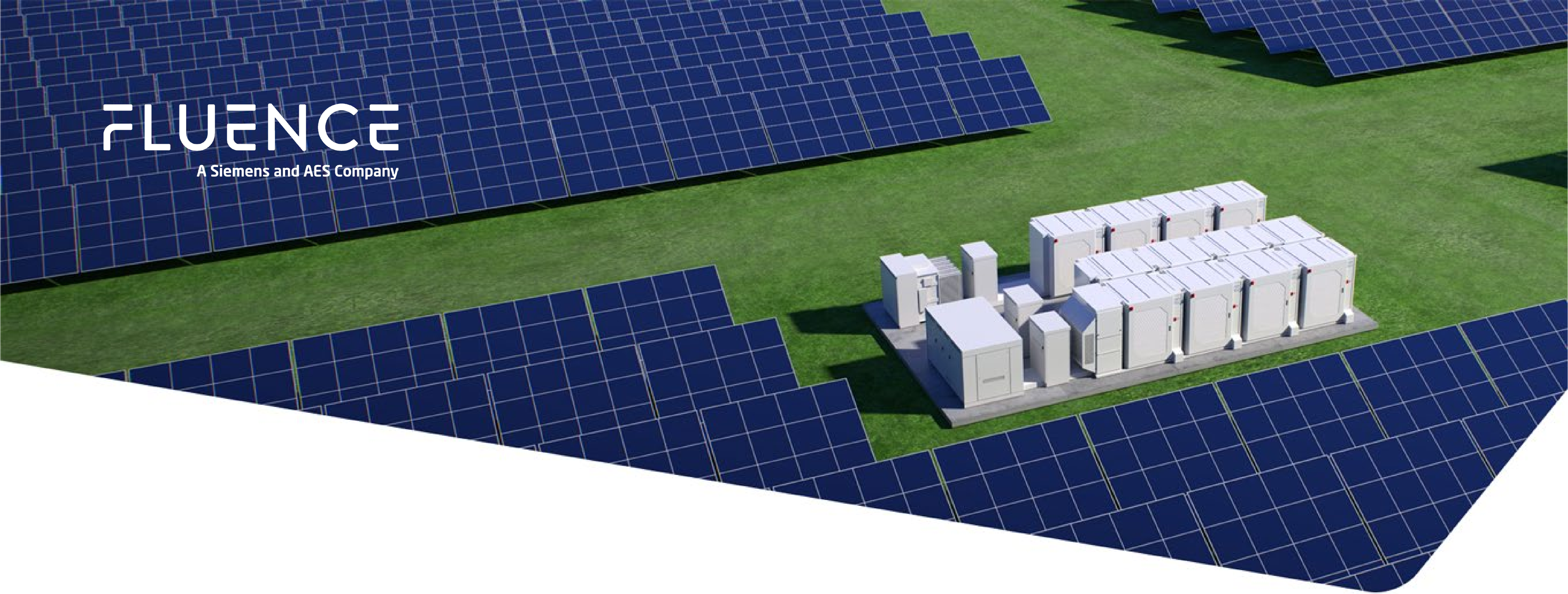


Designing the storage solution

November 7, 2022

A decade of storage innovation

Opening Markets | Developing New Applications | Unlocking Revenue Streams

First battery connected to PJM interconnection for frequency regulation
AES, Pennsylvania

First utility-scale hybrid wind + energy storage facility using lithium-ion batteries
12 MW AES Laurel Mountain, West Virginia

First hybrid thermal power plant + energy storage
12 MW AES Gener, Chile

First grid-scale battery to receive long-term capacity PPA (with SCE)
100 MW Alamitos, California

Largest battery supply agreement for energy storage
LG Chem + AES

Largest energy storage project for the 5th time
30 MW Escondido, California

First structure with storage owned by transmission and leased to a market participant
30 MW, Ballarat, Australia

Largest Solar + Storage project in South America
112 MW, Andes Solar, Chile

Fastest battery in the world, Frequency Response
11 MW, Statkraft Kilathmoy, Ireland

Largest portfolio in SE Asia
SMC Portfolio of 500+ MWs across 20+ projects

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

Proven energy storage products and digital solutions

ENERGY STORAGE PRODUCTS

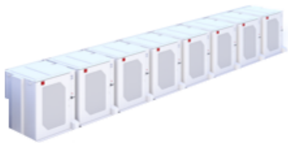
CUSTOMER SEGMENT

Grid-scale, industrial-strength energy storage

Mass customization.

CUBE
Single physical container

NODE
Cube or string of cubes connected to a DC bus



CORE
Collection of Nodes connected to a transformer

FLUENCE OS

REPRESENTATIVE GRID SERVICES

- Frequency Regulation
- Flexible Peaking Capacity
- Spinning Reserves
- T&D Deferral / Congestion Relief

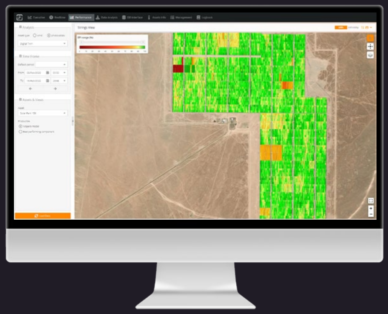
- Renewable Integration
- Firm Solar Output
- Solar Energy Time Shifting
- Ramp Rate Control

- Energy Cost Control
- Back-up Power
- Demand Charge Reduction
- Time of Use Bill Management

