Technical and economic study of two energy storage technologies in Spain

February 17, 2023

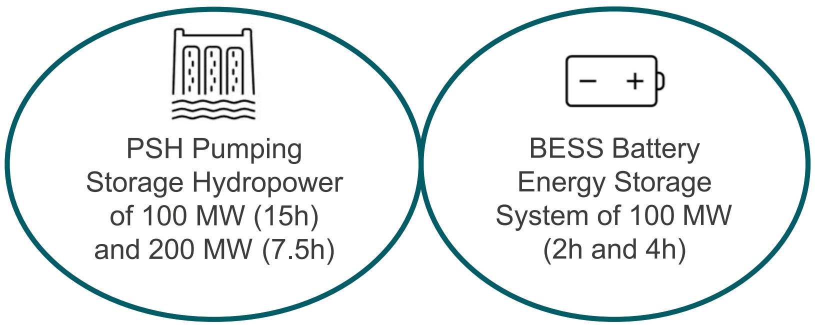
Content

Introduction

The study

Purpose

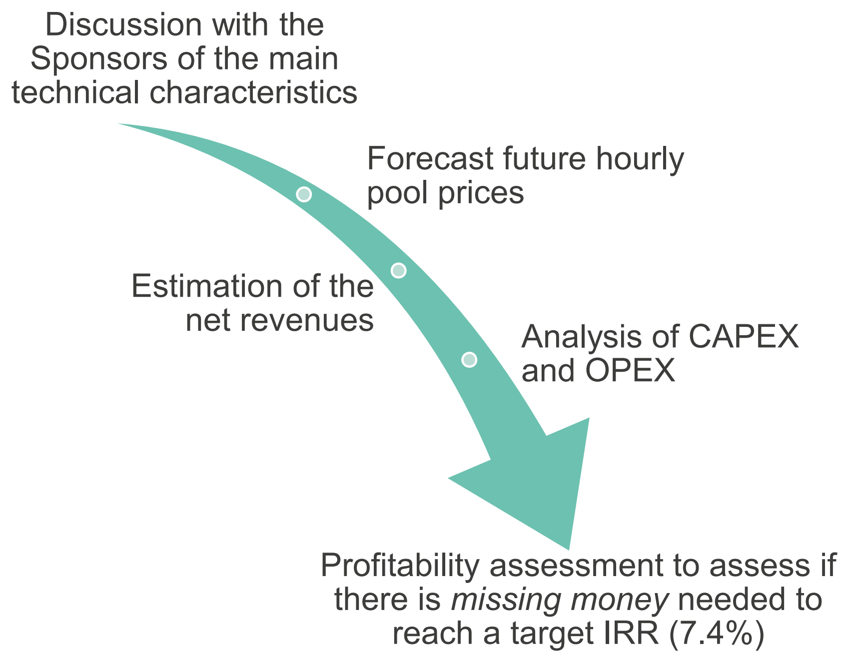
- Carry out an economic study of the profitability of two energy storage technologies in Spain.



- Assess the need to foster their installation.

- Analyze their profitability, and the convenience to establish support mechanisms.

Procedure



Storage Benefits

Benefits and services

Storage: Key role in decarbonization of electric power systems

Storage technologies:

- Mechanical: i.e. pump hydro
- Thermal: i.e. molten salts
- Chemical: i.e. hydrogen
- Electrochemical: i.e. batteries
- Electrical: i.e. supercapacitors

Services energy storage providers:

- Energy arbitrage
- Ancillary services
  - I. Frequency regulation
  - II. Load following
  - III. Voltage support
  - IV. Black start capability
  - V. Supplemental reserves
- Transmission and distribution infrastructure services
- Customer energy management services

Storage technologies and situation in Spain

Storage situation in Spain

Current situation

~ 3.3 GW

~ 870 MW

~ 0 MW

Pumping

- Around 3.3 GW of installed capacity (pure pumping).
- Used on a large scale in Spain for many years.
- Considerable Spanish pipeline under development.
- Confidence in this technology by relevant entities of the sector.

Molten salts in CSP Plants

- 870 MW of storage operative capacity.
- Used in Spain in CSP Plants
- Plants with specific remuneration.
- 10-15 years of track record.

BESS

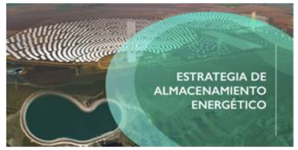
- Very early stage of implementation.
- Growing pipeline under development with wind and PV assets.
- Spanish suppliers entering the market.
- Positive impact on the access capacity auctions.

Barriers encountered historically

- High investment costs
- Lack of future objectives (Pre-PNIEC)
- Lack of clear regulation
- Lack of remuneration/subsidies

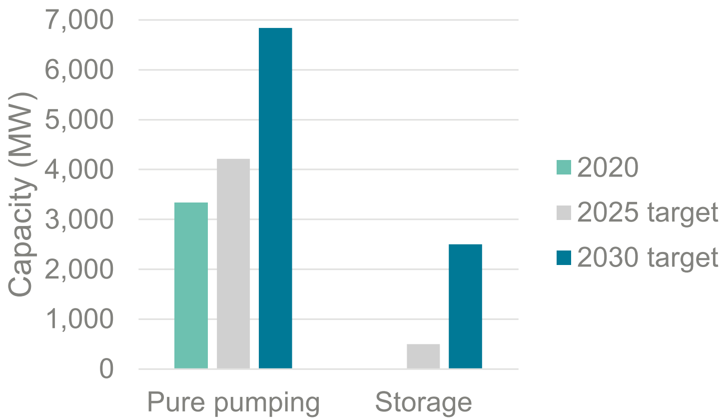
Storage technologies and situation in Spain

Objectives



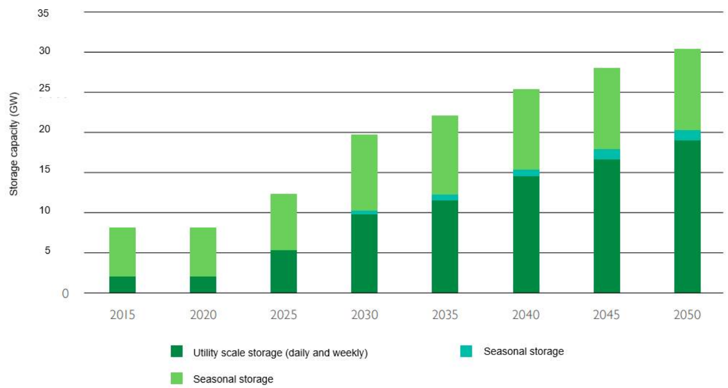
PNIEC (January 2020)

- Key to integrate the increasing renewable energy generation in the electric system.
- Applied in the hourly pool price forecast.



