competitive procurement	Obligations	Rationale
Synthetic inertia and fast frequency response	LIMITED	SOME	SOME	EXTENSIVE	As inertia provision is low cost, system operators often use obligations to procure it; although pilots of competitive inertia procurement are underway in certain geographies
Primary frequency response	LIMITED	SOME	SOME	EXTENSIVE	Obligations are the most common procurement mechanism as most, to all, generators possess this capability inherently; limited examples of competitive procurement of primary frequency response in specific geographies
Regulation	EXTENSIVE	EXTENSIVE	EXTENSIVE	SOME	Obligations are less common since smaller, less flexible providers are unable to meet requirements
Non-spin replacement reserves	EXTENSIVE	EXTENSIVE	EXTENSIVE	SOME	Competitive procurement is used as multiple generators can compete on cost/response time; obligations common as reserve requirements are standardizable
Capacity	EXTENSIVE	EXTENSIVE	EXTENSIVE	SOME	Most assets can provide capacity allowing for most procurement mechanisms to function; capacity obligations may lead to oversupply
Grid strength or inertia	SOME	SOME	SOME	EXTENSIVE	Obligations are common as inertia is inherent and low cost to provide so system operators require it system-wide rather than paying for it
Voltage regulation	LIMITED	SOME	EXTENSIVE	SOME	Non-competitive procurement dominates as voltage issues are node specific, meaning one or few providers can address a problem at a given location
Black start	SOME	EXTENSIVE	EXTENSIVE	SOME	Contracts and agreements are most common as reliable black start is needed at specific susceptible nodes to ensure system-wide resilience against blackouts

RMI Graphic. Sources: Electric Power Systems Research, FERC Final Rule, FERC Ancillary Services, FERC Wholesale Capacity Markets, HoustonKemp, The Electricity Journal

Exhibit 14 Competition and market structure considerations across procurement mechanisms

Competitive markets

Competitive long-term contracts

Non-competitive long-term procurement

Obligations based

		Competition level among providers		
Market structure	**Vertical integration type**	***High competition*** *Many qualified providers, frequent participation, strong price discovery*	***Moderate competition*** *Growing provider base but some uncertainty in participation*	***Limited to no effective competition*** *Few providers / monopoly with tech and location constraints price discovery*
Wholesale market	***Unbundled / full Independent system operator (ISO)*** *Separate system operator (SO), generation, and distribution with an ISO*	COMPETITIVE MARKETS COMPETITIVE LONG-TERM CONTRACTS	COMPETITIVE MARKETS COMPETITIVE LONG-TERM CONTRACTS	COMPETITIVE LONG-TERM CONTRACTS NON-COMPETITIVE LONG-TERM PROCUREMENT OBLIGATIONS BASED
	Partially integrated *Some vertical integration, SO may share ownership with assets*	COMPETITIVE MARKETS COMPETITIVE LONG-TERM CONTRACTS	COMPETITIVE LONG-TERM CONTRACTS NON-COMPETITIVE LONG-TERM PROCUREMENT	NON-COMPETITIVE LONG-TERM PROCUREMENT OBLIGATIONS BASED
Transitioning	***Moving to wholesale*** *Reform underway, emerging markets with incomplete unbundling*	COMPETITIVE MARKETS COMPETITIVE LONG-TERM CONTRACTS	COMPETITIVE LONG-TERM CONTRACTS NON-COMPETITIVE LONG-TERM PROCUREMENT	NON-COMPETITIVE LONG-TERM PROCUREMENT OBLIGATIONS BASED
	Single-buyer model *Competitive generation and centralized by a single buyer; the system operator is within or independent from buyer*	COMPETITIVE LONG-TERM CONTRACTS	COMPETITIVE LONG-TERM CONTRACTS NON-COMPETITIVE LONG-TERM PROCUREMENT	NON-COMPETITIVE LONG-TERM PROCUREMENT OBLIGATIONS BASED
Non-wholesale market	***Vertically integrated*** *Utility owns and operates generation, transmission, distribution, and system operation, with little or no independent generation or competition*	COMPETITIVE LONG-TERM CONTRACTS	COMPETITIVE LONG-TERM CONTRACTS NON-COMPETITIVE LONG-TERM PROCUREMENT	NON-COMPETITIVE LONG-TERM PROCUREMENT OBLIGATIONS BASED

RMI Graphic. Sources: GridBeyond, Florence School of Regulation, IEA, Energy Markets, Ofgem, Energetica India, RMI, Regulatory Assistance Project, CommonWealth, Lawrence Berkeley National Lab, Utility Dive, IEA

For many vertically integrated and single-buyer systems, Step 1 may narrow the feasible options to non-competitive long-term procurement and/or obligations. Step 2 is intended to help regulators evaluate the trade-offs, design considerations, and implementation priorities of the remaining options.

Step 2

Evaluate trade-offs and select the best-fit mechanism

Which mechanism best meets these requirements, and what are the trade-offs with the various design choices?

No procurement mechanism is universally preferable. The appropriate choice depends on the reliability service being procured, as well as the implementation complexity, commercial arrangements, and the level of investment needed. The following design considerations provide a structured approach for evaluating these trade-offs and selecting the procurement mechanism best suited to system conditions and policy objectives.