SOFTWARE PRODUCTS

Mosaic
Intelligent bidding software for solar, wind, and storage

\+



Nispera
Asset performance management for renewable energy assets

Gridstack AC

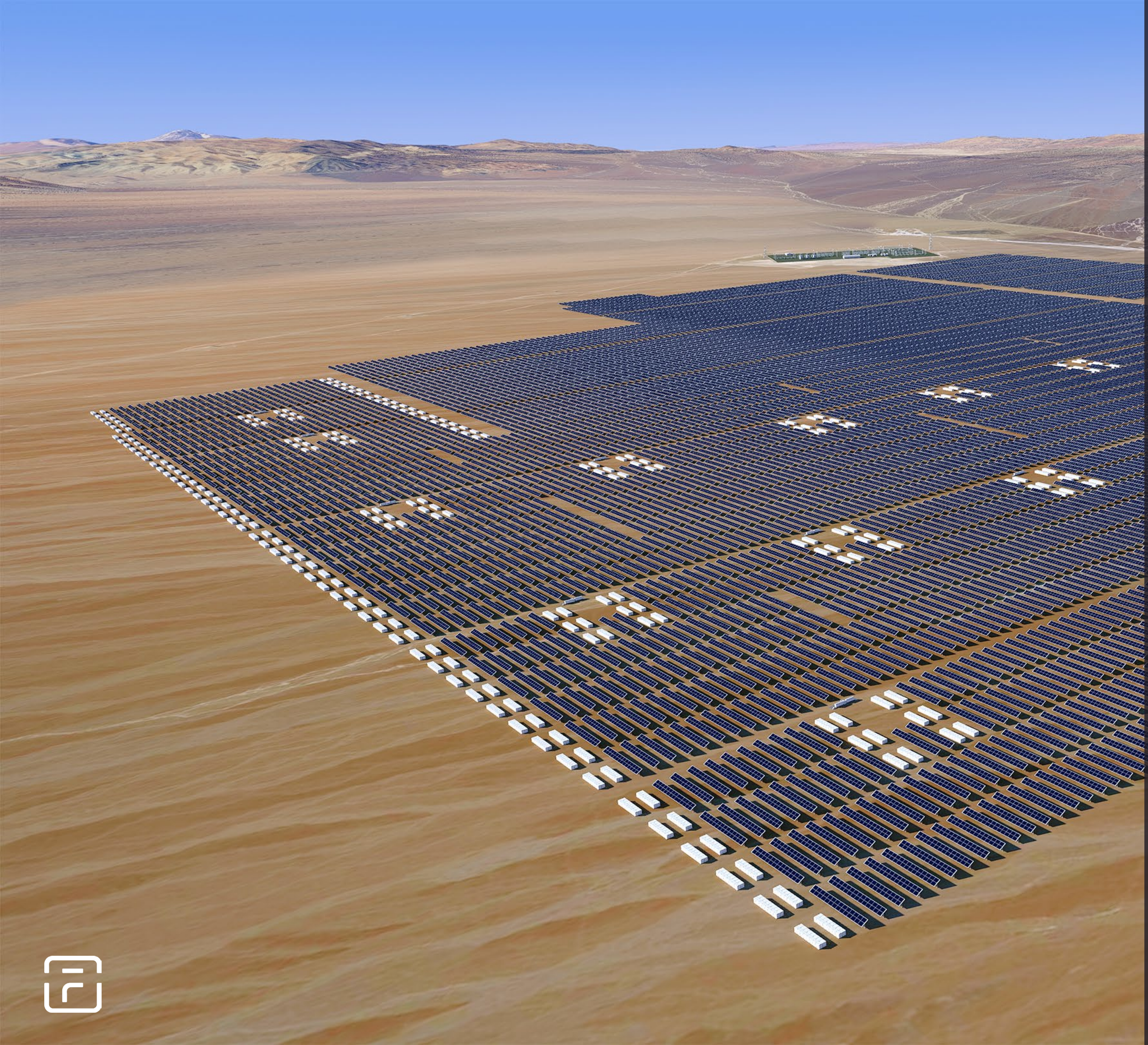
Münch Energie
Beuna, Deutschland
11,7 MW / >30 MWh

SERVICES

- InnoA tender
- Wholesalemarket Optimization
- Frequency response

IMPACTS

- AC-coupled Gridstack system co-located with 34MWp of solar
- Enables solar energy to be stored for up to 2 hours over 20 years
- Reduces exposure to several market risks



Sunstack DC

AES Gener

Antofagasta, Chile
112 MW / 560 MWh

SERVICES

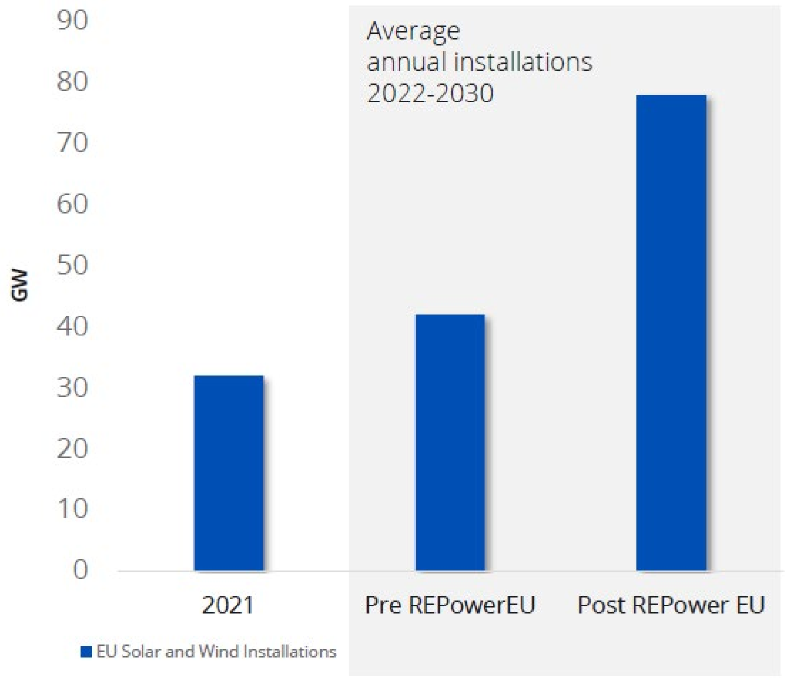
- Firm energy delivery
- Peaking capacity
- Frequency response

IMPACTS

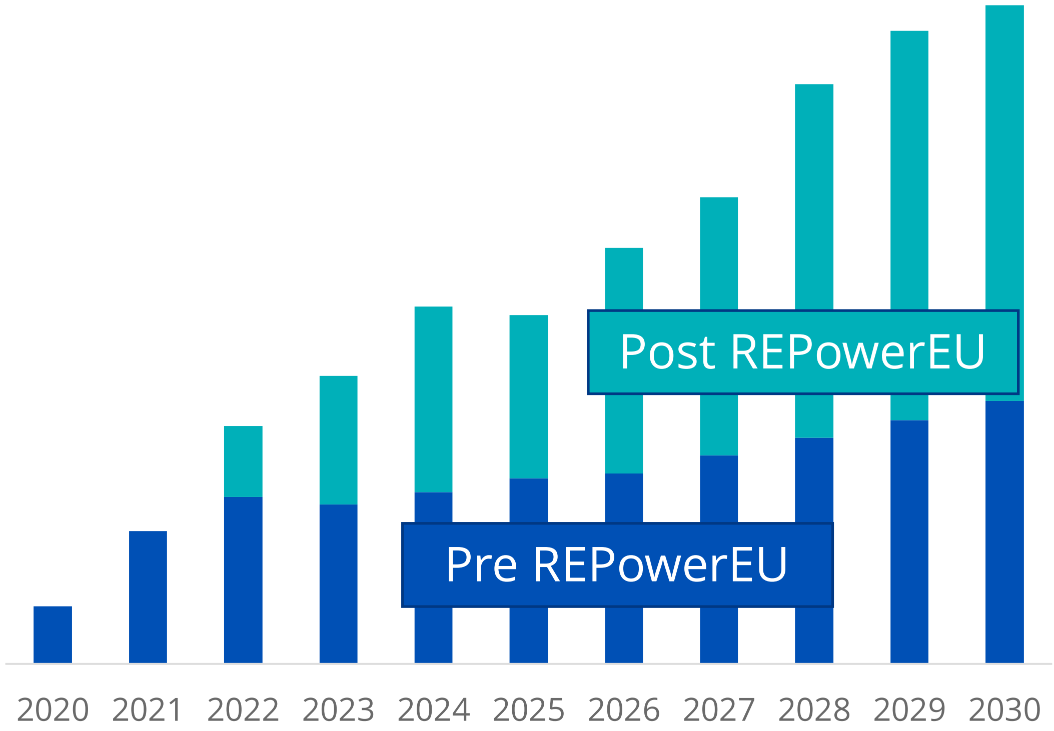
- DC-coupled Sunstack system co-located with 180MW of solar
- Enables solar energy to be stored for up to five hours
- Reduces exposure to several market risks
- Latin America’s largest solar + storage project

