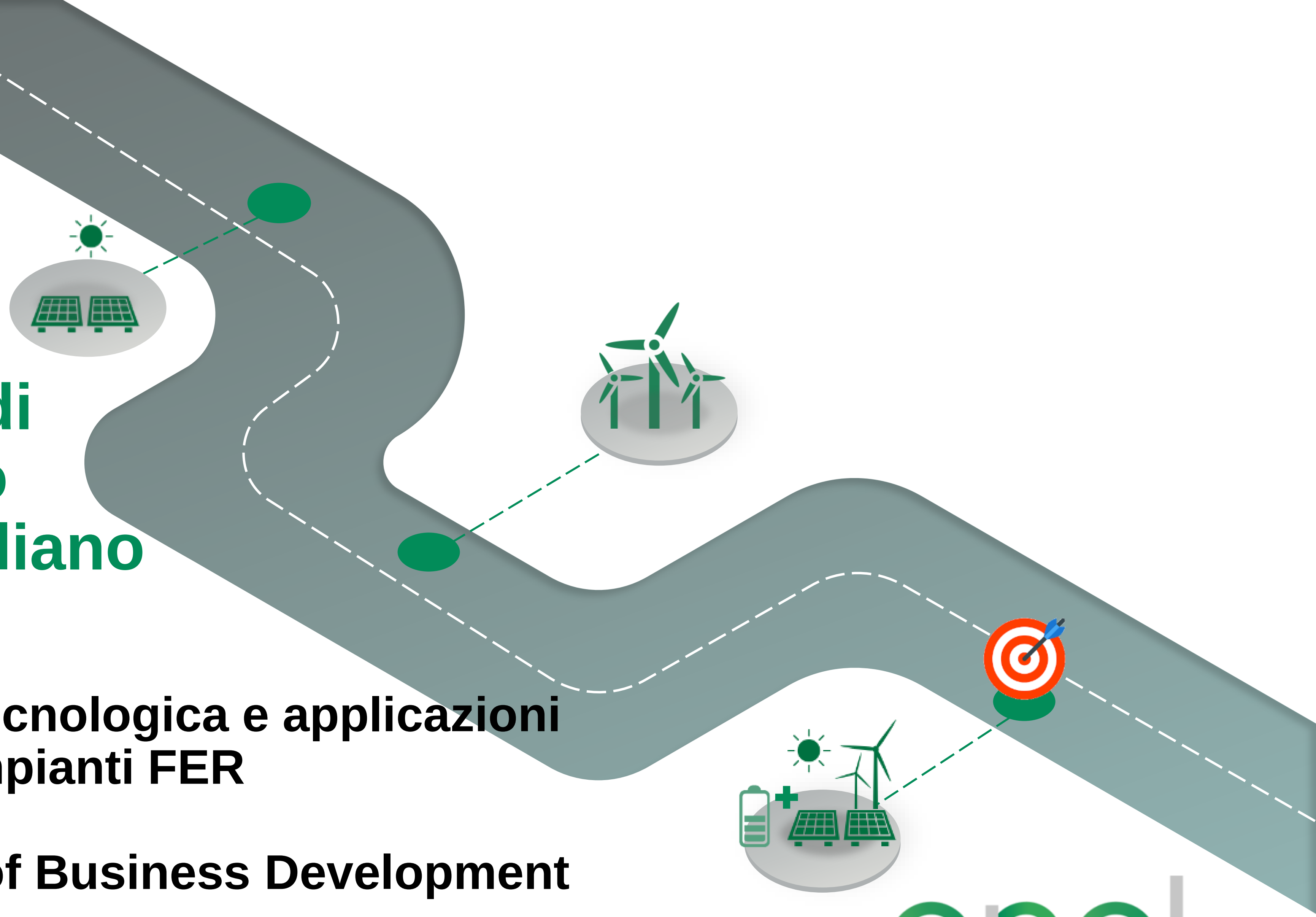
Il ruolo dei sistemi di accumulo nel futuro sistema elettrico italiano



Traiettoria di evoluzione tecnologica e applicazioni per accumuli integrati a impianti FER

Giuseppe Cicerani, Head of Business Development Energy Storage

Catania – Workshop AEIT 6 Dicembre 2019

Green Power

Ph. EGP Cremzow BESS 22 MW/35 MWh (Germany)

Agenda

1. Storage in EGP. Value proposition and applications for RES + BESS plants
2. Stage of technology development and cost scenario
3. A World Tour in the business models

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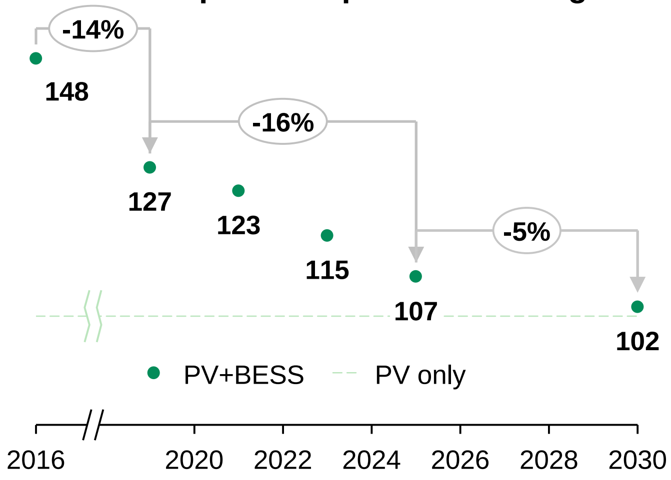
Why Renewables coupled with *Storage?*

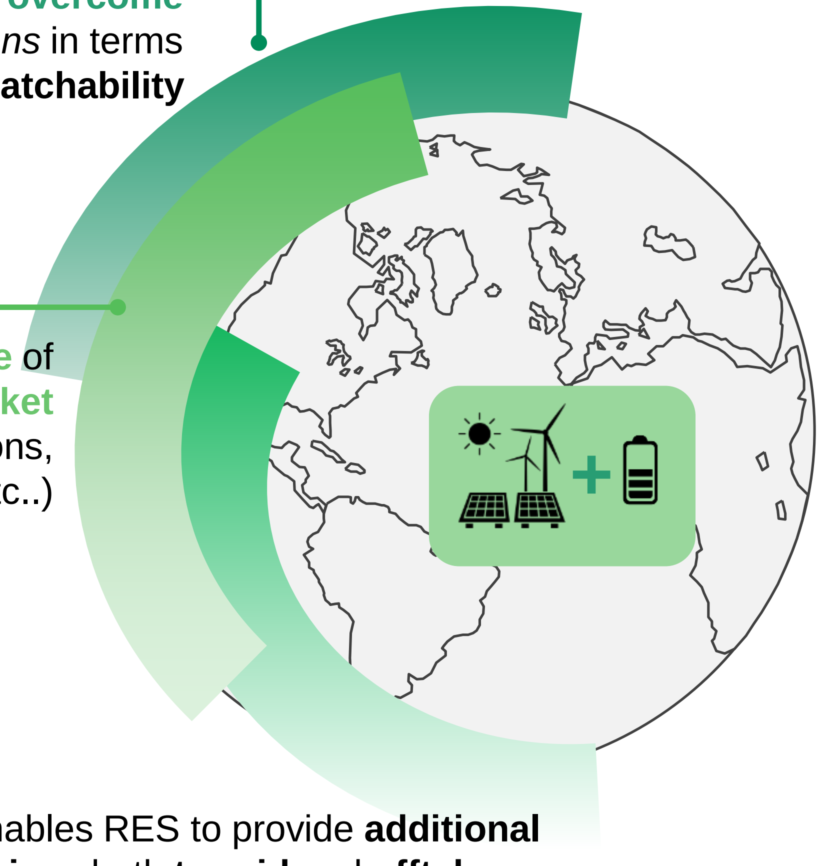
Strategic Rationale of Energy Storage in EGP

LCOE* evolution for a solar plant coupled with storage



1. An ancillary technology which enables RES to **overcome** their residual intrinsic *limitations* in terms of **flexibility** and **dispatchability**

2. It allows to reduce the **risk profile** of investments both in terms of **market** and **regulatory risks** (congestions, imbalances, etc..)



3. It enables RES to provide **additional services** both **to grid** and **offtakers**, entering into new «*blue ocean*» markets

*The **strategic target** for coupling **storage** with **RES plants** is to increase the **long term value** of generation assets, both by **adding new revenues streams** and **reducing risk** of investments*

**internal elaboration for specific Country/applications*

Storage, especially when coupled with Renewable Plants, is able to provide a wide range of services, *both to plant and to the grid*

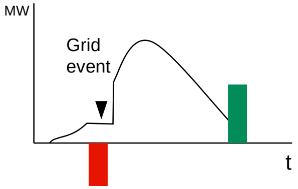
Storage coupled with Renewables

Stand-alone grid connected

Coupled with RES			Front-of-the-meter		Behind-the-meter
Imbalance costs savings	Firming capacity	Spin/Non spin reserve		Spin/Non spin reserve	Applications
Curtailment reduction	Energy shifting/arbitrage	Frequency control	Arbitrage	Frequency control	

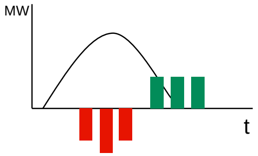
Grid and plant services

Applications for: **Power Plant** | **Power plant and Grid** | **Grid**



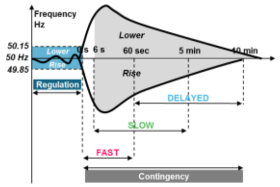
Recovery of power plant production (otherwise lost) due to **grid curtailment**

Curtailment reduction



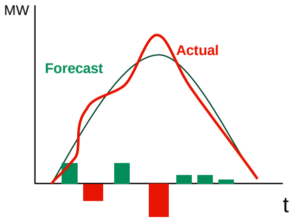
To charge and discharge battery in order to **move plant production** in hours where **energy has more value**

Energy Shifting/Arbitrage



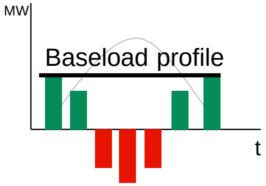
To help **grid stability** following a **grid event** in order to bring back system *frequency* within safe parameters