Energy storage strategy (February 2021)

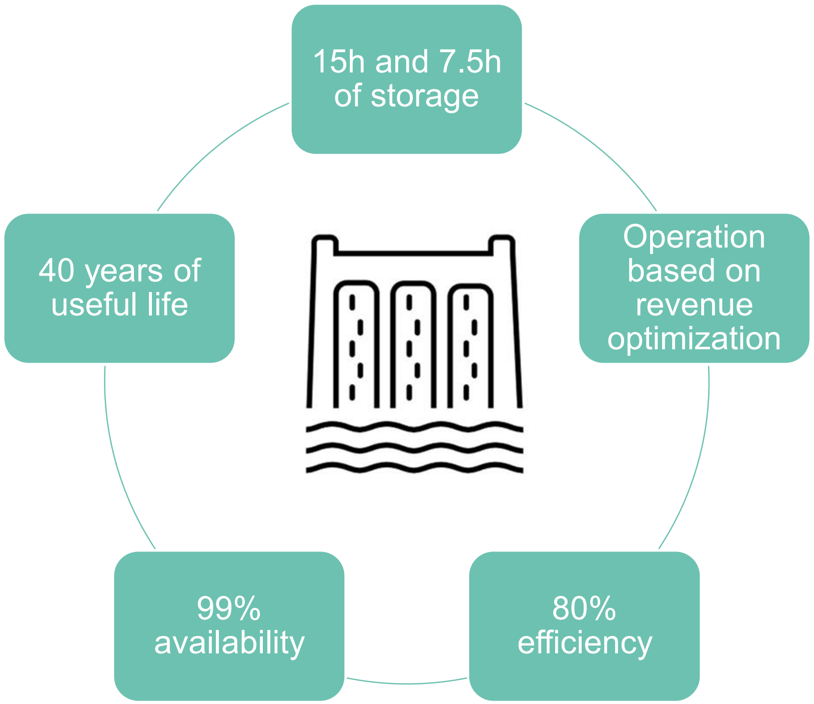
- Aim to ensure the effective deployment of energy storage.
- Spanish storage capacity from the current 8.3 GW, to 20 GW in 2030 and 30 GW in 2050.



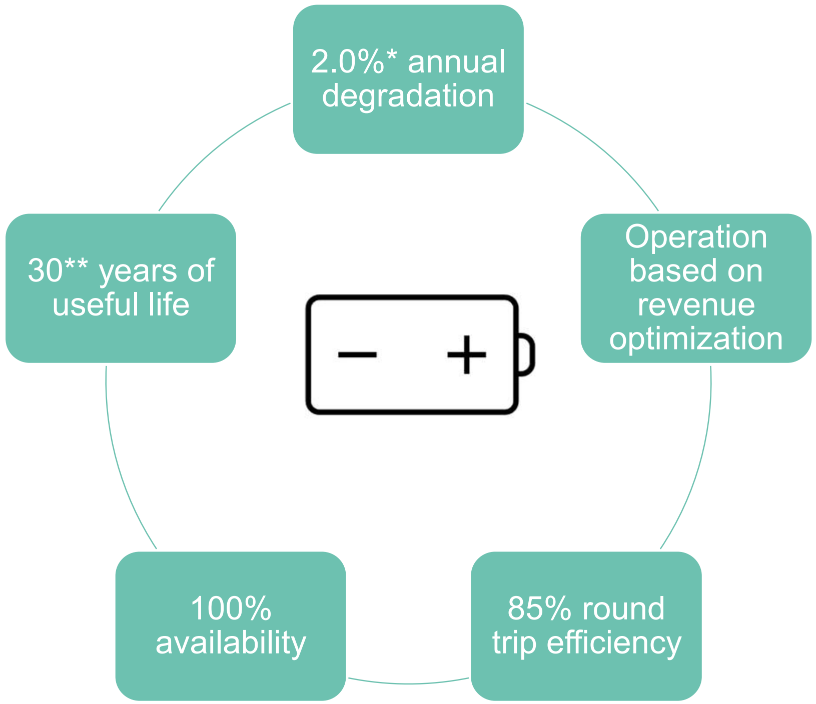
Storage technologies and situation in Spain

Technical characteristics

Pumping storage (100 MW and 200 MW)



BESS (100 MW)



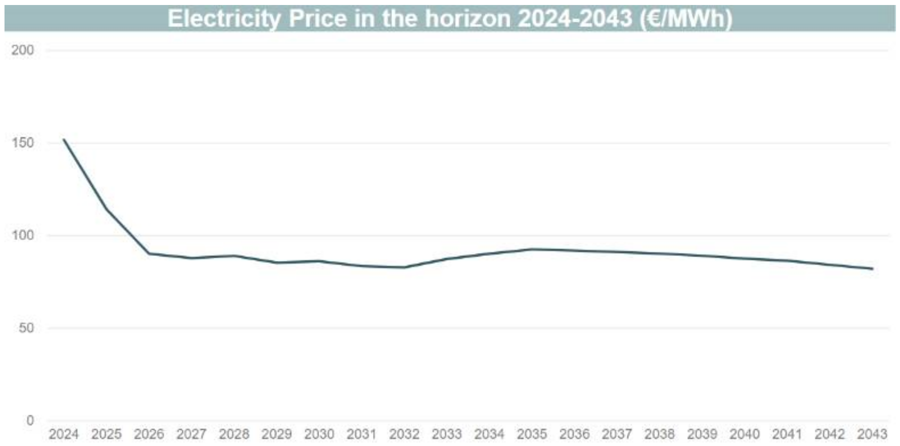
*2.5% for first year
** Revamping of battery racks and inverters in year 15

