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The impact of Germany's ramp constraints and grid limitations on the energy storage business case

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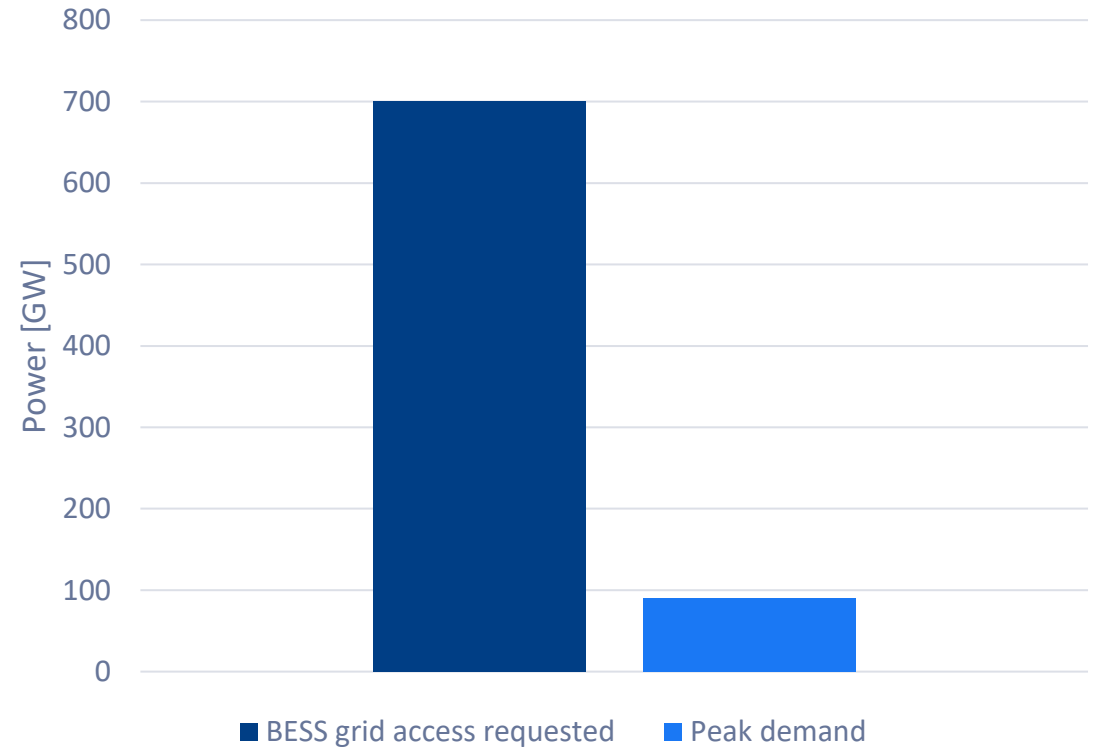
Limitations as new standard

Grid as a bottleneck for projects in Germany

- Grid requests by BESS exploded in 2025 → Most projects got a negative answer from their TSO/DSO
- If you are provided access, this comes under a Flexible Connection Agreement (FCA)
- As for EU reform of electricity markets* and then national legislation in Germany**, FCA allow for more flexible use of the grid in case of congestion

Before	Now
Fix grid connection	Flexible grid connection
Inject and withdraw whenever	Inject and withdraw when allowed
No grid access granted when congestion during some hours	Grid access can be granted even though congestions exist

→ FCAs are a requirement to get grid, not a fast-lane access



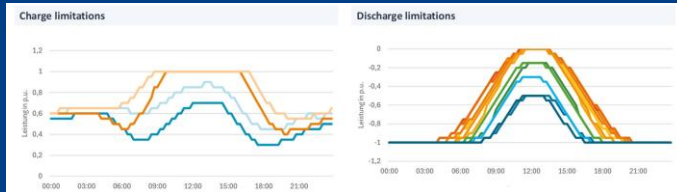
*Art. 6a Directive 2024/1711 (EBM-RL)

** § 17 EnWG and § 8a EEG

What conditions can be found in FCAs?

Four main types of conditions have been given to BESS projects in Germany so far:

Injection/withdrawal limitations based on an hourly profile



Ancillary services limitations % of nominal power for FCR, aFRR



Ramp rates % of nominal power/min



Order book freeze X hours before delivery



One size fits all? Not in Germany

- FCAs are defined by the local grid operator and there are **many** in Germany
- Even within one TSO/DSO FCAs can differ significantly

→ You never know what you will get, until you sign the grid connection agreement

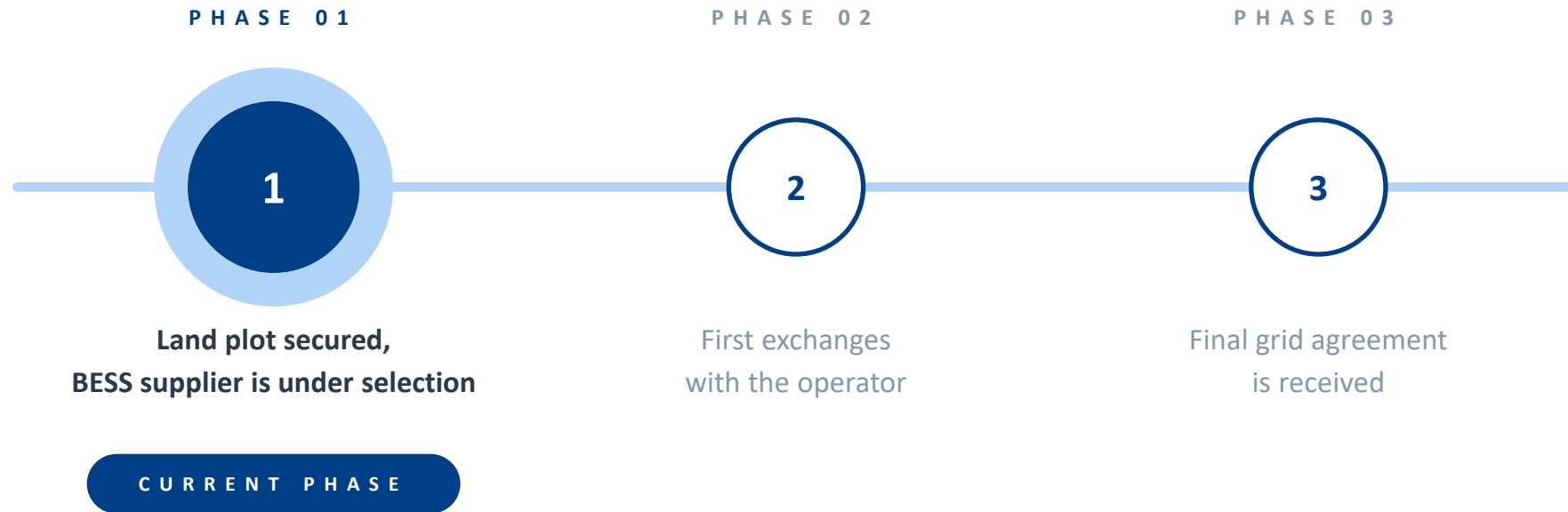
Some tendencies:

