DEPLOYING STORAGE FOR POWER SYSTEMS IN DEVELOPING COUNTRIES

POLICY AND REGULATORY CONSIDERATIONS

ESMAP
Energy Sector Management Assistance Program

THE WORLD BANK
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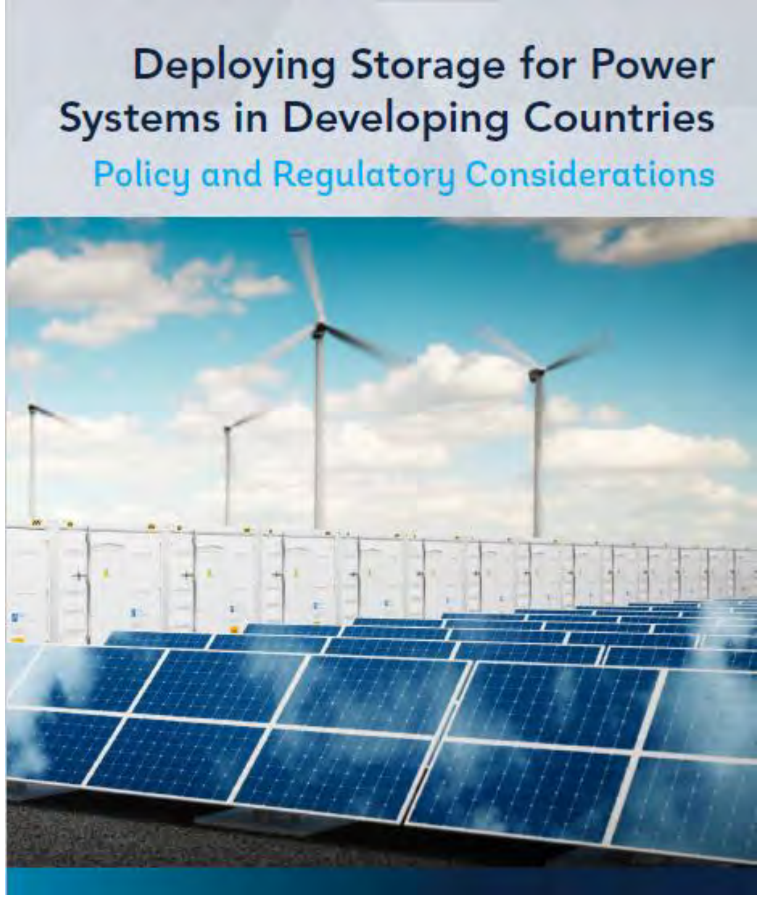
About the Upcoming Report

- Prepared under the umbrella of **Energy Storage Partnership** by ESMAP in collaboration with:
  - International Energy Agency (IEA)
  - International Council on Large Electric Systems (CIGRE)
  - China Energy Storage Alliance (CNESA)
  - European Association for Storage of Energy (EASE)
  - United States National Renewable Energy Laboratory (NREL)
  - South Africa Energy Storage Association (SAESA)

- Report provides guidance on:
  - Determining the value of storage from a system perspective and aligning with investors' perspective
  - Policy, market and regulatory considerations to facilitate storage deployment



Why Storage Policy and Regulation Matters

- Energy storage is one of the flexibility tools in power systems
  - Deployment is increasing rapidly (in particular for batteries) and this trend is bound to continue
- Storage can make a substantial contribution towards cleaner and more resilient power systems
  - Particularly well suited to developing countries' power system needs that often lack sources of flexibility; report focused in particular on weak grids (e.g. islands, Sub-Saharan Africa, etc.)
- Storage need is new in many systems and therefore policy, market and regulatory frameworks often lack storage-specific provisions
  - Policy makers and regulators need to establish robust remuneration mechanisms that accurately reflect its value to the system
  - Removing non-economic barriers must also be a priority