The case for co-located Solar+BESS installations: Combine renewable and battery ramp-up

REPowerEU calls for **nearly doubling the annual renewable build** (solar and wind) in Europe from 42 GW to 78 GW



+41 GW of battery-based energy storage forecasted to integrate accelerated renewable buildout targeted under REPowerEU



Source: Data adapted from range of sources including IHS Markit/ S&P Global, BNEF, WoodMac., Data includes some markets outside of the EU such as the UK

Source: IHS Markit

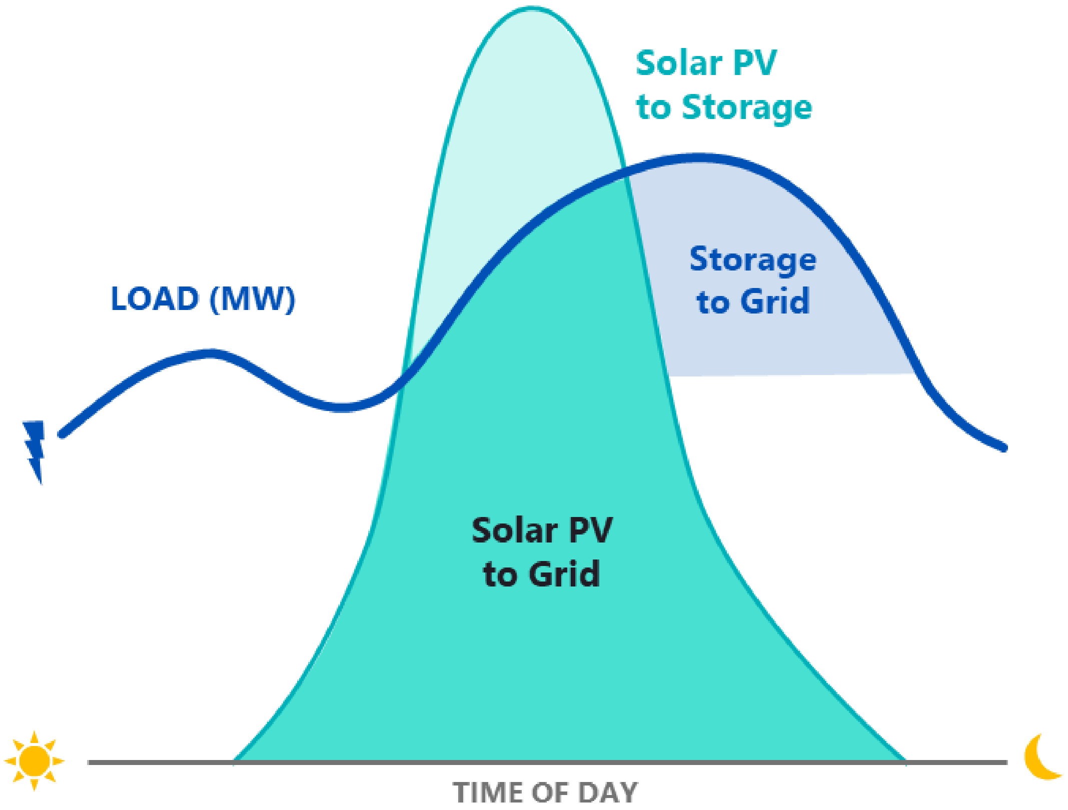
SECTION 1

Design Assumptions

The Solar + Storage Value

- Predictable **firm renewable energy** to meet energy guarantees 24 hours a day
- **Time shift energy** to maximize solar revenue
- **Plant stability** like generation smoothing and ramp limiting keep renewable output stable
- **Grid services** such as frequency regulation
- **Reduced costs** from co-located Solar + Storage balance-of-system up to 30% less than standalone

Time Shift Solar Output



Design Assumptions

General Considerations

- Application
- AC- vs. DC- coupling
- Project constraints: land, interconnection, etc.
- Overbuild vs. Augmentation (for AC coupled systems)
- CAPEX vs. OPEX budget
- Installation and O&M considerations

Innovation Tender (Germany) & PV + BESS in general

Innovation Tender (Germany)

- 1/3 of PV power must be available as BESS power for 2h charge duration after 20 years
- 20 MWp Solar → 6,67 MW, 2h (EoL, 20a) BESS

PV + BESS in general

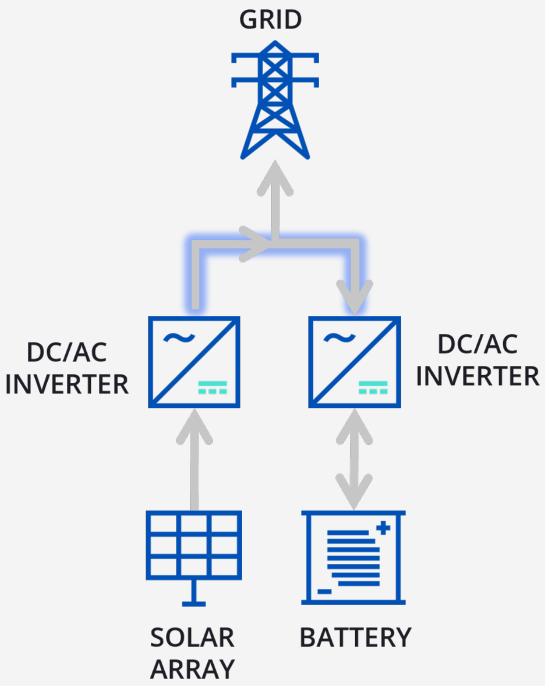
- Country specific
- No regulatory to be followed, between 3- 4h systems

