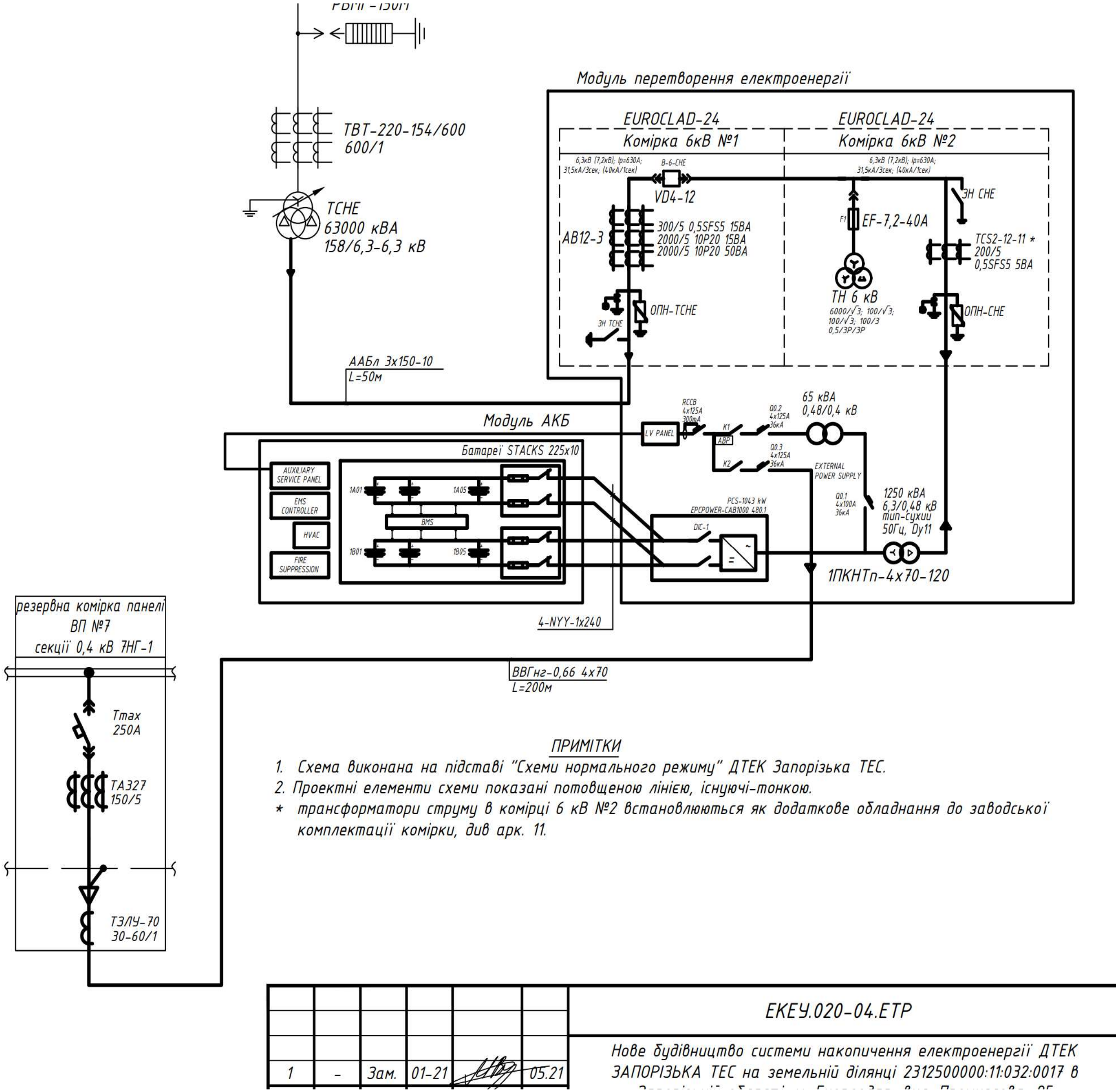
Workshop on the energy storage technologies: Lessons learned and way ahead for grid balancing

