## 2022 Energy Exemplar User Group Meeting

Modelling battery energy storage revenues - Lessons from the Greek Power Market

15th September 2022

ECONOMIC CONSULTING ASSOCIATES



#### **Agenda**

- 1. Introducing ECA
- 2. Introducing the project context
- 3. Revenue streams for BESS (DAM, AS, BM, CRM)
- 4. Using Plexos to model the operation of BESS in the Greek market
- 5. Key results for the operation of BESS
- 6. Concluding remarks









#### Economic consultants specialised in the energy and water sectors operating worldwide

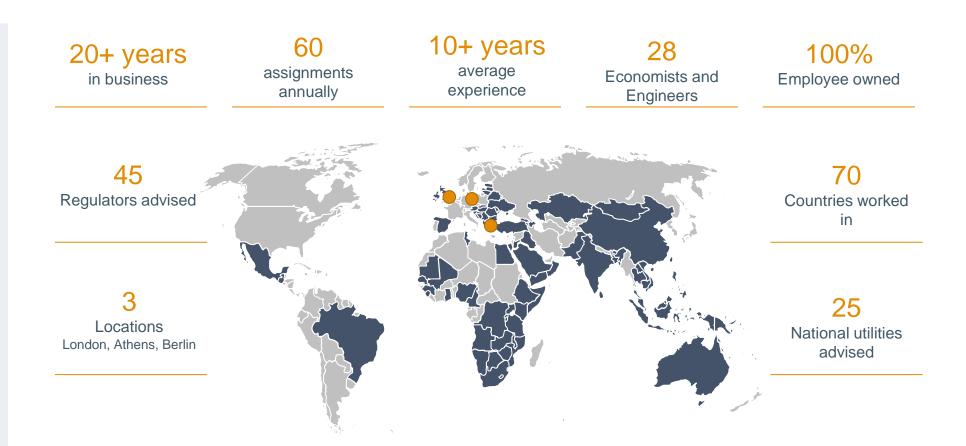
Specialised economic and regulatory consultancy

Focus on electricity, natural gas and water sectors

28 professional staff members, based in offices in **London**, **Athens** and **Berlin** 

Solutions to generation optimisation, net zero targets and energy transition challenges

International footprint with focus on UK, Ireland, southeast Europe, sub-Saharan Africa and southeast Asia



"ECA combines the application of economic principles and industry knowledge with best international practice to deliver implementable recommendations"



## Our experts support clients across four service areas covering economic regulation, markets, decarbonisation and investment planning

# **Economic Regulation Decarbonisation Strategy Markets & Commercial Investment Planning**

- Network and retail tariff design
- Cost of capital advice
- Allowed revenue determination
- Design of regulatory frameworks and incentive mechanisms
- Regulatory due diligence
- RE market integration mechanisms
- Energy efficiency regulation and policy
- Hydrogen strategies and integration
- Low carbon strategy and policy
- Energy storage investments
- Market due diligence
- Asset valuation
- Generation and storage revenue projections
- Wholesale power market design
- Ancillary service remuneration mechanisms
- Least cost development plans
- Investment strategy
- Electricity load forecasting
- Energy and water sector masterplans
- PPP policy and regulation frameworks



## Electricity market modelling in Greece to assess the business case for Battery Energy Storage Systems (BESS)

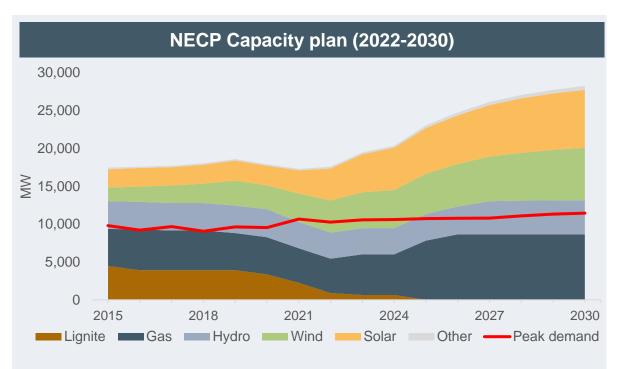
#### Objective

The objective of the engagement was to **develop a strategy for BESS investments** in Greece and assessing the commercial viability of BESS.

- The evaluation of storage assets was analysed in 4 scenarios that cover a breadth of potential evolutions of the electricity market in Greece.
- The electricity market was **modelled in Plexos** software.