Revenue estimation

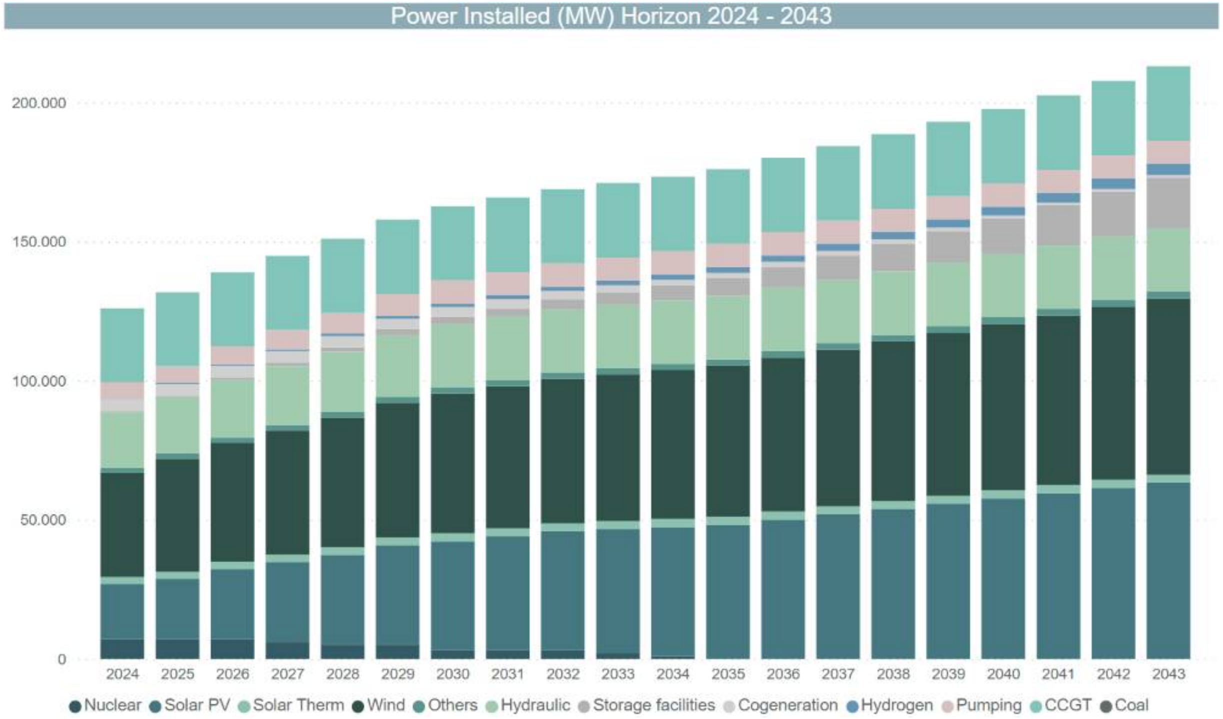
Pool price forecast: assumptions and results

The PNIEC scenario for the hourly pool price projection calculation for the 2024 - 2043 horizon has been carried out by the Advisor based on PNIEC objectives using the software xPryce®. The obtained results are used for the revenue calculations

Pool price forecast

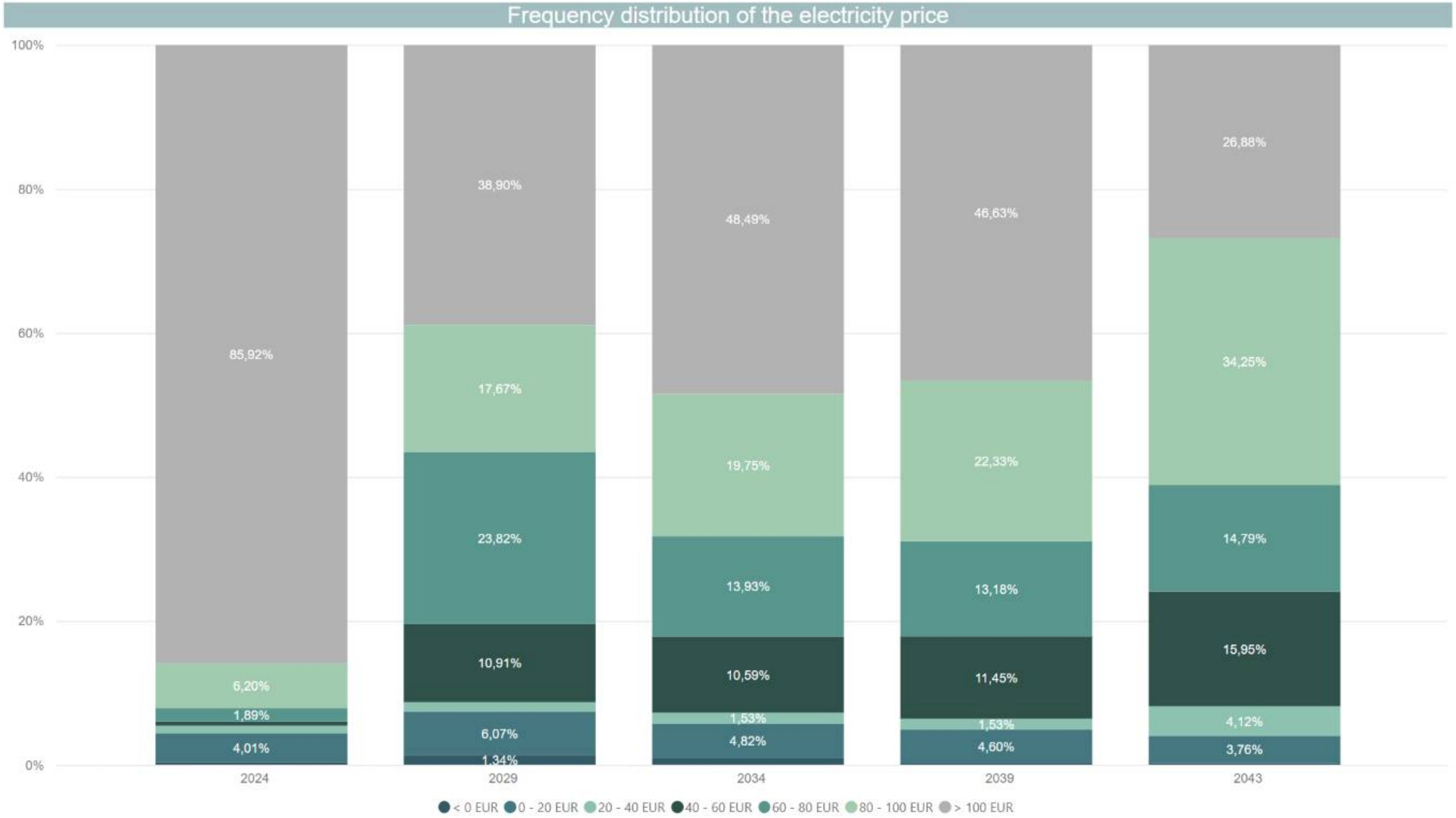


Generation capacity assumptions



Revenue estimation

Pool price forecast: Price distribution

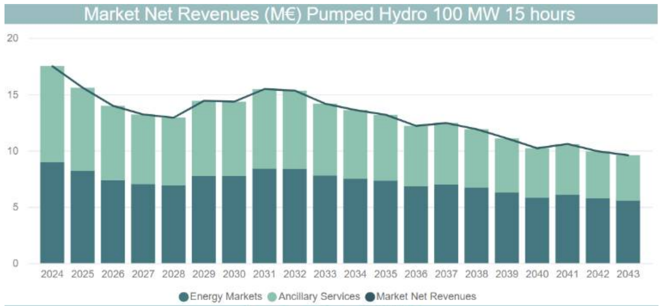


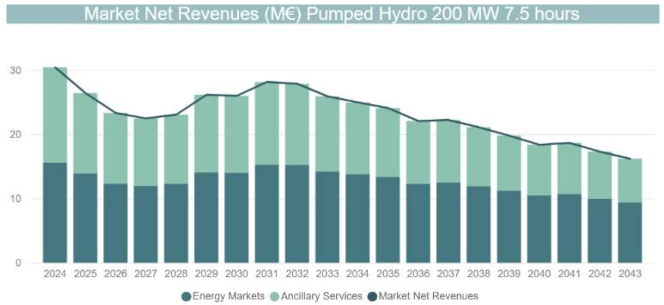
Highlights on the price distribution PNIEC scenario