SECTION 2

AC vs. DC Coupled

AC- vs. DC-Coupled

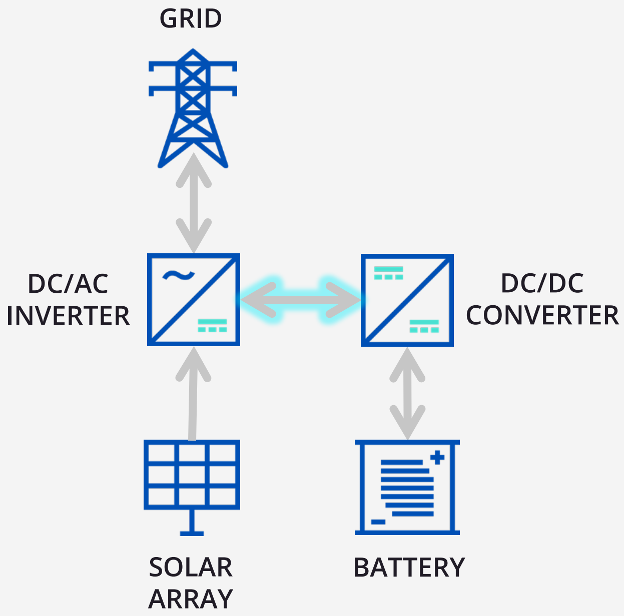
AC-coupled
Solar + Storage



- PV and ESS co-located
- Separate inverters for PV and ESS
- Can be dispatched together or independently

AC	Solar + Storage Considerations	DC
●	Separate inverters for PV and ESS	
	Captures clipped solar generation	●
	Eliminates one set of MV switchgear + transformer for interconnection	●
	Higher round-trip efficiency *when charged >50% from solar*	●
	Maximizes PV inverter DC:AC load ratio *High ILR 1.5-2*	●
	Simplifies interconnection process *due to single inverter*	●
●	**Charges from solar or grid**	●
●	**Eligible for ITC** *must show 75% of battery charging is from PV*	●
●	**Supports grid services**	○ *Limited*

DC-coupled
Solar + Storage



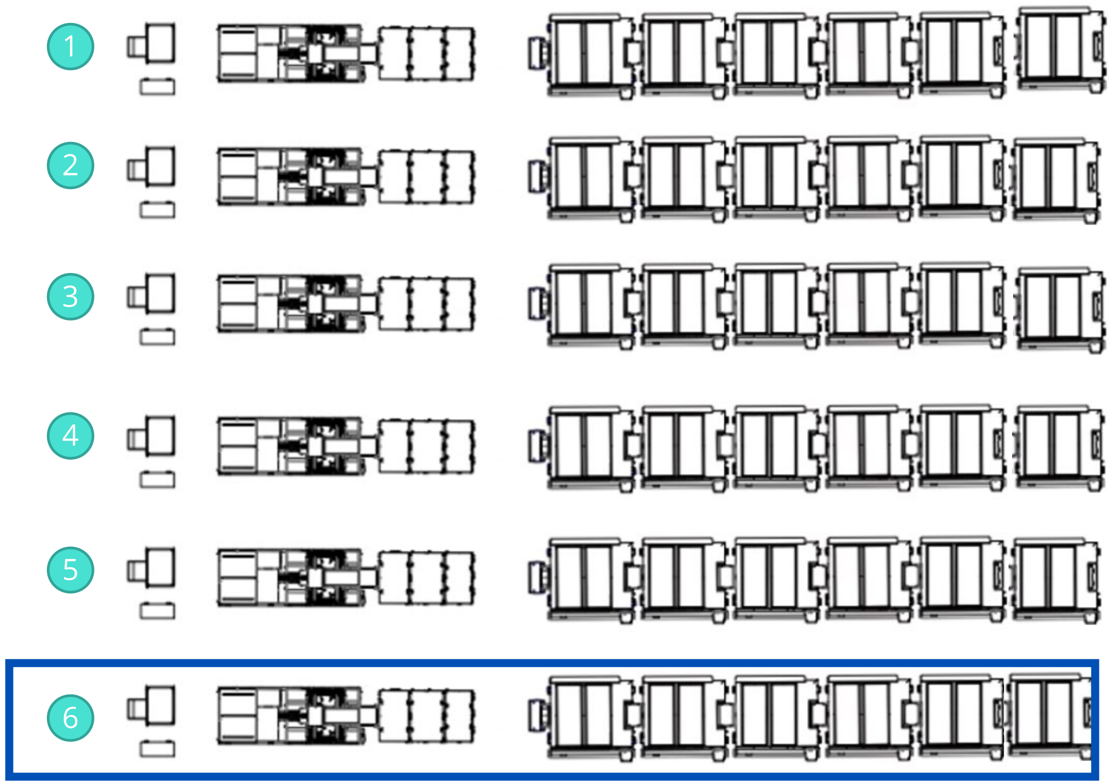
- PV and ESS co-located and share the same POIAA
- Same inverter for PV and ESS
- Connected on same DC bus
- Only dispatched together as a single source