The variables in design choice include:

- **Time horizon:** Urgency for reliability service
    - *Key question:* How quickly must this reliability need be addressed?
- **Location:** Geographic constraint/applicability of the service
    - *Key question:* Is the reliability need system-wide or geographically concentrated?
- **Product definition:** Degree to which service specifications target particular technologies or capabilities
    - *Key question:* Can the required service be specified using technology-neutral performance terms, or does reliable delivery require targeted technical capabilities or technologies?
- **Institutional readiness:** Ability of institutions to mandate and manage regulations
    - *Key question:* Do the legal authority, governance arrangements, policy objectives, staffing, procurement capability, funding, and technical capacity exist to implement and administer this procurement mechanism?
- **Risk tolerance/revenue certainty:** Financial risk allocation between stakeholders
    - *Key question:* How should risk be allocated between providers and the procuring entity to attract investment while meeting system needs?
- **Affordability/cost recovery:** Impacts of reliability reform on consumer affordability
    - *Key questions:* Who bears the cost of procurement? How are costs recovered? What is the impact on cost to the consumer? How should the value of the required reliability service be estimated or benchmarked to ensure that procurement delivers value for money, particularly where market-based compensation or cost-recovery mechanisms are not yet established?[iv]

[iv] Scaling up to use assets for multiple services entails important considerations of how to commercialize the assets and manage associated risk. More detail on this can be found in the accompanying report, *Making BESS Investable*.

Working together, regulators and system operators should use these variables to identify their procurement priorities and evaluate trade-offs associated with each feasible mechanism. Exhibits 15–18 summarize the key characteristics, design considerations, and implementation risks for each remaining option.

Institutional readiness is often a critical determinant of successful procurement. Regulators should assess whether the necessary legal, technical, and organizational capabilities are in place before implementing new procurement mechanisms. Regulators seeking a structured institutional readiness assessment and hands-on support can explore the Regulatory Institutional Energy Transition Health Check, a program conducted by the nongovernmental Regulatory Assistance Project, in collaboration with the Regulatory Energy Transition Accelerator and the Clean Energy Ministerial's Empowering Regulators for Accelerated Decarbonisation campaign.[15]

GEAPP and ESCOM exchange Grids of the Future MoUs at Malawi's BESS commissioning.

Mechanism 1: Competitive markets

Regulator role: Establish market rules, approve product definitions, oversee market performance, and ensure competition and consumer value.

Exhibit 15 **Characteristics and trade-offs of competitive markets**

Variable	Characteristics	Trade-offs to manage
Time horizon	• No procurement lead time required once market is established.	• Market design, rules, and infrastructure take years to develop.
Location	• Supports both nodal and system-wide pricing when there is sufficient competition and market monitoring.	• When regions or zones are less competitive, competitive markets can produce price distortions and inadequate locational signals.
Product definition	• Wide array of products by design; any resource meeting performance specifications can participate and compete.	• Performance specifications should be designed carefully to ensure that they don’t unintentionally favor incumbent technologies.
Institutional readiness	• Once established, competitive markets may reduce the need for repeated procurement process and scale efficiently over time.	• Requires significant up-front institutional investment in market systems, settlement infrastructure, and ongoing oversight.
Risk tolerance/ revenue certainty	• Efficient price discovery in liquid markets may reduce overall system costs; market-wide settlement diffuses payment risk across providers, reducing financial risk.	• Revenue volatility may deter investment in new provider classes; even strong market design cannot make up for provider liquidity constraints.
Affordability/ cost recovery	• Market prices provide ongoing price discovery with costs recovered through market clearing; competitive cost may minimize cost passed to consumers.	• In thin or immature markets, limited competition or market power during scarcity events can drive prices above competitive levels, increasing costs to consumers unless mitigated through market monitoring or pricing protections (e.g., offer caps).
BESS considerations	• Millisecond response time and accurate metering make it technically well suited to competing across multiple service markets. • Market rules must allow for co-optimization of stacked services like FFR, regulation, and capacity. Otherwise, the full-service value goes under-compensated.	

RMI Graphic. Source: US Environmental Protection Agency; US Federal Energy Regulatory Commission (FERC); IEEE; *Utilities Policy*; *International Transactions on Electrical Energy Systems*; *Energy Economics*

Mechanism 2: Competitive long-term contracts

Regulator role: Establish procurement rules, approve procurement approaches, and oversee contract performance and cost recovery.

Exhibit 16 Characteristics and trade-offs of competitive long-term contracts

Variable	Characteristics	Trade-offs to manage
Time horizon	• Well suited to transitional and structural needs as the contract length can be adjusted for the investment horizon and reliability requirements; relatively fast to implement.	• Effective implementation depends on aligning procurement timelines with anticipated reliability needs, allowing sufficient time for competitive procurement, project delivery, and commissioning.
Location	• Can be structured to include both system-wide coverage and locational requirements.	• Competition can become constrained for highly locational procurements unless there are sufficient credible providers across locations.
Product definition	• Can be designed for any product class, therefore enabling competition across many products.	• Contract terms can still unintentionally favor established technologies if specifications are not carefully designed.
Institutional readiness	• Easier to implement than a full competitive market design, especially if it builds on existing procurement and contracting capabilities.	• Requires RFP design, bid evaluation, contract negotiation, and performance monitoring, which some operators may not be able to support.
Risk tolerance/ revenue certainty	• May provide revenue certainty for providers, lower the cost of capital, and support new investment, but only to the extent that off-taker's creditworthiness is certain. • In jurisdictions with elevated sovereign or political risk, long-term contracts are generally a preferred pathway for financing and risk mitigation instruments as they establish defined contractual payment obligations that can be underwritten or guaranteed.	• Competitive bidding may produce few bidders or bid withdrawal where commercial risks (e.g., payment uncertainty) or non-commercial risks (e.g., currency, sovereign risks) remain high, as contract structure cannot overcome perceived payment risk.
Affordability/ cost recovery	• Competitive bidding provides price discovery, with costs recovered through contracted prices. Where competition is sufficient, contracts help reveal the cost of providing the required service while offering long-term price certainty for consumers.	• Long-term contracts provide price certainty but may expose consumers to above-market costs if technology costs decline or system needs change; limited bidder participation can also reduce competitive price discovery and increase procurement costs.
BESS considerations	• Long-term contracts can be structured to compensate BESS for defined services such as FFR or black start with fixed availability payments. • Contract design must account for how the same BESS asset can be capable of and required to provide for multiple services across timescales.	