Spin/Non spin reserve



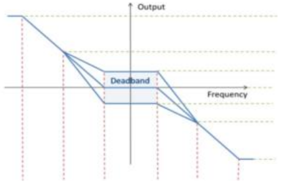
Battery charge and discharge in order to **nullify differences** between power plant **production forecast** and **actual real time** production, so **avoiding balancing costs**

Imbalance costs savings



To transform plant typical profile production into **a baseload profile** or to **match offtaker load**

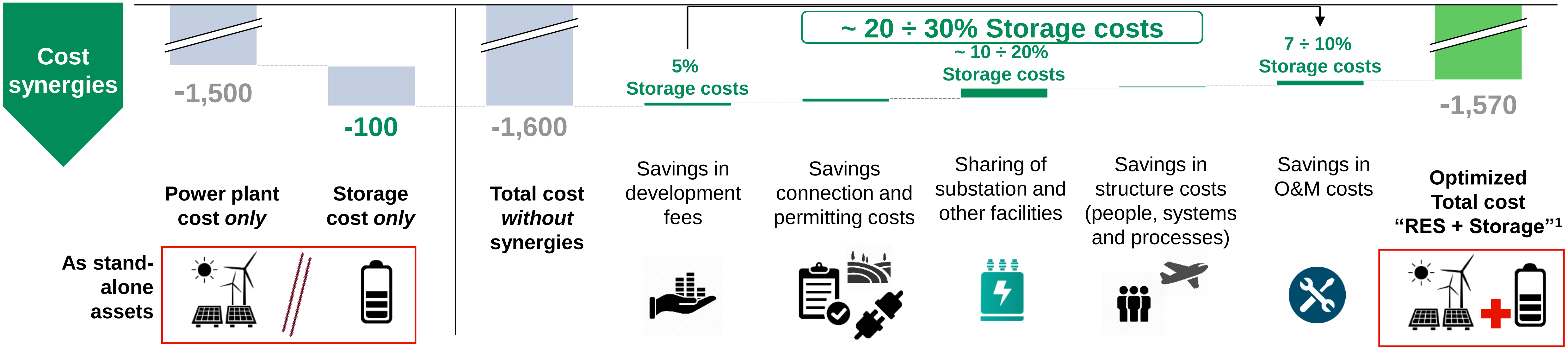
Firming capacity

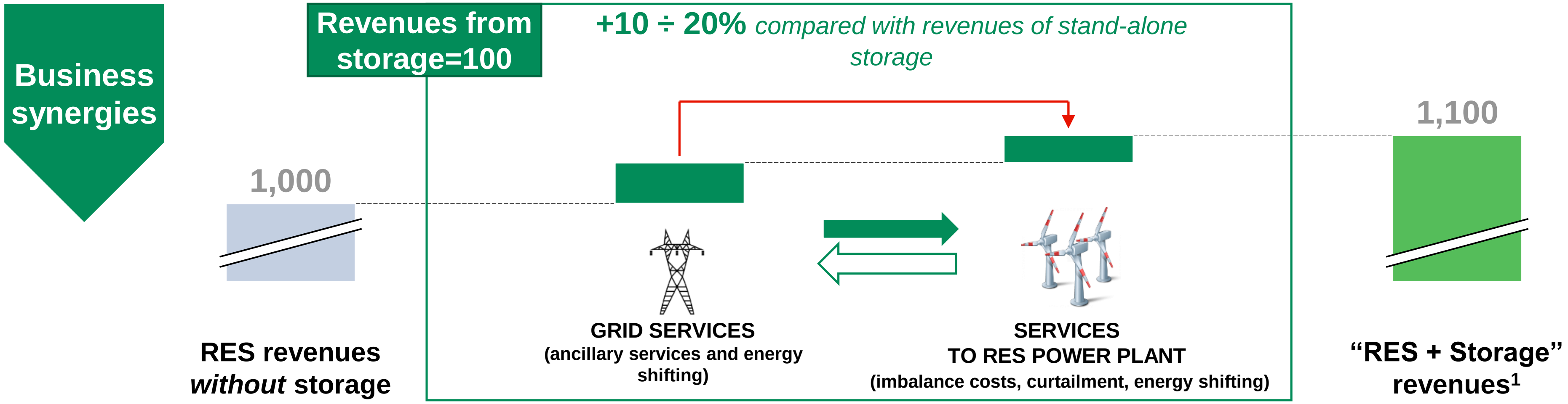


Service provided to the grid in order to improve **system reliability**. Awarded on a competitive auction.

Frequency control

Storage coupled with renewables plants, *key drivers*: cost and business synergies





Strong benefits of **joint development captured through <u>EGP internal integrated value chain</u>**

[1] Indicative figures, Storage costs/revenues = 100

Ph. EGP Cremzow BESS 22 MW/35 MWh (Germany)

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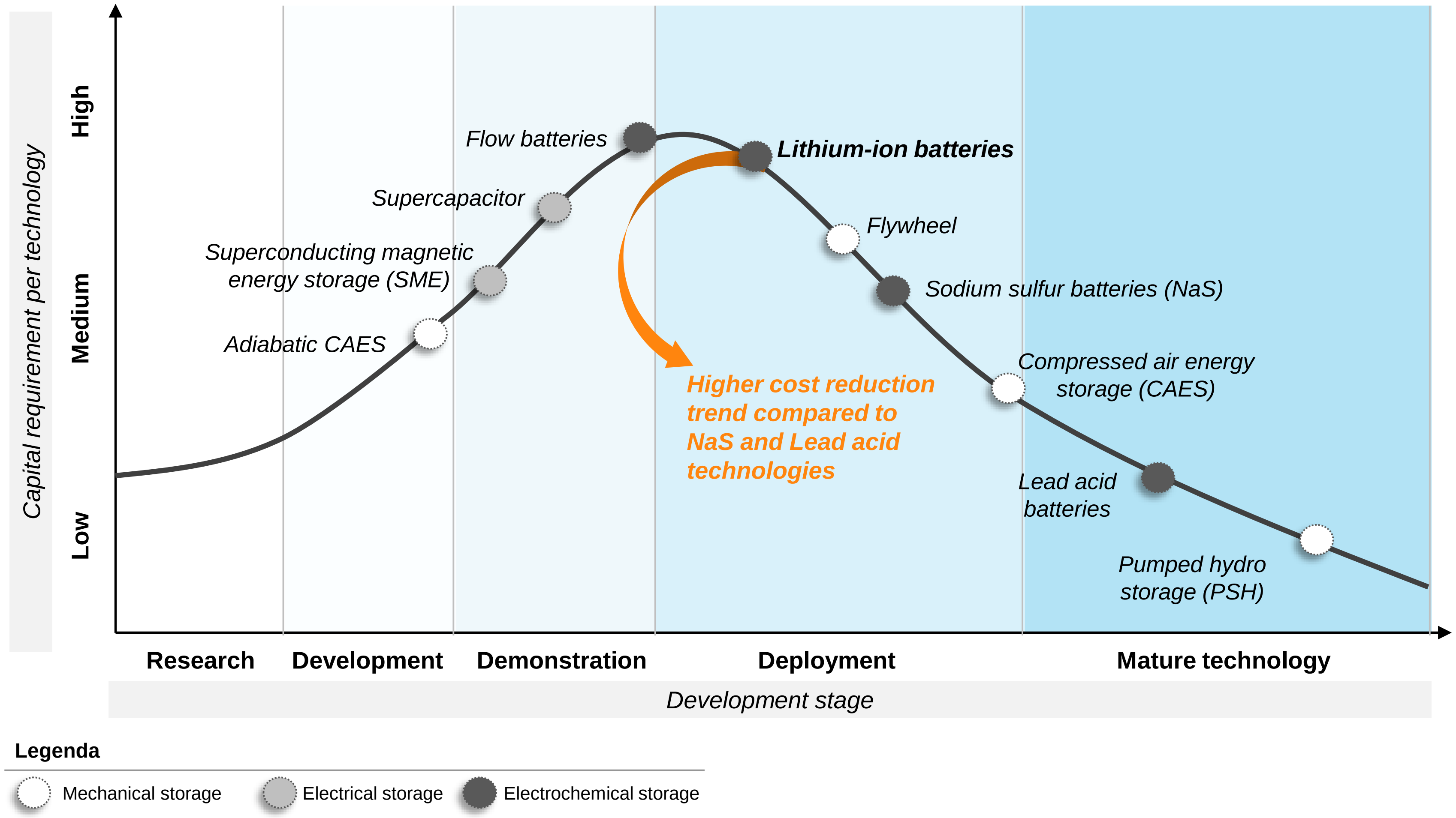
2 **Stage of technology development and cost scenario**

3 A World Tour in the business models

Green Power

Energy storage systems

Stage of technology development



Source: Pöyry analysis on public data

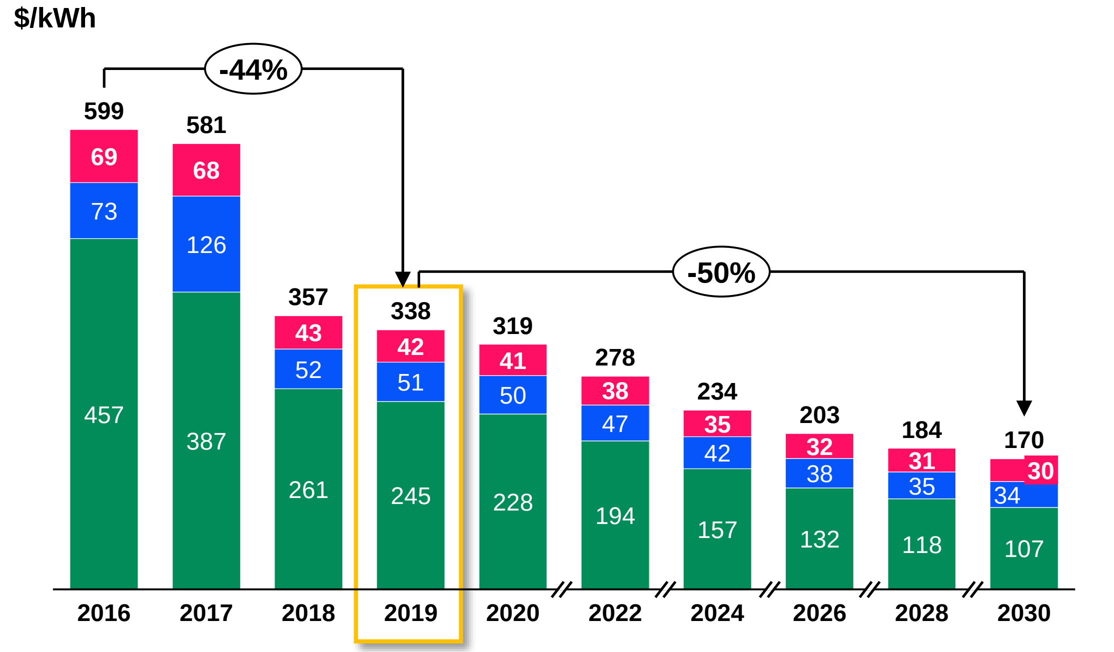
BESS turnkey BOP, Master Scada & EMS Other costs