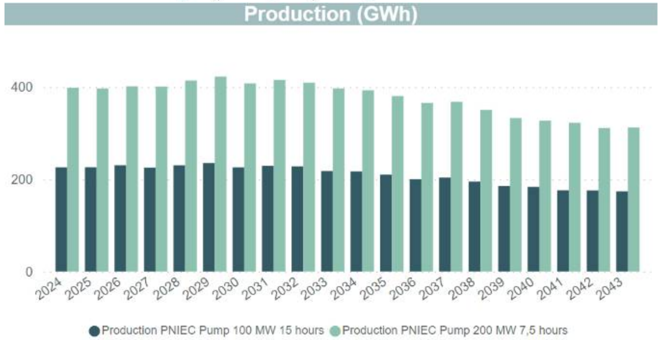
- ❑ The current peak in commodities prices results in high electricity prices still in the coming years, but prices will be decreasing slowly over the coming years.
- ❑ The **frequency of low prices** (<20 €/MWh) peaks at the end of this decade and then decreases throughout the horizon due to the integration of storage sources, as they add demand during low-price hours.
- ❑ The **frequency of very high prices** (>100 €/MWh) is reduced dramatically between 2024 and 2029; however, it increases again as nuclear plants are decommissioned and the demand rises due to the electrification of the economy.
- ❑ There is **high volatility in prices**, increasing as time passes (the frequency distribution of prices is more evenly distributed), due to the high penetration of renewables with intermittent production.

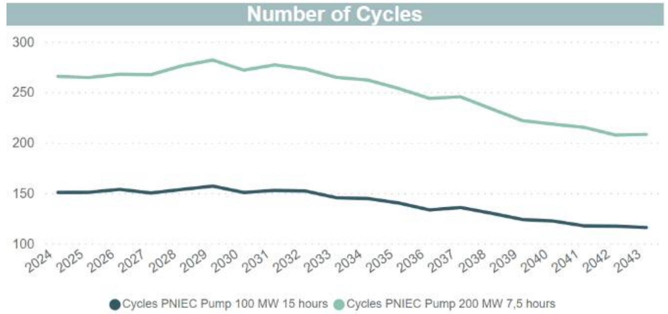
Results: Pumped storage hydropower

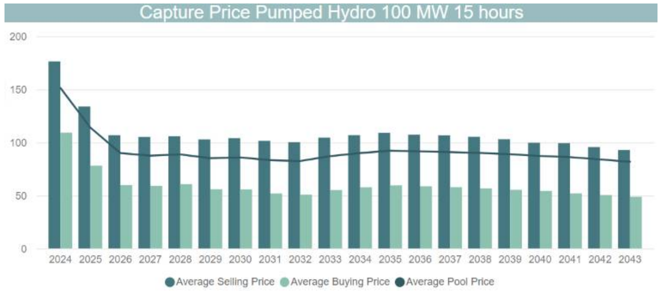
Revenue estimation

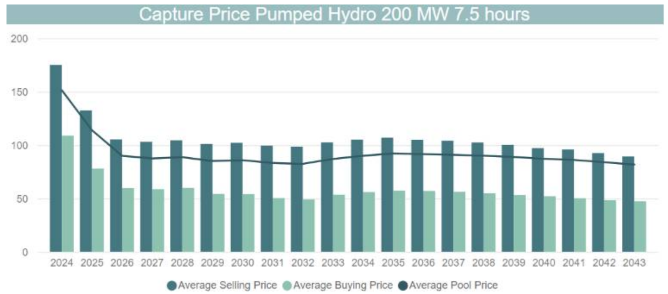










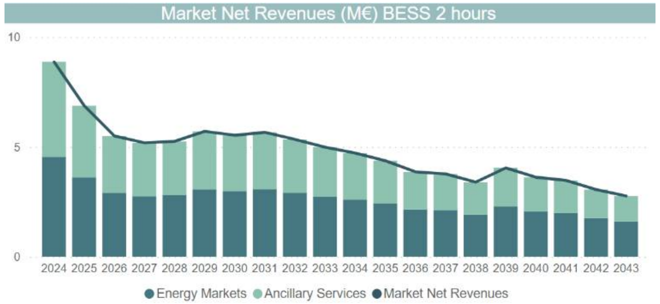


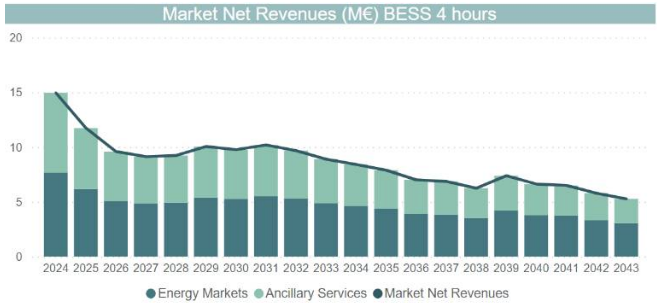
Highlights on the results of pumped storage hydropower

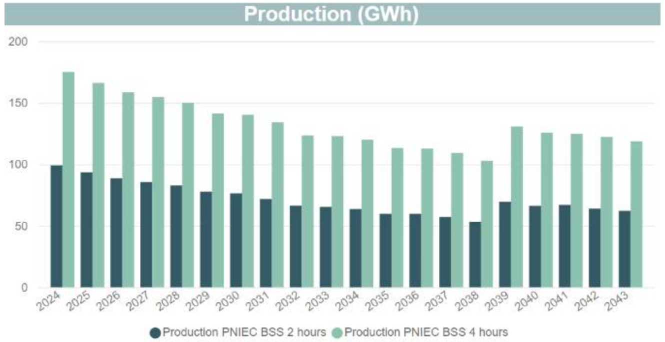
- Two configurations analysed: A pumped hydro system with **100 MW and 15 hours** and another with **200 MW and 7.5 hours**.
- For the pumped hydro with 100 MW and 15 hours, market net revenues begin with around 17.5 M€ in 2024 and decrease to around 13 M€ in 2028. After that year, the revenues increase slightly to around 15.5 M€ in 2032 and, after that, they decrease almost linearly to 9.5 M€ in 2043. Same behavior is presented for the pumped hydro with 200 MW and 7.5 hours, but with higher revenues, as they will store and discharge almost the double amount of energy.
- Both the production and the equivalent full **cycles** (number of times that the upper water reservoir can be fully emptied) remain stable for the first 10 years and then decrease almost linearly.
- Average **buying** (consumption) and **selling** (generation) **prices** evolve along the time horizon according the pool price. As expected, the higher the pool price, the higher the difference between buying and selling price. During most of the years, this difference is between €40 and €50 per MWh.