RMI Graphic. Source: California Public Utilities Commission, Connecticut Department of Energy & Environmental Protection, Energy Innovation, *Encyclopedia of Energy*, Energy Storage News, World Bank Group

Mechanism 3: Non-competitive long-term procurement

Regulator role: Approve procurement, ensure prudent cost recovery, and assess whether conditions support a transition to competitive procurement.

Exhibit 17 **Characteristics and trade-offs of non-competitive long-term procurement**

Variable	Characteristics	Trade-offs to manage
Time horizon	• Can be executed relatively quickly when a specific provider is already identified.	• Agreements and tariffs may lock in costs or reduce flexibility as needs evolve or new providers come on line.
Location	• Effective for location-specific needs where a single asset is positioned to deliver the needed services.	• Limits the solution to one location and one provider; limited opportunity to optimize across alternatives.
Product definition	• Appropriate when a specific technology or product is the only viable solution.	• Restricts competition and innovation by design; it should not be used where alternatives exist.
Institutional readiness	• Relatively simple to execute as it is a bilateral negotiation without a formal competitive process.	• Without competitive benchmarking, information asymmetries between the procuring entity and provider can make it difficult to negotiate fair-value contract terms.
Risk tolerance/ revenue certainty	• Creates revenue certainty to the provider to support financing specialized or novel assets; regulated utility ownership may be appropriate where competitive procurement is not feasible or where network operators require direct control of the asset to meet reliability needs. • In jurisdictions with elevated sovereign or political risk, long-term contracts are generally a preferred procurement pathway for financing and risk mitigation because they establish defined contractual payment obligations that can be underwritten or guaranteed.	• Full cost and volume risk sits with the operator with limited leverage to manage performance or cost over time; without competitive benchmarking, providers may price in substantial risk premiums. • Appropriate ring fencing, transparent cost recovery, and periodic regulatory review can help mitigate market distortion where competition may develop over time.
Affordability/ cost recovery	• Costs recovered through regulator tariffs and negotiated contract terms; revenue certainty can potentially lower financing costs, thereby offsetting costs passed to consumers.	• Without competitive price discovery, regulators must benchmark contract prices against avoided system costs, comparable procurements, or independent cost assessments. Weak benchmarking or contract oversight can lead to compensation above efficient levels and higher consumer costs over time.
BESS considerations	• Where BESS is identified as the preferred solution for a location-specific reliability need, and only a single provider can develop and operate the required asset, bilateral non-competitive procurement can be an efficient solution. • Non-competitive procurement should include both availability and performance payments to ensure reliable dispatch during system disruptions.	

RMI Graphic. Source: *Utility Dive*; US Department of Energy; US General Services Administration; Energy Innovation; *Applied Energy*

Mechanism 4: Obligations and compliance-based

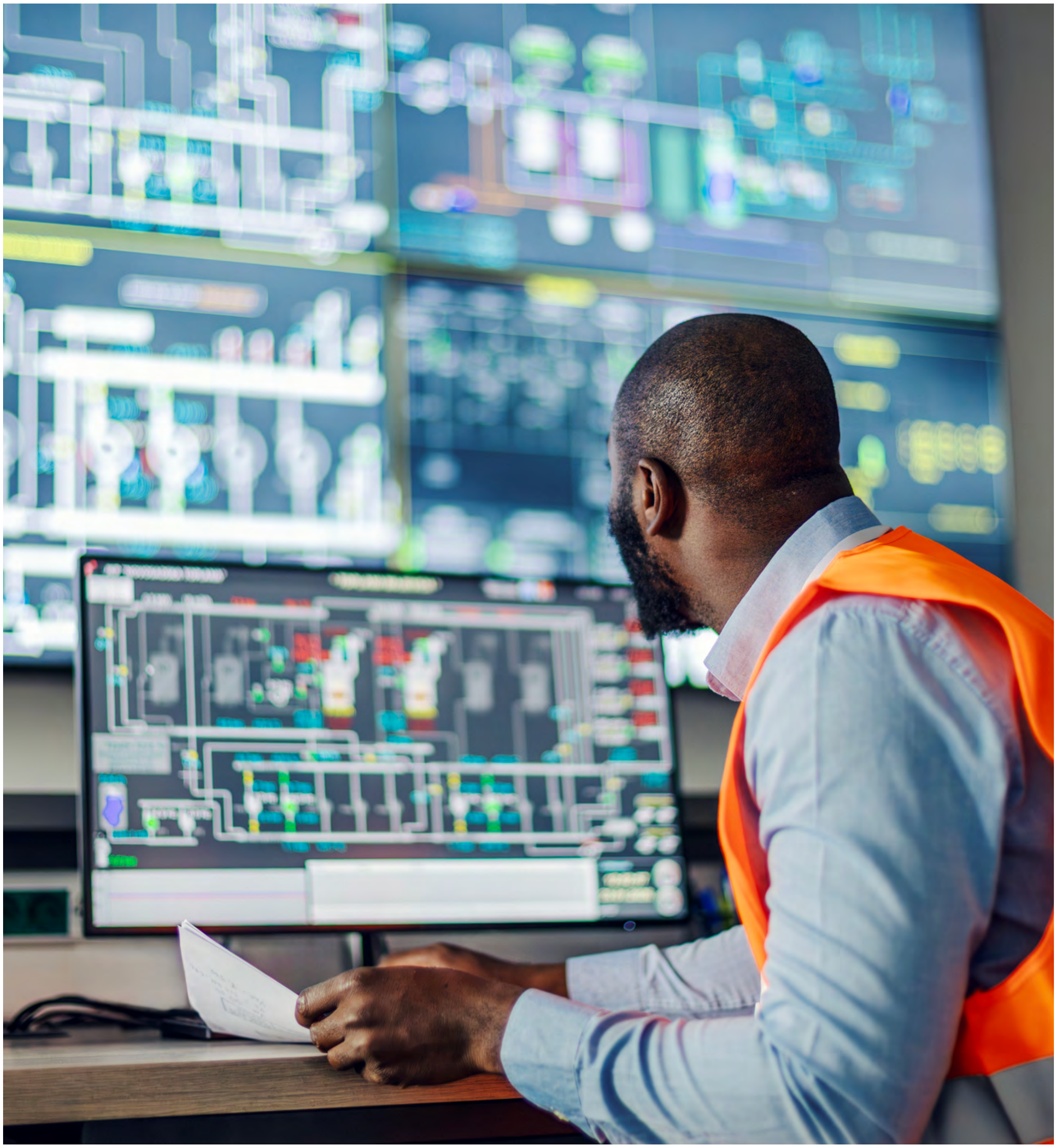
Regulator Role: Establish or approve compliance obligations, monitor implementation, and review requirements as system needs evolve.