	TSO	DSO
Injection/withdrawal limitations	Less common	Very common, partially standardized
Ancillary service limitations	Applied for big sites	Applied as DSO has no control/interest in AS
Ramp rates	6-20%/min	Anything from 1%/min to no ramp rate restrictions
Order book freeze	Applied for redispatch purposes	Less common



Developer journey step by step : example of a 50 MW/ 4h project

TIMELINE

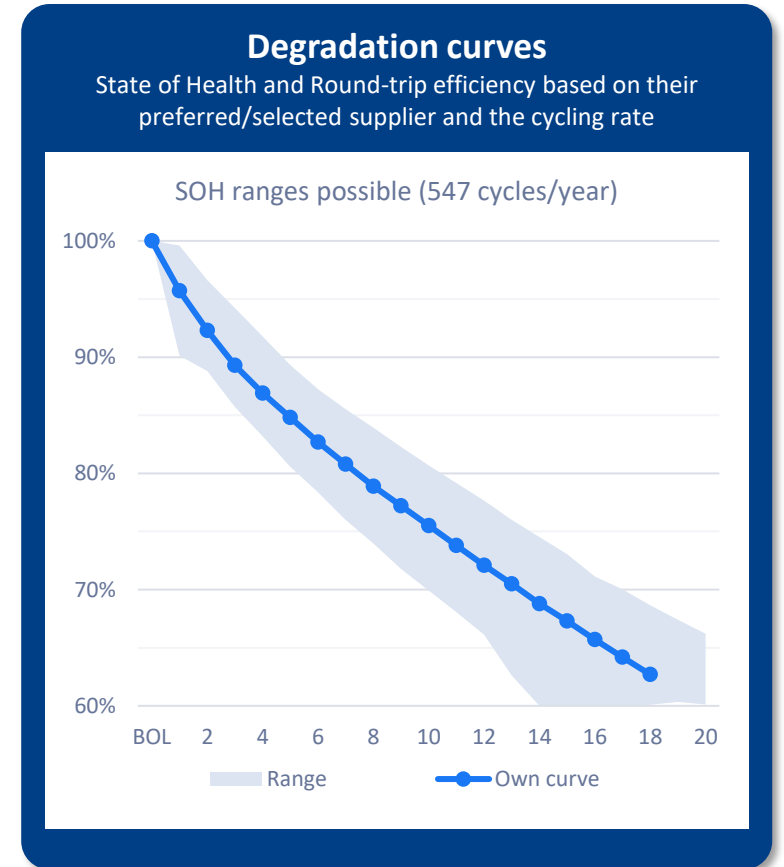
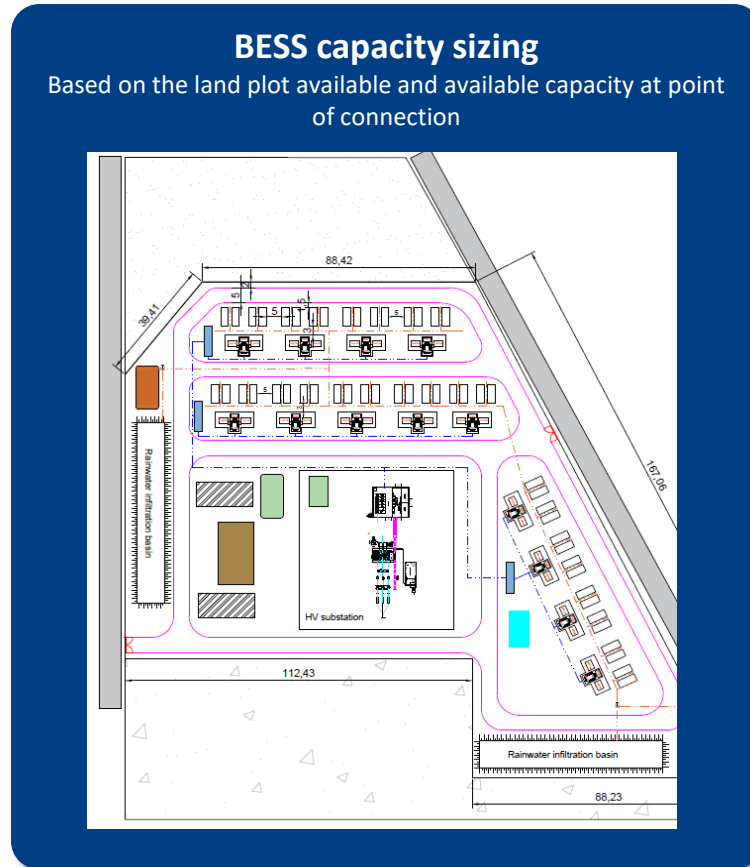
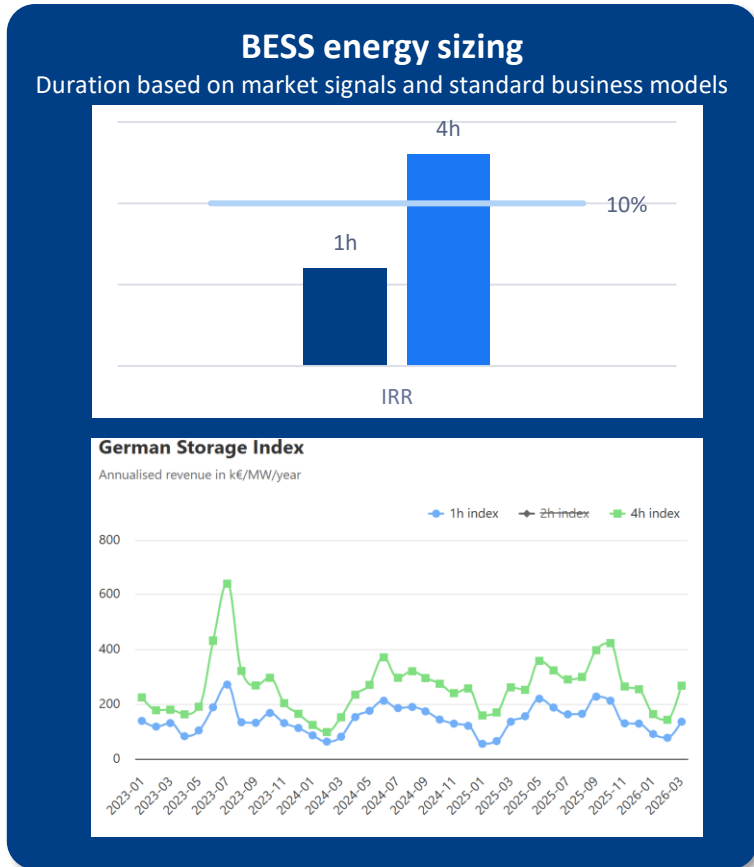


PROJECT STATUS

Based on German standard business models and market trends, the optimal BESS duration has been chosen (here 4-hour). The BESS power is maximized on the secured land plot (here 50 MW).