SECTION 3

Overbuild vs. Augmentation for AC coupled systems

Overbuild

Power and Capacity

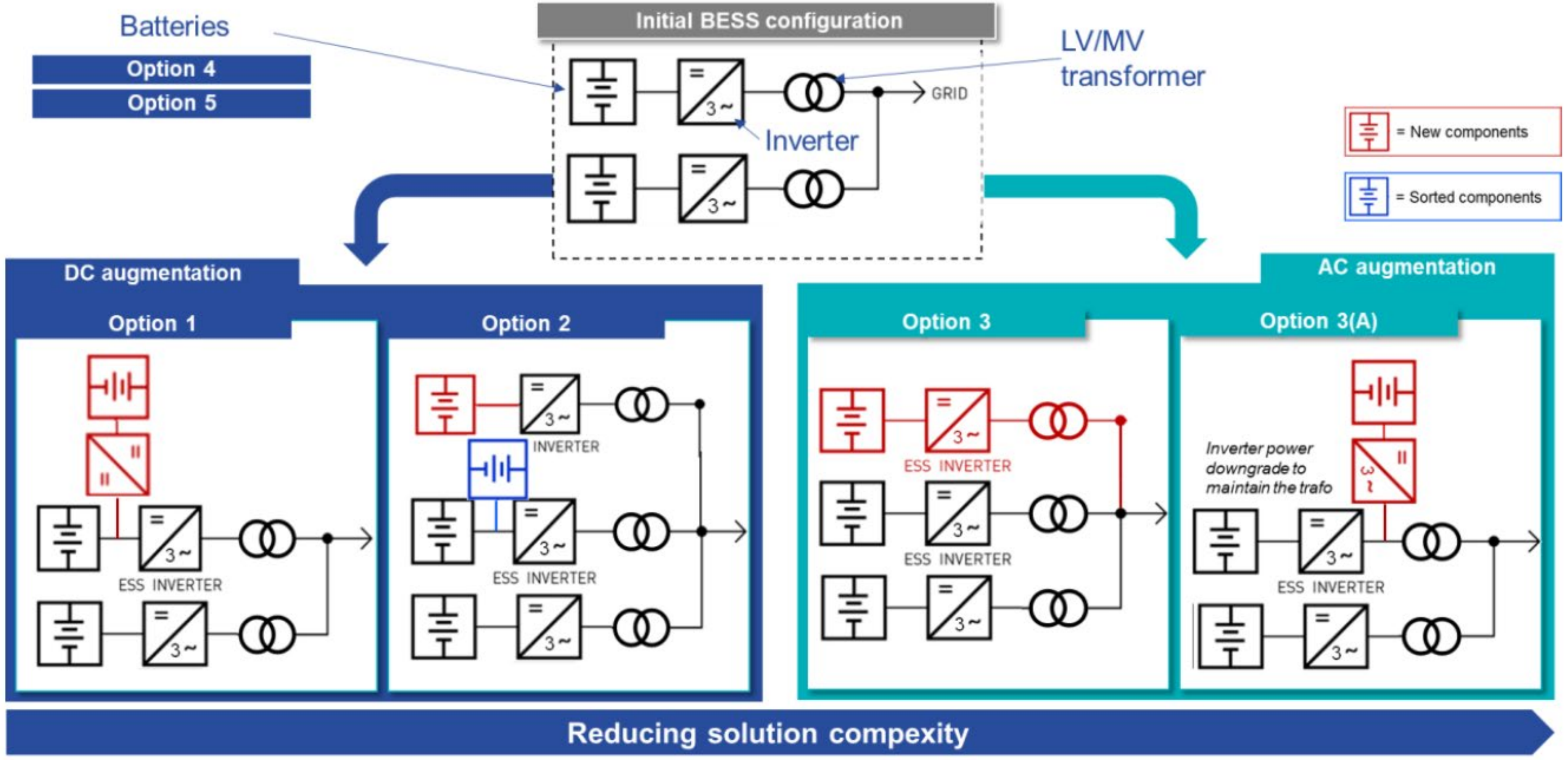


Capacity

- Future Application, cycling etc.

There are many possible augmentation approaches

Which is best depends on project specific considerations, timing, top up vs duration reconfiguration etc.

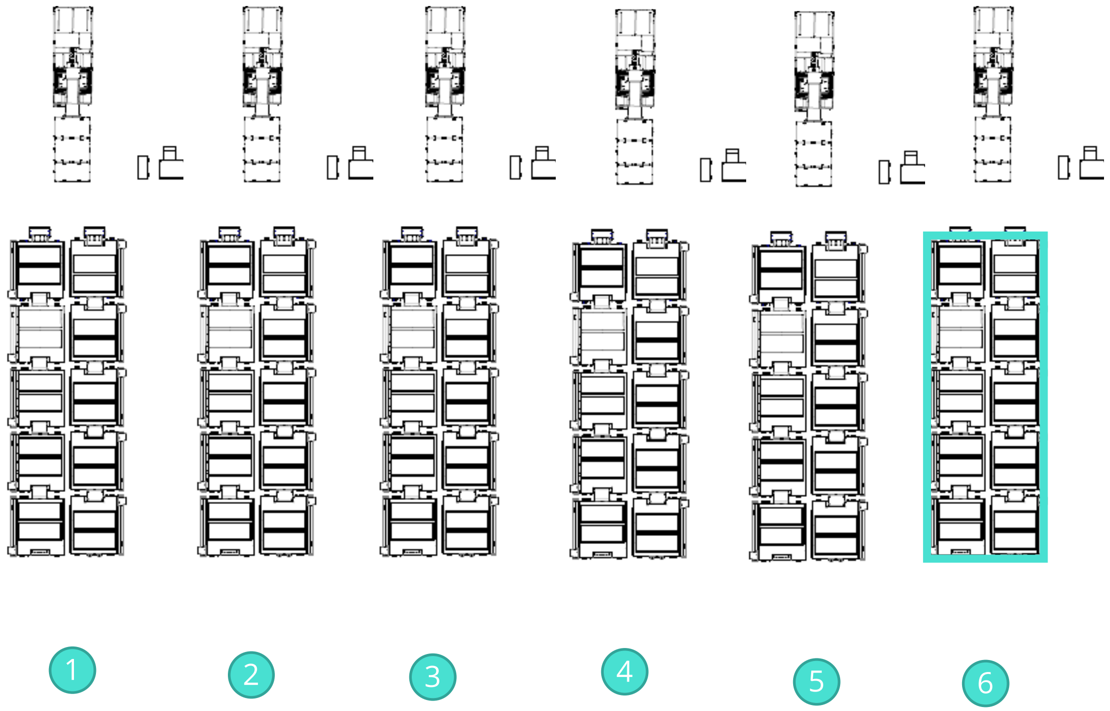


- **Space** – how much physical footprint will the option take relative to other options in the set over time (if additional capacity is added).
- **Cost (CAPEX)** – upfront CAPEX definitely needed to be spent.
- **Cost (OPEX)** – future OPEX that may need to be spent to augment capacity (relative importance of this parameter depends on NPV).
- **Futureproofing** – how much optionality is there to the accommodation of technology improvements, different cell types / dimensions over time.
- **Compatibility** – what degree of risk is there in the technical feasibility of the solution?