Exhibit 18 Characteristics and trade-offs with obligations and compliance-based mechanism

Variable	Characteristics	Trade-offs to manage
Time horizon	● Can be implemented through regulatory action without procurement processes or contract negotiation.	● Obligations set at a given point in time may become outdated quickly as system conditions and technology evolve.
Location	● System-wide obligations are straightforward to administer and can be applied across all qualifying providers.	● Difficulty in targeting obligations to specific locations without creating complex, provider-specific regulatory requirements.
Product definition	● Obligations can be written in product-neutral performance terms applicable to all provider types.	● Poorly designed obligations may unintentionally favor incumbent technologies or prevent innovative resources from demonstrating equivalent performance.
Institutional readiness	● Builds on existing regulatory authorities and compliance frameworks, which may reduce implementation burden.	● Modifying obligations requires regulatory processes that can be slow, contested, and resource intensive; because it is the only mechanism that introduces costs and no provider benefits, it sometimes requires grandfathering.
Risk tolerance/ revenue certainty	● Revenue is often based on cost recovery as the service is secured as a condition of market participation or connection.	● Provides little incentive for investment in new capacity; may be unnecessarily expensive or lead to procuring more resources than the system needs.
Affordability/ cost recovery	● Compliance costs are typically embedded within provider operational budgets and recovered through regulated tariffs; the result is low to moderate impact on affordability.	● Because compensation is determined administratively rather than through competitive price discovery, regulators should periodically review system needs and benchmark compliance costs to ensure that obligations remain cost-effective and proportionate to the reliability benefit delivered.
BESS considerations	● Obligations can effectively ensure that already-installed BESS delivers baseline services such as primary frequency response or synthetic inertia as a condition of grid connection. ● Compensation arrangements should be considered where providing the obligated service imposes costs on providers or limits participation in other remunerated products.	

RMI Graphic. Source: FERC; Iris Carbon; *Oxford Review of Economic Policy*; *Renewable and Sustainable Energy Reviews*

For further information about the design considerations for various procurement mechanisms, see “Effective Ancillary Services Market Designs on High Wind Power Penetration Systems” and “Integrating Fast Frequency Response Ancillary Services: A Global Review of Technical, Procurement, and Market Integration Challenges.”[16]



When to use each procurement mechanism?

Exhibits 19–26 illustrate how different procurement mechanisms have been implemented to address specific reliability needs and highlight lessons from implementation. Where relevant, examples from emerging economies are included throughout the report to illustrate early-stage regulatory reforms, pilot procurements, and institutional development that are laying the foundation for future flexibility markets.

Competitive markets

Competitive markets are best when you have a mature, competitive ecosystem of providers that want a self-sustaining, scalable system that enables variable, lower-cost solutions without ongoing procurement overhead.

Exhibit 19

The Philippines — Creating a co-optimized energy and reserve market through previously established competitive long-term contracts

Overview

- Historically, ancillary services were procured through competitively awarded five-year ancillary services procurement agreements (ASPAs), providing long-term revenue certainty for new providers.
- In 2024, the Philippines launched a co-optimized energy and reserve market, allowing certified providers to participate in real-time reserve markets without an ASPA, while maintaining both ASPA-based procurement and competitive market participation pathways.

Key takeaways

- Long-term competitive contracts helped establish an initial provider base and demonstrate BESS performance before transitioning to a competitive spot market.
- Co-optimization expanded opportunities for BESS to earn revenue from reserve services alongside energy markets. Batteries now make up more than half of registered regulating reserve providers.
- Market implementation was iterative, with rule refinements following the initial launch before the enduring market design was adopted.