Li- On based storage costs trends

The declining capex during last years and analysts consensus

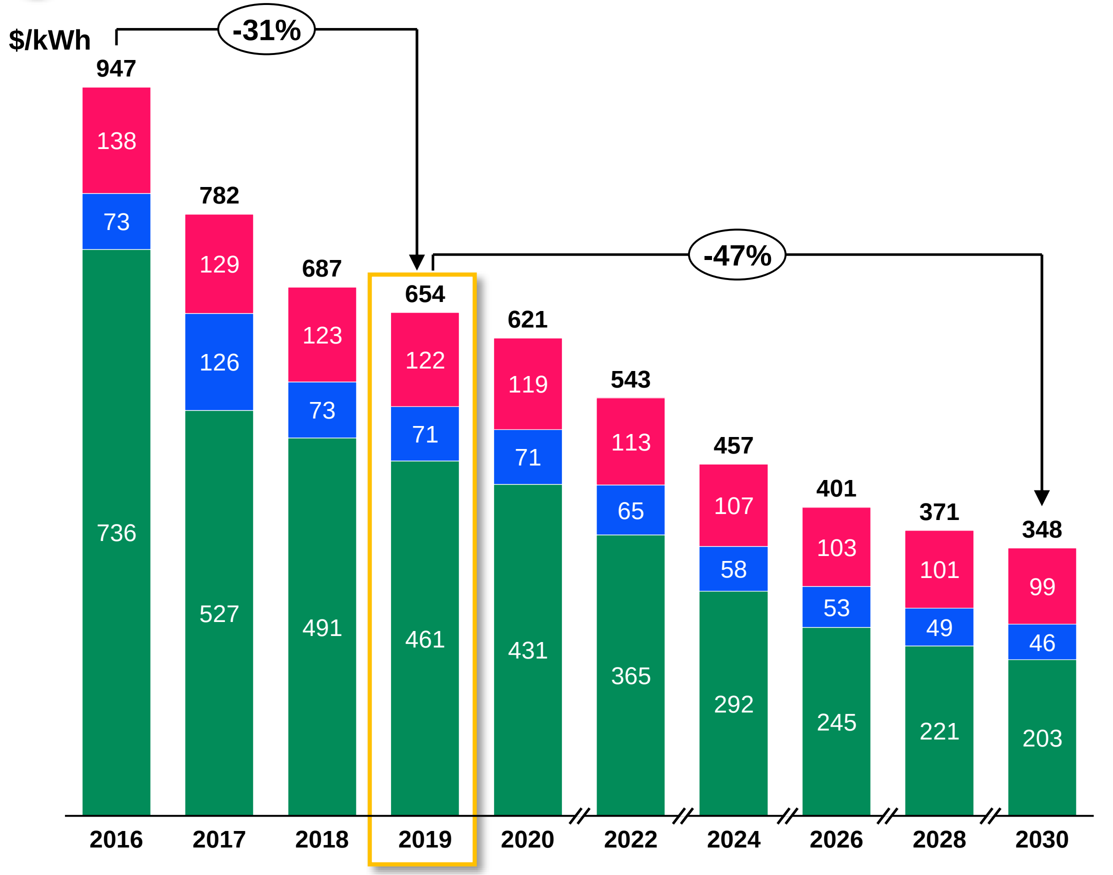
Green Power

1 Energy intensive – Load Shifting (*C-rate:0.25*)*



** BNEF projection as of July 2019 for BESS 20MW/80MWh*

2 Power Intensive - Ancillary services (*C-rate:4*)**

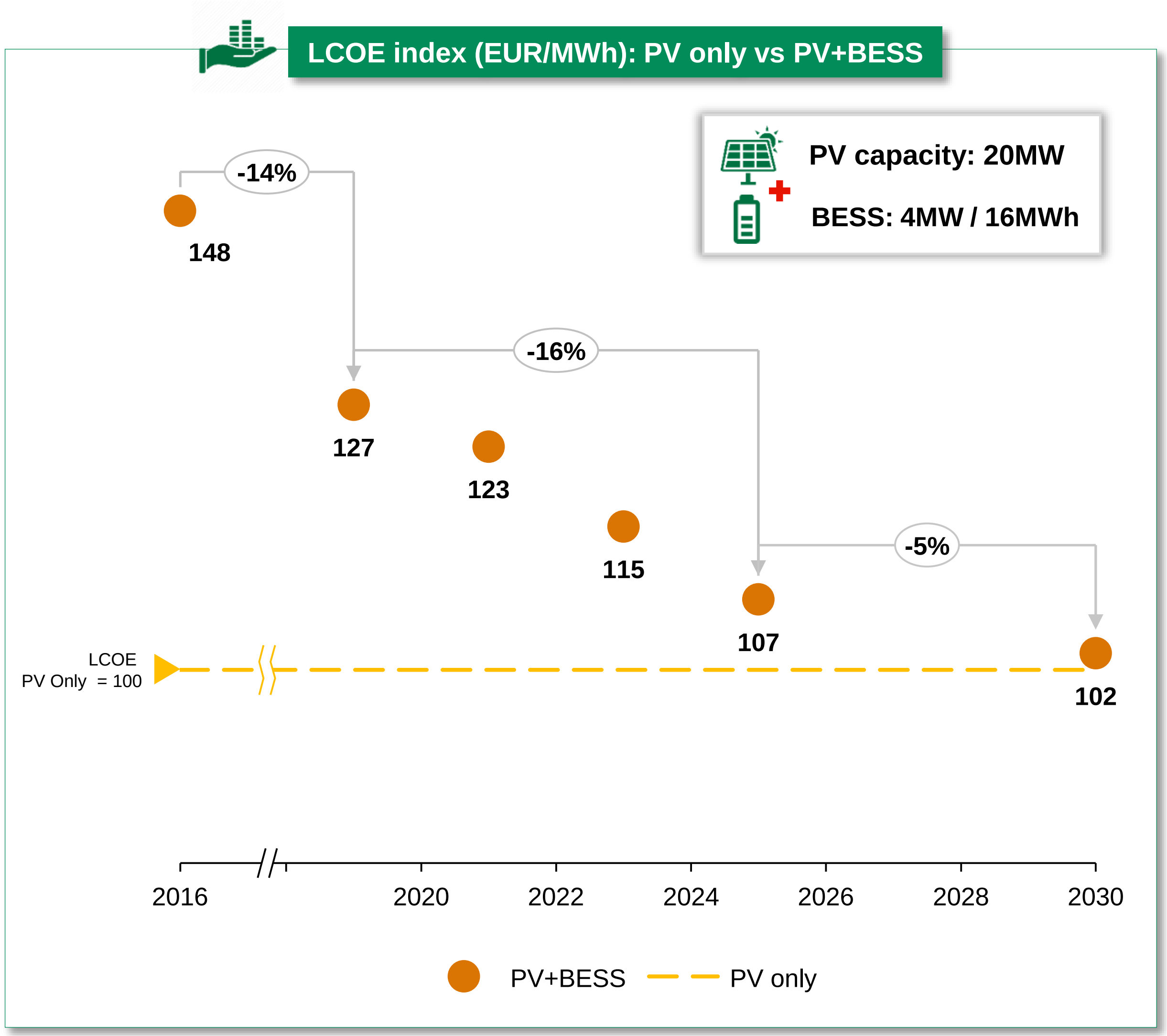


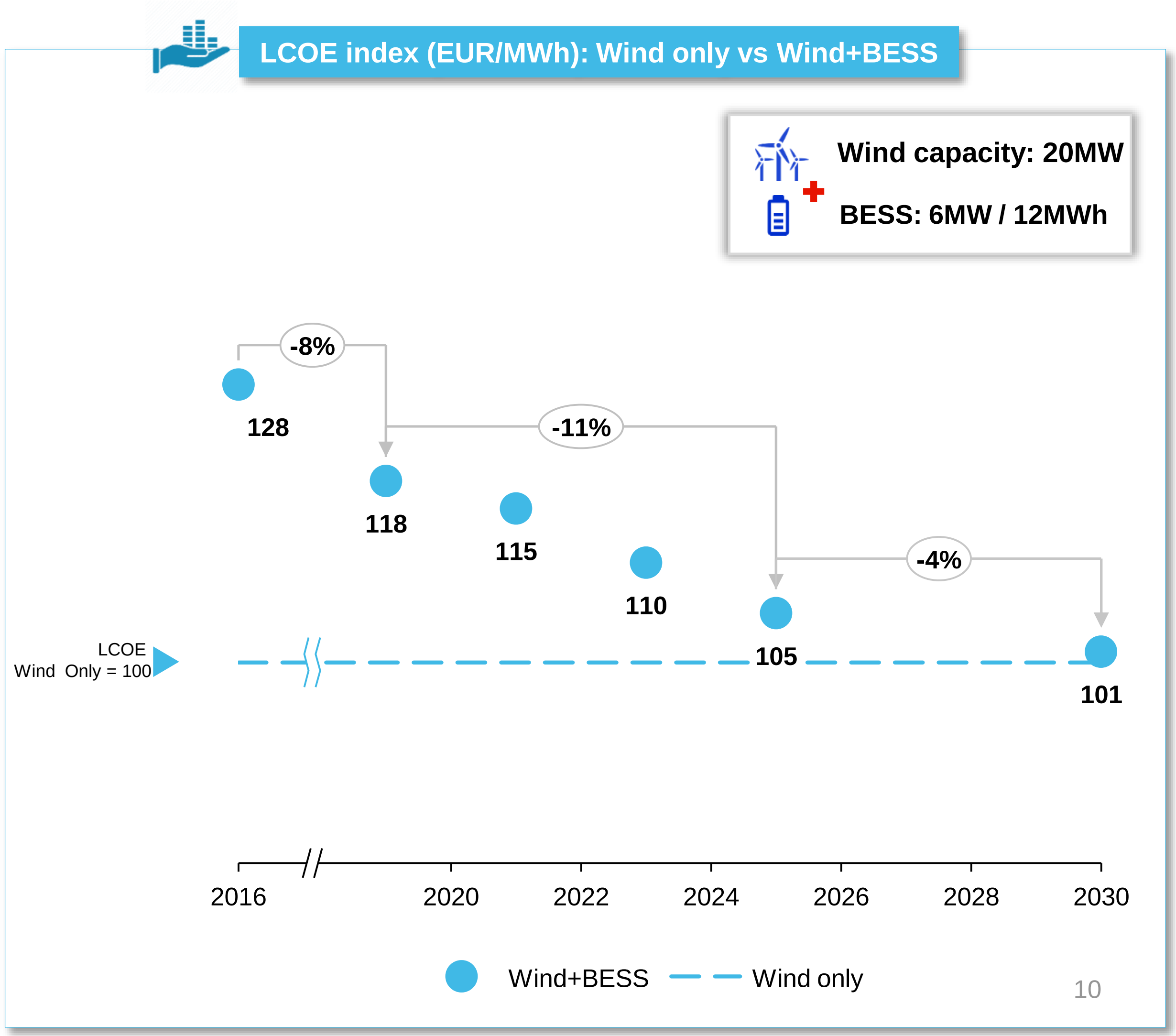
*** BNEF projection as of July 2019 for BESS 40MW/20MWh*