Energy Community 2023-10-14

Vadym Utkin, Energy Storage Lead, DTEK

DTEK Energy in action

DTEK ESS SLD and specs



Pmax = 1000 kW

E = 2025 kWh

C rate = 0.5

LFP cells by CATL

Stack and EMS designed by Powin Energy

Power Plant Controller designed by Honeywell

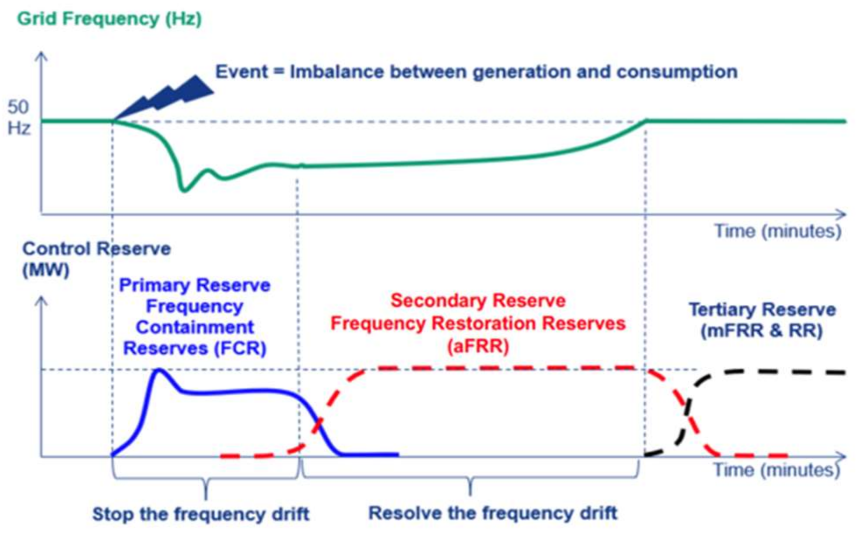
PCS – EPC Power CAB1000

Air cooling

Tender shortlist: Hengrui Technology Co Ltd (HRESYS), Narada Power Source, Storage Power Solutions Inc, BYD, Indrivetec AG, Honeywell, SAFT

- Contract signed July 2020
- Invertor energizing – 18:54 Mar 25th 2021
- Opening ceremony – May 20th 2021
- TSO market participation test – Sep 2nd 2021