RMI Graphic. Source: Philippine Department of Energy (DOE); DOE; Independent Electricity Market Operator of the Philippines (IEMOP)

Exhibit 20

ERCOT — A revamped real-time co-optimization plus batteries market to allow BESS participation

Overview

- As solar and wind generation increased, ERCOT updated its energy-only spot market to procure services that balance supply and demand, maintain frequency, and manage operational uncertainty by integrating BESS alongside existing resources.
- Designing the real-time co-optimization plus batteries (RTC+B) market took years of iteration and saw high participation of BESS.
- The RTC+B market enabled BESS to provide fast response and reserve services.

Key takeaways

- Existing competitive markets can accommodate new flexibility resources without creating separate technology-specific procurements.
- Refining performance standards and updating ways to track performance can ensure that new flexibility resources are meeting reliability needs.
- Automated co-optimization improved the efficiency and utilization of flexible assets.

RMI Graphic. Source: ERCOT News Release; ERCOT Ancillary Services; Ascend Analytics

Competitive long-term contracts

Competitive long-term contracts are best when you need to draw investment into new or emerging resource classes by offering revenue certainty and cost stability without committing the full infrastructure of a permanent market.

Exhibit 21

Italy — Terna tests BESS ability to provide ultra-fast frequency through the Fast Reserve pilot auction

Overview	• As Italy's renewable penetration increased and system stability needs became more dynamic, Terna created the Fast Reserve pilot to test an ultra-rapid frequency regulation service. • The service was designed for very fast active-power response, with full activation time no greater than one second and differentiated from the frequency-regulation products already defined in Italy's Grid Code. • Procurement was zonal to address location-specific grid needs across the country, and providers were separately selected for each zone.
Key takeaways	• Long-term, competitive contracts demonstrated new ultra-fast reliability services while reducing investment risk for early BESS deployment. • Availability commitments were complemented by opportunities to participate in other markets, supporting revenue stacking (e.g., winners for this Terna procurement received a fixed annual payment for availability for up to 1,000 availability hours per year, leaving batteries to pursue other opportunities after the annual requirement).

RMI Graphic. Source: Terna; Terna; *Energy Storage*

Exhibit 22

South Africa — Leveraging BESS to move toward decentralized market for capacity, energy, and ancillary services through the BESIPPPP

Overview	• BESIPPPP was created to specifically test grid-scale battery storage to support system reliability, reduce constraints on renewable integration, and increase usable grid capacity in constrained supply areas. • The program was set up to procure capacity, energy, and ancillary services — including instantaneous reserves, regulating reserves, 10-minute reserves, and supplemental reserves. • Each bid window is site-specific, with one preferred bidder per specified grid site/substation. • Competition level increased throughout the multiple bid windows, from 17 bids in bid window 1 to 33 bids in bid window 3, signaling steady growth in confidence for a BESS market to provide required services.
Key takeaways	• Long-term competitive procurement addressed near-term grid needs allowing regulators to deploy, test, and refine new flexible resources over several years (15 years in this case) while also gradually building a decentralized, competitive mechanism framework for the future. • Running multiple long-term competitive procurement rounds over time allowed providers to enter the market as they became technically and commercially ready, strengthening market depth.

RMI Graphic. Source: South Africa Ministry of Mineral Resources and Energy; Ministry of Electricity and Energy; Ministry of Electricity and Energy; *Energy Storage*

Non-competitive long-term procurement

Non-competitive long-term procurement is best when there is only one viable product for a specific location or technical need and therefore the speed and certainty of service delivery outweigh the benefits of competition.

Exhibit 23

Australia — Network support and control ancillary services (NSCAS) delivered through a bilateral network support agreement

Overview

- NSCAS is a non-market ancillary service procured to maintain power system security and reliability of supply at a specific network location. NSCAS addresses ongoing, locational technical needs such as voltage control, system strength, and network loading support that cannot be solved by the market.
- The procurement is tailored toward BESS. ElectraNet's Dalrymple ESCRI Battery in South Australia is a 30 MW, 8 MWh BESS on the Yorke Peninsula and is the only asset positioned for local voltage/network support at the 132 kilovolt (kV) node. Therefore, NSCAS was directly contracted with it for this purpose.

Key takeaways

- NSCAS addressed ongoing, locational needs (e.g., voltage control, system strength) that competitive markets were not well suited to procure.
- The arrangements allowed the BESS assets (such as ElectraNet) to stack revenue from NSCAS in addition to energy market participation, improving the asset's viability.
- Where only one provider could meet the need, bilateral procurement was more practical than competitive tendering.

RMI Graphic. Source: **AEMO NSCAS Description**; **AEMO South Australian Electricity Report**; **Australian Renewable Energy Agency**

Exhibit 24

Brazil — Reactive power/voltage support secured through bilateral arrangements under an administratively set tariff

Overview

- Brazil's system operator (ONS) compensates specific generating units connected to the grid to provide reactive power voltage support through bilateral arrangements with ONS, rather than competitive tenders.
- The compensation is administratively set through the TSA (Ancillary Service Tariff), rather than competitively determined. It is reset periodically by Agência Nacional de Energia Elétrica and set on a nodal basis.

Key takeaways

- Bilateral arrangements provided location-specific reactive power and voltage support where competition was limited, which is why Brazil has defaulted to bilateral, non-competitive arrangements rather than competitive procurement.
- The bilateral, administered tariff model provided revenue certainty for technical obligations without competition among providers.