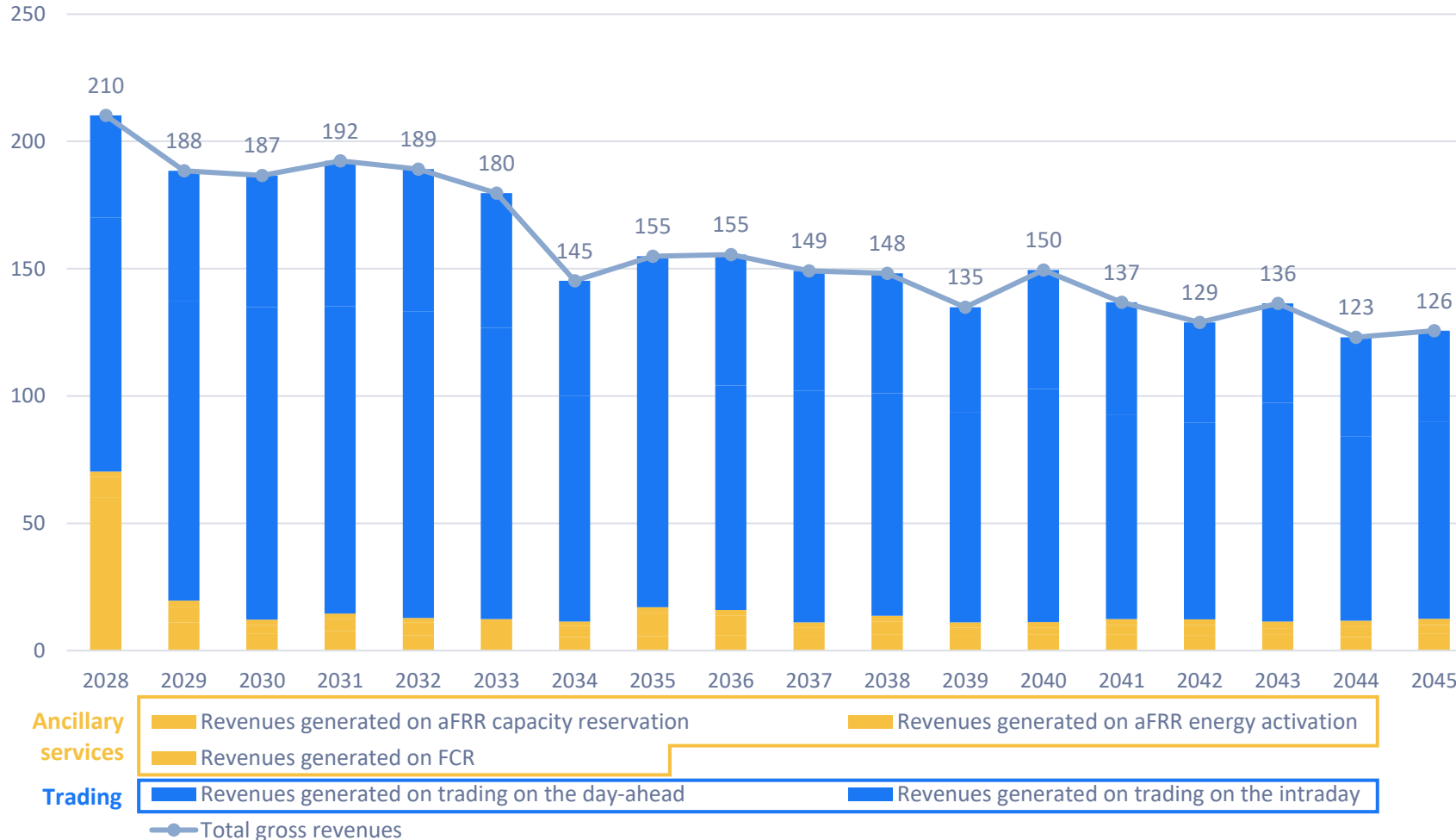
Well ahead signing the connection agreement, a first tailored business model is built

When developing a project, it has always been key for developers to be able to include the specificity of their BESS project. Before the introduction of FCAs, the focus is on:



While these tailored features are key, they are standardly modelled by forecast provider

Gross Revenue Stack of the 50 MW / 4h project
In k€/MW



First tailored features are specific to the project but common to all BESS projects

Project : 50 MW, as the land plot allows to fit it

Duration : 4h, as long durations BESS are becoming more profitable in Germany, benefiting from high revenues on the day-ahead and intraday

SOH and RTE curves : included to build the revenue stack, based on the selected supplier

Commissioning : January 1st 2028

Cycling rate : 547 cycles/year (1.5 cycles per day in average) and 3 cycles maximum per day

Going forward, terms of the grid connection agreement are shared

TIMELINE



PROJECT STATUS

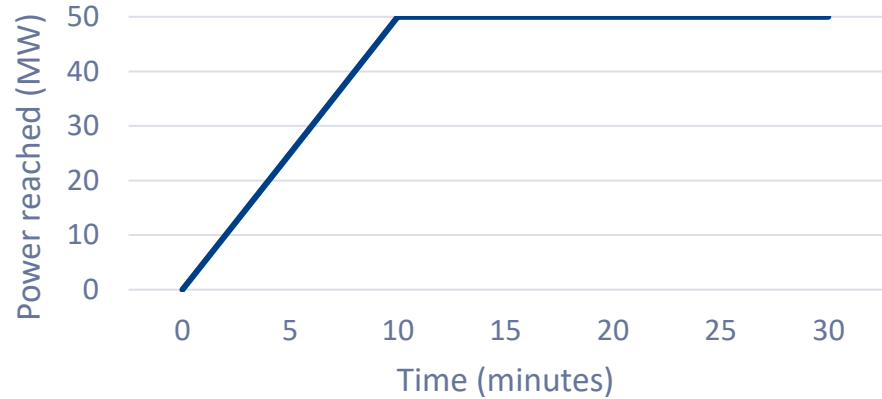
While the land plot is located near a substation with available power, the network operator starts to precise the conditions and limitations associated with the connection of the BESS asset

With grid connection reservation, more visibility is given on potential constraints