Grid balancing: non-reactive (committed) balancing

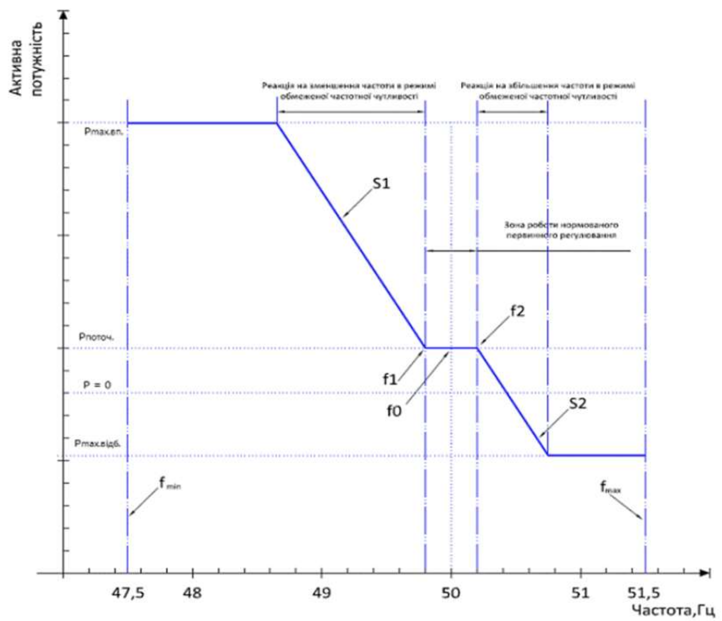


Ergebnisse

Lokaler Grenzpreis nach Produktzeitscheibe und Ländern

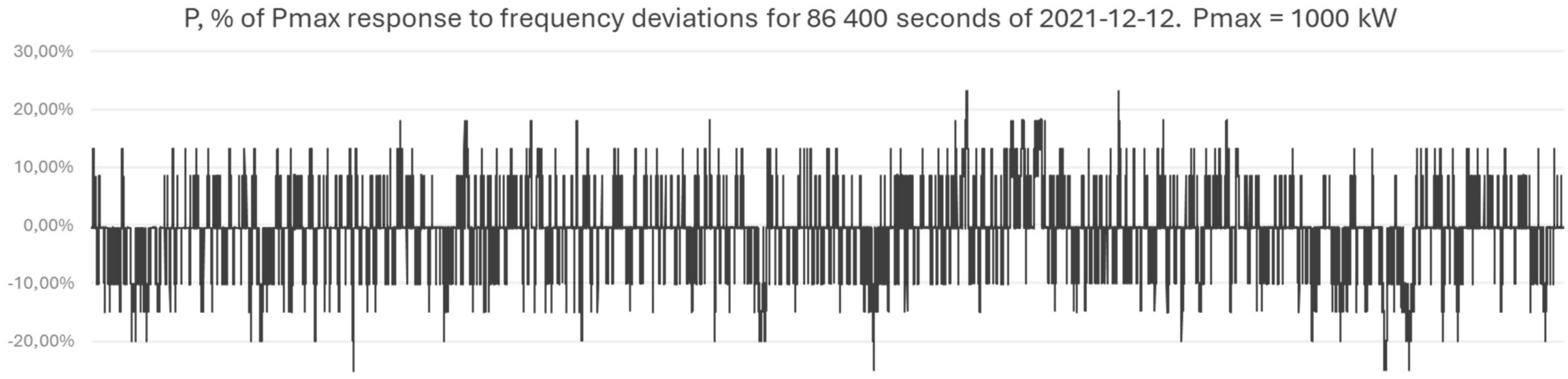
Land	NEGPOS_00_04	NEGPOS_04_08	NEGPOS_08_12	NEGPOS_12_16	NEGPOS_16_20	NEGPOS_20_24
						Lokaler Grenzpreis (€/MW)
Belgien	415,2	415,2	415,2	415,2	415,2	415,2
Dänemark	78,8	102,6	74,9	137,72	75,6	54,4
Deutschland	78,8	102,6	74,9	137,72	75,6	54,4
Frankreich	6	4,48	24	24	21,45	12
Niederlande	78,8	102,6	74,9	137,72	77,777	54,4
Österreich	78,8	102,6	74,9	137,72	75,6	54,4
Schweiz	78,8	102,6	74,9	137,72	75,6	54,4
Slowenien	78,8	102,6	74,9	137,72	75,6	54,4
Tschechien	78,8	102,6	74,9	137,72	75,6	54,4

	Product	Demand, MW per hour	Price cap 2022/2023, UAH.	Gate closure time	Auction results	Cleared as
1	FCR±	135 (UA+MD)	1339,82	14:15 D-1	14:30	Pay as bid
2	aFRR±	50?	1339,82 + БР	14:15 D-1	14:30	Pay as bid
3	aFRR+	700	973.39 + БР	14:15 D-1	14:30	Pay as bid
4	aFRR-	421	366.43 + БР	14:15 D-1	14:30	Pay as bid
5	mFRR+	—	438.02 + БР	14:15 D-1	14:30	Pay as bid
6	mFRR-	—	164.89 + БР	14:15 D-1	14:30	Pay as bid
7	RR+	—	389,36	14:15 D-1	14:30	Pay as bid
8	RR-	—	146,57	14:15 D-1	14:30	Pay as bid
9	BM	—	—	-45 хв D-0	10 днів	Pay as cleared
10	DAM	—	2000/4000	12:0 D-1	12:30	Pay as cleared

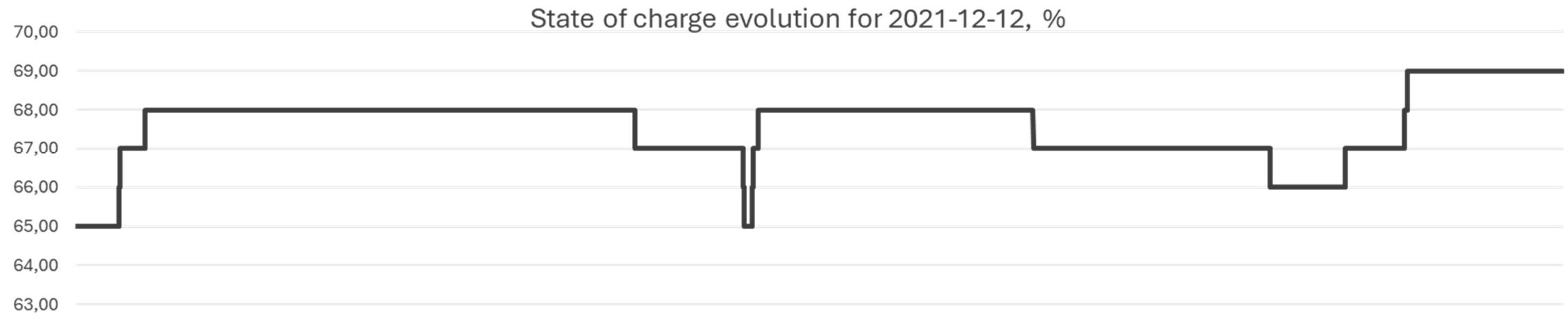


12 Dec 2022: one day of FCR delivered by ESS

Power response stays within 30% limit of Pmax before synchronization with ENTSO-E. After 2022-03-16 volatility has increased (200 mHz, 100 mHz -> 15 min, 50 mHz ->20 min).