RMI Graphic. Source: **Cenário Energia**; **The Brazil Business**; **University of Campinas**

Obligations- and compliance-based procurement

Obligations-based procurement is best when you need to set a baseline capability that is immediately guaranteed across all providers; the service can be required as a condition of participation rather than incentivized through payment.

Exhibit 25

Great Britain — Ensuring universal mandatory frequency response through grid code connection obligations

Overview

- Mandatory frequency response (MFR) is a compliance-based obligation that requires all generators that are connected to the transmission system to adjust their active power in response to frequency deviations. This is to ensure that system frequency remains at the 50 hertz target.
- The obligation is enforced as a part of the grid connection process; after operations commence, NESO prioritizes procuring frequency response from specific assets following a least-cost model.
- NESO's proposed grid code modifications would create a required pathway for BESS to participate in MFR; this is expected to be implemented by 2030.
- Although generators cannot opt out of MFR, they can indicate commercial unwillingness by paying a £9,999/MWh (US$13,561/MWh) penalty.

Key takeaways

- Baseline obligations like MFR established a critical baseline across all eligible resources at a lower administrative cost to the system, leaving competitive procurement as the vehicle for higher-value or differentiated services.
- Mandatory service requirements evolved as new resource types entered the power system.

RMI Graphic. Source: NESO Mandatory and Commercial Frequency Response; NESO GC0185

Exhibit 26

India — Expanding technology-inclusive frequency response (with primary response obligation) through the Indian Electricity Grid Code

Overview

- As India shifted toward inverter-based renewable generation, there was a reduction in automatic system inertia, leading to grid-wide frequency challenges. The Central Electricity Regulatory Commission (CERC) overhauled the Indian Electricity Grid Code in 2023 to expand the Operating Code for frequency control and reserves obligations.
- India has written BESS into the compliance requirements as renewables can fulfill their primary response obligation through energy storage systems or pumped storage plants. BESS behavioral mandates are directly in the mechanism design.
- Compliance has recently lagged the mechanism design as the CERC has indicated that some renewable energy projects have failed to provide reserves during frequency events; only a minimal number of projects have achieved full compliance.

Key takeaways

- Technology-neutral performance requirements expanded reliability obligations to include inverter-based resources.
- Performance standards and real-time verification became increasingly important as participation requirements expanded.
- Compliance challenges highlighted the importance of verification and enforcement alongside new obligations.

RMI Graphic. Source: Indian Electricity Grid Code; *ESG News*

Step 3

Adapt implementation lessons through international benchmarking

How has this been implemented elsewhere, and what design lessons can I apply?

Procurement does not end with contract award. Regulators should work with system operators to monitor provider performance, evaluate whether procured services continue to meet system needs, and periodically refine procurement approaches as technologies, markets, and reliability requirements evolve. International benchmarking supports this process and helps regulators adapt proven implementation approaches while avoiding common design pitfalls. Rather than replicating another market, regulators should identify jurisdictions with similar system characteristics, institutional capacity, and policy objectives, and assess how procurement and market design choices can be tailored to local conditions.

International benchmarking can be used to:

- Identify implementation steps for translating identified reliability needs into procured services
- Compare procurement and contract design approaches across different market structures and institutional arrangements
- Evaluate trade-offs between cost, competition, investment incentives, and speed of deployment
- Understand sequencing strategies for moving from pilot procurements and targeted interventions to enduring market and regulatory frameworks

BESS facility at Kanengo, Lilongwe, Malawi.

Procurement in practice: Great Britain's evolution from early procurement to competitive markets

Part I: Define reliability needs and service requirements

Great Britain demonstrates how to take advantage of intentional procurement mechanism strategies and leverage battery technology to improve flexibility and stability of the grid. As renewable generation increased and system inertia declined, the system operator, NESO, needed new ways to procure fast frequency response while maintaining reliability. Well before net-zero targets became legally binding in 2019, National Grid and NESO had started implementing and testing new technologies to provide reliable frequency services with a focus on improved capabilities like sub-second response times. As NESO leads on design, implementation and operation of reliability services, Ofgem, the regulator, determines whether NESO is delivering services based on system needs while also ensuring that affordability is prioritized for customers.

Part II: Design procurement mechanisms

The evolution of Great Britain's frequency response market followed three key stages:

- **Stage 1: Competitive long-term contracts:** In 2016, National Grid's Enhanced Frequency Response tender paved the way for batteries.[17] This was the first time battery storage was used for balancing services at grid scale. It also enabled de-risking BESS investments and multiyear guaranteed bankable revenue contracts for asset owners.
- **Stage 2: Trial procurement and refinement:** By 2017, batteries were a proven technology to provide frequency services at grid scale in Great Britain. Consequently, NESO designed long-term contracts to test the newer, faster performance standards in daily competitive market conditions for all technologies. BESS emerged uniquely positioned to meet the updated performance standards.
- **Stage 3: Enduring competitive market:** Lessons from the pilot and trial phases informed the development of the Dynamic Services Suite, establishing a permanent competitive market for FFR that continues to evolve alongside changing system conditions.

Great Britain's frequency performance standards confirm the capabilities of batteries

In Great Britain, batteries performed strongly in competitive daily markets to procure frequency services via the Dynamic Services Suite. Based on data published on NESO's Enduring Auction Capabilities data portal, batteries account for about 90% of cleared volume in response and reserve services. Additionally, the same data shows that batteries represent over 95% of all dynamic suite products.[18] Meanwhile, volume cleared for Dynamic Services has gradually increased over the past few years, demonstrating the capability of batteries to meet demand. The balancing mechanism has made revenue opportunities very attractive for BESS providers.[19] There is a wide, and growing range of services that can be stacked, jumped, co-delivered, and split.[20]

Supporting early market development

In many emerging economies, regulatory reforms alone are often insufficient to attract private investment. Commercial arrangements frequently need to evolve alongside procurement frameworks before large-scale deployment can occur. Particularly in single-buyer or vertically integrated procurement models, commercial arrangements such as revenue certainty, payment security, and credible procurement entities often need to evolve alongside procurement frameworks before projects become commercially viable. As a result, governments frequently require additional support to translate new regulatory frameworks into operational projects.