Ramp rate

% of nominal power/min

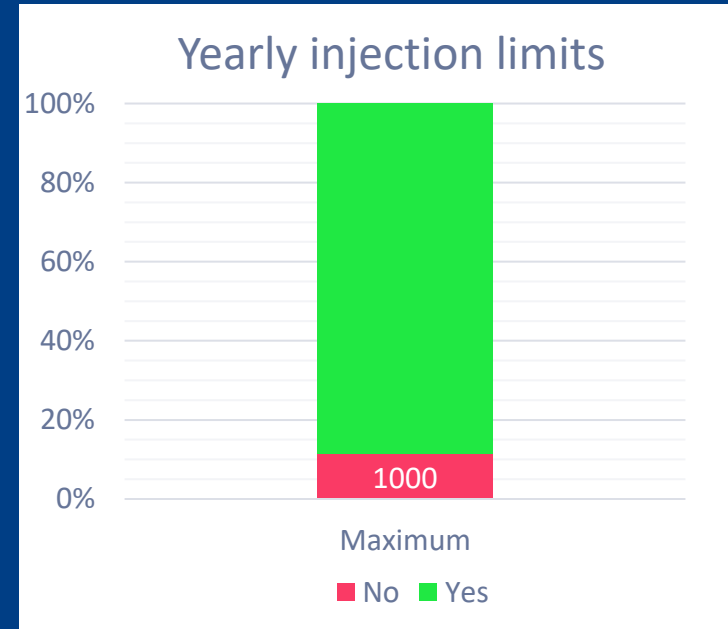
10 %/min



Injection limitations

Number of hours

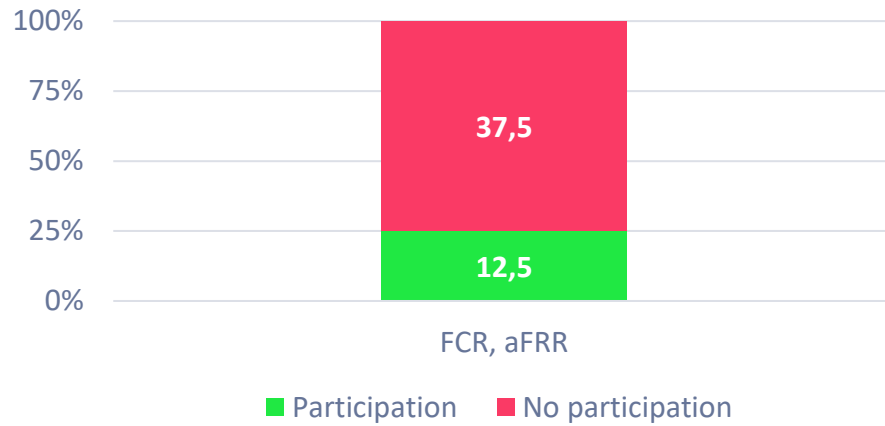
1000 random hours per year



Ancillary services limitations

% of nominal power for FCR, aFRR

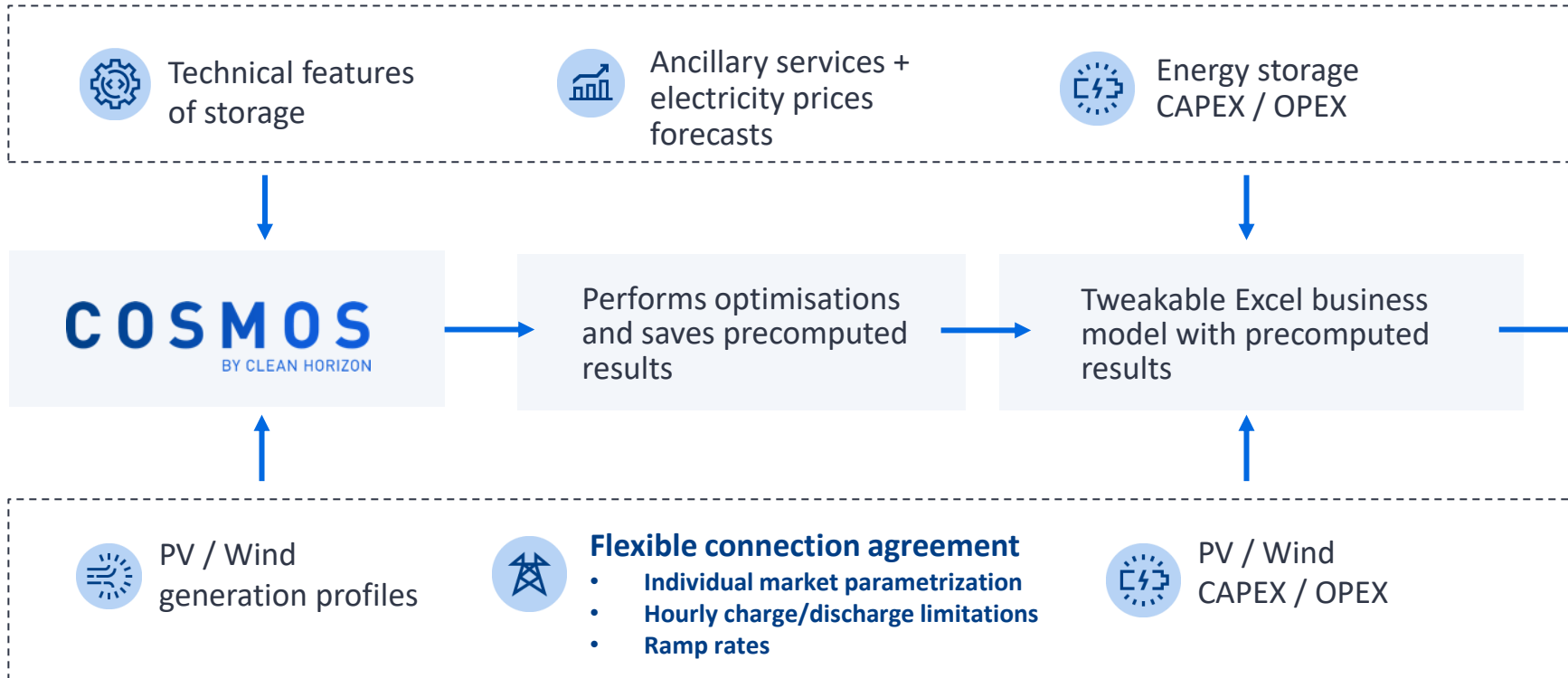
Capped to 25%



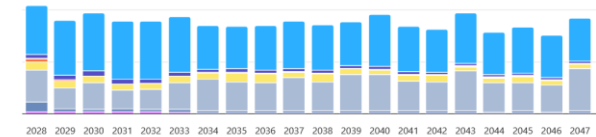
No more need for numerous case studies

COSMOS can simulate your FCA

From Clean Horizon



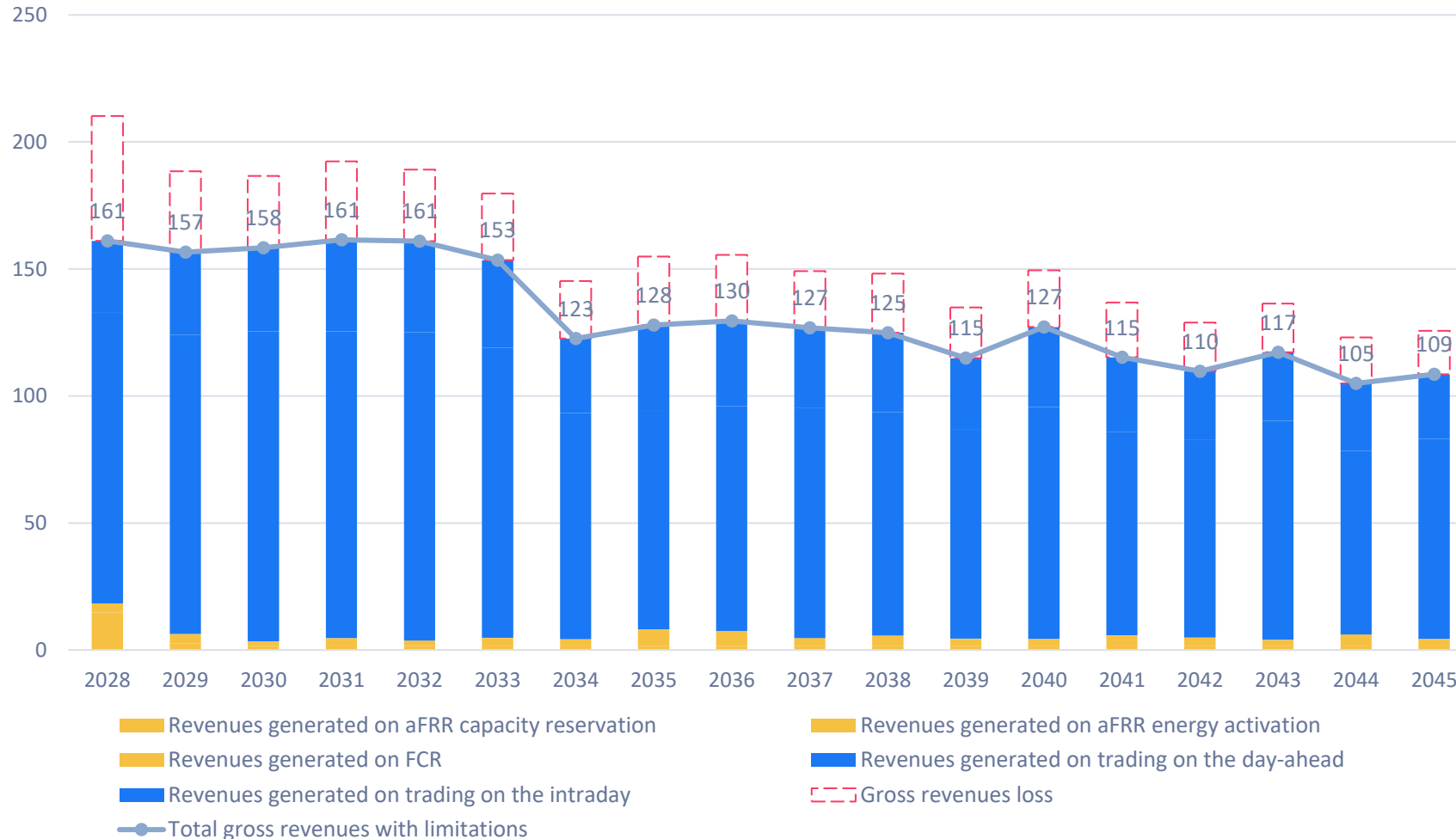
Optimal system sizing + sensitivity analyses



From Client

FCAs are impactful : the combination of the 3 constraints resulted in an average revenue loss of 16%/year

Gross Revenue Stack of the 50 MW / 4h project
In k€/MW



3 Operational constraints are modelled together

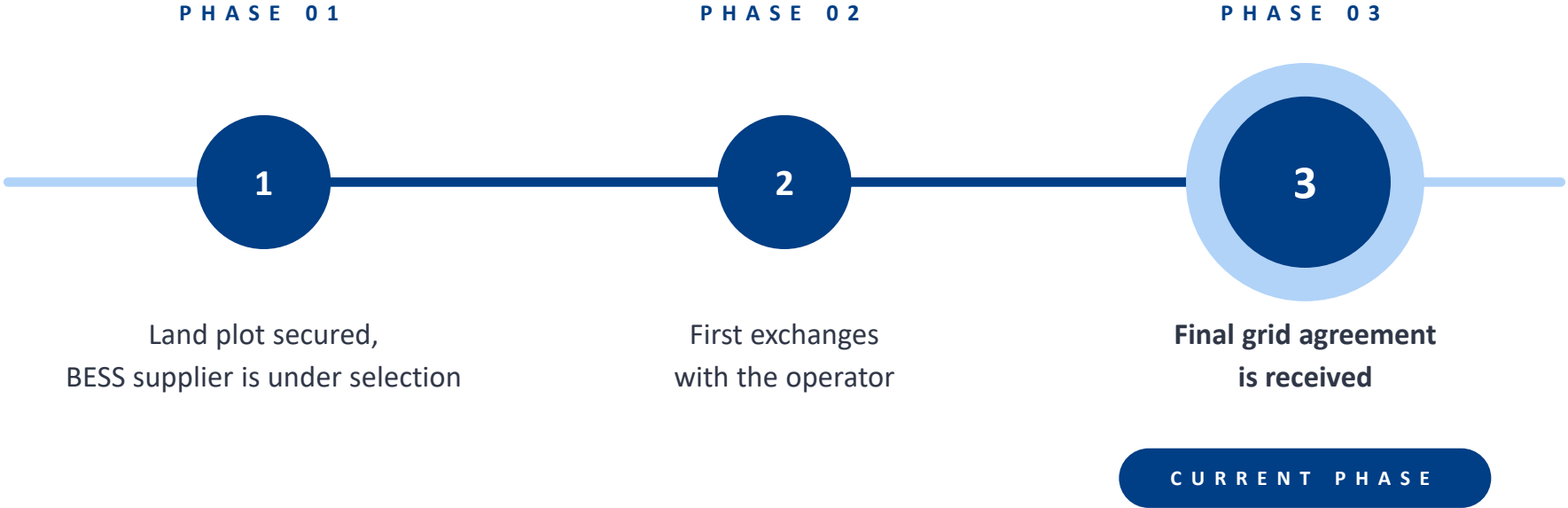
- The ancillary services participation cap is mostly impactful at beginning of life (2028)
- But the 25% cap participation did not result in 75% loss of balancing revenue : the balancing revenues have reduced by 60% in average
- In 2028, the trading revenues (day-ahead and intraday) are even 2% higher than the trading revenues for the unlimited case : the BESS has shifted operation to trading because of the aFRR cap
- Trading revenues have in average decreased by 10%/year considering the 10 %/min ramp rates and the 1000 hours of injection limits (ie 11.4%/year)

The impact of each limitation depend on its value, but also on project parameters

Types of limits	Ramp rates	Balancing services cap	Hours of limitations
Range of values for the limit	From 6%/min (15 min to reach full power) to 20%/min (5 minutes to reach full power)	From 0 to 100%	Direction (injection and/or withdrawal), Overall number of hours, Positions (random, concentrated on a certain season, linked to PV or Wind production ...)
Project parameter that influences the impact	BESS durations and cycling : Long durations BESS and high cycling rates are less impacted by ramp rates limits because they are likely to maintain a position for multiple consecutive timeslot	Date of commissioning : As ancillary services will progressively be cannibalized by BESS, this cap will be less and less impactful	Market-situation : If multiple markets provide high opportunities, it decreases the impact as BESS can re-optimize