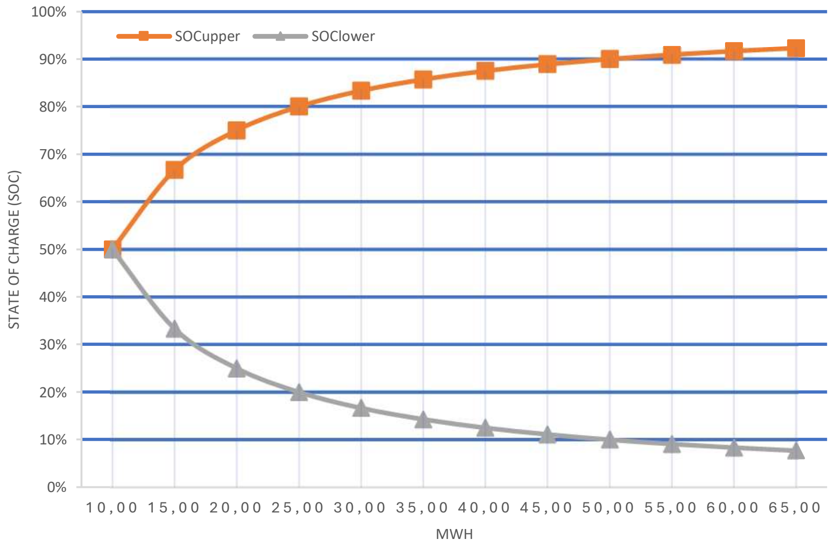


SOC management is a complex task, since the unique discharge profile of Li-ion and temperature sensitivity.



Safe permissible energy capacity for the frequency response

‘Safe’ energy capacity largely depends on market rules and FCR product design. Simulation for 20 MW FCR. This will also impact the business case through the CAPEX.



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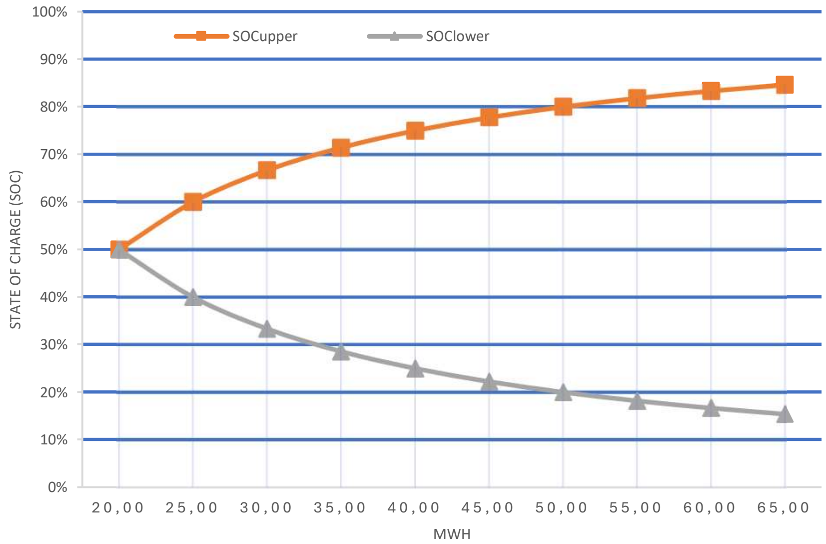