Variable Renewables Lead to New System Requirements

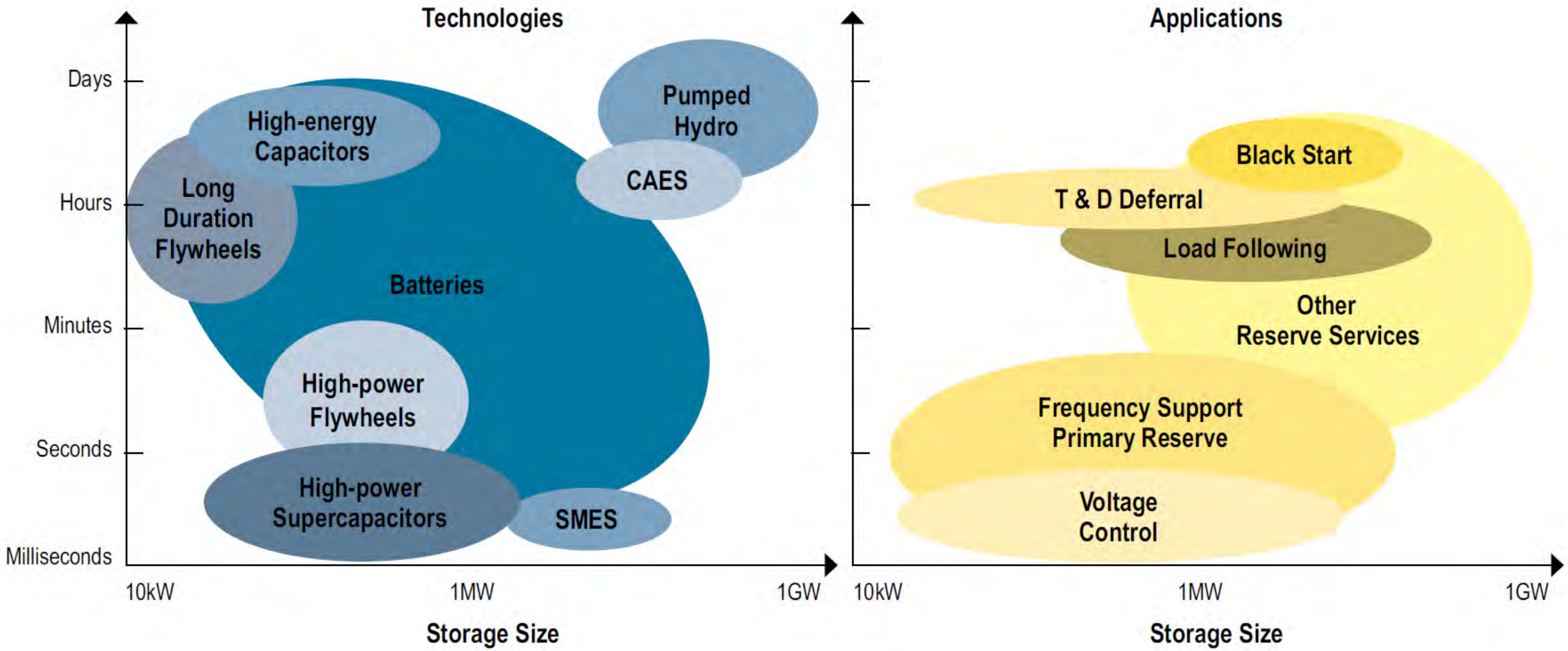
Phase	Phase characteristics from a system perspective	Key transition challenges	Flexibility options to enable transition
Phase 6	VRE electricity is main energy supply, large scale production of green gases & fuels	Substituting other fuels in areas that cannot be electrified directly	Large scale use of green hydrogen and its derivatives across end use sectors, including reconversion to electricity
Phase 5	VRE generation systematically exceeds classical electricity demand for longer periods	Absorbing large volumes of otherwise surplus VRE generation	Electrification of transport, heating; large-scale interconnection for continental balancing
Phase 4	The system experiences periods in which VRE makes up almost all generation	Ensuring robust power supply during periods of high VRE generation	Advanced technology to increase stability, digitalization and smart grid technologies, energy storage, DSR, flexibility from VRE
Phase 3	VRE generation determines the operation pattern of the system	Accommodating greater variability of net load and changes in power flow patterns on the grids	Plant retrofits for flexibility, improved grid infrastructure, interconnections, effective short-term wholesale markets
Phase 2	VRE has a minor to moderate impact on system operation	Minor changes to operating patterns of existing power systems	Improve VRE forecasting, economic dispatch
Phase 1	VRE has no noticeable impact on the system		