Battery pricing has shown a steep decline over the recent years and is expected to further decrease over time due to technology improvements, manufacturing scale and competition between suppliers

Impact on plant's LCOE

LCOE evolution for a renewable plant coupled with storage





* Elaboration on internal and data provider scenario

Ph. EGP Cremzow BESS 22 MW/35 MWh (Germany)

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Applications in US wholesale market

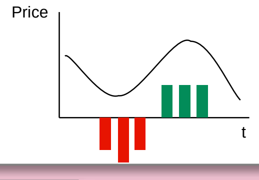
ERCOT (Texas) market

Green Power

Economic benefit

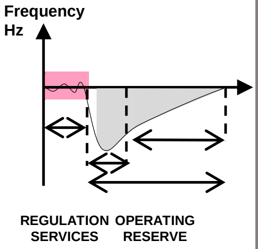
Impact on project economics

Energy Arbitrage



Storage can capture the intraday **price spread** by charging during low prices hours and discharging during high prices hours.

Ancillary Services



Regulation Services (Up/Down)

Regulation is an ancillary service, aimed at counteracting **grid frequency fluctuations** due to unexpected changes in supply/load balance. For all regulations services (both conventional and FRRS) the same price is applied.

Operating Reserves (RRS and Non Spin)

Operating Reserves are used to **protect the system against unforeseen major grid events.** RRS must increase output in compliance with ERCOT instructions in **less 10 minutes** while NSR must comply in **less than 30 minutes**.

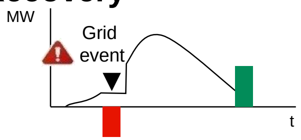
Investment Tax Credits

ITCs only apply to BESS in a **coupled configuration** with a qualified RES asset; BESS receives a credit of **30% of hard capital costs of the project** if it charges **100% through PV** for at least 5 years.

Risk mitigation

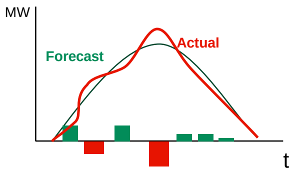
Impact on project risks

Curtailment Recovery



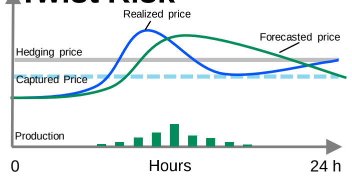
Storage allows to **recover power plant production (otherwise lost) due to potential grid curtailment**.

DA/RT Imbalance Risk



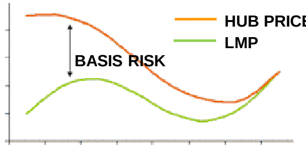
Any deviation from forecasted production represents an **exposition to real time market**, which is typically **more volatile than the DA market**. Storage represents a natural hedge against **DA/RT imbalance risk**.

Twist Risk



The hedge of solar production is settled on the nearest liquidly traded hub average price (i.e. **round-the-clock-hedge**); unfavorable variations of the hourly prices profile may occur, representing **a shape risk**, which can be naturally hedged with storage.

Basis Risk

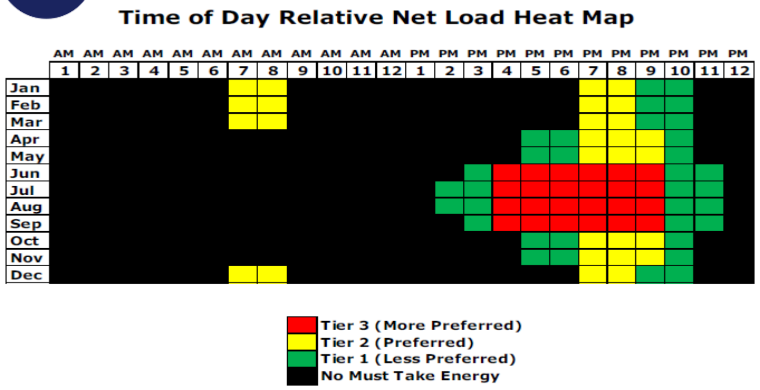


The **basis** is the price difference between the **Locational Marginal Pricing Node** (LMP) and the **nearest liquidly traded hub** (physical delivery pricing vs financial settlement through PPA). It can be mitigated by shifting production in the minimum price differential.

APS Regulated tender for peaking capacity

Tender rules and storage use case

Product



Peaking capacity: Option to deliver energy during the requested hours at fixed price, differentiated by order of preference. Preferred delivery during summer months, 16-21 hours.

Eligible resources: **Existing** or **new capacity** with **COD** between January and June **2021**. Total capacity awarded will be 400-800 MW, out of which **100 MW maximum for RES coupled with storage**. Open also to CCGT/OCGT, RES coupled with storage, stand-alone storage and Demand Response

Requirements and constraints for RES + Storage projects

Mandatory

- Maximum output of the whole plant must be equal to storage capacity (MW); 25-100 MW Minimum/Maximum size for storage.
- No possibility to charge from the grid; the storage must be fully charged before to using the renewable energy portion for any other purpose;
- Minimum 80% average load factor during Tier 3 (red) hours;
- The plant must be able to complete at least two dispatches each day during Tier 2 (yellow) hours.

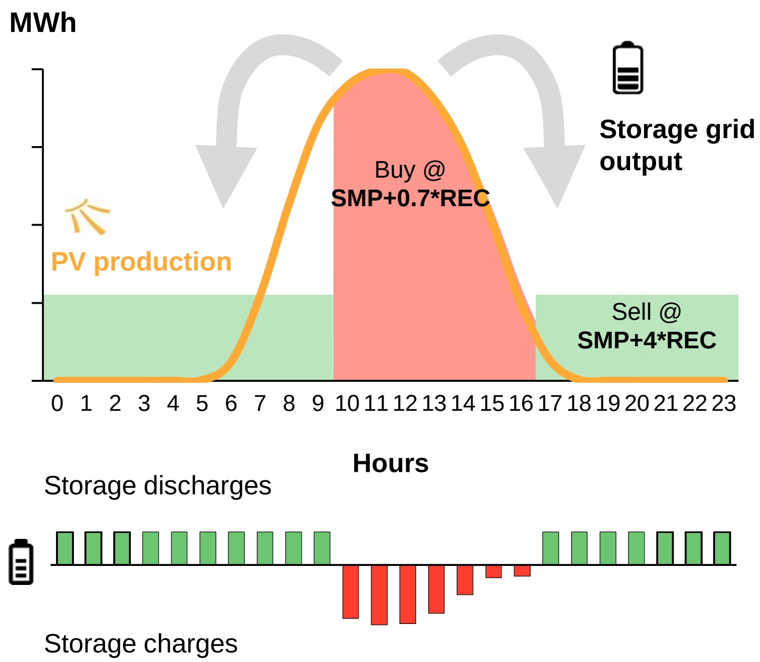
Preferred

- Energy delivery only during Tier 2 and 3 hours (red and yellow);
- Shorter term transaction preferred over longer term
- Partial discharge during evening peak and completing discharge during following day’s morning peak

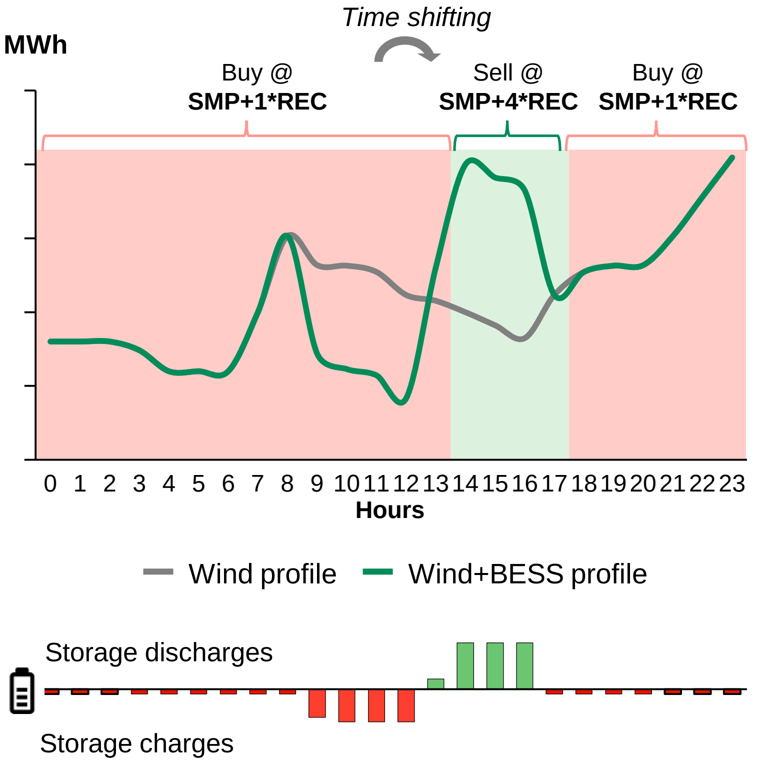
South Korea wholesale market

Wind and PV with BESS support scheme under Renewable Portfolio Standard

*The energy produced by the PV plants **from 10 to 16** and shifted through the battery in other hours, is **remunerated with 4* green certificates vs 0.7** awarded to energy injected directly by the PV plant only.*