SECTION 4

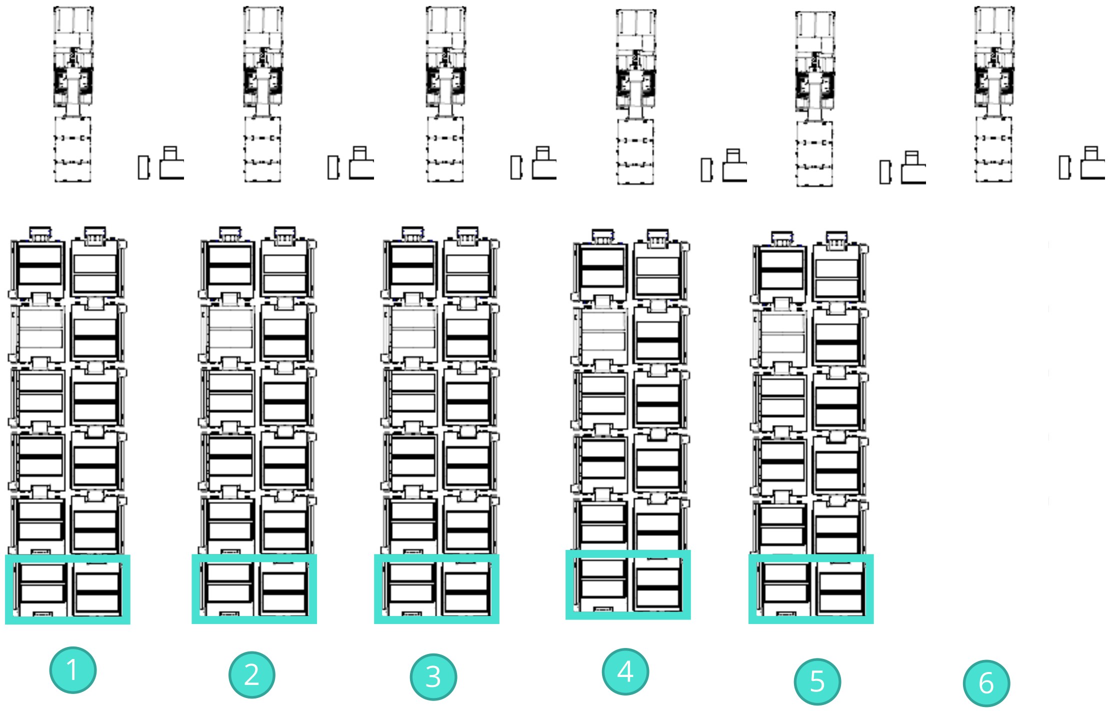
Example 3 – incremental capacity addition 2hr system

DC Augmentation Practical Example



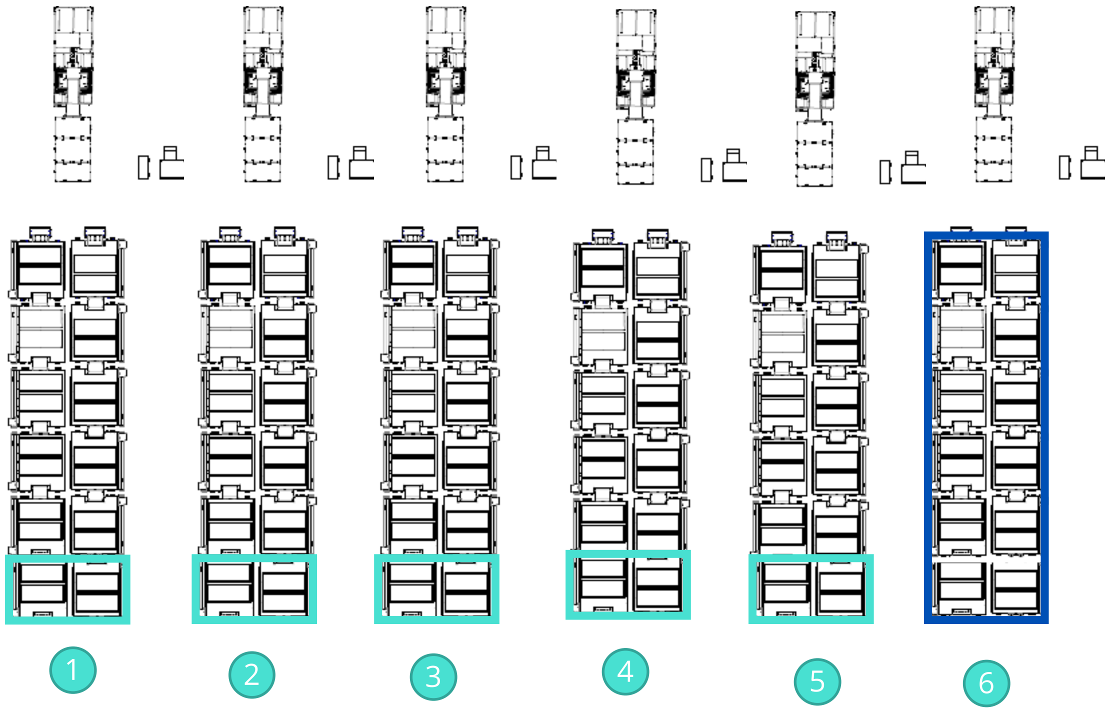
Example 6 core Gridstack SD Cube arrangement of 60 cubes.

DC Augmentation Practical Example



Step 1: The cubes from core 6 reallocated to similar SOH cubes in core 1-5, freeing up an inverter bay.

DC Augmentation Practical Example



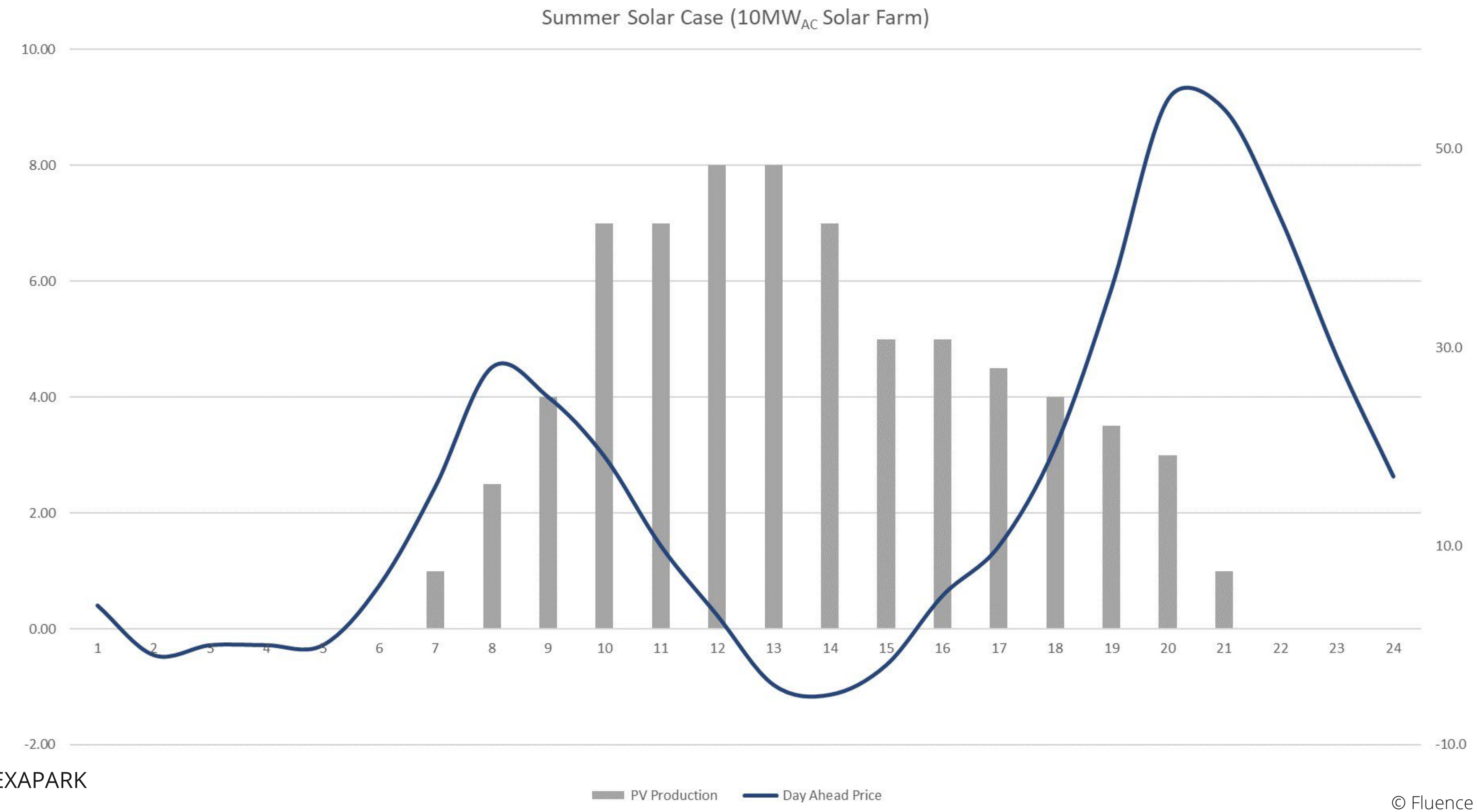
Step 2: New cubes with new batteries delivered and installed behind Core 6. Due the agonistic design of the cube and F.OS controls, the new cubes may take advantage of a new or different chemistry.