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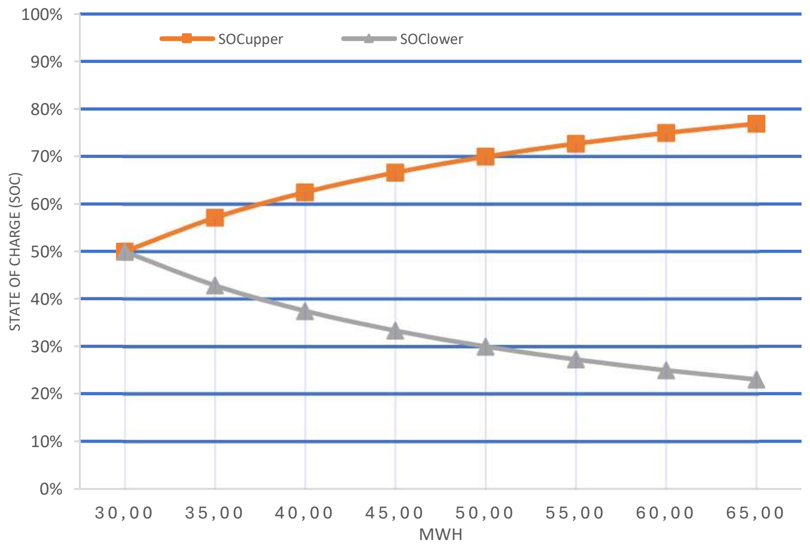

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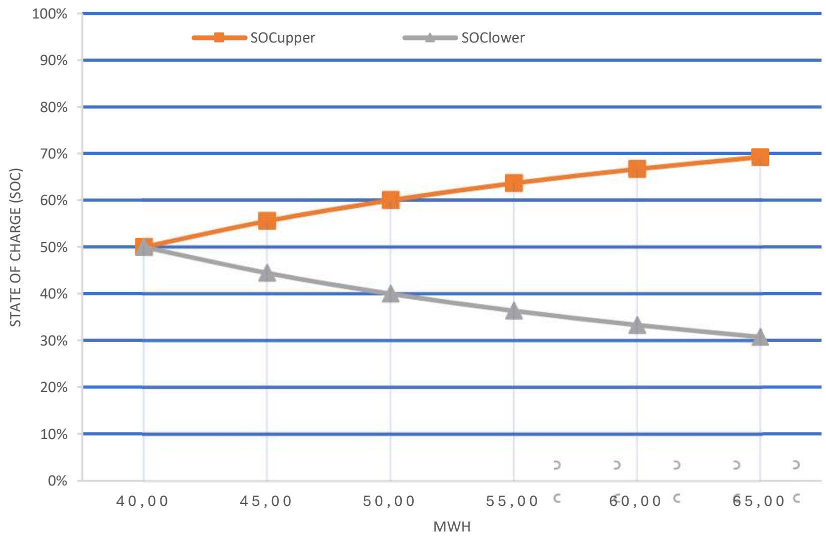

