BUSINESS MODEL INNOVATIONS IN DEPLOYING STORAGE FOR POWER SYSTEMS IN DEVELOPING COUNTRIES

ESMAP
Energy Sector Management Assistance Program

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A Business Case Inventory for Storage Deployment

- **Objective**: Provide a broad set of up-to-date examples of innovative approaches for establishing business models for energy storage

- **Output**: Extensive power point presentation that
  - Provides classification of different use cases
  - Summarises experience on innovative business models for energy storage
  - Highlights country contexts where a particular business model is particularly well-suited
- **Approach**:
  - Desk research of existing literature
  - Interviews with World Bank staff working on BESS projects and experts on the ground
  - Summaries most relevant business models according to use-case and country context

USE-CASE CLASSIFICATION

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 Establishing a Business Model

	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)	Capacity & Energy	Energy / (Capacity)	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					

Source: Deploying Storage For Power Systems in Developing Countries – Policy and Regulatory Considerations

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

Economic Viability Occurs Sooner for Some Use-Cases

	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)	Capacity & Energy	Energy / (Capacity)	Large energy volume	

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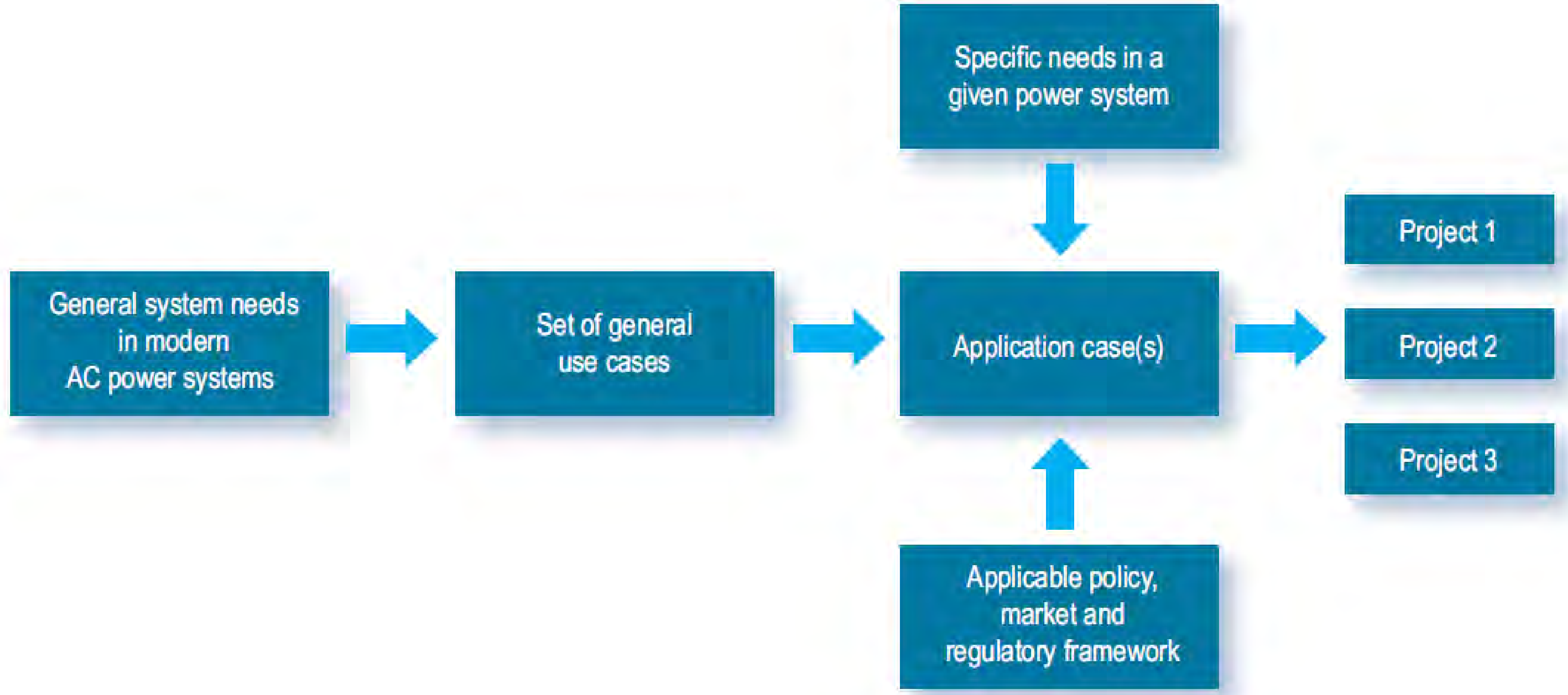
Total potential market size for energy storage
Increasing cost-pressure to move to longer term flexibility

Economically viable battery storage use-cases in developing countries now include providing peaking capacity via BESS in a growing number of cases, reflecting rapid progress in BESS applications.

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



Source: [Deploying Storage For Power Systems in Developing Countries – Policy and Regulatory Considerations]

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.