Up to the final terms and the signature of the grid connection agreement

TIMELINE



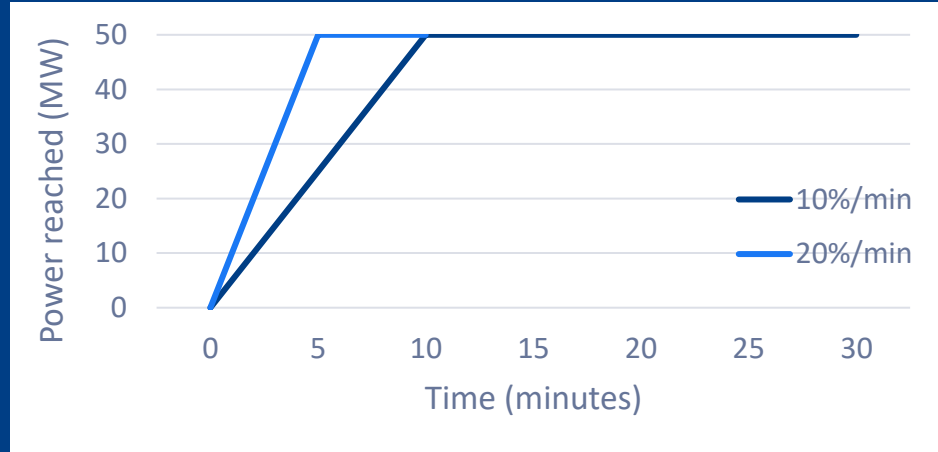
PROJECT STATUS

Final contract with framed limitations is signed

Final grid connection constraints are set in the signed grid connection offer

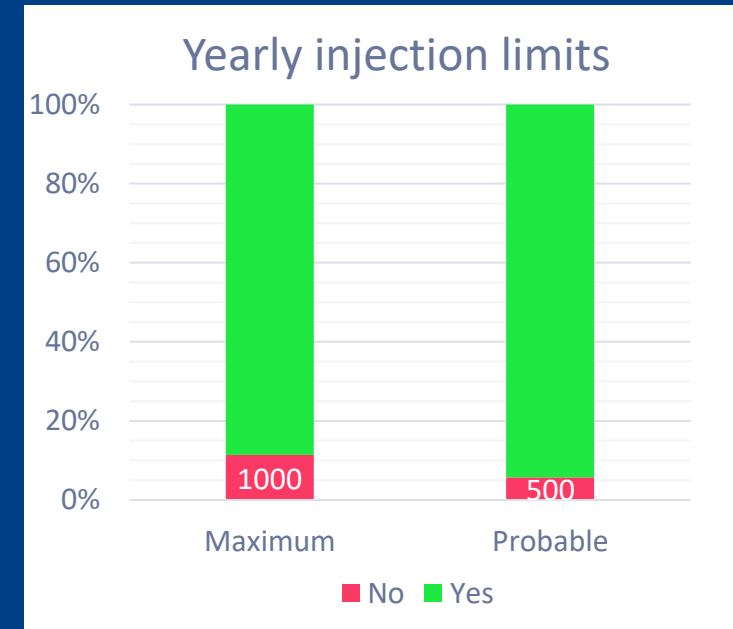
Ramp rate
% of nominal power/min

Ramp can vary
between 10 to
20 %/min



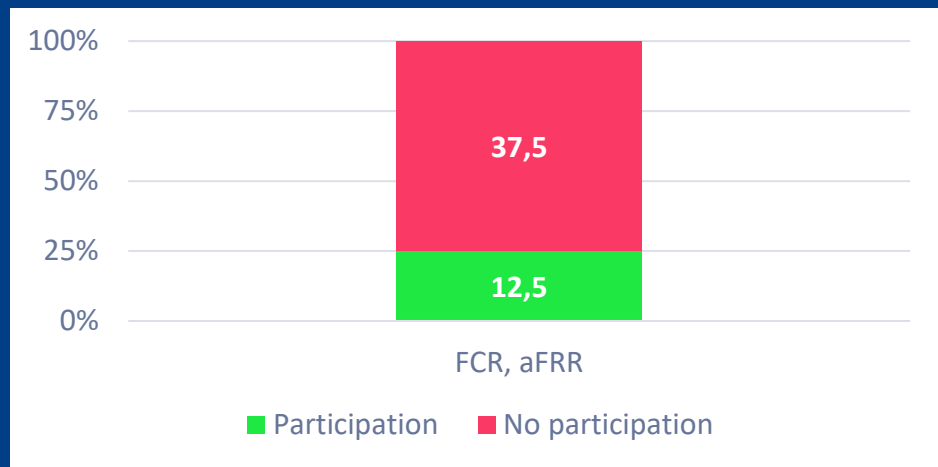
Injection limitations
Number of hours

500 hours expected up to 2035,
and then 0 (grid study)