Regulatory sandboxes, small-scale demonstration procurements, and pilot projects provide a practical way to test procurement approaches, build operational experience and demonstrate technical and commercial viability under local conditions. These activities help regulators, system operators, and utilities strengthen institutional capability while reducing implementation risks.

Development banks, bilateral agencies, and other development partners play an important role in providing technical assistance, analytical support, and concessional financing needed to bridge this gap. Beyond supporting individual projects, these efforts should also prioritize building local institutional and technical capability so that governments, regulators, system operators, and utilities can independently plan, procure, and oversee reliability services over the long term. The Malawi BESS project illustrates how coordinated technical assistance, concessional finance, and institutional collaboration can help translate early reforms into a bankable project while building the institutional capability needed for future competitive procurements.

Storage in practice: Malawi's path from cyclone crises to battery-backed resilience

After Cyclone Freddy caused Malawi to lose one-third of its firm hydropower capacity, driving renewable energy curtailment, frequent system outages, and growing reliance on expensive diesel peaking generation, the Electricity Supply Corporation of Malawi identified battery storage as a priority reliability solution. Supported by the Global BESS Consortium and the Global Energy Alliance for People and Planet, the project combined grant financing with technical assistance and a collaborative delivery model involving government institutions and technical partners to procure Malawi's first 20 MW/40 MWh BESS within the country's existing legal and procurement framework.

During commissioning tests and the early operating period starting in June 2026, the project demonstrated system-wide benefits including reduced renewable curtailment and deemed-energy charges by approximately 50%, improved grid reliability by shifting solar generation to meet evening demand, reduced reliance on diesel peaking generation, and helped manage system frequencies and voltages within accepted bands.

From a policy perspective, the project paved the way for establishing technical, regulatory, and institutional foundations for future BESS deployment in Malawi. It also led to the establishment of the Southern Africa BESS Centre of Excellence at Mzuzu University to support training, applied research, and knowledge sharing anchored around real project data, helping build local expertise and accelerate future BESS deployment across the region.

Conclusion

Power systems are changing rapidly, and as flexibility becomes increasingly valuable, regulators face the challenge of ensuring that reliability services evolve alongside changing system conditions. This requires more than selecting procurement mechanisms. It requires working across institutional boundaries to ensure that reliability needs are identified, services are clearly defined, performance requirements are measurable, procurement frameworks enable effective competition, and commercial arrangements support long-term investment.

Whereas system and market operators may be responsible for identifying reliability needs, conducting the technical studies, or administering procurements, regulators are responsible for ensuring that these activities remain aligned with broader policy objectives, consumer value, and the long-term evolution of the power system. The procurement and compensation frameworks described in this report are rarely end points in themselves. Flexibility reforms are implemented incrementally as reliability needs change, institutional capabilities mature, and deployment of flexible solutions like BESS scales.

This report focuses on the procurement and compensation design of services that enable flexibility in the grid. Its companion report, *Making BESS Investable*, builds on these foundations by examining the revenue, market access, regulatory, and delivery conditions needed to support commercially viable and repeatable BESS deployment. Together, the two reports lay out a framework for regulators looking to procure services that are required to meet system needs and create commercially successful conditions needed to sustain BESS and other flexible solutions at scale.

Appendix

System Need Assessment Approach — Strengths and Limitations

Part A: Operational and market signals

Not all jurisdictions will have access to every monitoring tool listed below. Countries can begin with the operational data and monitoring systems available to them and progressively expand analytical capability as institutional capacity and data improve. Exhibit A1 summarizes common monitoring and analytical tools used to identify emerging reliability needs.

Exhibit A1 **Descriptions of tools for monitoring reliability indicators**

Purpose for monitoring	Tool	Description
Measurement	Supervisory control and data acquisition (SCADA)	The fundamental real-time control system that remotely monitors key grid signals (e.g., power flows, voltages) and controls field equipment (e.g., switches, circuit breakers) from a central control room
	Wide-area monitoring system (WAMS)	A high-speed grid situational awareness system using synchro phasor sensors such as phasor measurement units to measure voltage phase angles and frequency dozens of times per second to provide early warning of grid instabilities or disturbances across large regions
	Advanced metering infrastructure (AMI)	A network of smart meters and two-way communication links that provide frequent, automatic, granular data on electricity usage and instantaneous detection of local outages
Prediction	Load and renewable forecasting systems	Predictive analytics tools that use historical trends and weather data to forecast future electricity demand (load) and variable generation (e.g., solar and wind output). These forecasts guide operators in scheduling generation in advance to meet system needs
	Loss-of-load probability (LOLP) resource adequacy model	A probabilistic simulation of load, weather, and generator outages that estimates frequency, duration, and magnitude of unmet load — informing how much capacity to procure and how much different resources contribute to resource adequacy
Grid management	Energy management system (EMS)	High-level software suite (built on data from SCADA) for transmission grid operators to monitor and optimize generation dispatch and power flows on the high-voltage network
	Distribution management systems	Real-time monitoring and control platform for the distribution grid
Process management	Outage management systems (OMS)	An information system that aggregates outage reports (from customer calls, smart meters, etc.) and the network model to pinpoint power outages on the grid and collect historical data on customer outage duration, frequency, and restoration

Those tools can be used to monitor important indicators for reliability. Common drivers of reliability risk are listed in Exhibit A2, alongside example indicators of those risks, and the tools that typically capture that information. If the operational indicators are trending or anticipated to trend past an acceptable level, a specific follow-on study may be required.