SECTION 5

System Size

Innovation auction example: Profile shaping is necessary

Profile Shaping to mitigate Capture Risk: Project will lose market premium when prices go negative, forcing curtailment to avoid paying negative prices for generating AND miss out on most valuable spot prices.



Source: PEXAPARK

Innovation auction example: Profile shaping is necessary

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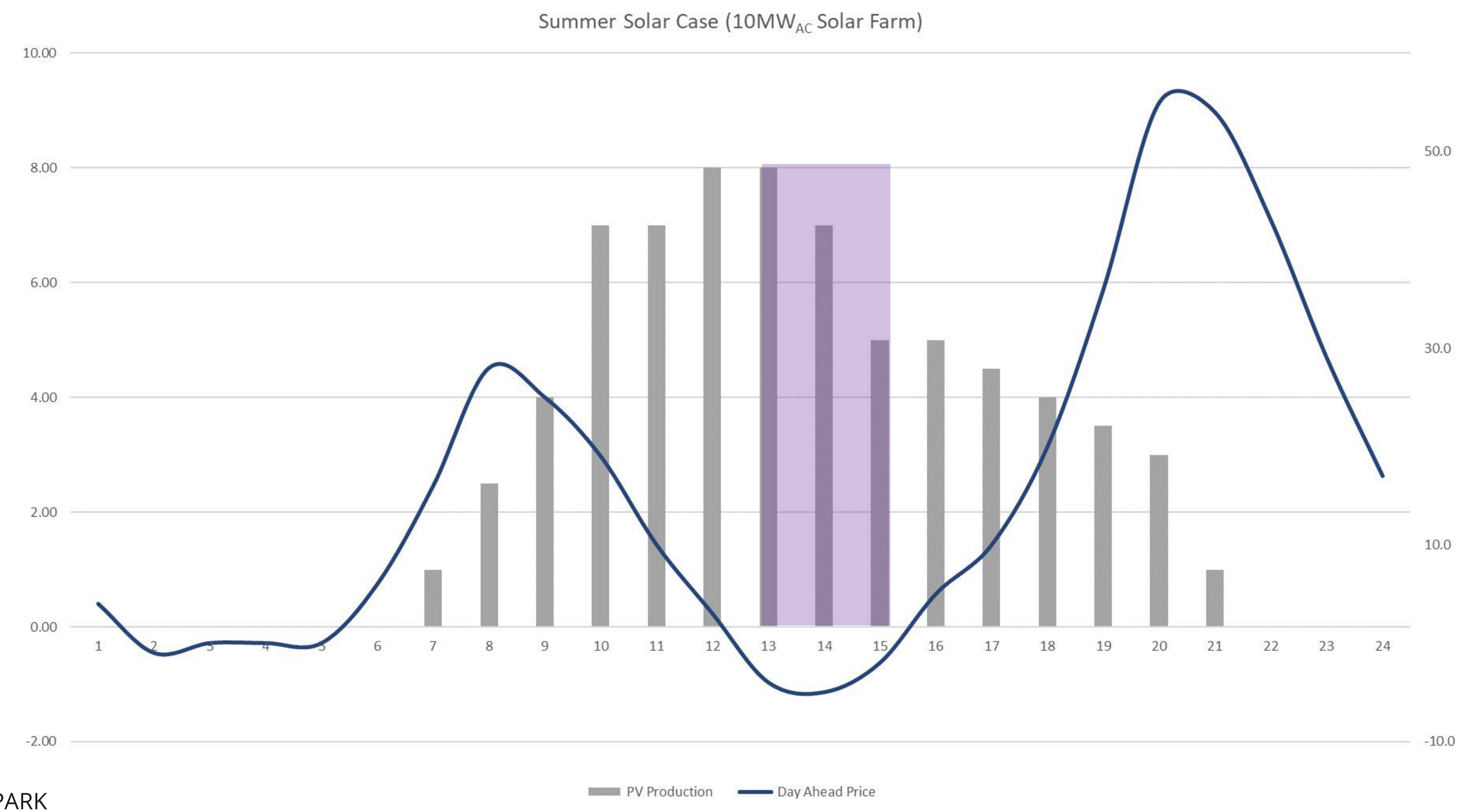
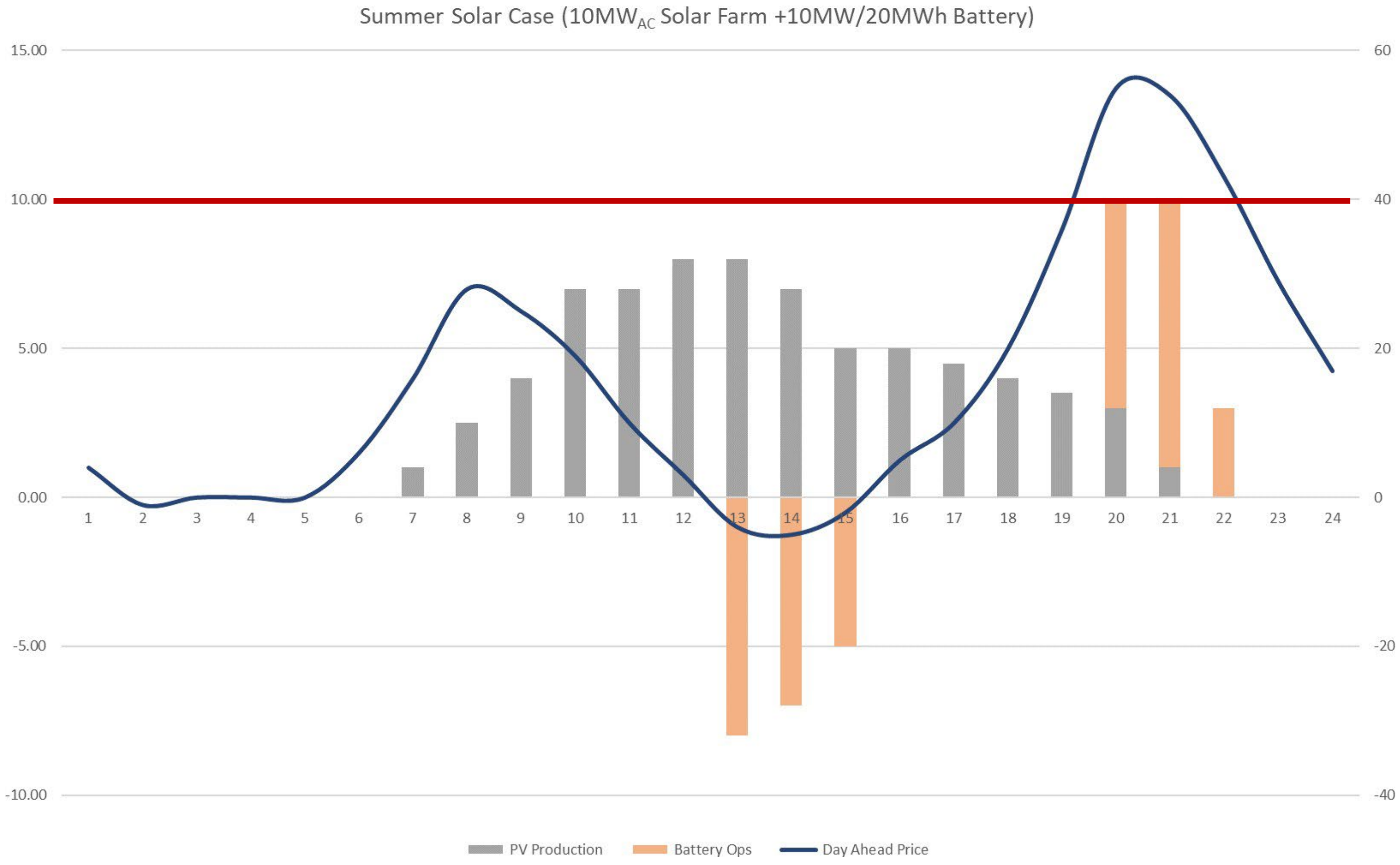


