Special session on reserve dimensioning

Working Group Balancing

15.02.2023 - Kristof De Vos

Objectives of the workshop

1.

Presentation of Elia’s proposal for a new aFRR dimensioning method

What ? Present Elia’s proposal for a new aFRR dimensioning methodology for implementation, including improvements on the method formerly recommended by Elia (cf. aFRR dimensioning study)

Why ? Elia presented a method and implementation plan for a dynamic probabilistic aFRR dimensioning method in 2020 allowing better volume / risk management (closer to-real-time based on expected system conditions). The implementation was put ‘on hold’ after discussions with CREG on the role of the FRCE quality. The volumes were temporarily reduced to 117 MW as from July 2022 following a request for modification of the CREG (in view of gas crisis and balancing capacity procurement cost)

Launch public consultation of the LFC block operational agreement on 24/02

2.

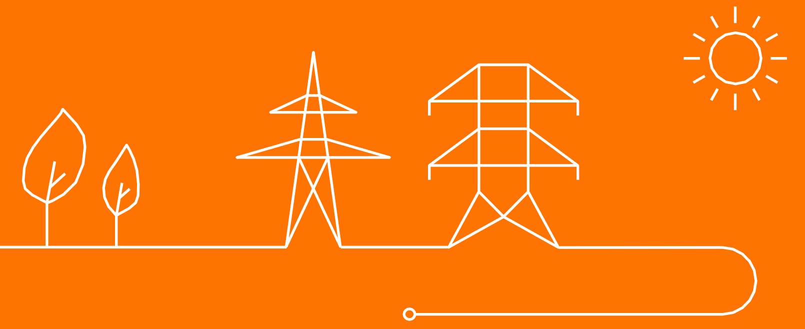
Presentation of projections on Elia’s reserve capacity needs and balancing capacity requirements

What? Present an update of Elia’s FRR, aFRR, mFRR reserve projections up to 2034, including an outlook on the balancing capacity to be procured by Elia. These projections will be used in Elia’s ongoing and upcoming studies (cf. Adeqflex 2023, MOG 2 System Integration, …)

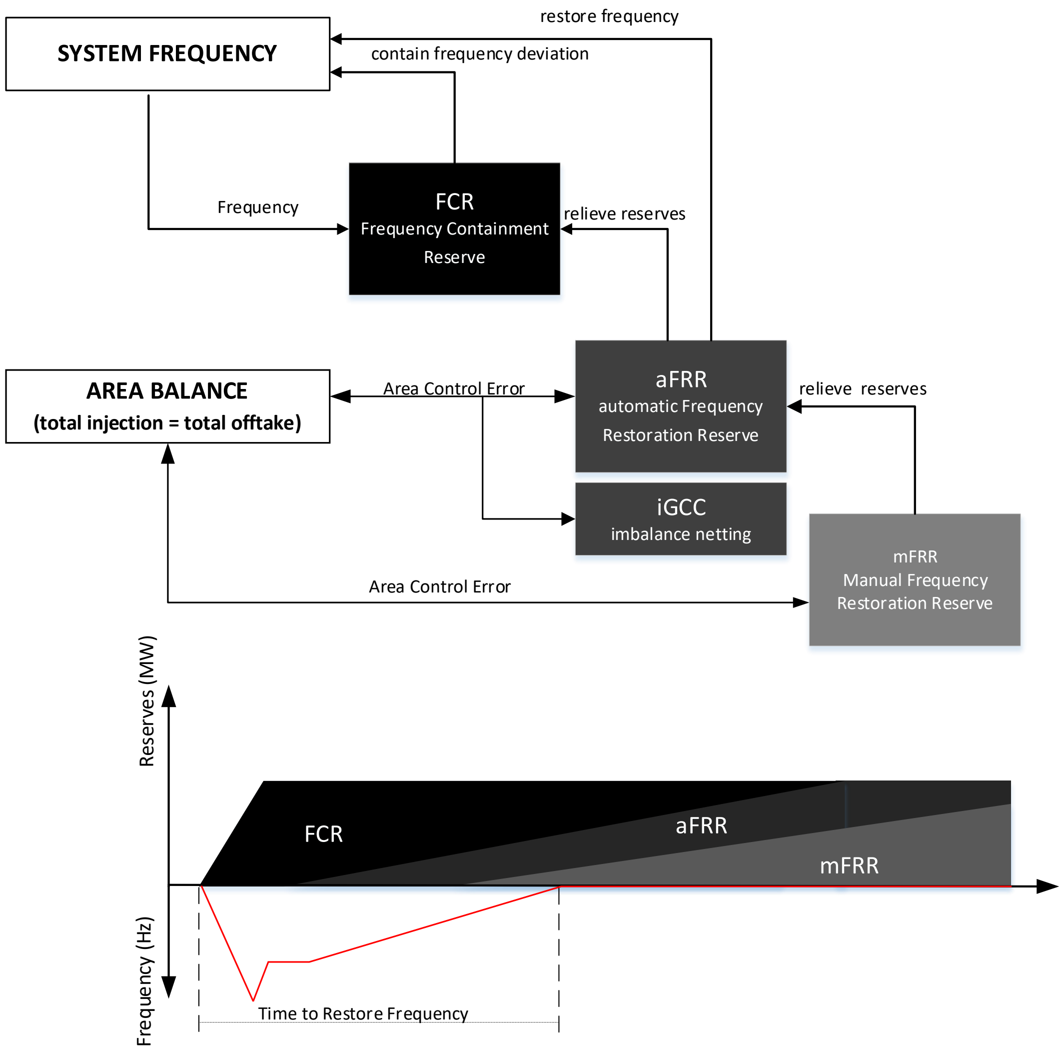
Why? After presentation of the executive summary in the TF MOG 2, stakeholders requested for in depth discussion. In general, stakeholders requested visibility on evolutions of future reserve capacity / balancing capacity.