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.

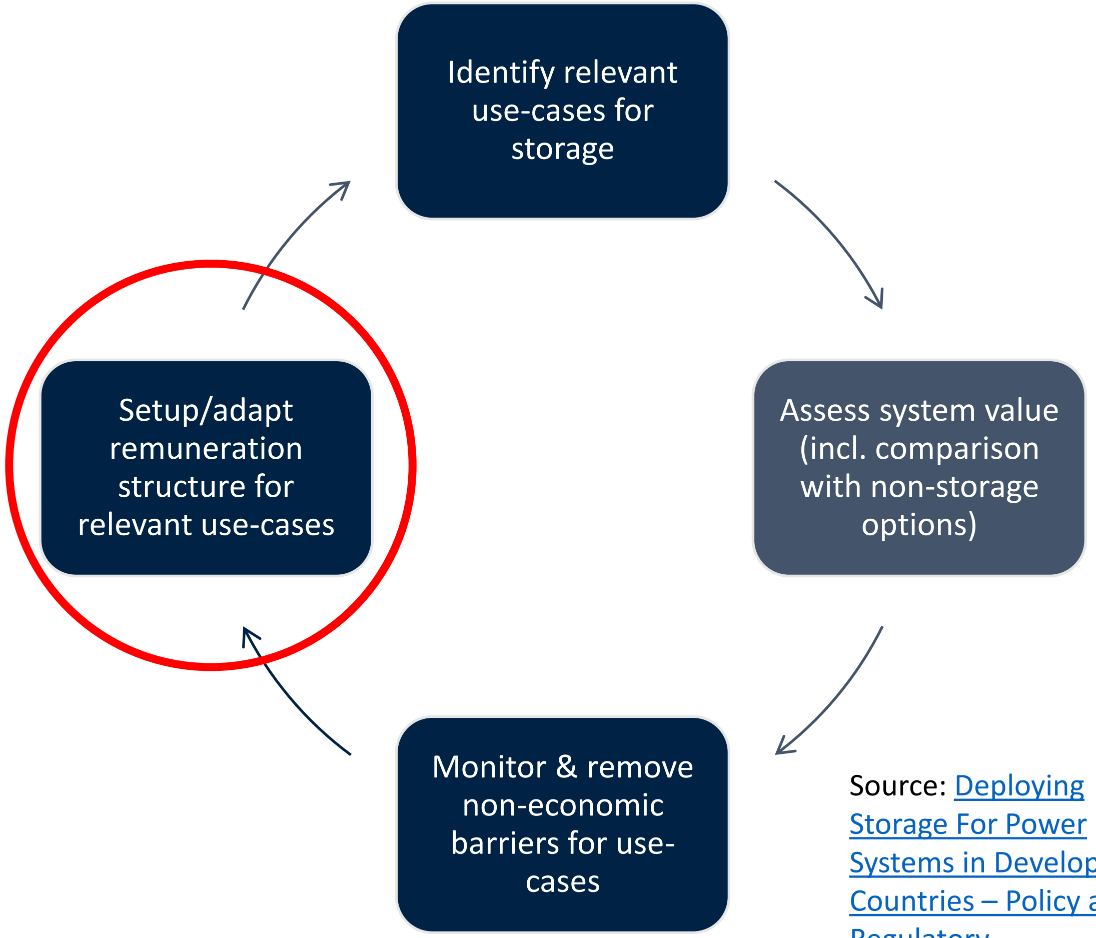
RESULTS ON USE-CASE STATUS

- All use-cases are being commercially deployed with the exception of new seasonal storage.
- Frequency control remains the most common use-case for battery projects, but its market size is inherently limited in all systems.
- Multi-hour storage combined with solar PV has become economically attractive, opening a much larger market.
  - PV + storage allows meeting evening peak-demand, (partially) displacing new fossil plants as least-cost capacity additions
- Institutional barriers and contractual complexity lead to segmentation into separate projects, even where several use-cases are economic.

Methodology for Use-Case Analysis

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



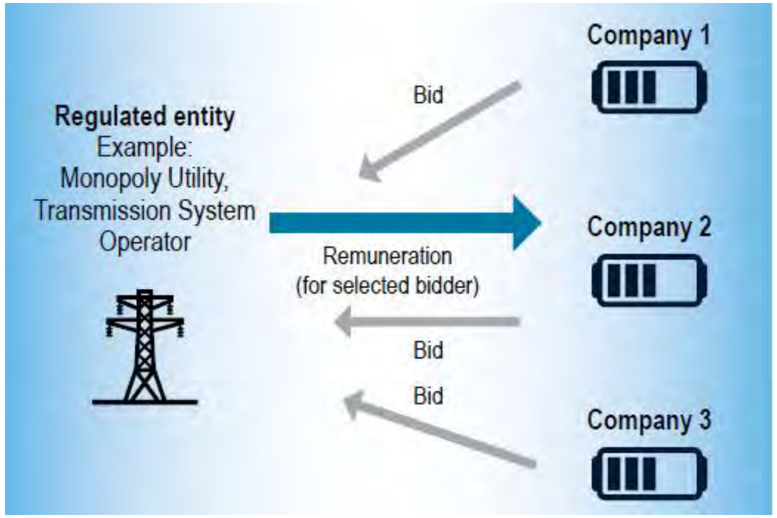
Source: Deploying Storage For Power Systems in Developing Countries – Policy and Regulatory Considerations

Policy, market and regulatory frameworks need to align economic system value and financial project value. They create the basis for a feasible business model.