*Storage coupled with a wind farm has to **discharge** during the defined window (remunerated with **4** green certificates**) and **charge** during all other hours.*



* #5 RECs/MWh for BESS coupled with PV plants with COD before end of 2019, #4 starting from COD 2020

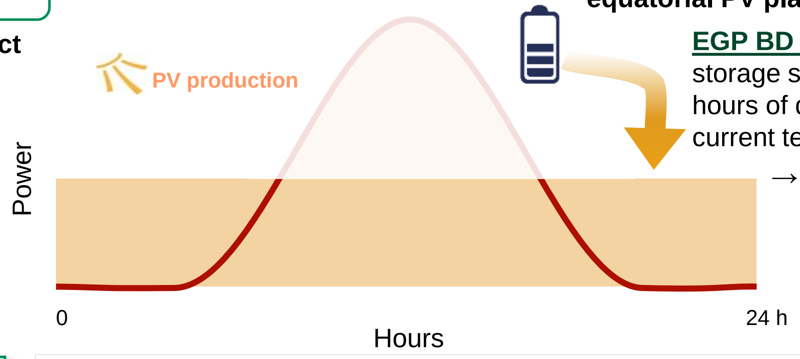
Brazilian regulated tenders

Leilão Sistema Isolado Roraima

1 Power

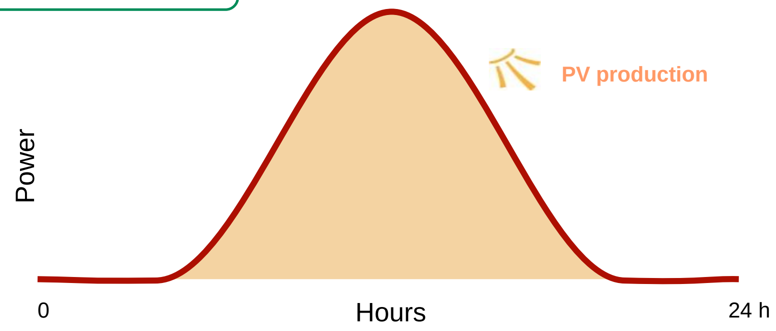
Favorite product

Baseload profile achievable on **equatorial PV plants**



EGP BD Storage preliminary proposed storage size of ~70% PV (MW) with 5 hours of duration (MWh) on the basis of current tender rules and information
→ **Allowed power bid**

2 Energy



	1 Power	2 Energy
Remuneration	R$/MW for firm power and R$/MWh for associated energy	R$/MWh pay as generated
Allowed solutions/ technologies	Plants with capability of load modulation and flexibility for variable operations, for which delivery commitments consist of **Power availability** in MW and the **associated energy**, in MWh RES + Storage plants Thermal + storage (optional) power plants	Only plants whose primary source is renewable and for which the delivery commitment is the **yearly energy production** in MWh RES power plants only*
PPA duration	**15** years for RES+ Storage and Gas plants, 7 years for other plants	**15** years

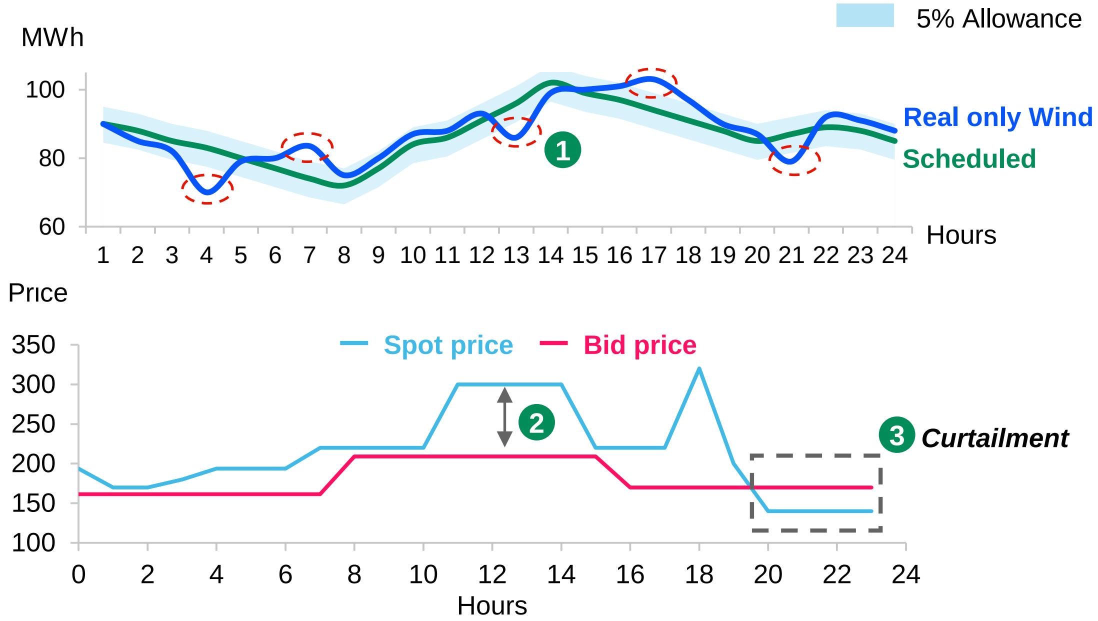
Inflexibility: for the Power product it is possible to declare the so-called «inflexibility», that is the minimum amount of «must run» hours. Inflexibility is a mechanism designed for gas plants with take-or-pay obligations of gas supply contracts. For RES+Storage it is limited to 50%.
Reliability requirement: In order to ensure that instantaneous demand is met throughout the contractual horizon, solutions for the Power product should be sized so that are able to:
a) meet the contracted power at any moment, throughout the contractual term and in a reliable way;
b) provide the maximum power for **seven** consecutive days (penalties not yet disclosed).
Genset Generation: biofuel should be part of the renewable solution due to Brazilian regulation

* RES paired with storage are allowed to bid for energy product, but no additional remuneration/premium provided for storage

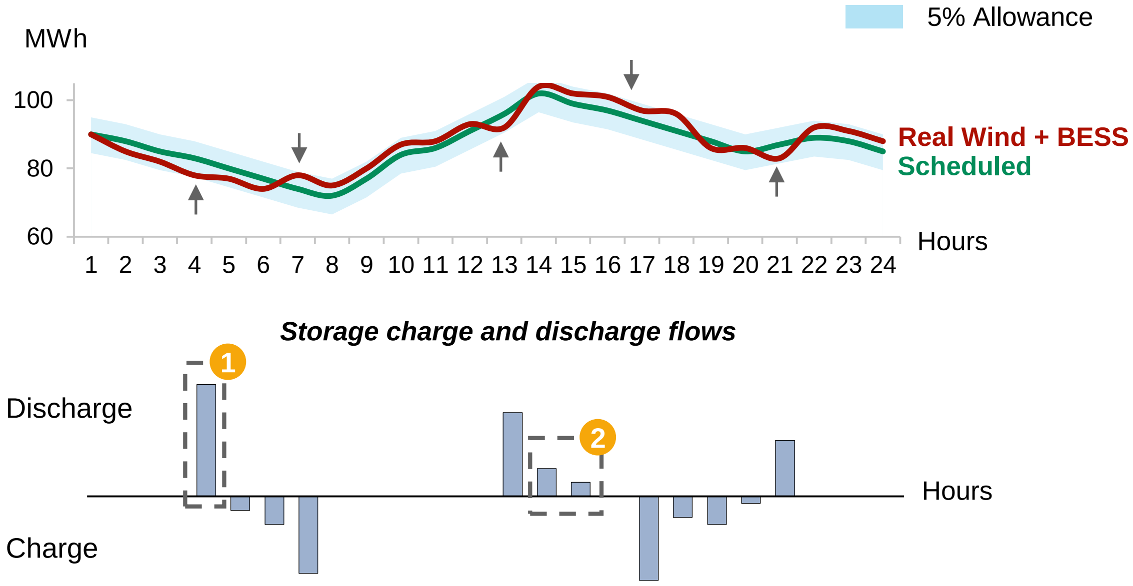
Application in Colombia wholesale market

Focus on unbalancing costs reduction

Wind production only



Storage inclusion



Deviations between real and scheduled production settled on hourly basis:

1. Imbalance penalties applied when **Actual Production deviates from Day Ahead schedule more than 5% in absolute value**
2. Penalty is equal to the amount of deviations > 5% (1) x absolute difference between the spot price and the bid price (2)
3. In case of bids above the spot price the plant is not dispatched