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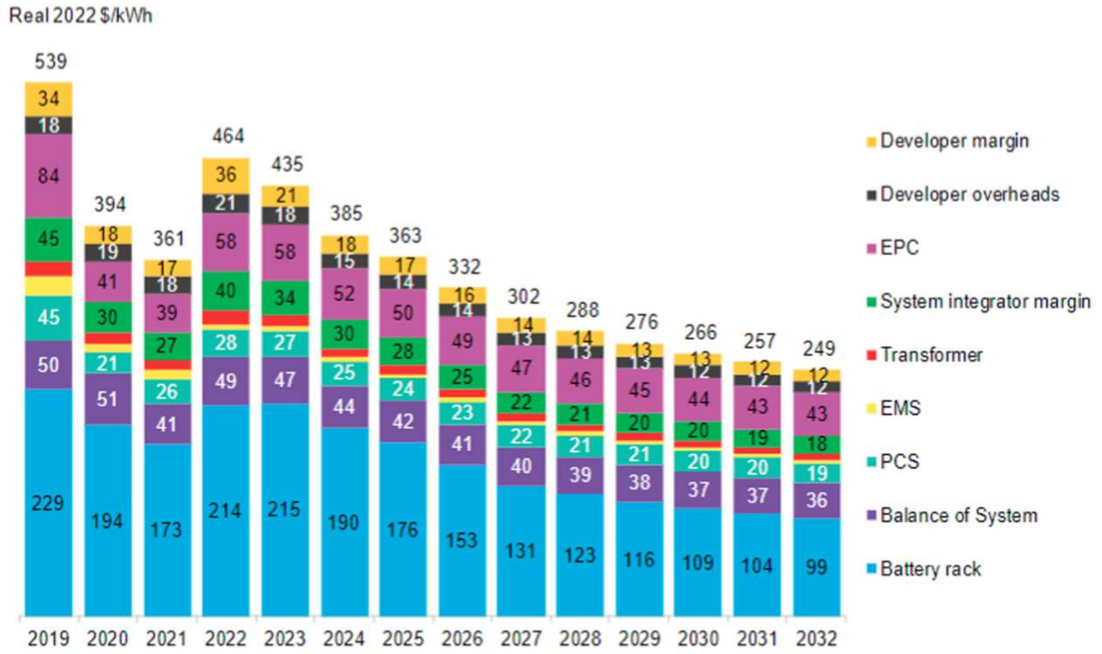
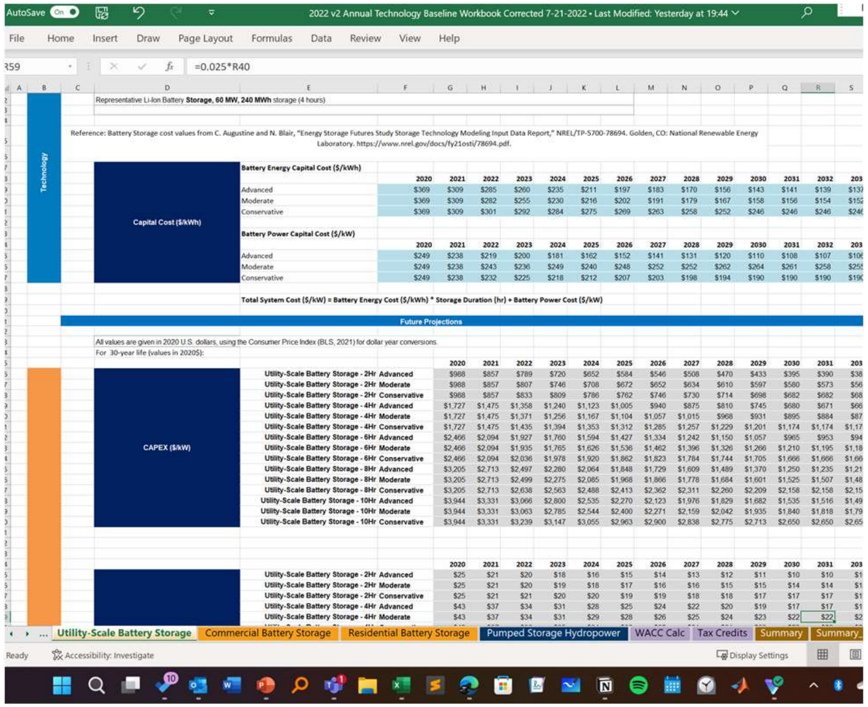
ESS costs: 2022 was outliers, prices are going down

Cost structure	Category	Inclusion
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price / DC-side battery system	Battery rack	Consists of multiple cells/modules, the BMS, wiring and rack housing. The rack housing is generally a skeletal frame that holds the modules in place. Based on usable capacity, rather than nameplate capacity.
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price / DC-side battery system	Balance of system (BOS)	Includes electrical infrastructure, containers, thermal management system, fire suppression devices, battery operation monitoring system and sensors
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price	Power conversion system (PCS)	Converts DC to AC when discharging, and AC to DC when charging
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price	Energy management system (EMS)	Optimizes the behavior of a storage asset to maximize revenue or avoided costs for the owner
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price	Transformer	Steps-up or down the voltage depending on where a project is connected to the grid
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price	Expenses	Expenses relating to system shipping, tariffs, on-site installation and testing. Sometimes they are undertaken by component suppliers or EPC providers.
Energy storage project cost / Fully-installed energy storage system cost / Turnkey energy storage system price	System integrator margin	Net profit to the system integrator
Energy storage project cost / Fully-installed energy storage system cost	Engineering, procurement and construction (EPC)	EPC includes project design, site preparation, project debugging and electricity infrastructure deployment. EPC costs include the labor cost, materials cost, engineering and construction costs, administration cost during this process.
Energy storage project cost / Fully-installed energy storage system cost	Grid connection	Charge from a utility or network operator for connecting to the grid
Energy storage project cost	Developer overhead	Project permitting, environmental impact assessment, legal and administration costs
Energy storage project cost	Developer margin	Net profit in developing the project or after selling the project