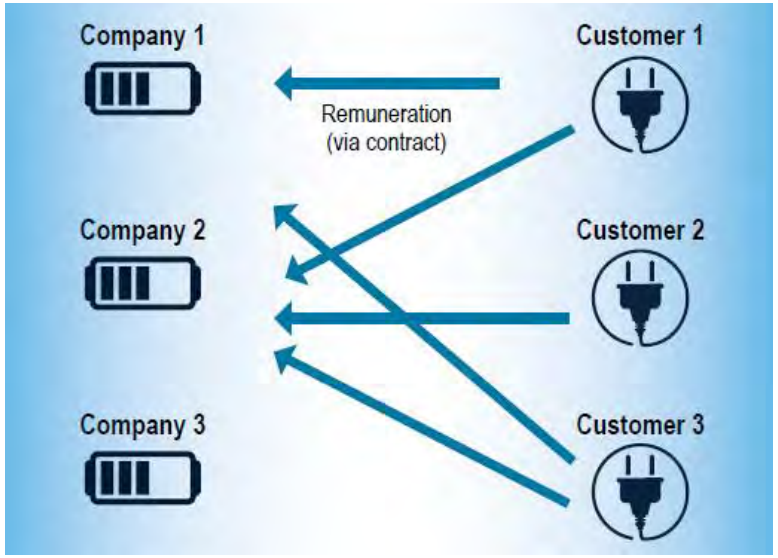
Remuneration Mechanisms for Energy Storage

Non market

Single buyer



Full market



Source: [Deploying Storage For Power Systems in Developing Countries – Policy and Regulatory Considerations]

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

- 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

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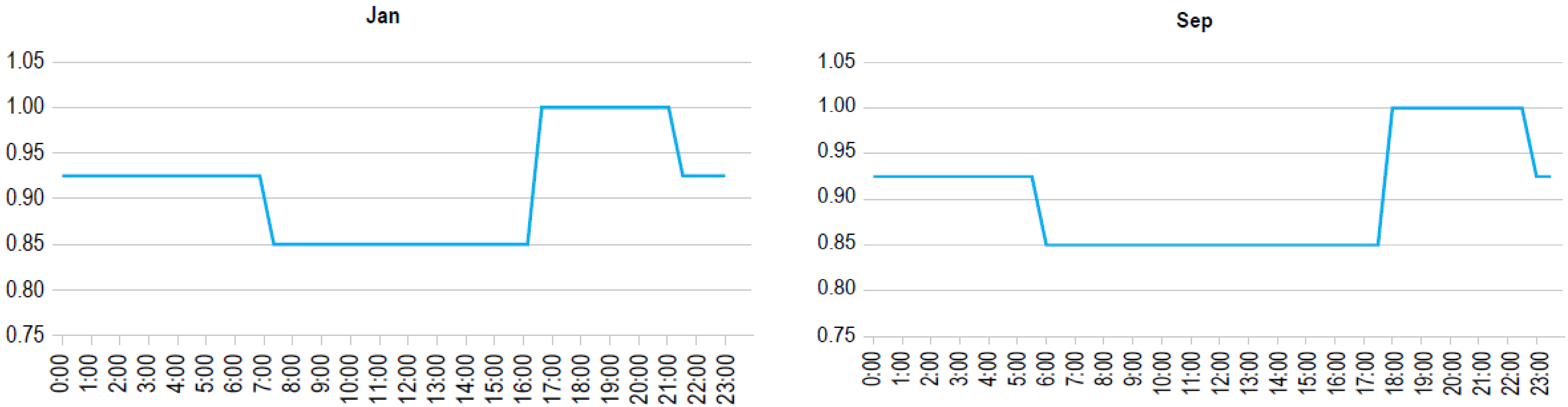
PPAs can Align System and Project Values

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



Source: Deploying Storage For Power Systems in Developing Countries – Policy and Regulatory Considerations

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)

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Finding Use-Cases That Yield System Value

Identify system challenges

- **Possible issues**: financial viability, high supply costs, low grid reliability, low access, high carbon intensity
- **Information sources**: Existing technical and financial reports, stakeholder dialogues

Select use-cases to address system challenge

- **Approach**: screen use-cases for ability to resolve main sector challenges
- **Results**: Short-list of priority use-cases for further analysis

Assess system level economics

- **Approach**: techno-economic modelling of power system
- **Results**: cost-benefit assessment for different use-cases; comparison with non-storage alternatives

First, assess which type of storage projects bring net benefits for the power system

Assessing Financial Project Value – Improving it if Needed

Establish project portfolio for assessment

- **Approach**: Screen available project pipeline and existing project ideas
- **Results**: Selection of tentative projects, including information of costs, development challenges and revenue options

Analyse financial project value

- **Approach**: net present value (NPV), rate of return (IRR), etc. calculation across scenarios
- **Results**: Economic viability under current regulatory environment

Update policy, market & regulatory frameworks

- **Approach**: test updates of market design / regulation, change contract terms
- **Results**: Understanding how new framework conditions can help secure project viability

Second, test if economically viable projects are financially attractive.
If not, propose changed to framework conditions.