Present reserve projections to stakeholders as these will be integrated as input in upcoming studies and assessments

General introduction on reserve dimensioning



Intro: European reserve dimensioning framework



1. The **Frequency Containment Reserve (FCR)** is used to stabilize the frequency and contain frequency deviations in the synchronous area

Dimensioning on ENTSO-E level methodology in line with SO Regulation and implemented in SAFA

Dimensioning based on reference incident, complemented by probabilistic method (as from 2024)

Allocated to LFC blocks based on weight in generation and demand

2. The **Frequency Restoration Reserve (FRR)** must free up the FCR of the synchronous zone and ultimately bring the frequency to its nominal value, Each control area is therefore obliged to maintain its balance which is monitored by means of the Area Control Error (ACE)
    1. The automatic FRR (aFRR) is mainly used to compensate for short and random imbalances.
    2. The manual FRR (mFRR) serves as compensation for long, persistent and/or very extensive imbalances

Dimensioning by Elia in line with SO Regulation and implemented national regulatory framework

Dimensioning based on dimensioning incident (N-1) and probabilistic method (system imbalances)

Intro: National reserve dimensioning framework

- In line with **Article 157 of the SO Regulation**, **Elia determines the reserve needs (FRR / aFRR / mFRR needs)***
  - *FRR / mFRR needs are dimensioned dynamically, i.e. on a daily basis based on expected system conditions;*
  - *Elia presented in 2020 an implementation plan for a dynamic dimensioning of aFRR needs.*

LFC block operational agreement

FRR needs
- aFRR needs
- mFRR needs

LFC Means

- Availability of reserve sharing with other regions
- Availability of non-contracted balancing energy bids
- aFRR balancing capacity
- mFRR balancing capacity

- In line with **Article 32 of the EBGL**, **Elia determines in its LFC Means the optimal provision of reserve capacity** taking into account sharing of reserves, the volumes of non-contracted balancing energy bids and the procurement of balancing capacity. This is currently still based on a 'static' approach.
  - *Elia calculates on a periodic basis the availability of non-contracted capacity balancing energy bids and the availability of shared FRR capacity;*
  - *Potential 'firm' capacity is subtracted from the required mFRR / aFRR needs in order to determine Elia's balancing capacity (to be procured);*
  - *Elia presented an implementation roadmap of dynamic balancing capacity calculation towards 2027.*