Exhibit A2 **Drivers of reliability risk and example operational indicators**

Reliability need	Drivers of increased reliability risk	Example operational indicators of drivers	Tools used to evaluate and monitor risk
Resource adequacy	**Declining reliable capacity of existing fleet**	• Generator forced outage rates • Pace and scale of generator retirements • Capacity credit of individual technologies	• SCADA/EMS • Load and renewable forecasting systems • LOLP resource adequacy model
	Changing timing of scarcity hours	• Timing of recorded scarcity hours • Timing of projected scarcity hours • Significant change in mix of capacity by generation technology	
	Rapid load growth	• Change in projected load growth	
Balancing (ramping flexibility)	**Increasing unexpected ramps because of forecast error**	• Load forecast error • Renewable generation forecast error	• SCADA/EMS • AMI • Load and renewable forecasting systems
	Decreasing ability to meet fast ramps	• Available capacity at different required ramp speeds (e.g., 5, 10, or 15 minutes)	
	Increasing net load ramp requirements	• Maximum annual one-hour up/down ramp	
	Decreasing ability to balance across space	• Number and duration of binding transmission constraints	

Reliability need	Drivers of increased reliability risk	Example operational indicators of drivers	Tools used to evaluate and monitor risk
Stability (frequency support)	**Increasing severity of frequency events**	• Rate of change of frequency • Nadir • Settling frequency • Largest credible contingency	• SCADA/EMS • WAMS
	Frequency increasingly outside of normal operating conditions	• Annual standard deviation of frequency • Time outside normal frequency operating band	
	Decreasing frequency support resources	• Available frequency response resources • Available physical and synthetic system inertia	
Stability (voltage) *Voltage-related indicators should generally be assessed at the local or nodal level because voltage support is inherently location-specific.*	**Increasing frequency, duration, and magnitude of voltage events**	• Voltage deviations beyond acceptable limits • Post-contingency steady-state voltage deviation • Voltage recovery time	• SCADA/EMS • WAMS
	Change in voltage events	• Proportion of high-voltage events to low-voltage events	
	Decreasing voltage support resources	• Reactive power imports • Static and dynamic reactive power margin	
	Factors correlated to decreasing reactive power	• Locationally concentrated retirement of conventional resources • Locationally concentrated increase in penetration of IBRs that do not provide dynamic reactive power • Locationally concentrated load growth	

Source: RMI review of international guidance and industry practice, including: North American Electric Reliability Corporation (resource adequacy, voltage); US Department of Energy (voltage); AEMO (frequency); University College Dublin (frequency); EU Agency for the Cooperation of Energy Regulators (balancing)

With these tools in place, system operators can leverage their experience and data to inform system planners about grid needs. System planners can then integrate this information into their long-term planning processes (such as multiyear demand forecasts, transmission planning, and generation interconnection assessments). These operational indicators provide an early warning of emerging reliability risks. Where they indicate persistent or worsening conditions, regulators should work with system operators to undertake more detailed reliability assessments. Part B summarizes the principal study types used to evaluate these issues in greater depth and inform procurement decisions.

Part B: Reliability study types

Exhibit A3 summarizes the primary analytical tools used to assess reliability across resource adequacy, balancing, and stability.

- Quantifying different reliability needs across resource adequacy, balancing, and stability requires different technical methods and analytical tools.
- The results of these studies inform decisions ranging from real-time operations to long-term capacity planning.
- This table summarizes these study types and highlights how methodologies — particularly for resource adequacy — are evolving to reflect changing system conditions.

Exhibit A3 Reliability study types and use cases

Reliability component	What are the studies?	What decisions do they inform?	When are they conducted?
Resource adequacy	Resource adequacy (RA) study	Whether future capacity is enough to meet RA criteria such as LOLE and expected unserved energy, informing procurement actions such as capacity market auctions or long-term contracts	Usually annually or biennially as part of planning process, or when major assumptions change
Balancing	Production cost modeling, chronological dispatch simulation	Whether the system has enough operational flexibility, reserves, ramping capability, and dispatchable resources to balance supply and demand across hours and dispatch intervals, informing reserve requirements and procurement actions	Usually as part of planning and operational studies, often alongside or following resource adequacy analysis
Stability (static analysis)	Grid strength	Whether parts of the system are weak, whether additional system strength support, grid-forming capability, or network reinforcement is needed	In weak-grid areas, especially as inverter-based resources rise
	Power-voltage or reactive power-voltage curve assessments	Voltage stability and reactive power support needs, whether additional voltage control capability or local reinforcement is needed	In weak-grid or voltage-constrained areas, and when power flows materially change
Stability (dynamic analysis)	Root mean square model	System-wide transient performance amid disturbances (e.g., faults, line outages, and generator or load trips) informing need for frequency response, inertia, and other stability-related services	Periodically, when reliability issues emerge
	Electromagnetic transient (EMT) model	Localized electrical and sub-second behavior informing need for technical mitigation, controller tuning, or more detailed interconnection requirements	When localized detail is needed, especially in weak grids

Source: RMI

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