Capacity vs Energy Payments for BESS

- Most common payment types are
  - Payment per unit of energy delivered
    (possibly differentiated by when it is delivered)
  - Payment per unit of capacity available
    (for availability rather than use)
  - Leads to different risks:
    - Capacity payment induces a risk for BESS owner in case of over-usage, because effective available battery capacity declines with use
    - Energy payment induces a risk for BESS owner in case of under-usage, because number of cycles determines revenue
    - Mix of payment types can provide hedge
- Duration of payments (contract tenure)
  - Different lifetimes for batteries (10-20yrs), solar PV (25+yrs)
  - Reliable prediction of system requirements only possible for several years ahead (max. 5-10yrs), use-cases may not be robust
  - Contract durations reflect this variability, with rental/service contracts shorter than BESS/PV lifetime
  - Public ownership can provide more flexibility to shift use-case

Different types of remuneration for BESS projects

Type	Payment modality
Energy Payment	$/MWh
Capacity Payment	$/MW per Month
Net Energy Potential Payment	$/MWh of potential - underperformance
Rental	Rent + (de)mobilization fee
Market participation	Fluctuating market price
Corporate off-takers	$/MWh

Country and Use Cases Examples

Covering a Broad Set of Countries and Use-Cases

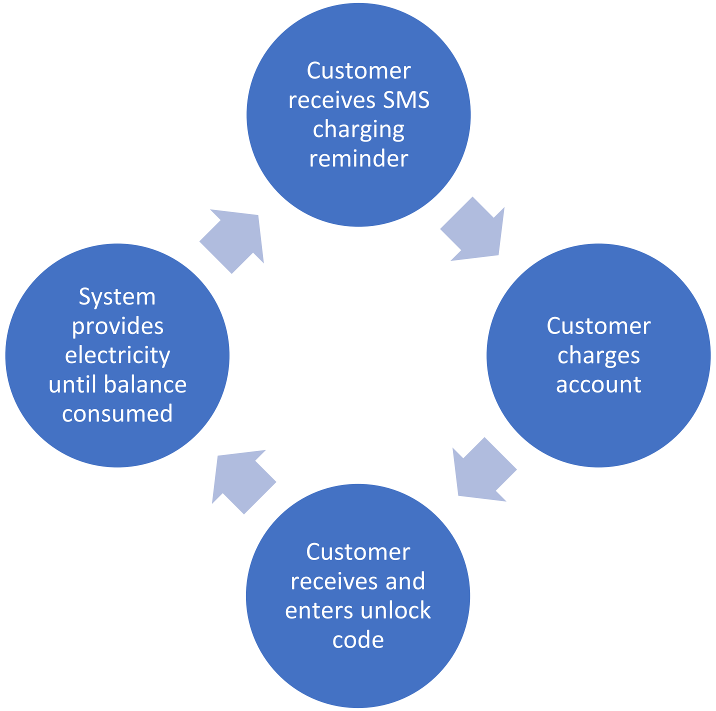
- Country coverage:
  - Several country examples from World Bank projects
  - Diverse technical and regulatory circumstances
  - Additional input from US / Australia etc.

- Use-case coverage:
  - Very broad coverage of use cases from generation / grid categories
  - Stronger role for use in RE firming meeting multi-hour peak demand
  - Possible addition of customer side use-cases

Country	Use Cases
Burkina Faso	• Frequency and voltage control • VRE generation time shift / firm capacity
India	• VRE generation time shifting • Firm capacity • T&D avoidance
Maldives	• Frequency and voltage control • VRE generation time shifting • (Electrification of transport)
Ukraine	• Frequency control (containment and restoration reserves)
Zanzibar	• T&D deferral • Firm capacity • Frequency control • Microgrid islanding

Example 1: Market-Driven-Access via Pay-As-You-Go Models

- System challenge and use-case:
  - Energy access in off-grid areas; use-cases: VRE generation shift, micro-grid islanding in community projects
- Innovation: Apply prepaid billing to electricity access
  - Remove up-front cost barrier to customer
  - Use existing payment channel for mobile phone
  - Provide service only if customer has sufficient balance in pre-paid account
- Key actors:
  - Energy service provider: system procurement, customer acquisition, technical and commercial management
  - Mobile network operator: payment service provider
  - Financiers: provide funds to cover up-front costs for energy service provider
- Applicable in countries that
  - feature remote communities without grid-access
  - medium- to long-term energy access strategy is consistent with off-grid and mini-grid solutions