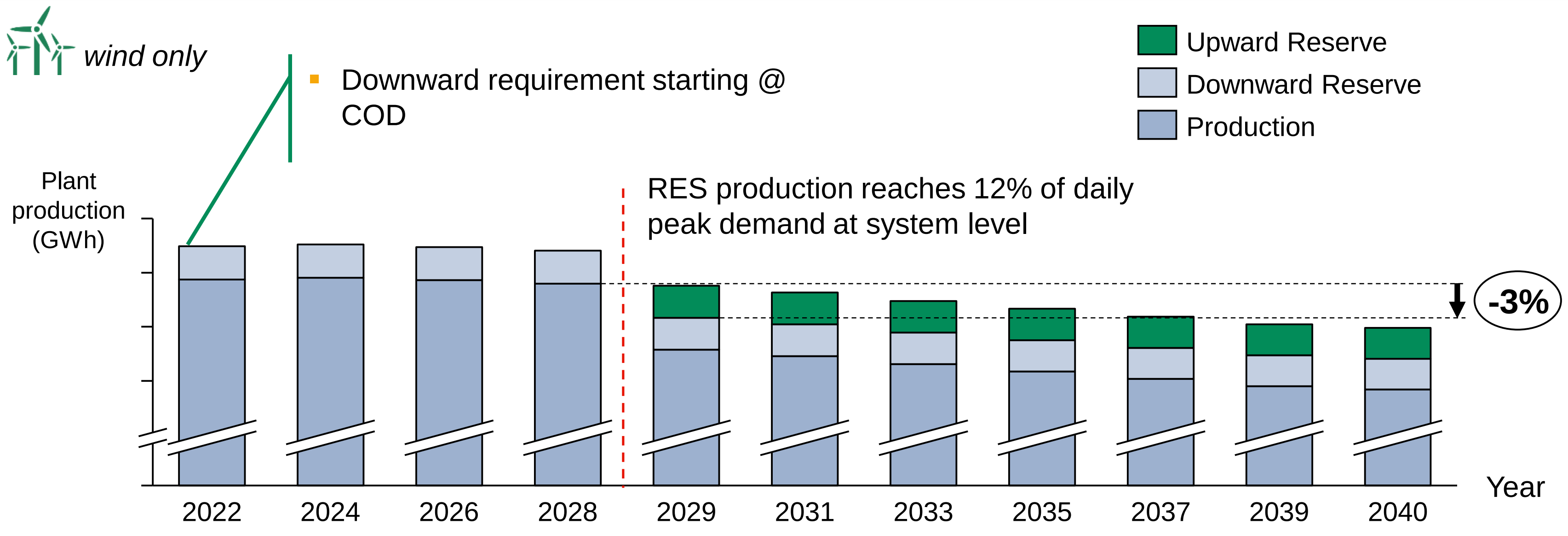
Storage charges and discharges in order to:

1. **Reduce deviations** between real and scheduled production above 5%, saving imbalance penalties
2. **Rebalance its State-of-Charge** within the allowance to manage plant future imbalances

Application in Colombia wholesale market

Primary upward reserve substitution

Primary frequency regulation



- Starting from 2029, it is expected that the TSO will send upward signal also to RES plants; Consequently, from 2029, Wind Farm production it is reduced to have backup capacity in order to comply with upward signals

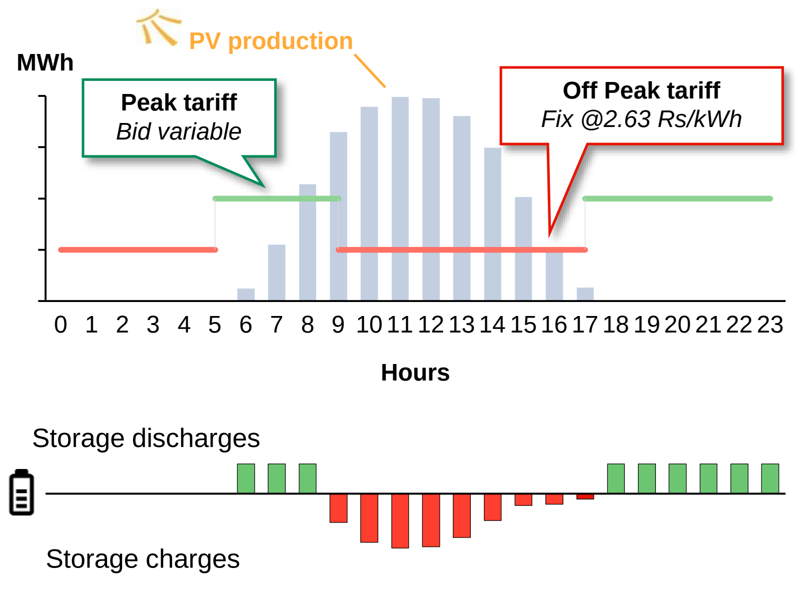
Impact of storage inclusion

- ***Introducing a BESS on a Wind Farm unlocks additional 3% of production, allowing the full production of the backup turbine that should be used to comply with upward reserve requirement***
- ***Moreover BESS will be able to recover energy lost due to downward signal****

Indian and Moroccan regulated tenders

SECI and Noor Midelt II tenders

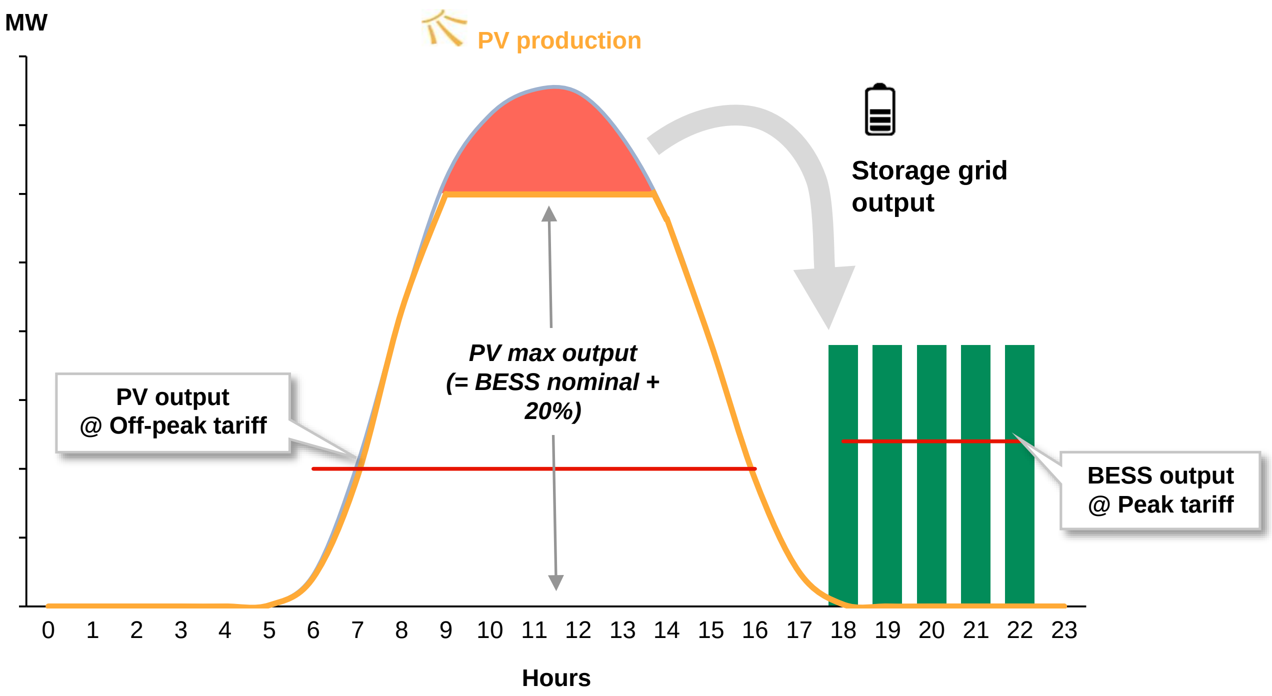
SECI tender for hybrid plants



PPA and tariff scheme

25 years flat tariff with SECI, fixed price for PV production (off-peak price), bid on storage shifted energy tariff (peak price)

Noor Midelt II tender for PV + BESS and CSP



PPA and tariff scheme

25 years duration, bid on storage shifted energy tariff (peak price - P) and base PV tariff (off-peak price - OP).
Considering that: $OP = 85\% * P$

Applications in Australian Wholesale market

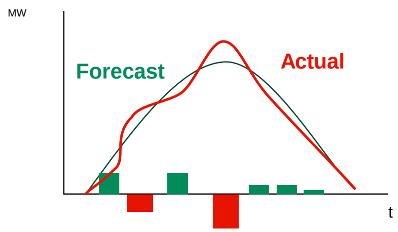
Services provided by the BESS to the plant and to the grid

Green Power

Applications for storage coupled with renewables plants, relevant* for Australia *(NEM, National Electricity Market)*

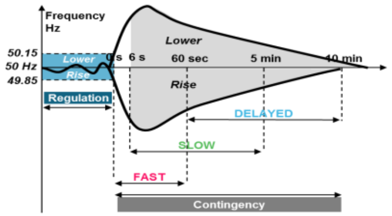
1 Reduction in unbalancing costs

- Battery charge and discharge in order to minimize differences between power plant production forecast and actual real time production, so reducing unbalancing costs



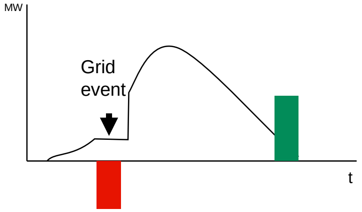
3 Frequency Control Ancillary services

- Services provided to the system by the plant, in order to maintain grid stability. In Australia (NEM) FCAS are remunerated both for availability and delivery of services



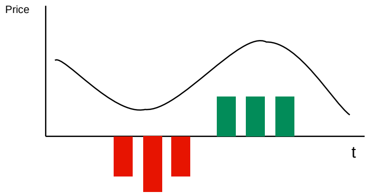
2 Curtailment avoidance

- Recovery of power plant production (otherwise lost) due to potential grid curtailment.



4 Energy shifting/Arbitrage

- To charge and discharge battery in order to capture volatility of wholesale power prices



*Not exhaustive

Applications in Australian Wholesale market

FCAS markets in Australian National Energy Market and recovery mechanism

- **Ancillary Services** in **NEM** market are based on the concept of a *two way* market, where the overall system costs for ancillary services are apportioned to market participants. The participants that deviate from their scheduled generation/load pay the service sold by those that intervene in supporting the grid.
- During each dispatch interval (5 min), AEMO enables the sufficient amount of each of **8 FCAS markets** to meet the requirement on the basis **merit order of cost**. The highest cost offer enabled set the marginal price for the FCAS category.
- FCAS prices are based on a capacity payment for enabled capacity. The energy provided or withdrawn during eventual activations is settled at power spot price.
- The **BESS** participates in this mechanism both **(1)** by reducing PV plant deviation from its scheduled generation, and **(2)** by selling its capacity at times the PV is non-producing at maximum power.