PHASE CHARACTERISTICS FROM A SYSTEM PERSPECTIVE

KEY TRANSITION CHALLENGES

FLEXIBILITY OPTIONS TO ENABLE TRANSITION

Energy Storage – Different Technologies and Use-Cases



Note: CAES = compressed air energy system; SMES = superconducting magnetic energy system; T&D = transmission and distribution

Storage can provide a multitude of services for power systems.
Use-cases capture these different services.

DEFINING USE-CASES

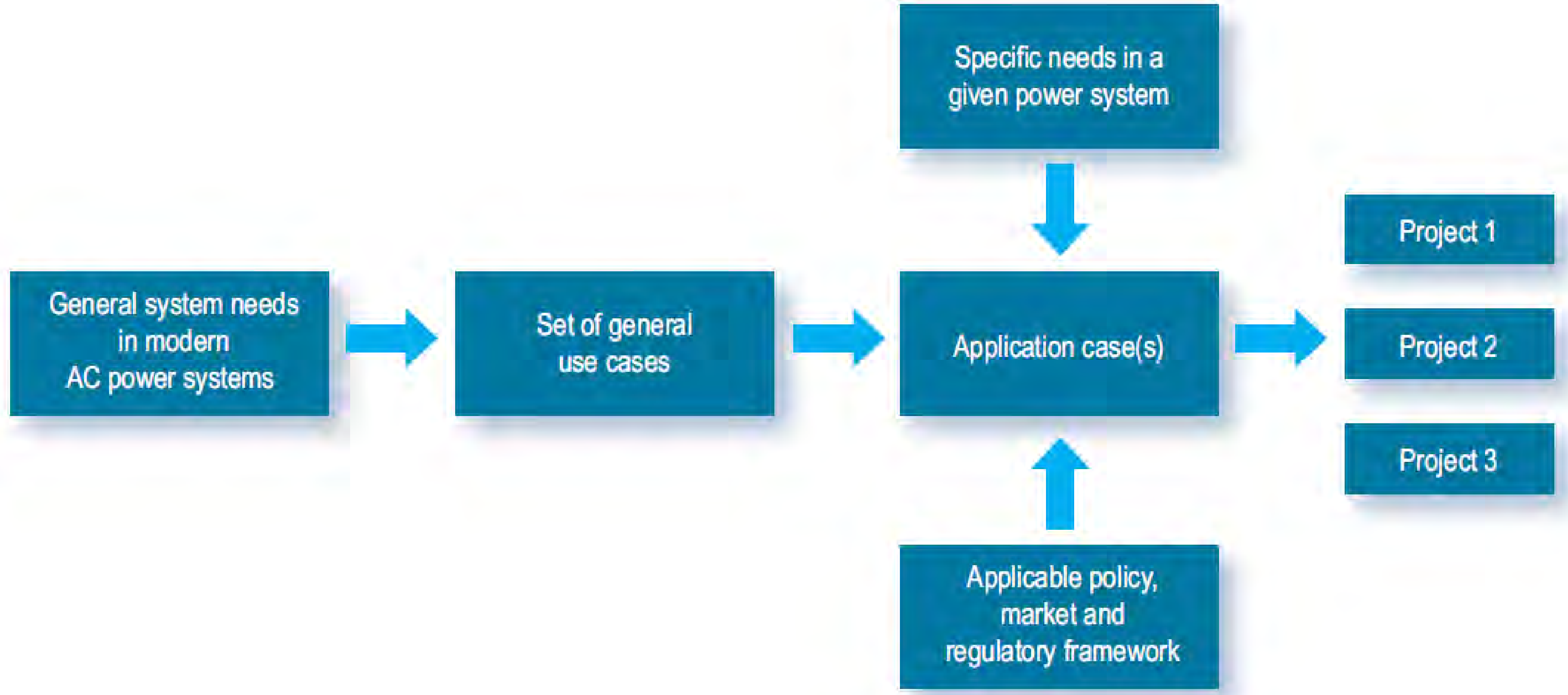
- A **use case** is defined as a specific power system need, which occurs frequently in most system contexts, and which is significant enough to justify the deployment of a technology solution tailored to meet it.
  - As an example, the provision of frequency control services constitutes a use case.
- Use cases *do not* imply a specific technology solution, (i.e., energy storage may or may not be the best suited option for a particular use case).
- However, there are certain use cases where storage offers distinct advantages over alternative options.