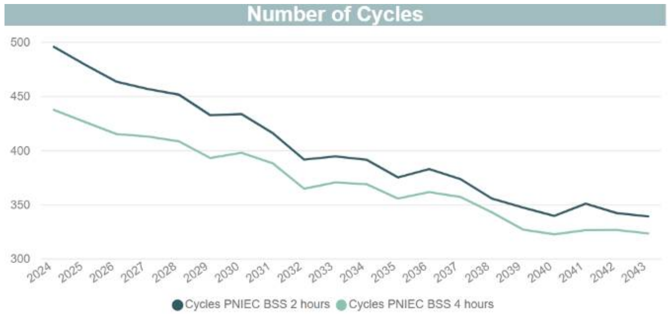
Results: Batteries (ion-lithium)

Revenue estimation









Highlights on the results of batteries as storage technology

- Two configurations analysed: **100 MW BESS with 2 hours and 4 hours** of storage capacity.
- For the BESS 2h, market net revenues begin with around 9 M€ in 2024 and decrease to 3.4 M€ in 2038. Due to the revamping of the batteries in 2039, market net revenue increases again to 4 M€ and decreases almost linearly over the time horizon. The same behavior is presented for the BESS 4h, but with higher revenues, as they will store and discharge almost the double amount of energy.
- Both the production and the equivalent full **cycles** (number of times that the battery capacity can be fully emptied) remain stable for the first 10 years and then decrease almost linearly throughout the whole time horizon. The production is affected by the revamping of the unit after 15 years.
- Average **buying** (consumption) and **selling** (generation) **prices** evolve along the time horizon according the pool price. As expected, the higher the pool price, the higher the difference between buying and selling price. During most of the years, this difference is between 50 and 70 €/MWh for the BESS 2h, and 40 and 60 €/MWh for the BESS 4h.

Profitability assessment

CAPEX and OPEX

Pumping

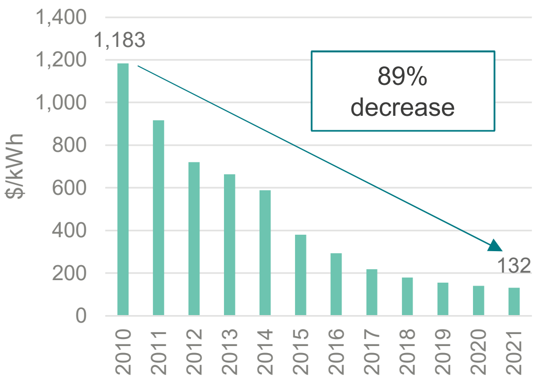
- CAPEX of 1,300 - 1,500 EUR/kW
- OPEX as 3.0% and 3.3% of the CAPEX

Source: IRENA

BESS

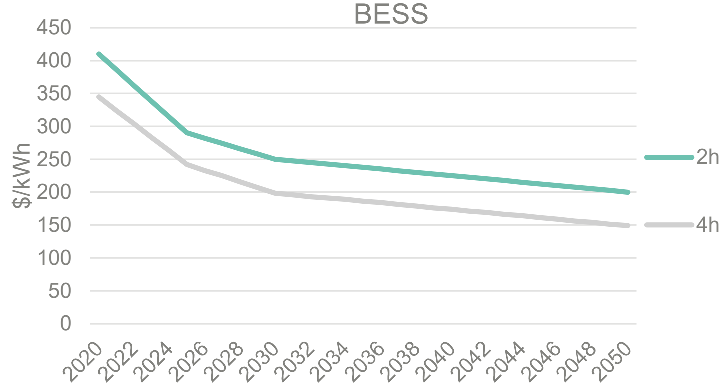
- Cost of ion-lithium racks decrease
- CAPEX decrease expected
- Impact of economy of scale
- Overall CAPEX of 308 EUR/kWh (2h) and 262 EUR/kWh (4h) in 2023
- OPEX as 3.0% of CAPEX

Ion-lithium batteries cost ($/kWh)



Source: BNEF

Long-term CAPEX estimation for 2h and 4h BESS



Source: NREL

Profitability assessment

Financial and technical assumptions

Financial assumptions

Discount rate of 7.4% subject to each financial approach

Linear depreciation of the assets

Target Internal Rate of Return (IRR) of 7.4%

- Within the range normally observed for this kind of projects
- Rate applied in the specific remuneration regime for renewable assets

Technical assumptions

Different construction periods starting in 2023:

- PSH: five years
- BESS: one year

Operation of the assets based on optimization of revenues.

No inflation considered in the OPEX.