Frequency Control Ancillary Services – *supply side*

FCAS *(8 markets)*

Regulation
- Raise and Lower

Contingency
- 6 sec (Raise and Lower)
- 60 sec (Raise and Lower)
- 5 min (Raise and Lower)

The BESS can participate to all 8 FCAS markets

Frequency Control Ancillary Services - *demand side*

Contingency Raise

Regulation

Contingency Lower

Generators

Customers

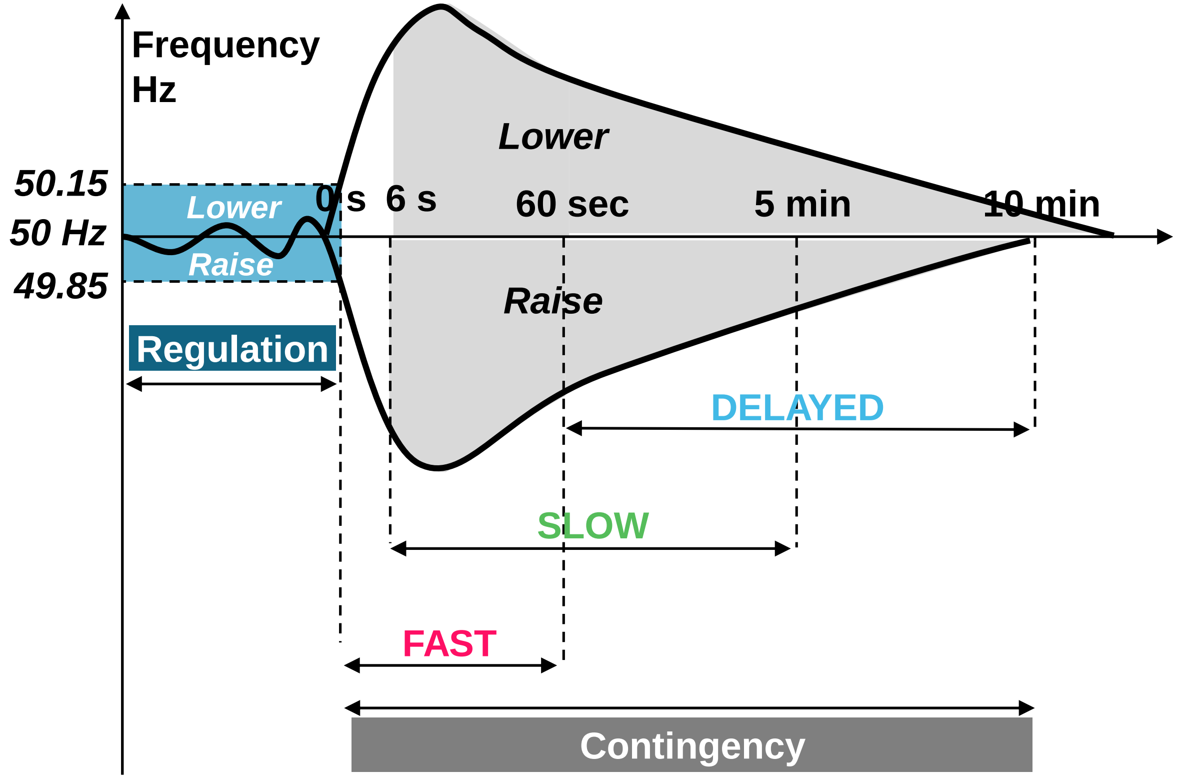
The generators pay for Contingency Raise and Regulation Services. Storage reduces the deviations from the scheduled profile up to 90%.

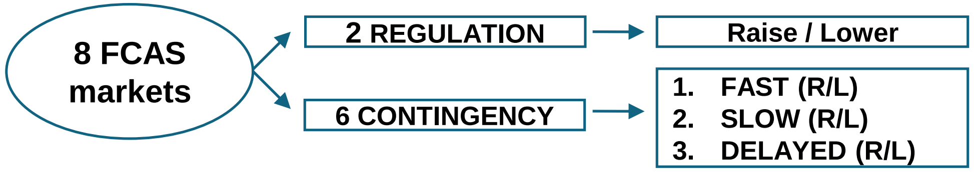
Applications in Australian Wholesale market

FCAS Markets Overview

Green Power

REGULATION & CONTINGENCY SERVICES





- The **regulation frequency control services** are provided by generators with the objective is to maintain the frequency within the normal operating band of 49,85 – 50,15 Hz.
- **Contingency services** are provided when there's a frequency deviation outside the normal operating band. There are 3 contingency services, with different response times.

REMUNERATION SCHEME

Volumes enabled are remunerated at the marginal clearing price (regardless of energy activated).

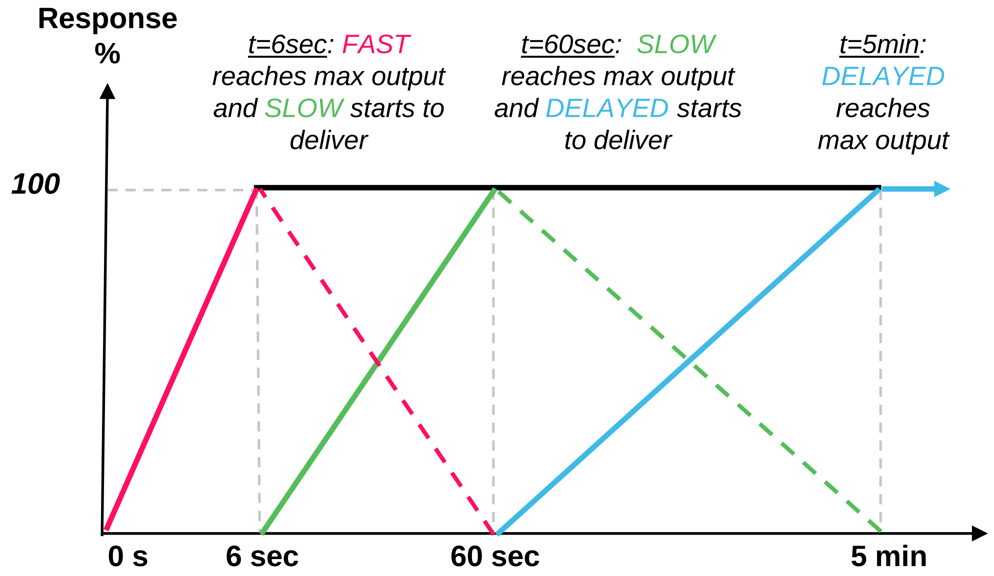
Applications in Australian Wholesale market

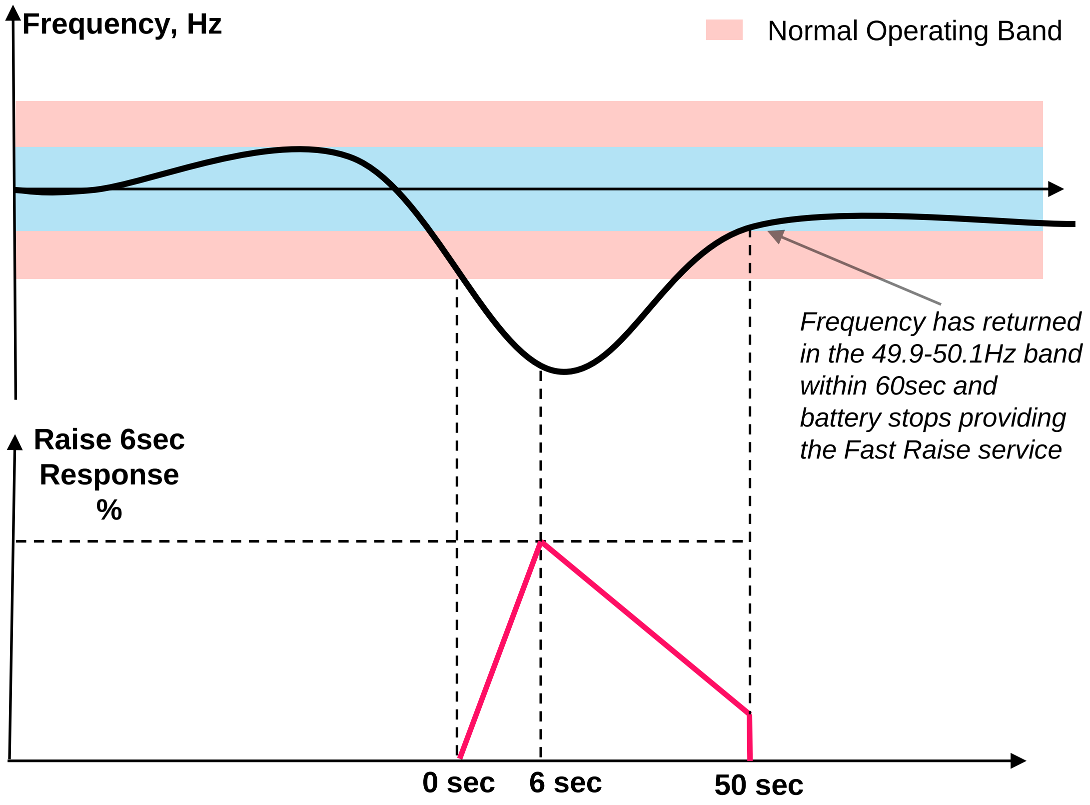
FCAS markets in NEM – Contingency services

Green Power

- Contingency services are activated when frequency exceeds the normal operating band (49.85-50.15Hz), and are deactivated when frequency returns in the band (49.9-50.1Hz).