USE-CASES ARE THE BASIS FOR STORAGE POLICY AND REGULATION

	Short-Term Flexibility			Medium-Term Flexibility	Long-Term Flexibility	
Timescale	Sub-seconds to seconds	Seconds to minutes	Minutes to hours	Hours to days	Days to months	Months to years
Relevant asset characteristic	Response latency Capacity	Capacity / Energy	Energy		Large energy volume	
Use Cases	**Generation Based**					
	• Frequency and voltage control • Short circuit current • VRE ramp control		• Frequency control • VRE forecast error correction • Firm capacity • VRE generation time shift	• Black start • Firm capacity	• Balancing seasonal and inter-annual variability	
	Customer Based					
	• Uninterruptible power supply		• VRE self-consumption optimization • Demand response • Time of use optimization • Network charge reduction • Micro grid islanding	• Backup power / Micro grid islanding	• Backup power / Micro grid islanding	
	Network Based					
	• Grid congestion relief & T&D avoidance / deferral					

Use cases cover generation based, customer based and network based applications across a wide range of time-scales.

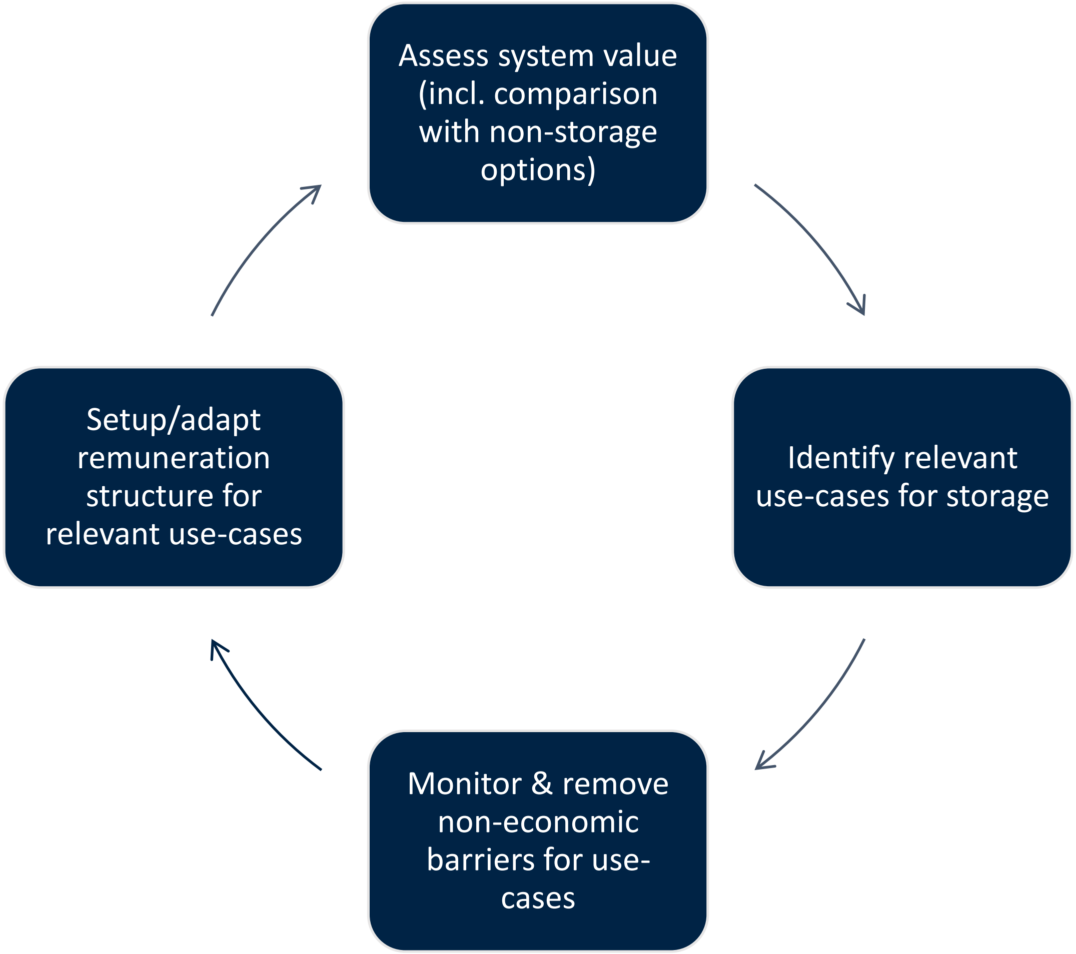
Relationship Between System Need, Use-Case, Application-Case