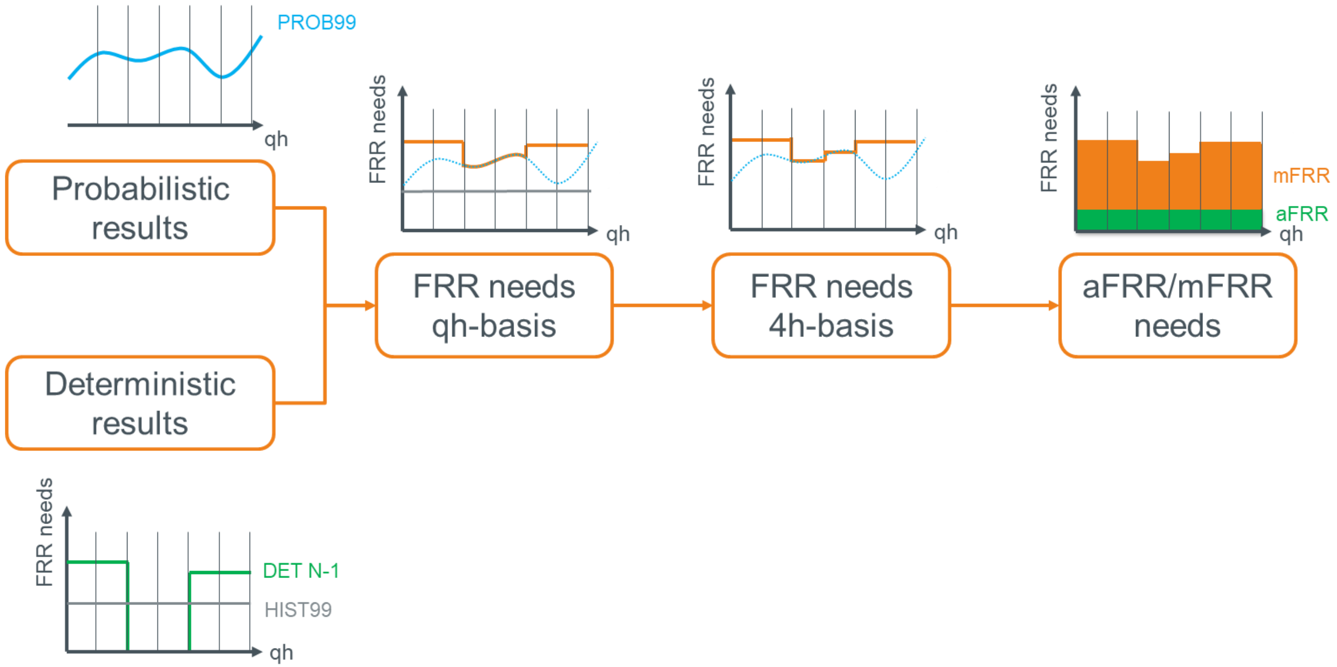
The methodologies are specified in Elia's LFC block operational agreement and the LFC Means, both documents subject to public consultation and regulatory approval