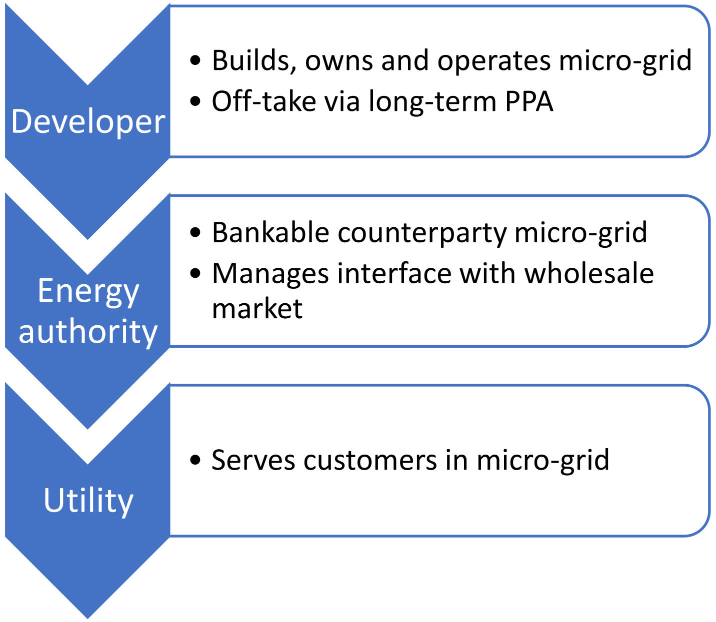


Source: IRENA, Innovation landscape brief: Pay-as-you-go Models

Example 2: Innovative PPA-Structures

- System challenge and use-case:
  - Reliable and affordable low-carbon power; use-case: VRE generation shift, micro-grid islanding
- Smart contract structure: reliable offtake and possibility to sell to grid
  - Bankable PPA for micro-grid developers
  - Reliable, low-carbon power at competitive rates for customers
  - Electricity sales to main power grid
- Key actors:
  - Developer: project development, financing, operations
  - Energy authority: provides bankable PPA
  - Local utility: sells power to customers in micro-grid area
- Applicable in countries that
  - suffer from unreliable main grid
  - allow regulated retail activities from local utilities and provide options to setup long-term PPAs

Example of innovative PPA-setup from California, US

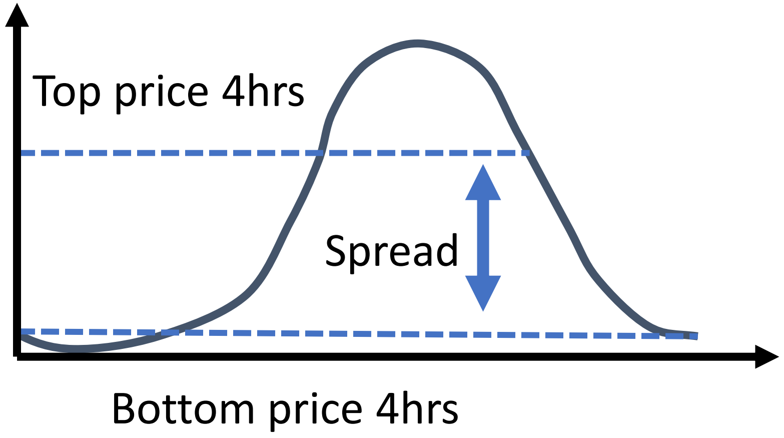


Sources: Concentric Power Gonzales Energy Authority project, [Gonzales Electric Authority Enters into Agreement with CPI], [City of Gonzales: Local Governments Empowering Energy Solutions]

Australia: Storage Swap-Contract

- System challenge and use-case:
  - Generation time-shifting of solar PV generation; firm capacity
- Smart contract structure: revenue certainty for storage & RE
  - CfD-Contract based on spread between lowest and highest 4hrs of day
  - If spread is below strike level generator pays to storage
  - If spread is above strike level storage pays to generator
- Key actors:
  - RE-generator or electricity supplier: hedges risks of extreme price spreads
  - Storage operator / owner: stabilise revenues using physical hedge against extreme volatility
  - Power exchange (Renewable Energy Hub): facilitate match making
- Applicable in countries that
  - have a relatively developed power market with financial contracts
  - Reach very high shares of variable renewable energy with growing need to provide firm capacity (and where storage can supply this)

Principle of 'Virtual Storage' contract



Source: The 'Virtual Storage Product' as a game-changing energy deal

ZANZIBAR

- Power System Background:
  - Unguja interconnector (IC) only main source of electricity for Zanzibar's main island (apart from local, unreliable Diesel backup at Mtoni substation)
  - Island peak demand is expected to exceed IC capacity of 100MW by 2022/23
  - Challenge to integrate solar PV on the island due to lack of flexible resources
- Energy storage use-cases:
  - Transmission investment deferral
  - Frequency control
  - Renewable energy generation time shift
  - Micro-grid islanding
- System value and business model challenge
  - Very high system value due to possibility to implement multiple use-cases
  - Funding provides for EPC costs and first three years of O&M
  - Revenue gap for operation of facility after initial O&M contract expires