The combination of use-case and system specific factors (technical, regulatory) defines an application case. The application case is the basis for a concrete project.

ALIGNING ECONOMIC SYSTEM VALUE AND FINANCIAL PROJECT VALUE

- Economic system value:
  - Net benefit for entire power system
  - Factors include: saved CAPEX, OPEX, increased reliability, reduced load shedding etc.
  - Assessed via modelling tools
  - Includes comparing storage to alternative options
- Financial project value :
  - Value of the project for investors
  - Strongly depends on policy, market and regulatory framework

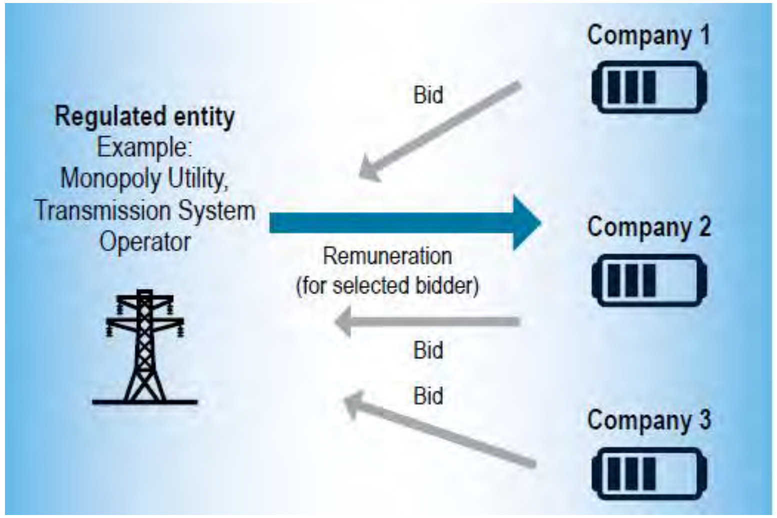


Policy, market and regulatory frameworks need to align economic system value and financial project value.