Profitability assessment

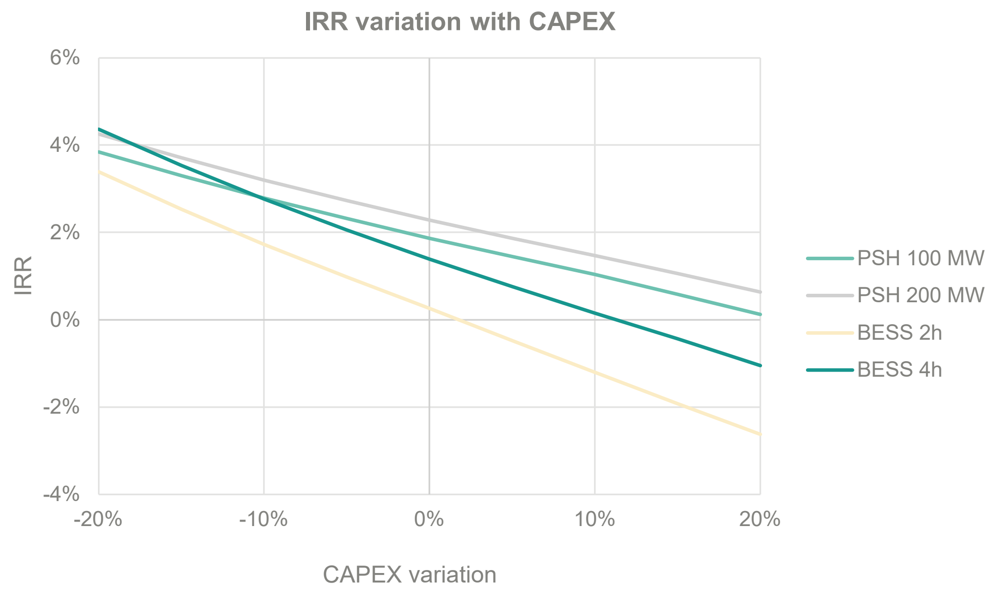
Results

Base case with no additional revenues

IRR BESS
0.3% & 1.4%

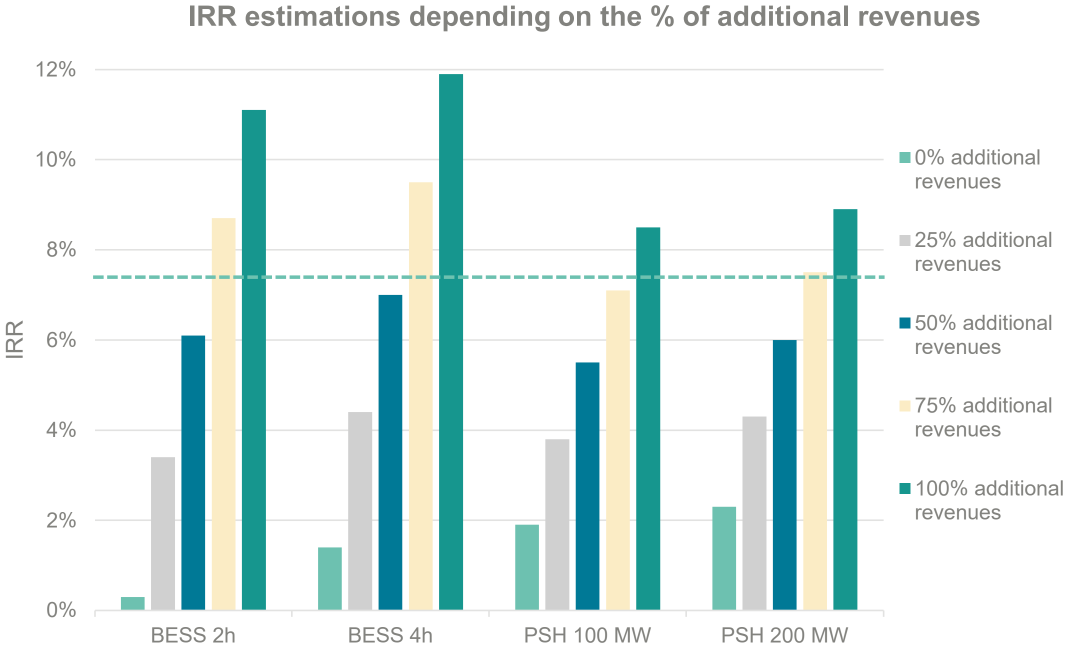
IRR PSH
1.9% & 2.3%

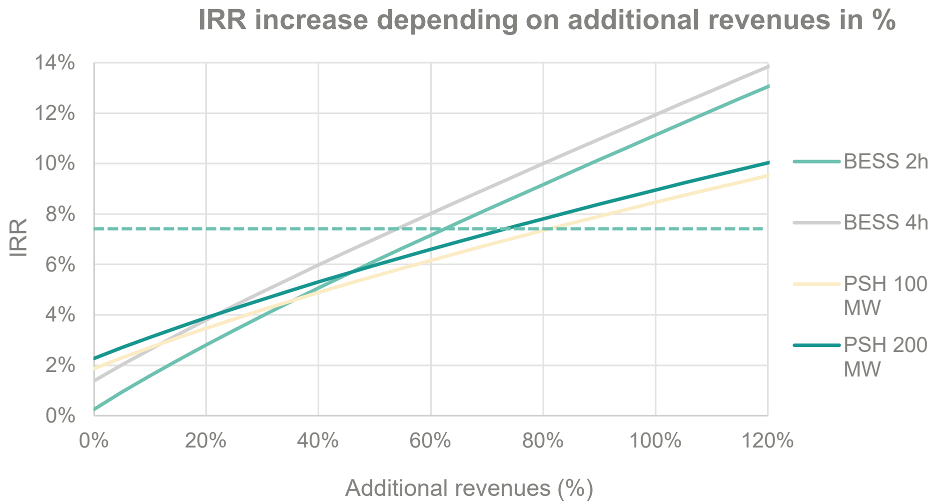
- Relevant CAPEX impact: better IRR for BESS 4h than BESS 2h and PSH 200 MW and PSH 100 MW.
- With a 20% decrease in the CAPEX, IRRs close to 4% without additional revenues.



Profitability assessment

Results



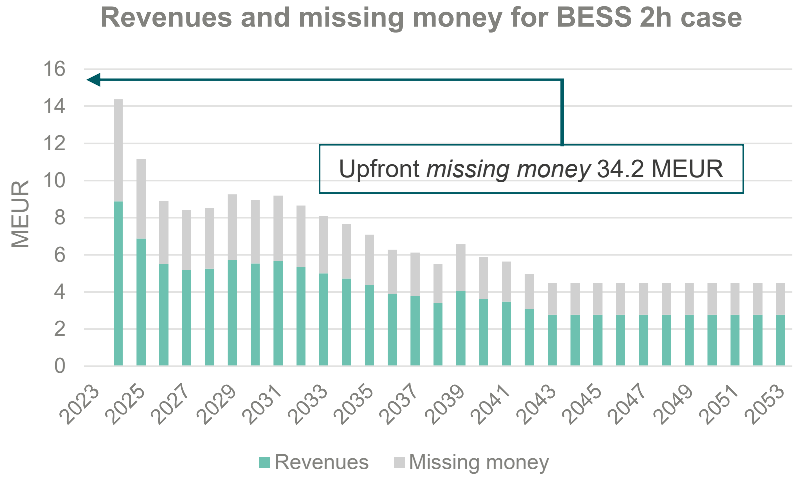


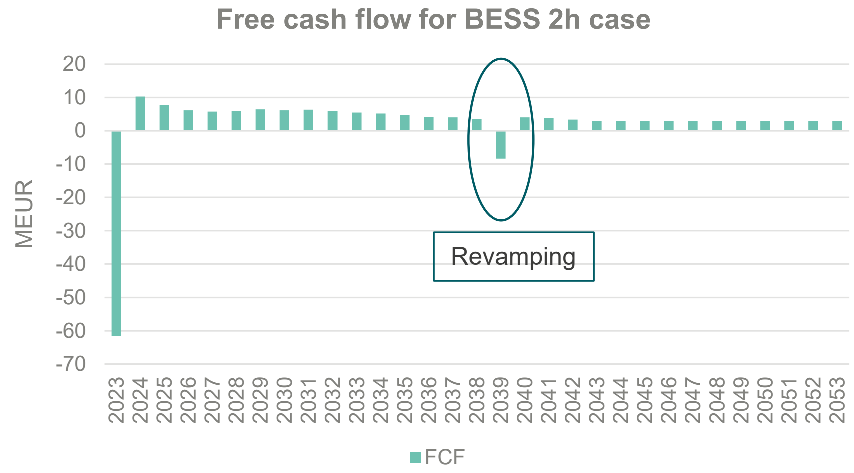
- Additional revenues needed for BESS range 54%-62%.
- Additional revenues needed for PSH range 73%-82%