Dynamic dimensioning of the FRR needs

Specified in Elia's LFC block operational agreement

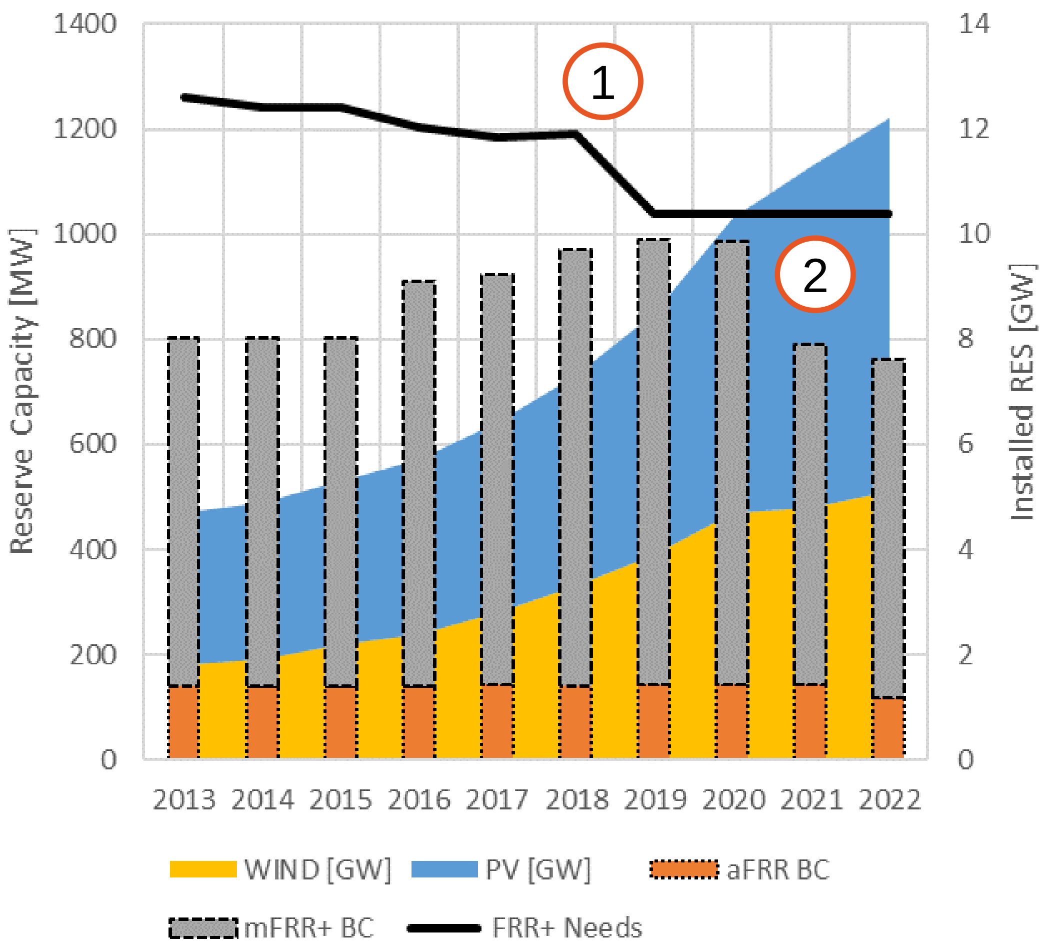
- FRR reserve capacity is determined based on a probabilistic methodology in line with Article 157(2)b of the SOGL covering 99.0% of the LFC block imbalance risks

- It takes into account two deterministic thresholds :
  - Always larger as the dimensioning incident in line with Article 157(2)e and Article 157(2)f
  - Always covering 99.0% of historic LFC block imbalances in line with Article 157(2)h and Article 157(2)i