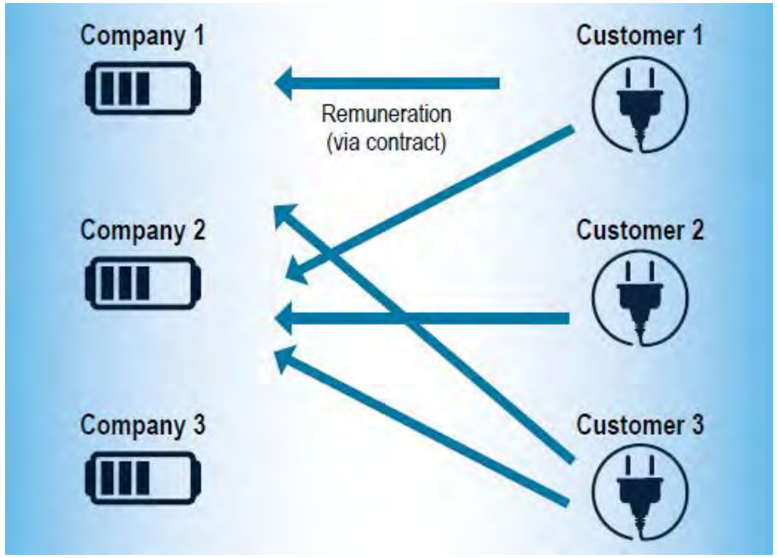
REMUNERATION MECHANISMS FOR ENERGY STORAGE

Non market

Single buyer



Full market

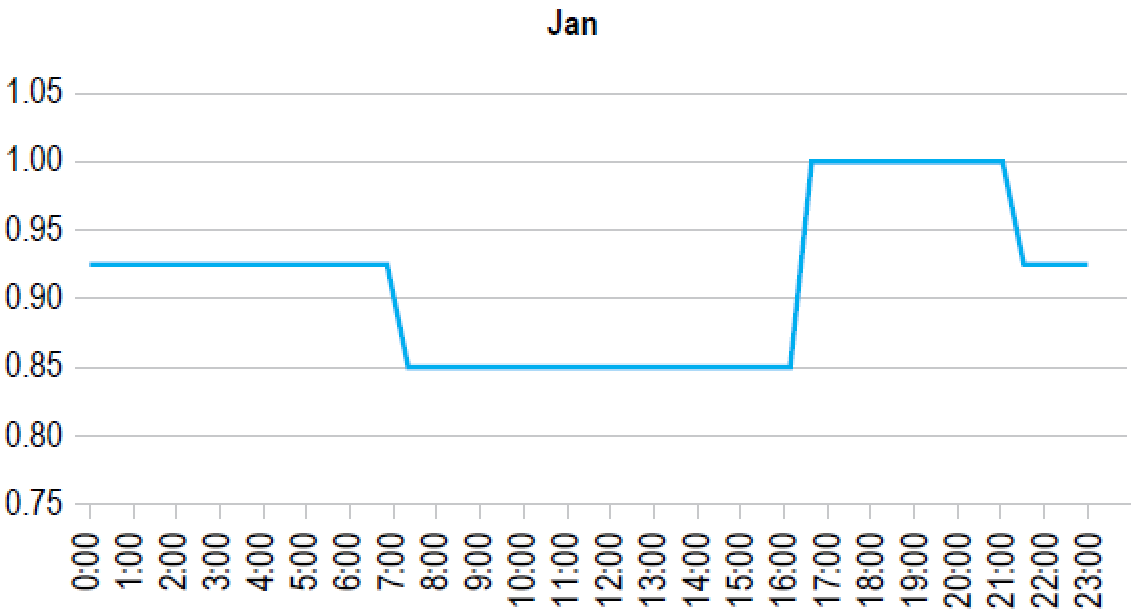


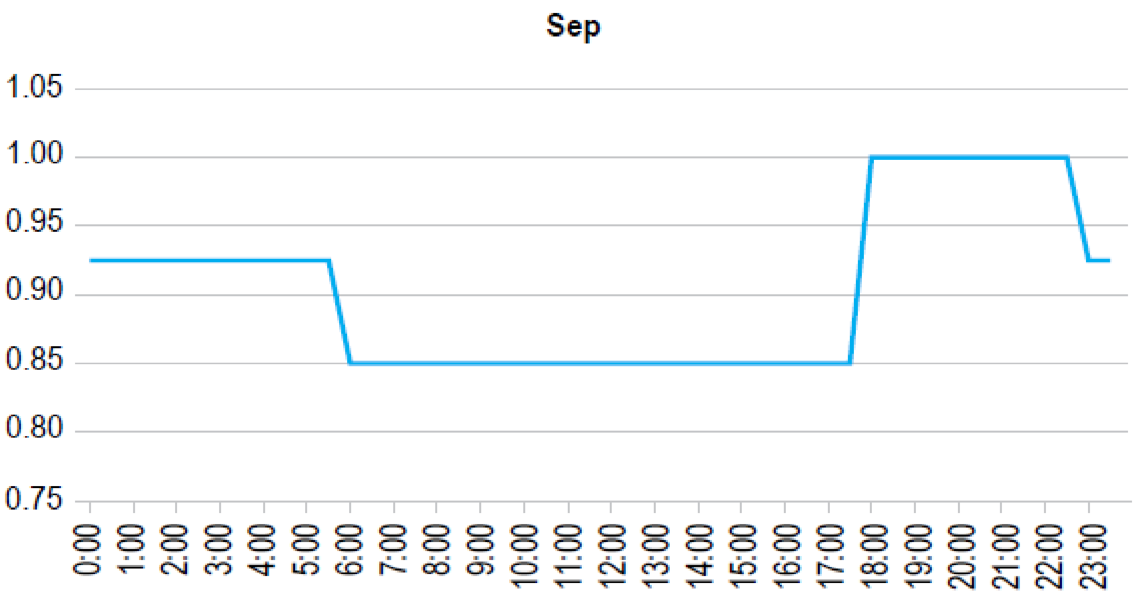
- There are three basic models to remunerate storage
- Which model is best suited depends on the specific use-case and overall power system governance structure
  - Different models can be used in the same system for different use-cases (e.g. network services use “non-market” while firm power can be procured through “single-buyer” under a PPA)
- For developing countries, the non-market and single-buyer market models are particularly relevant

Note: Contract arrows illustrate different possible constellations. Full market transactions are frequently handled via a clearing house (exchange).

PPAs Can Align System and Project Values

Sample PPA Structure Using a Time of Use Based Multiplier for Two Selected Months





Time-of-use PPAs can align system and project value by paying a higher price when electricity is needed most (e.g. evening peak in most developing countries)

Tackling Non-Economic Barriers is a Priority

- Definitions and standards:
  - Storage must be considered as its own legal and regulatory category, definitions should not arbitrarily place storage into existing categories.
- Permitting, commissioning and grid codes:
  - Storage may not yet be subject to established rules for permitting, and existing technical codes may be poorly adapted for energy storage.
  - Under such circumstances permitting agencies and system operators should not impose excessive requirements on developers.
- Taxes, surcharges and levies:
  - Establish a level playing field for energy storage projects that reflects the value of storage from a system perspective.

Role of Stakeholders in Energy Storage Roll-out