Source: PEXAPARK

Innovation auction example: Profile shaping is necessary

Profile Shaping to mitigate Capture Risk: Charging the energy storage asset during low or negative pricing will both: (1) Preserve the Fixed Market Premium for PV Generation and (2) Benefit from higher spot prices.



Source: PEXAPARK

SECTION 6

Conclusion

Conclusion

Key Takeaways

Power	PV + BESS in general	InnoTender	CAPEX
<10MW	AC + Overbuild	AC + Overbuild	AC + Overbuild
10- 50 MW	AC + Overbuild	X	AC + Augmentation
50 – 100 MW	AC + Augmentation	X	AC + Augmentation
> 100 MW	DC + Overbuild	X	AC + Augmentation

- Currently 70% PV + BESS are AC coupled
- Between 2 - 4h duration
- For AC coupled systems an AC Augmentation easier than DC
- AC Solution is better when adding storage to existing PV
- Design depends on many different factors

THANK YOU

Contact information

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SECTION 6

Backup

From Cube to Array

CUBE

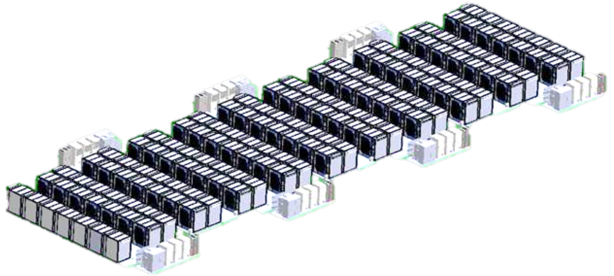
Single physical container

NODE

Cube or string of cubes connected to a DC bus

CORE

Collection of Nodes connected to a transformer



ARRAY

Collection of Cores connected to an interconnection

Application Use Cases

Different application use cases impact how AC- or DC-coupled systems perform

Controls can be more complicated with AC-coupled

When interconnection is limited, bidirectional DC-coupled can do everything as well as AC- coupled, but with benefit of capturing more solar energy.

Grid charging is not allowed for unidirectional DC-coupled

Application	AC-coupled	AC-coupled Limited POI	DC-coupled Uni-directional	DC-coupled Bi-directional
Energy Time Shift	»»»»	»»»»	»»»»	»»»»
Firming Solar Capacity	»»»»	»»»»	»»»»	»»»»
Curtailment Mitigation	»»»»	»»»»	»»»»	»»»»
PV Clipping Capture	–	–	»»»»	»»»»
Low Voltage Harvest	–	–	»»»»	»»»»
Ramp Rate Control	»»»»	»»»»	»»»»	»»»»
Volt-VAR Regulation	»»»»	»»»»	»»»»	»»»»
Frequency Response	»»»»	»»»	»»	»»»
T&D Deferral	»»»»	»»»	»»	»»»
Transmissional Charge Reduction	»»»»	»»»	»»	»»»

Source data adapted from an EPRI report.

Installation and O&M Considerations

AC-coupled might have slight advantage in installation and O&M costs, especially for larger projects.

AC-coupled

Storage system centralized adjacent to PV field

DC-coupled

Storage system distributed within PV field

DC-coupled

- **Installation costs** slightly higher labor due to distributed layout.
- **O&M costs** slightly higher if separate service contractors are used for solar EPC and BESS.
    - No difference if same service contractor is used or owner services the whole plant.