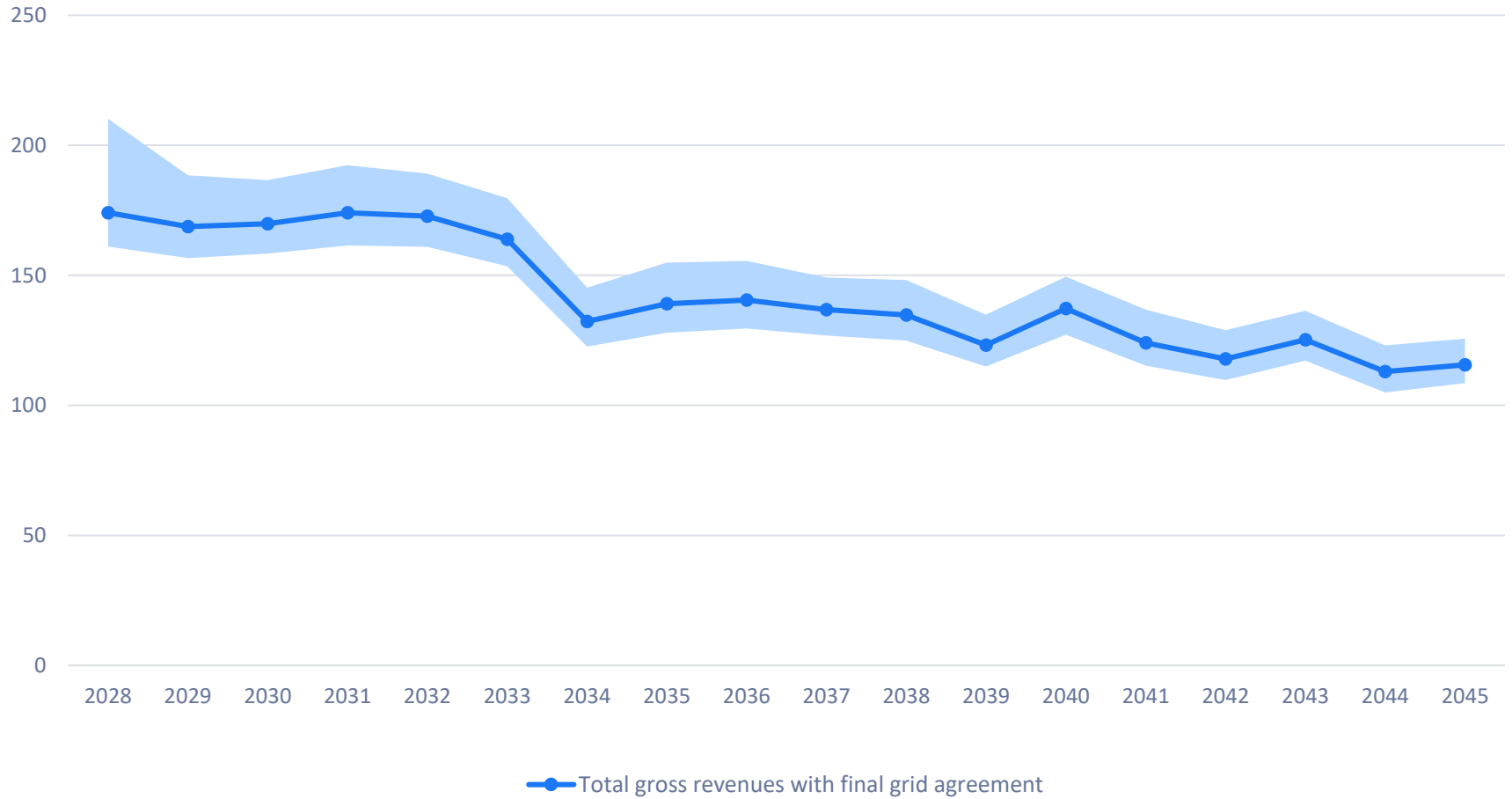
Ancillary services limitations
% of nominal power for FCR, aFRR

Cap of 25% is
confirmed



From one to multiple tailored-business models : revenue has increased by 8%/year based on latest constraints

Gross Revenue Stack of the 50 MW / 4h project
In k€/MW



Flexibility is everywhere

A new business model with a 10%/min ramp rate and 500 hours of limitations up to 2035 is done.

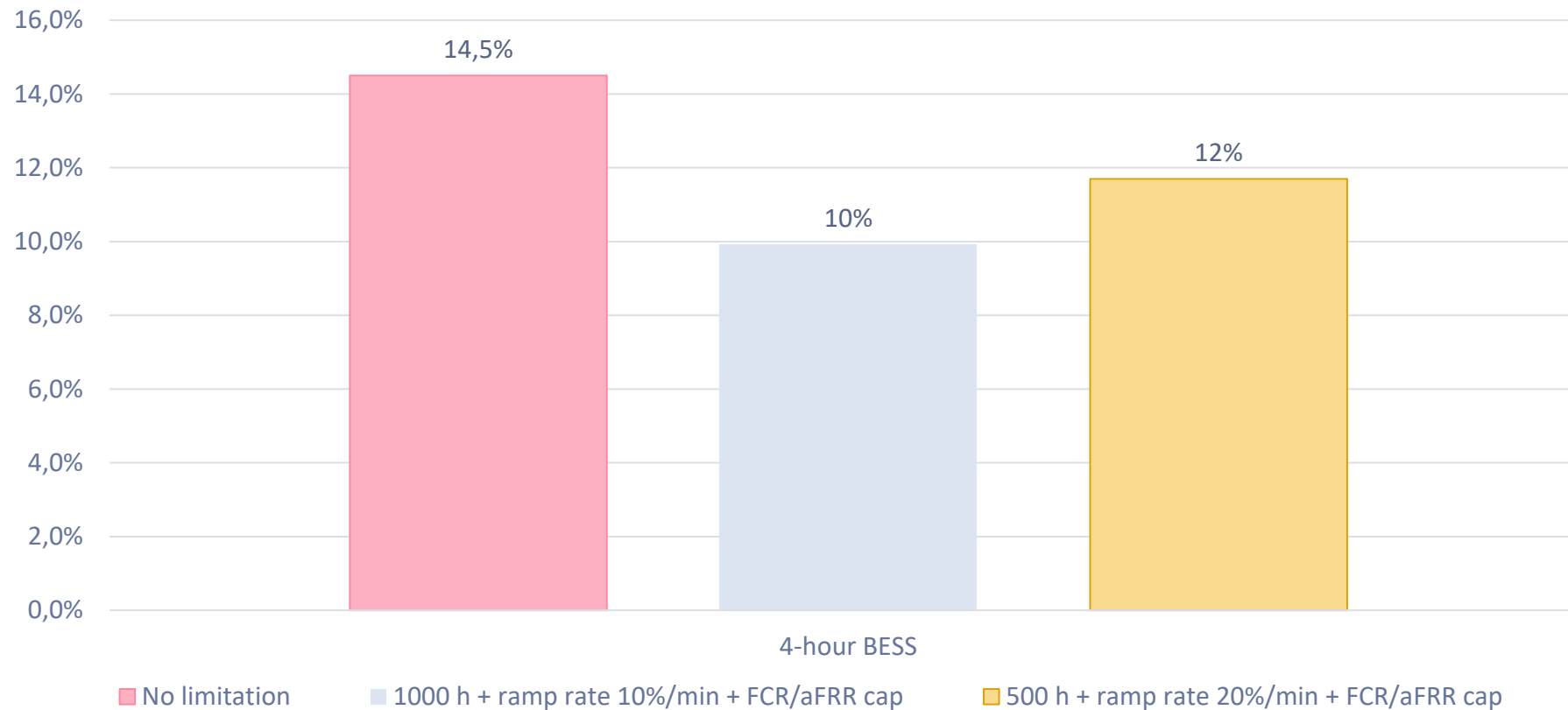
This leads to a range of revenues possible for the same project instead of one fixed business model.

Final limitations have resulted in a 2.5% loss compared to the untailored business model

Internal Rate of Return (IRR) of a 50 MW / 4-h BESS with different scenarios of limitations

BESS IRR

In % (real 2026)



In addition to revenue curves, the costs of the project are accounted for to compute its overall profitability.

Costs that must be accounted for include :

- CAPEX
- Operation and Maintenance costs
- Performance guarantees,
- Product warranties,
- Auxiliary consumption costs
- Land lease

Etc ...

Opening: From business models to financial close?