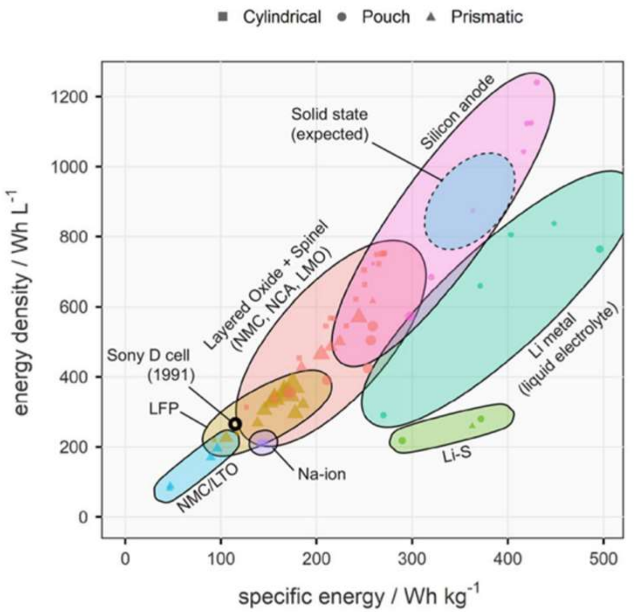
2h ESS CAPEX (AC, fully installed, BOL).

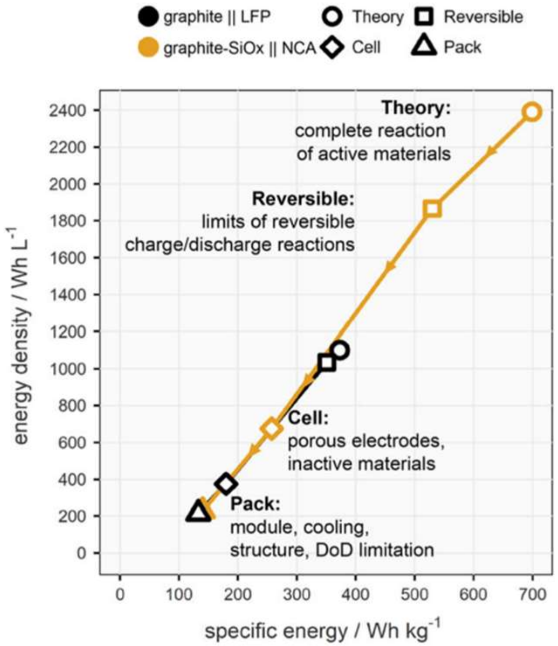


The 2024 total cost ranges from $355 to $390/kWh while the 2025 projects are expected to be in $315 - $370/kWh range (for turnkey including BOP from Tier 1 suppliers)

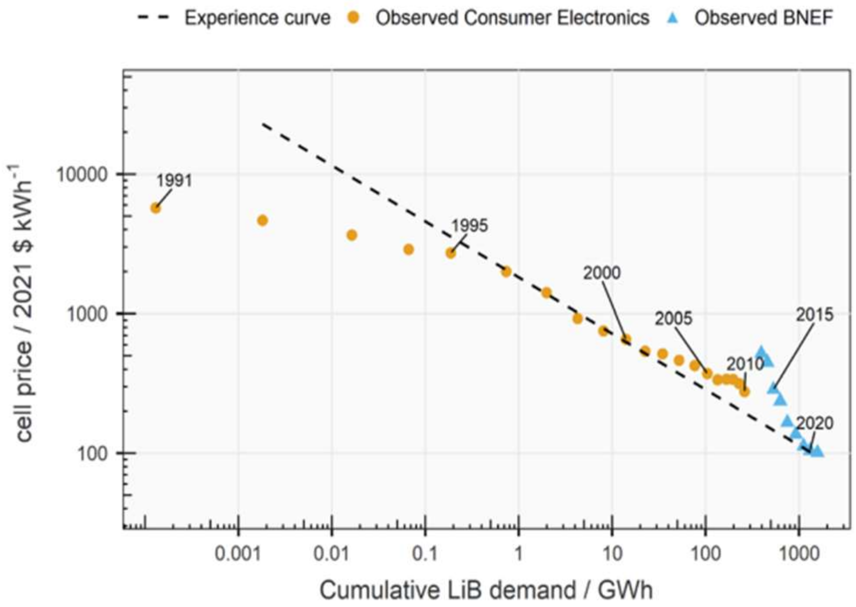
Annual Technology Baseline (ATB) NREL
https://atb.nrel.gov/electricity/2022/data