#### **Approach**

- The modelling analysis conducted included the electricity market in **Greece and the power systems in interconnected neighbouring countries** to capture the impact of imports/exports on market prices and on the dispatch of power plants.
- The results were then applied into a **BESS** financial model to analyse the commercial viability of storage assets.



- Greece's renewable energy contribution to the EU target for 2030 is 35%.
- The National Energy and Climate Plan (NECP) foresees the development of 1,200 MW of battery from 2024 to 2030.
- On November 2020 Greece reached a significant milestone by launching the European Target Model.



## We quantified and modelled the four key revenue streams for BESS: energy arbitrage, ancillary services, balancing energy and capacity remuneration

Energy Arbitrage
opportunities in the DAM
Day Ahead Market

BESS revenues from energy arbitrage may be derived by exploiting **opportunities for charging at low prices and discharging at high prices**. The potential for revenues from arbitrage increases as the spread of the hourly market prices increases within the DAM. Energy arbitrage entails a certain amount of risk for BESS considering that BESS are price takers and hourly prices in the DAM cannot be predicted with certainty.

Capacity provision for Ancillary Services

**Provision of reserves** for upward and downward Frequency Containment Reserve (FCR), manual Frequency Restoration Reserve (mFRR), and automatic Frequency Restoration Reserve (aFRR) are compensated by the TSO on a **pay-as-bid** basis. Technically BESS have a competitive advantage as they can provide capacity and energy to the grid in milli seconds. Revenues from participation to the AS market are firm, based on bid prices.

Activation of energy in the BM

Balancing Market

**Balancing energy** is remunerated at the marginal price per Balancing energy product (namely mFRR and aFRR) in each period.

Capacity
Remuneration Mechanism
CRM

There is currently **no CRM available for BESS in Greece**, and no such additional revenue has been considered in the analysis. A CRM should incentivise the implementation of sufficient investment in new capacity, to the extent that expected revenues from other revenue streams fall short from the required revenues for the recovery of relevant fixed costs. A CRM is typically employed where long-term reserve requirements cannot be met without such a mechanism.



## The Greek electricity market was simulated in Plexos applying a two-step approach

#### Day-ahead market run

# Input data

- Electricity system data: demand forecast, power plant technical parameters, fuel and CO2 prices, RES generation and hydro availability, etc
- System hourly reserves requirements (FCR, FRR, aFRR)

# Plexos approach

- Enable the **Flat files writing** in report object for the output properties:
  - Price Received
  - SRMC
  - Available capacity
  - Undispatchable Capacity
- ST Schedule run: Co-optimisation of hourly dispatch in DAM and for the provision of reserves

## Outputs

- DAM hourly market prices
- BESS charge/discharge in the DAM
- BESS capacity allocated for reserves provision

#### Balancing market run (real-time)

- Start from the DAM model
- Changes:
  - Load is based on balancing energy requirements
  - Generation capacity available is based on the results of step 1 co-optimisation



- The objective:
  - to meet imbalance energy needs.
  - Using available capacity from the DAM run
  - And price signals based on SRMCs, and Price received

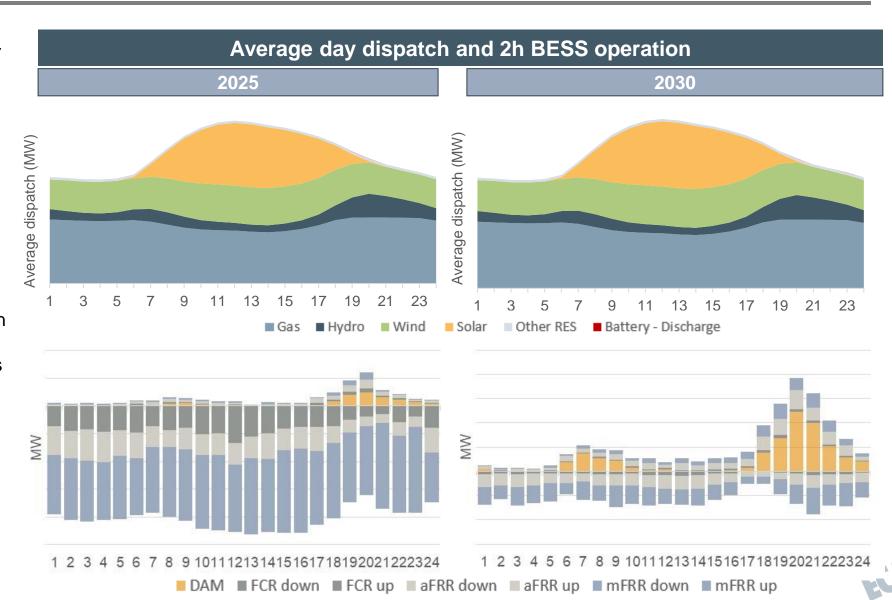


- BESS energy activation for balancing energy
- BM hourly prices
- Data post-processing in a Financial Model