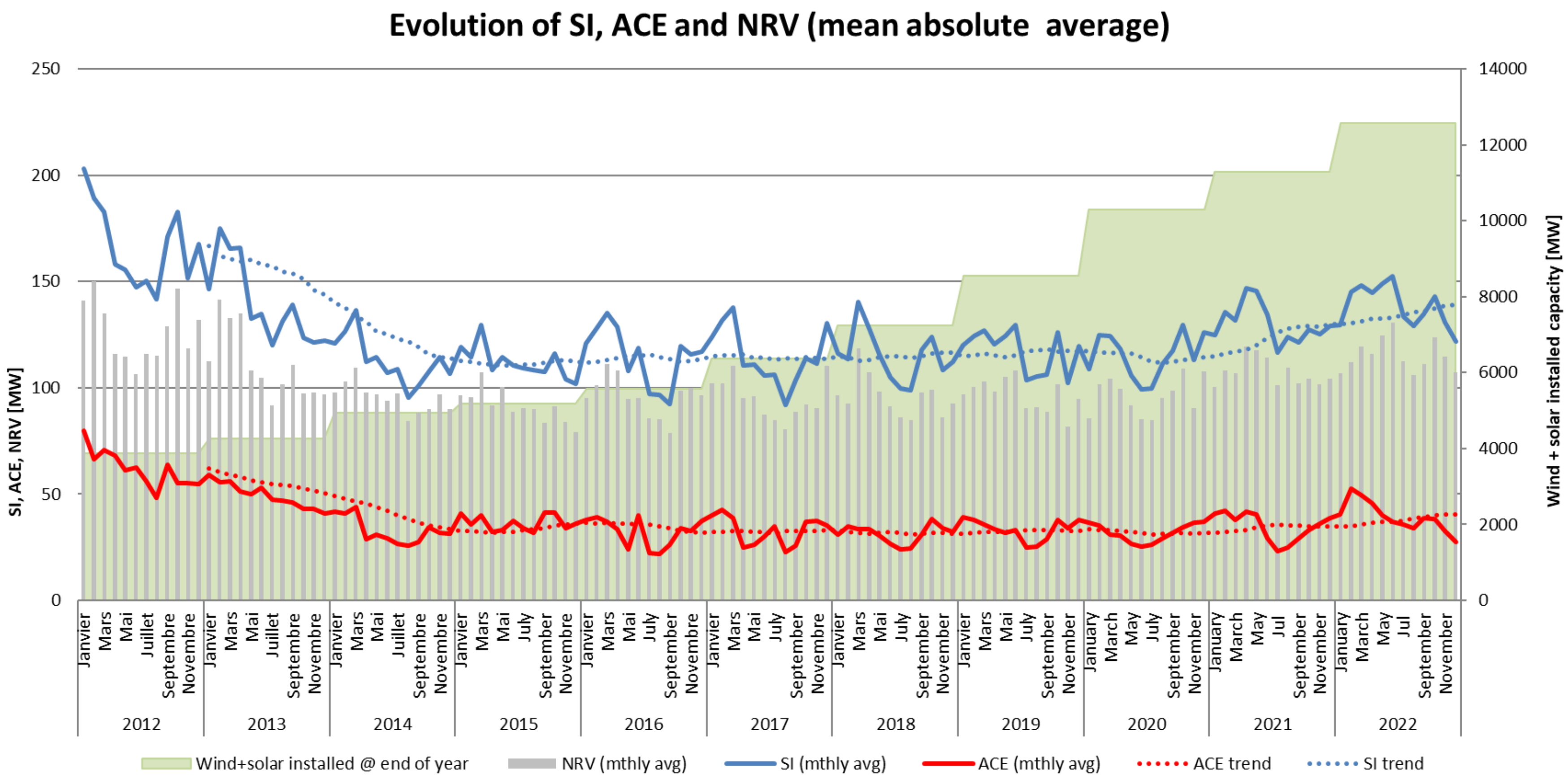
The required positive and negative reserve capacity on FRR is calculated by Elia each day before 7 AM for every period of 4 hours of the next day

Historic trend : managing more with less



- Elia's FRR needs and balancing capacity requirements were gradually reduced, despite the gradual increase in renewable energy
  - Wind and solar installed increased from around 4 GW in 2013 to over 12 GW in 2022
- Explained by the reliability reduction in line with SOGL (99.0%) together with the introduction of dynamic dimensioning in 2019-20 (1)
  - Dynamic dimensioning allows better volume / risk managed following dimensioning closer-to-real-time
  - In addition, balancing capacity requirements were reduced increasing the contribution of reserve sharing with multiple neighbours (2)
- aFRR needs (equal to balancing capacity requirements) remained relatively stable until 2022 (cf. request for amendment of CREG)

System imbalance quality remained stable until 2021, but recently started to increase



- System imbalances and area control error remained relatively stable until 2021
- Increasing trend in system imbalance and area control error is noticed in 2022

System evolutions with impact on reserve dimensioning

- **General renewable developments and offshore developments as from 2028 are expected to increase flexibility and reserve needs (cf. adequacy and flexibility study 2021)**

- **But additional flexibility is expected to become accessible through consumer flexibility (as from 2023-24) :**
  - Elia's CCMD proposals are expected to unlock new flexibility providers
  - Following Elia's Adequacy and Flexibility study 2032, Elia's aims to stop procuring mFRR, most of the time, after 2032
  - Elia communicated an implementation planning for dynamic procurement strategies as from 2027 in order to reduce mFRR balancing capacity procurement following the availability of non-contracted balancing energy bids.