Unguja IC connecting Zanzibar to Tanzania

Burkina Faso: Different Business Models by Use-Case

- Technical system challenge:
  - Growing power demand and reliance on expensive HFO / diesel generation
  - Weak grid infrastructure hampering the scale-up of solar energy
  - Mismatch between evening peak demand and solar PV generation
- Energy storage use-cases:
  - Frequency and voltage control
  - VRE generation time shift / firm capacity
- Business models implemented
  - Project 1: BESS procured by public utility (SONABEL)
    - Allows using BESS primarily for system services to increase solar PV hosting capacity (stability) and reduce curtailment (time shift)
    - EPC contract managed by SONABEL; full possibility of benefit staking, but up-front clarity on technical specifications key
  - Project 2: IPP offering solar PV and storage
    - BESS supplements IPP-based solar PV project; substitutes old HFO generation and increases the amount of useful PV generation
    - Single PPA combines solar PV and BESS

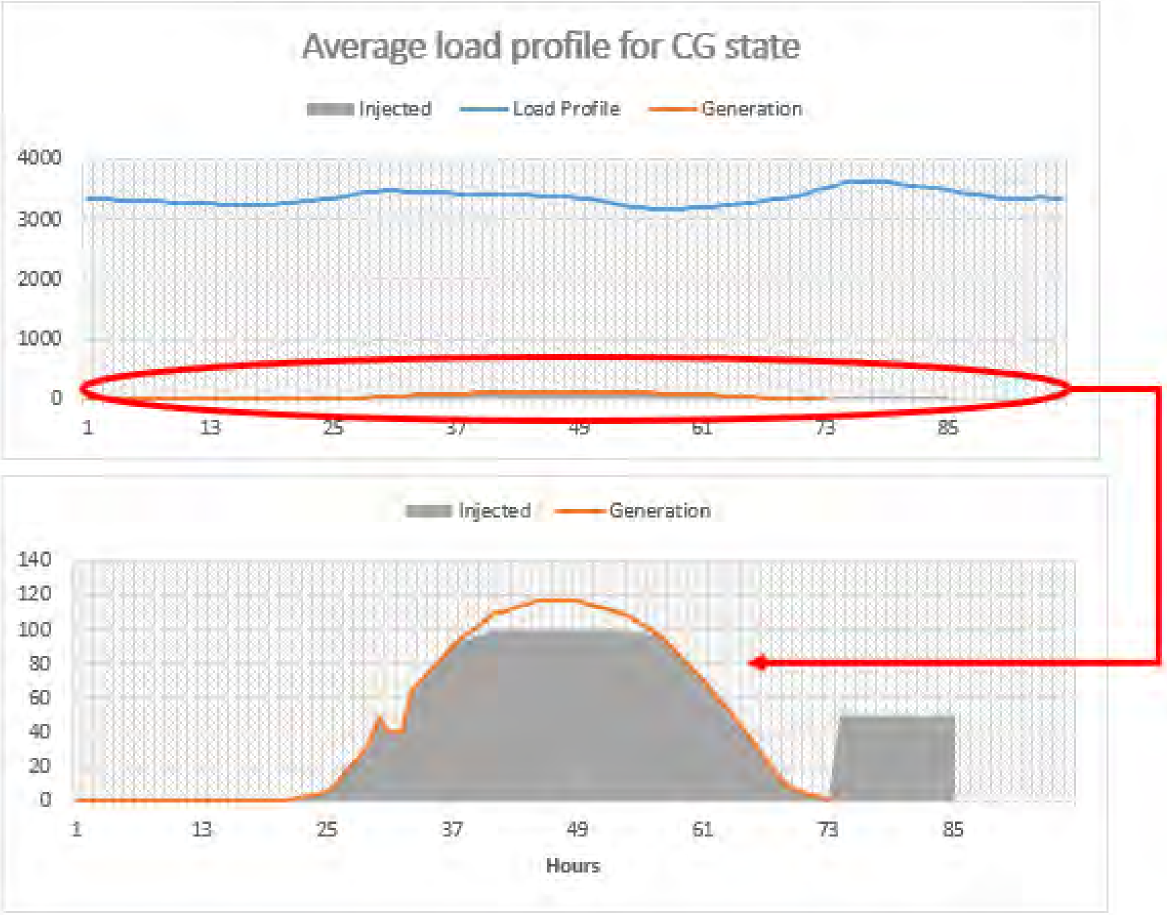
India: Meet Peak Demand Reliably

- Technical system challenge:
  - State of Chhattisgarh deficient in peaking capacity despite overall generation surplus
  - Shifting of PV generation to achieve 40 MW / 120 MWh during evening peak desired