Profitability assessment

Results

Example for BESS 2h



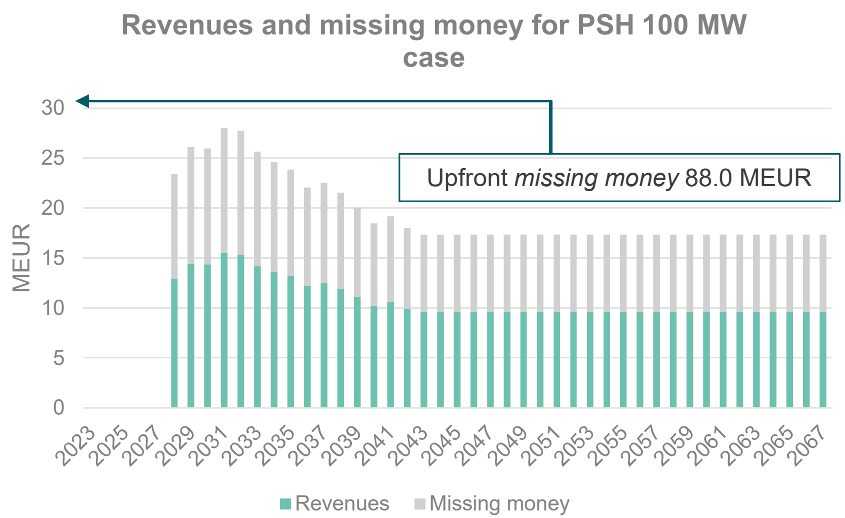


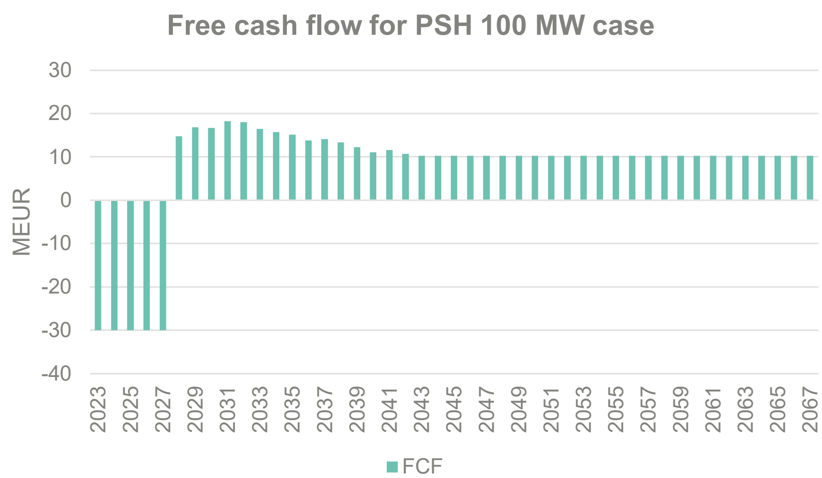
- High revenues on the first operative years. Less storage capacity “cannibalism” and higher pool prices forecast.
- Revamping in year 2039

Profitability assessment

Results

Example for PSH 100 MW





- Long construction period affecting good income period.
- High CAPEX distributed across several years, entailing higher % of additional revenues to increase IRRs.
- No CAPEX needed in the useful life of the asset.

Profitability assessment

Remuneration mechanisms

Direct subsidy

- **One-off upfront payment**.
- Calculated in MEUR, as % CAPEX, in kEUR/MW and kEUR/MWh (MWh of storage capacity)

Specific remuneration (kEUR/MW/yr)

- **Annual payment**
- Rinv as for the regulated renewable energy assets, considering a regulatory life equal to the useful life.

Capacity payment (kEUR/MW/yr)

- Similar to the draft of the order for creating a capacity market in Spain published in 2021.
- Annual payment for the first **5 years** of operation.

Auction scheme (EUR/MWh discharged)

- Based on REER auctions as per RD 960/2020, with a **period of 12 years**

Total CAPEX	*150 MEUR*	*260 MEUR*	*62 MEUR*	*105 MEUR*
	PSH 100 MW	PSH 200 MW	BESS 2h	BESS 4h
Direct subsidy	**88.0 MEUR** 59% of CAPEX 880 kEUR/MW 59 kEUR/MWh	**140.0 MEUR** 54% of CAPEX 700kEUR/MW 93 kEUR/MWh	**34.2 MEUR** 55% of CAPEX 342 kEUR/MW 171 kEUR/MWh	**52.9 MEUR** 51% of CAPEX 529 kEUR/MW 132 kEUR/MWh
Specific remuneration	**98.7 kEUR/MW** 6.6% of CAPEX	**78.5 kEUR/MW** 6.0% of CAPEX	**30.8 kEUR/MW** 5.0% of CAPEX	**47.6 kEUR/MW** 4.5% of CAPEX
Capacity payment	**309.9 kEUR/MW** 20.7% of CAPEX	**246.5 kEUR/MW** 19.0% of CAPEX	**90.5 kEUR/MW** 14.7% of CAPEX	**140.0 kEUR/MW** 13.4% of CAPEX
Auction scheme	**136.4 EUR/MWh**	**127.7 EUR/MWh**	**131.9 EUR/MWh**	**120.4 EUR/MWh**

Support mechanisms to storage projects

European Union

UK

- February 2022 Capacity Auction 2025/2026
- 30.59 k£/MW/year
- Total 42 GW, 2.5 GW for pumped storage, 1.1 GW for batteries

Italy

- February 2022 Capacity Auction 2024
- 70 k€/MW/year for authorized new storage facilities
- Total 41.5 GW, of which 3.8 GW of new capacity (15 years), being 1.1 GW storage facilities

Germany

- May 2021 Innovation tender
- Price ranging from 33.3 to 48.8 €/MWh, on top of market revenues
- 258 MW of solar plus storage.