Energy ministries	• Articulate an overall strategy for energy storage within the countries' broader energy strategy and policy goals
Regulators	• Proactively update regulations to remove barriers to storage and enable fair remuneration of services that could be offered by storage
System planners	• Assess different use cases in which energy storage can help reduce overall system costs
System operators	• Balance obligation to ensure security of supply with recognition of the future contribution that storage can bring to meeting systems needs
Permitting entities	• Learn from international best practice and where possible consolidate the number of required permits (a "one-stop shop" approach)
Manufacturers	• Consider to specific requirements of developing countries and adapt product specifications and characteristics in line with countries' needs.

Summary and Conclusions

- Energy storage is growing rapidly; it can make a substantial contribution towards cleaner and more resilient power systems
  - Facilitate rapid uptake of variable renewable energy
  - Support reliability and energy access in developing countries
- Establishing enabling frameworks for storage requires understanding costs and system benefits of energy storage
  - Role of energy storage depends on system needs, which vary across countries
  - Robust and detailed power system models can help identify best use-cases
- Energy storage is usually not the only option to meet power system needs
  - Analysis should benchmark against alternatives (grids, demand response, generation)
- Policy makers and regulators need to establish robust remuneration mechanisms that accurately reflect storage's value to the system
  - Three remuneration models possible depending on use-case and system contexts
  - Removing non-economic barriers to storage deployment must also be a priority

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