Technology challenges





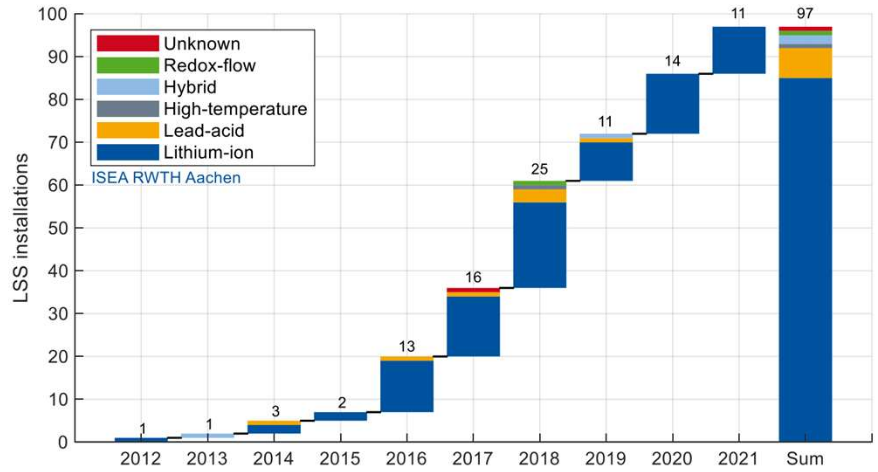
A non-academic perspective on the future of lithium-based batteries, James T. Frith, Matthew J. Lacey Jan 26th 2023



Every double of Li-ion use results in 25% price reduction.

Why Li-ion is dominating?

1. Large installed and knowledge base. Engineers are not afraid to work with Li-ion.
2. They are bankable.
3. Li-Ion is largerly driven by automotive.



Grid scale ESS in Germany. The development of battery storage systems in Germany – A market review Jan Figgener

The death of ESS: when and why?

DTEK

Degradation causes

Growth of SEI	Solid Electrolyte Interface begins from the very first cycle at the factory. SEI is protecting anode (graphite) but at the same time reduces Li deposit. SEI growth decrease the Li+ volatility and correlates to volage and temperature. SEI is growing even without cycling!
Lithium plating	Function of high C-rates and low temperature. Very dangerous.
Electrodes cracks	Physical damages during the intercalation phase and cycling.

Year	SOH	Nameplate Capacity, MWh	SOH	Nameplate Capacity, MWh
0	100.00%	44.032	100.00%	44.032
1	94.95%	41.808	92.15%	40.574
2	92.15%	40.574	87.79%	38.655
3	89.83%	39.555	84.19%	37.07
4	87.79%	38.655	81.01%	35.67
5	85.92%	37.833	78.11%	34.392
6	84.19%	37.07	75.41%	33.205
7	82.56%	36.352	72.87%	32.088
8	81.01%	35.67	70.47%	31.028
9	79.53%	35.018	68.17%	30.015
10	78.11%	34.392	65.96%	29.042

Real life experience: 10 years and 5000 – 7000 cycles after (1,2 – 2 cycles per day) 1 hour ESS at 75..85% SOH.

NMC and NCA are layered oxides (A_xMO_2). High mobility of Mn^{3+} damage the layers and transform to spinel.

LFP has a conductive polyaniline with high sensitivity to C-rates.

5.5.2 Cycle lifetime

Cycle lifetime gives the number of full charge-discharge cycles the EES system is capable to provide within its calendar lifetime. Some technologies (predominantly batteries and electrochemical capacitors) see a degrading of their properties (mainly capacity and internal resistance) with the growing number of charge-discharge cycles. In that case the end of life is commonly defined as the number of cycles after which the actual capacity has reached a given reduced value. Expected lifetime of a system in a defined application can be prolonged by deploying a hybrid EES system that combines the high cycle life of a high-power EES technology (such as supercapacitor or flywheel) with the high energy of a low cycle life EES technology (e.g. battery).

For many battery types, their applicable performance standards state the EoL capacity. For example, IEC 60896 (stationary lead-acid batteries) and IEC 62660-1 (Li-ion batteries for electric vehicles) state 80% as the EoL capacity, while IEC 62620 (Large format secondary lithium cells and batteries for use in industrial applications) and IEC 61960 (Secondary lithium cells for portable applications) use 60% remaining capacity as the EoL criterion. For many battery technologies, small cycles are less damaging than deep cycles. This means the processed energy (integral of discharge power over the lifetime) can be increased significantly if the allowable depth of discharge is reduced. In such cases, cycle life as a function of DOD should be given for a number of DOD values relevant for the EES application.

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