- Energy storage use-cases:
  - RE generation time shift / firm capacity
  - T&D avoidance (smaller evacuation line capacity)

- Business models implemented
  - Solar Energy Company of India (SECI) manages EPC procurement for solar PV system (100 MW AC, 160 MW DC) and 40 MW/120 MWh storage capacity
  - State then signs PPA with SECI at a flat tariff of max. Rs. 4/kWh (ct USD 5.5) while required to meet the peak load coverage constraint; avoiding costly peak electricity purchases from India power market

Matching battery discharge with peak demand



Maldives 1/2: Public Financing in BESS

- Technical system challenge:
  - Heavy reliance on high-cost polluting generation in remote island systems
  - Insufficient flexibility for renewable expansion on remote island system
- Energy storage use-cases:
  - Frequency control
  - Renewable energy generation time shift
- System value and business model challenge
  - Enable reliable and economic integration of large amounts of solar PV
  - Ensure off-take of solar electricity generated by IPPs (see figure)
  - Unlock utility investments in BESS despite challenging project financials

Solar PV generation in Maldives

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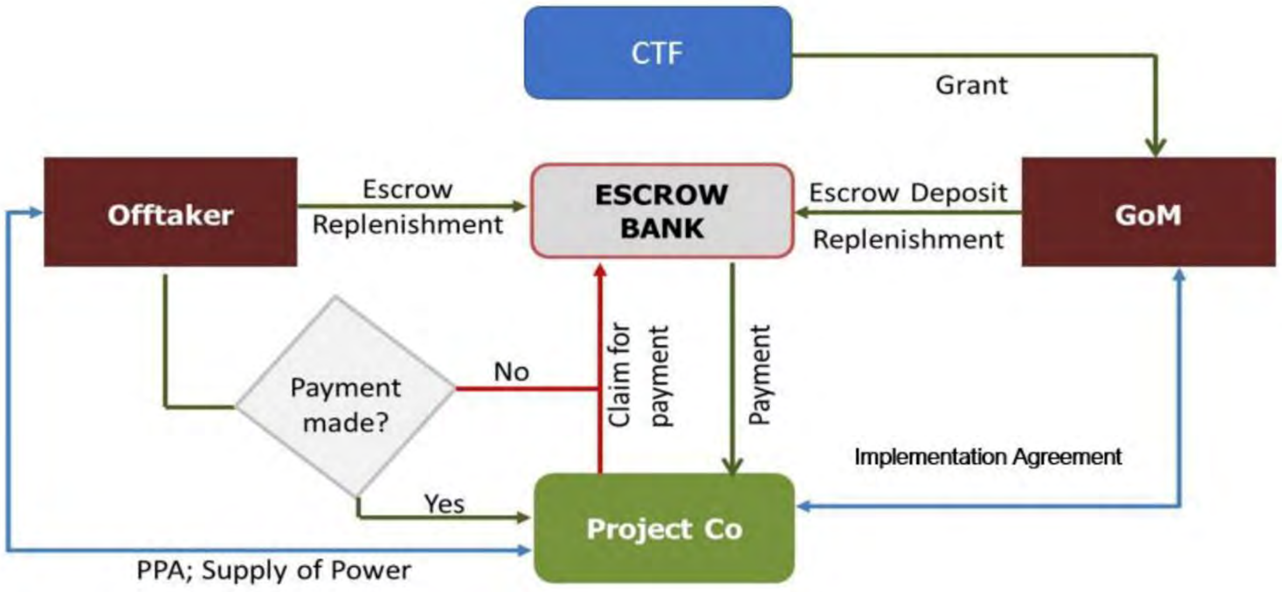
Maldives 2/2: Public Financing in BESS

- Feasible business case:
  - Provide concessional financing to the public utility FENAKA for enabling investment into BESS projects (in turn, this makes PPAs with IPPs feasible)
  - Use IPPs for investments in separate renewable generation projects (see figure)
- Lessons and outlook:
  - Flexibility investments by SoE utilities in BESS can enable private sector investment into renewable energy projects via PPAs
  - Concessional financing can be used to bridge moderate financial gaps for BESS projects in the absence of other options to reflect BESS' system value