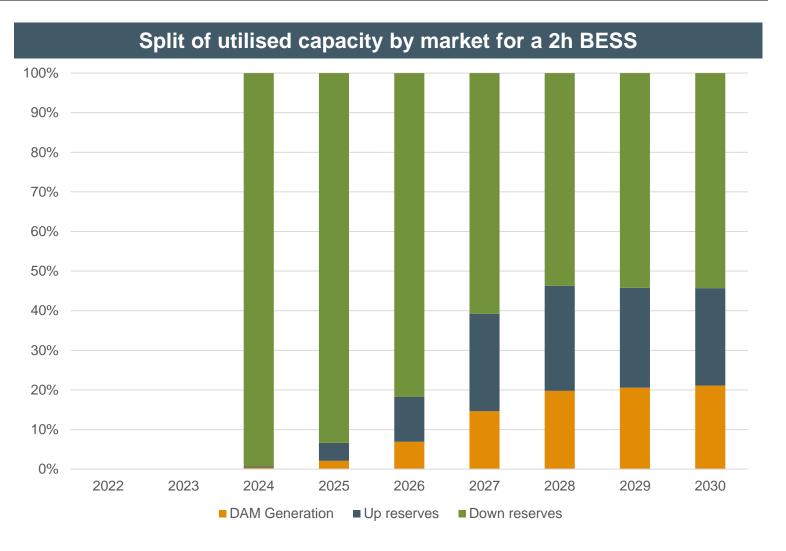
## Illustration of results – operation of 2h BESS in 2025 and 2030 highlights the importance of reserve markets

- Plexos offers the capability to cooptimise energy and ancillary service provision.
- In 2025 most of BESS capacity is allocated for the provision of **down reserves** throughout the day.
- In 2030 most of BESS capacity is allocated for the provision of both **up and down reserves**.
- Most of the **up reserves** provision is concentrated early morning and, in the evening, when there is need for fast response to balance phasing out (or in) Solar PV generation.
- In the DAM, BESS mainly charge during the daytime and discharge in the evening



#### For BESS, the reserves market makes up the large majority of BESS utilisation and therefore defines the business case

- The majority (48%-100% depending on year and scenario) is selected to provide down reserves
- Low capacity utilised is selected for energy arbitrage in the DAM
- The utilisation of BESS in the DAM increases over time but remains low at close to 20%





#### Plexos as a flexible tool to accommodate the complexities of markets

	Wider project BESS investment case conclusions	Plexos as a flexible tool
	Using PLEXOS we were able to optimise the operation of BESS in the DAM, for AS provision and in the Balancing Market:	
Revenue streams	<ul> <li>The modelling results revealed that energy arbitrage in the DAM was not enough to bring profitability for BESS projects.</li> </ul>	Using PLEXOS Software, we were able to model the complexities of the co- optimisation between day- ahead and reserve markets as well as the real time unit commitment of the balancing market.
	<ul> <li>This constitutes the modelling of AS provision and the BM as extremely important to evaluate properly BESS projects.</li> </ul>	
	<ul> <li>Capacity provision for Ancillary services was predominant for BESS - revenues from AS provision was the most important revenue stream for BESS under all scenarios.</li> </ul>	
BESS duration	Within <b>PLEXOS</b> we modelled alternative duration types for BESS investments (1h, 2h and 4h). We evaluated the utilisation and profitability of alternative duration types for BESS to inform investment decisions.	Worked together with EE staff to overcome modelling issues.
Timing of investment	We were also able provide insights regarding the optimum year (in terms of profitability) for the investments of BESS given that capital costs are forecast to decline.	<ul> <li>Plexos as an intuitive and versatile tool in many markets ECA works in</li> </ul>
CRM	Using Plexos outputs we were able to determine required level of prices for CRM to make BESS projects profitable.	



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