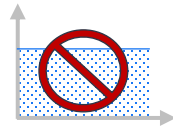


Route-to-market

Most Route-to-Market (RTM) providers are new to FCAs

- Limited experience in operating with these constraints
- Unable to estimate long-term revenue impact

→ **Unable to give a (interesting) toll**



Lendor

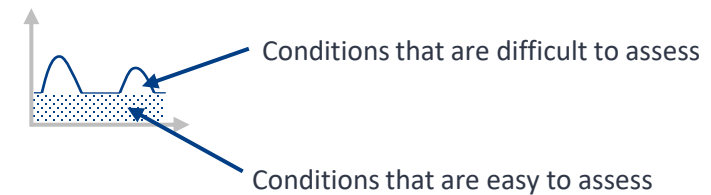
Lenders have to deal with an additional level of uncertainty: FCA conditions

- Several scenarios must be calculated and the risk of each scenario individually assessed
- Higher sensitivity on the risk associated to each market (i.e. DSCR)

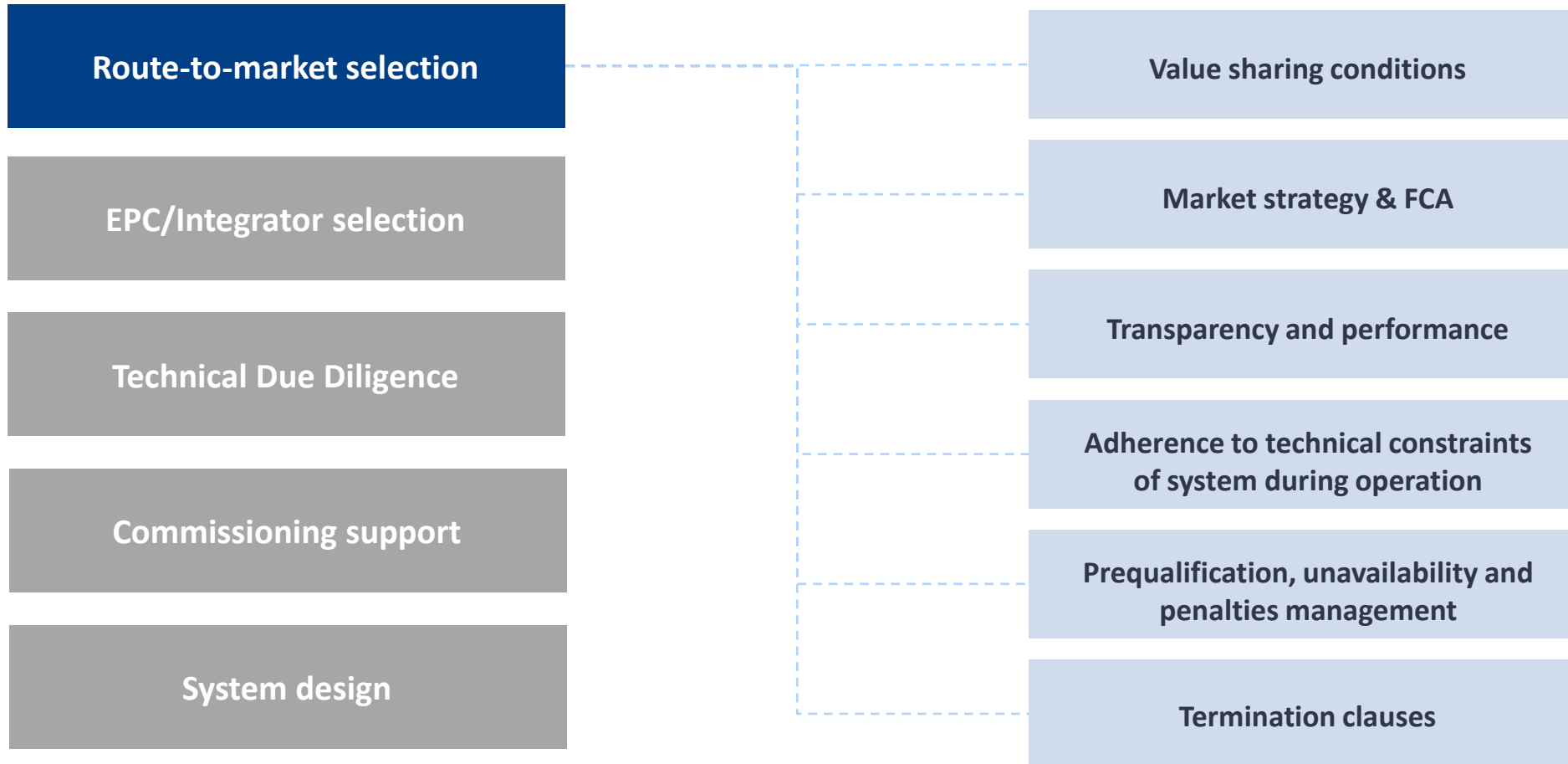
→ **More complex analysis of revenues require several simulations**

...Or maybe a lower gearing

Floor with merchant upside as workaround



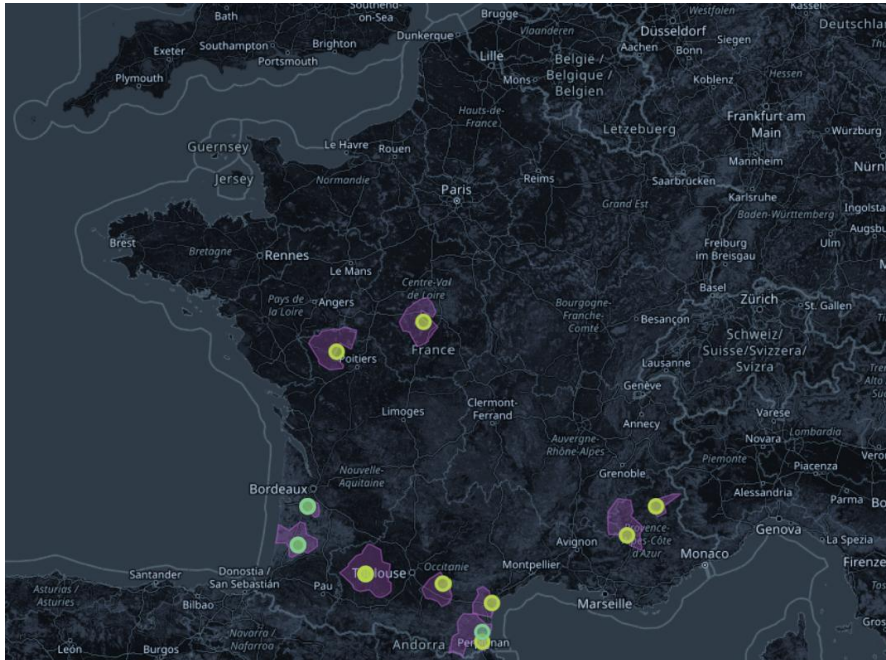
Need support in navigating complex RTM contract?



Other European countries start including flexible connection schemes

Example of France with

- Fixed profiles (operating template or operating 'gabarit') defined in advance
- Zones in which it applies are accessible on an online map
- Soon a withdrawal pattern and the geographical zones in which it applies will also be shared



Injection Operating template in France





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