Secured Payment Mechanism Arrangement for solar PV



Ukraine 1/2: Market Based, Benefit Stacking

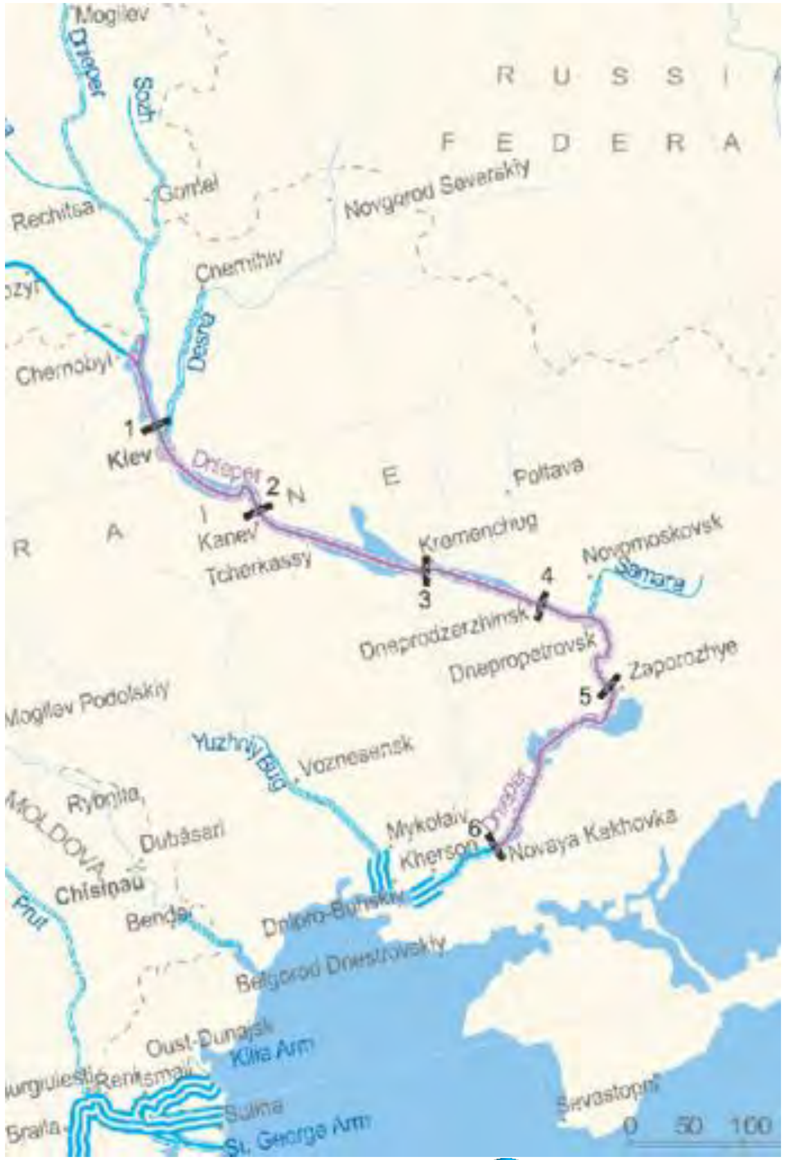
- Technical system challenge:
  - System to be synchronised with ENTSO-E and de-synchronised from Russian grid (this was achieved as an emergency measure at the beginning of war in Ukraine but the planned storage will facilitate the provision of affordable ancillary services and balancing services after the war and in particular once several coal plants retire)
  - Available system service capabilities insufficient for providing ENTSO-E grid code-compliant fast acting frequency reserves (FCR, aFRR) with sufficient certainty
  - Limited availability of new fossil gas generation
  - System inflexibility inhibiting renewable energy uptake

- Energy storage use-cases:
  - Frequency control
  - Renewable energy generation time shift

- System value and business model challenge
  - High system value due to immediate frequency control need
  - Large volumes of storage cost-effective for renewables heavy, least-cost system expansion
  - No business case for storage including due to inefficient market design for system services
  - System operator cannot own storage asset for compliance with EU regulations

Ukraine 2/2: Market Based, Benefit Stacking

- Selected projects:
  - Four battery energy storage systems (40-60 MW each) co-located with existing hydro generators
- Regulatory update:
  - Reform of system services market, raising bidding cap for fast frequency reserves
- Feasible business case:
  - Assets owned by state-owned Ukrhydroenergo (private sector would not absorb risk due to short-term market revenues – no long-term PPA)
  - Revenues for system services expected to be sufficient due to reform
  - Ukrhydroenergo uses assets for co-optimisation with hydro units
- Lessons and outlook:
  - BESS part of least-cost expansion via variable renewables in system with inflexible legacy coal plants and constraints on gas expansion
  - System service markets can provide sufficient revenues, but short-term market risks may still deter investment
  - Public companies can invest in BSS projects that generate market based revenues
  - Project could also help to optimize exports to EU, creating revenue streams for Ukraine in the recovery phase however project may be delayed depending on how situation in Ukraine evolves



SUMMARY AND NEXT STEPS

- New output under the ESP focusing on specific business model innovations
  - Builds on conceptual framework developed as part of the ESP
  - Provide a broad set of up-to-date examples of innovative approaches for establishing business models in real on-the=ground projects
- Main findings
  - Multi-hour storage combined with solar PV has become economically attractive, opening a much larger market than more established system services use-cases
  - Institutional barriers and contractual complexity lead to segmentation into separate projects, even where several use-cases are economic but value stacking is difficult
- Next steps
  - Presentation made available to all ESP partners for their use and possible additions to the case studies presented
  - New workstream going in details into structuring of PPAs for solar+storage hybrid projects
  - Output to be delivered during FY23

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