France

- March 2020 Storage Auction for new capacity
- 7-year contracts with clearing prices around 28-29 k€/MW/year
- 253 MW of storage facilities

Conclusion and discussion

- The massive deployment of renewable generation in Spain (PNIEC and beyond) will make **necessary** the installation of a **huge amount of energy storage systems**, in order to:
  - Assure a reliable energy supply.
  - Make possible the integration of intermittent renewable energy.
- This report concludes that **storage systems are not profitable under the current Spanish regulatory framework**, where the revenues are obtained in short-term markets:
  - Arbitrating in the energy markets (day-ahead, intraday).
  - Providing some ancillary services.

Conclusion and discussion

- **Specific support mechanisms** will be necessary to facilitate and speed up the deployment of storage systems:
  - Proper **remuneration of all the services** provided by the different technologies.
  - The design of **specific long-term support mechanisms** (such as capacity payments, capacity auctions or direct subsidies) will reduce the uncertainty in the revenues and make these projects bankable.
  - It is crucial to design these mechanism **taking into consideration the storage capacity** of the different technologies and facilities.
  - These support mechanisms must comply with the European Regulation and be compatible with the ongoing European fund programs. Some Member States are already implementing them.
  - If Spain aims to be a front-runner in the energy transition process, storage will definitely have to be an important part of it and the implementation of these mechanisms have to be analyzed and considered in the short term.

Muchas gracias

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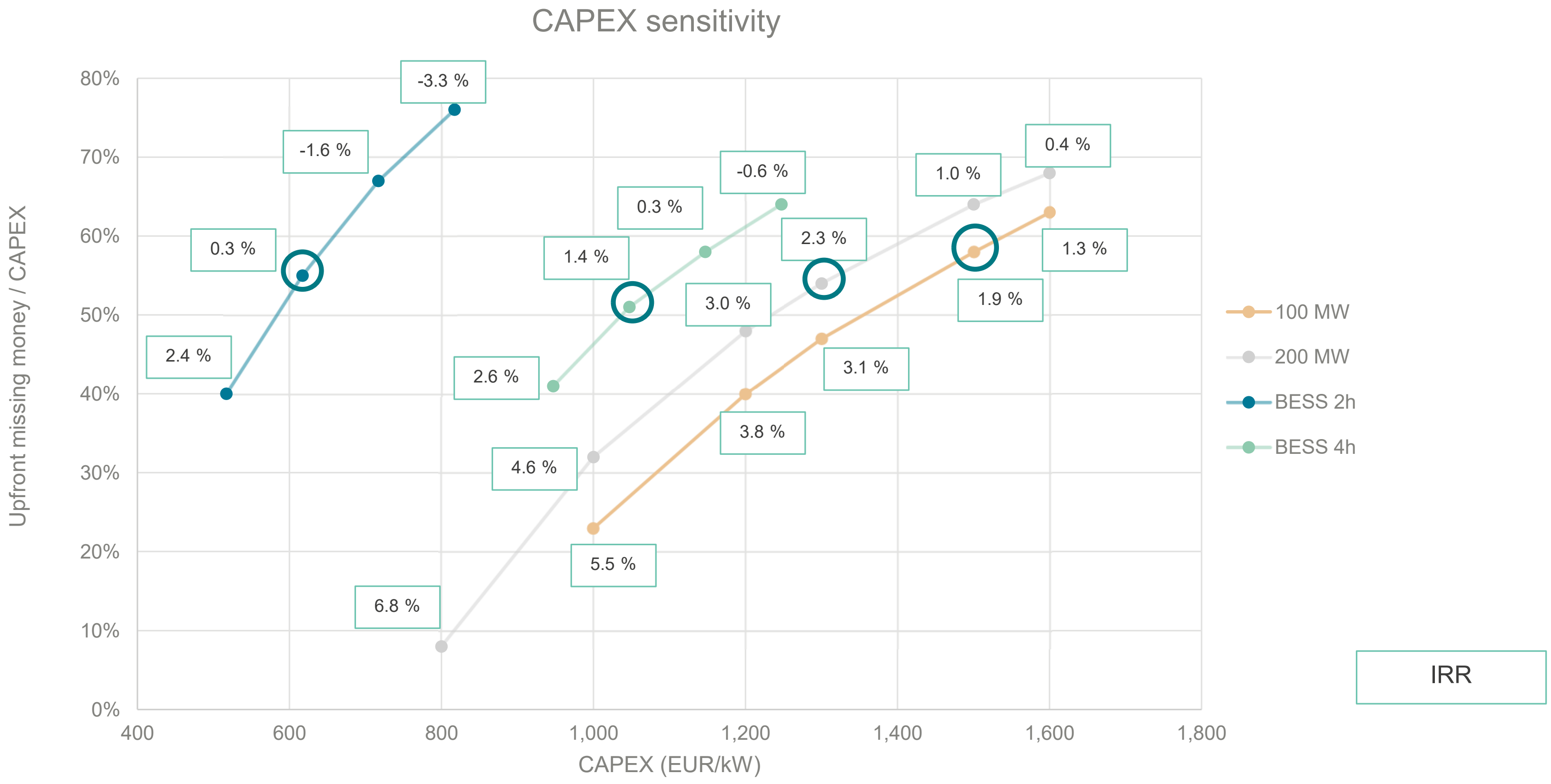
Annex

CAPEX sensitivity



Storage Benefits

Additional services

	Batteries	Pumping	Time response
Daily Arbitrage			
Intradaily Arbitrage			
Weekly Arbitrage			
Seasonal Arbitrage			
Black start			
FCR (Primary Reserve)			
aFRR (Secondary Reserve)			
mFRR			
RR (Tertiary Reserve)			
Load Following			
Frequency stability of weak grids			
Voltage support			
EFR			30' - 60''
SIR			45''
DRR			40-300 ms
FFR			2' - 8''
FPFAPR			
RM			1h - 8h
Capacity firming			2-4 h
Contingency grid support			
End-user peak shaving			
Maximizing self-production & self-consumption			
Limitation of upstream disturbances			1h - 10h
End-user peak shaving			

Legend
Very Good performance
Good performance
Poor performance
Not possible

Additional services:

- Frequency Containment Reserve (FCR)
- Automatic Frequency Restoration Reserve (aFRR)
- Manual Frequency Restoration Reserve (mFRR)
- Replacement Reserve (RR)
- Load Following
- Frequency stability of weak grids
- Black start
- Voltage support
- Daily/weekly/seasonal Arbitrage
- Dynamic Reactive Response (DDR)
- Enhanced Frequency Response (EFR)
- Fast Post-fault Active Power Recovery (FPFAPR)
- Ramping Margin (RM)
- Synchronous Inertial Response (SIR)
- Contingency grid support
- Maximizing self-production & self-consumption of electricity
- Limitation of upstream disturbances
- Capacity firming
- End-user peak shaving