CONTINGENCY SERVICES – RESPONSE RULES





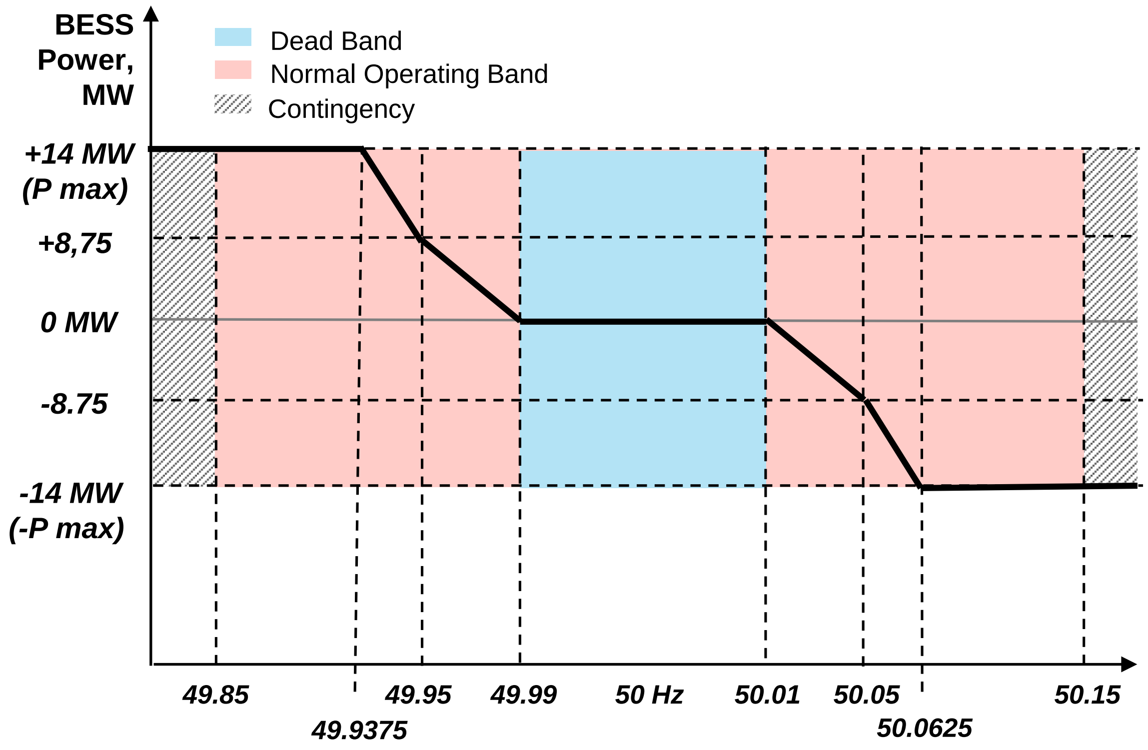
- The total output of the 3 contingency services must always be constant and equal to the volumes enabled.
- The supply of contingency services must be guaranteed for a total of 10 minutes.

Applications in Australian Wholesale market

FCAS markets in NEM – Regulation services

- While FCAS contingency services activations are occasional, regulation services are provided in the continuum to compensate the grid frequency deviations inside the Normal Operating Band.

REGULATION SERVICES – RESPONSE RULES (SIMPLIFIED)



Note: The figure illustrates a proxy of the power response of a 14MW BESS: the actual response is a function of the frequency historical trajectory as well.

Battery provides Regulation Services according to the following response rules:

- **Deadband [49.99-50.01Hz]**: No response
- In the **Normal Operating Band [49.85-50.15Hz]**, battery responds inversely proportional to frequency deviation;
- **A Contingency event** happen when frequency exceeds the outside Normal Operating Band.

Thank You

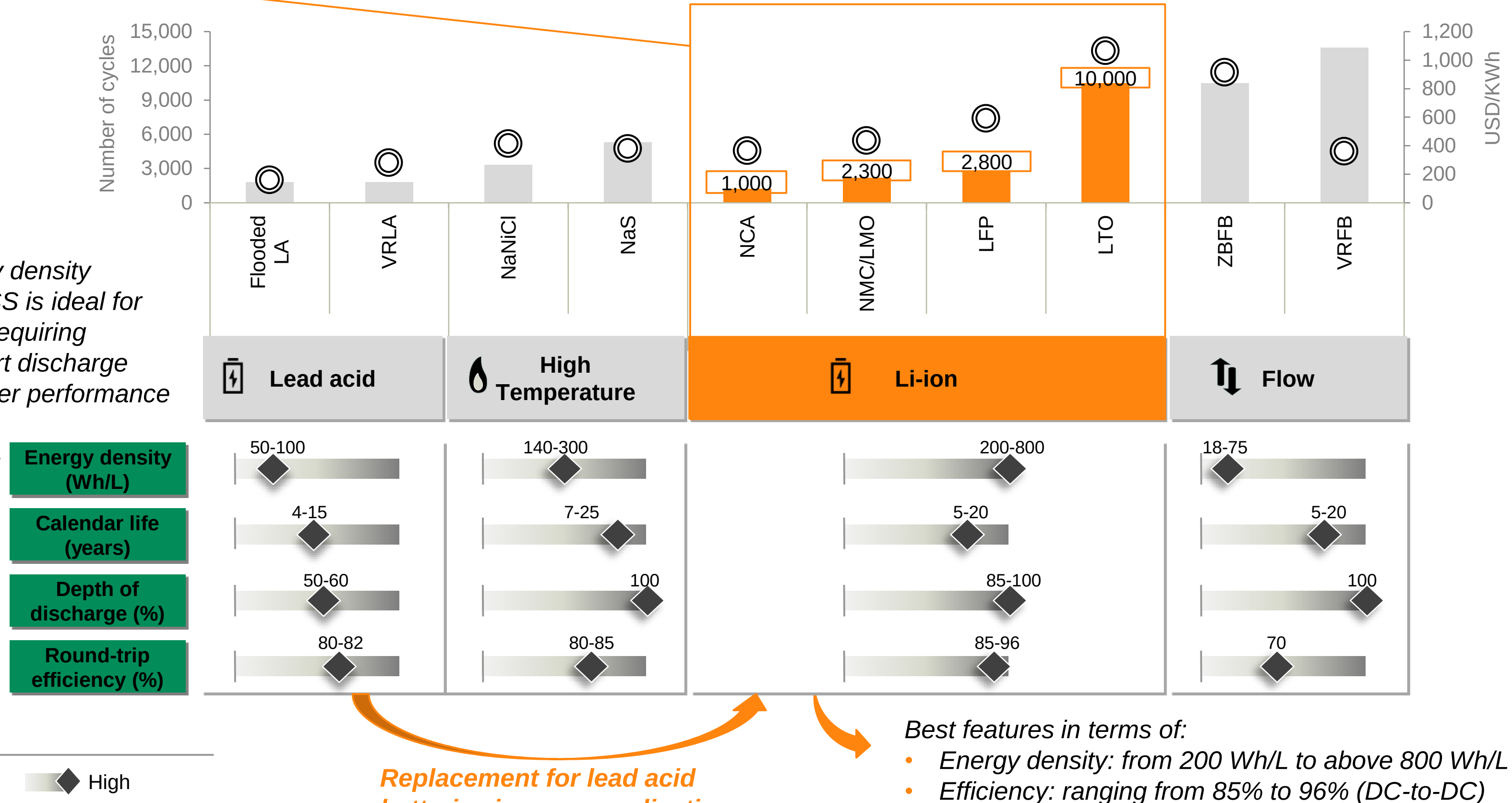
BACKUP

Focus on BESS (Battery Energy Storage Systems)

Technical/commercial characteristics

Comparable/lower number of cycles for Li-ion batteries affect the possible applications of this technology. Furthermore comparable/higher CAPEX, highlight the importance of carrying out an economical optimization for the storage sizing

A high energy density means a BESS is ideal for applications requiring relatively short discharge and high power performance



Replacement for lead acid batteries in many applications

Best features in terms of:

- *Energy density: from 200 Wh/L to above 800 Wh/L*
- *Efficiency: ranging from 85% to 96% (DC-to-DC)*
- *Lifetime: ranging from 5 to 20 years*

Source: Pöyry analysis on IRENA 2016 data

Note: NMC/LMO – nickel manganese cobalt oxide/lithium manganese oxide; NCA – nickel cobalt aluminium oxide; LFP – lithium iron phosphate; LTO – lithium titanate

Focus on BESS (Battery Energy Storage Systems)

Features, applications, pros & cons

Enel Green Power

Conventional

Used for small devices' applications only, Almost completely replaced by Lithium technology

NiCd	NiMH	Lead acid	Li-ion
Main features: • Rapid charge (10 minutes to 2 hours) • Inexpensive for low power applications Drawbacks: • Memory effect leading to loss of capacity • More expensive than lead acid for the same capacity (> 4 times) • Possible damage by overcharging Applications: • *Gradually being phased out in favor of Lithium for their its energy density performances*	Main features: • Rapid charge (possible in 1 hour) • High energy density (+100% than lead acid, +60% of Li-ion) • Wide operating temperature range (-30°C to +75°C) • Safer than Lithium based cells Drawbacks: • High self discharge rate and memory effect leading to loss of capacity Applications: • High voltage automotive applications • *In consumer applications almost completely replaced by Li-ion*	Main features: • Oldest and most widely deployed rechargeable battery • Low cost and large existing market Drawbacks: • Relatively low energy density • High heaviness and • Bad response to deep discharging Applications • numerous applications (EV, off-grid Power Systems, UPS…) • Widely applied to the deployment of RES (so far coupled with numerous solar and wind power plants)	Main features: • High energy and power density • Long lifetime • Low self discharge rate Drawbacks: • Low thermal stability lead to safety issue related to chemical reactions – Need to integrated battery management systems (BMS) Applications: • Dominant technology for portable electronics and electro mobility • Increasingly becoming an economic option for stationary applications

High temperature / Flow

Dependency on a small number of manufacturers

NaS	NaNiCl ("ZEBRA")	Flow Batteries
Main features: • High cycle lifetimes at low costs • High power and energy density technology (>4 times than lead acid) • Very low self-discharge rates Drawbacks: • Operating temperature at 300-350°C leads to the need of a heat source, and safety issues Applications: • Especially used in USA and Japan for grid services (e.g. load levelling) • So far only commercialized in stationary applications	Main features: • Good energy density and low maintenance • Lower temperature variant of NaS • Low self-discharge rates • Good discharge capabilities • Safer than NaS (fire risk is negligible) Drawbacks: • Operating temperature at 157-270°C, leads to the need of a heat source Applications: • Stationary applications • Mobile applications (materials less corrosive than NaS)	Main features: • Can operate at close to ambient temperatures • Can use relatively inexpensive and abundantly available raw materials • Very deep discharge rates without high impacts on cycle life • Short response time and suitable for large scale applications Drawbacks: • A cooling system is needed for the heat released during charges and discharges of the battery • Complex system architecture Applications: • Stationary applications

Note: NaNiCl – sodium nickel chloride; NaS – sodium sulphur; NiCd – nickel cadmium; NiMH – nickel-metal hydride; ZEBRA – Zero emission Batteries Research Activities