- **Regional balancing market integration**
  - MARI / PICASSO are expected to give access to additional non-contracted balancing energy bids as from 2023
  - Proposals on regional sizing and procurement (legal framework of the clean energy package) will give a role to Regional Coordination Centers in reserve dimensioning : current proposals focus on :
    - regional limits of sharing agreements (coordination of regional risks such as adequacy, storms)
    - contribution of non-contracted balancing energy bids (in excess of reserve capacity needs)

PART 1 – Elia’s proposal for the new aFRR dimensioning method

Intro: status aFRR dimensioning

The past

‘Static’ methodology for calculating the aFRR needs for the upcoming year

Based on covering 79% of expected 15’ LFC block imbalances variations

- aFRR needs are determined symmetrically based through the absolute values of the variations
- Expected 15’ LFC block imbalances result from an upscaling of 15’ historic LFC block imbalances (based on forecast errors of incremental renewable capacity)
- Reliability level is determined based on acceptable historic FRCE-quality

For 2020, the aFRR needs increased to 151 MW but the volume was ‘freezed’ to the former value of 145 MW while awaiting new method

The current

In July 2021, Elia updated the aFRR needs following a request for modification of the CREG, and market context (gas crisis impacing price of balancing capacity)

Based on an update of the ‘static’ methodology, complemented with imbalance netting

- 15’ historic LFC block imbalance variations are calculated after taking into account imbalance netting

Based on this calculation, a volume reduction resulting in a symmetrical 117 MW aFRR capacity was justified

It was stressed this had to be seen as a temporary, short-term measure, while awaiting implementation of a more enduring method

The future

At the end of 2020, Elia recommended a new aFRR dimensioning methodology following a study (link)

Elia recommended a dynamic probabilistic method to determine the aFRR needs for the next day

- The method determines aFRR needs to cover 99% of the simulated aFRR activations for the next day
- Based on machine learning algorithms to capture historic behavior of LFC block imbalances and imbalance netting

The proposed implementation plan was delayed following discussions with CREG on the role of the FRCE target parameters in the methodology.

Based on these discussions, the methodology has now been elaborated with an FRCE feedback loop

General overview of the new method

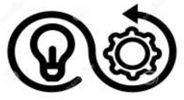
SUMMARY

- In 2020, Elia recommended after public consultation a **dynamic probabilistic method** in its aFRR dimensioning study..
  - The method was designed to cover 99% of the expected aFRR activations (based on 5' system imbalances, imbalance netting and simulated mFRR activations)
  - The method determines the aFRR needs for the next day with help of machine learning algorithms based on the aFRR activation risk
  - The method dimensions the aFRR needs in order to maintain the FRCE close to zero and minimize Elia's contribution to European frequency deviations

- Following discussions with CREG on the role of the FRCE target parameters in aFRR dimensioning, considered to be the legal minimum requirements, Elia proposes to complement the method with an **FRCE feedback loop** based on Elia's FRCE performance in the previous month and year. This enables to achieve :
  - Absolute aFRR needs reductions when facing structural over-performance on these legal minimum requirements (or vice versa) ➔ Elia is currently over-performing
  - Seasonal aFRR needs reductions when facing seasonal over-performance in (or vice versa) ➔ Elia observes higher performance during Summer than Winter

- By means of implementing **caps and floors on the correction of the probabilistic aFRR needs** brought by the FRCE feedback loop:
  - The method recognizes that 15' FRCE target parameters are not the unique dimensioning criteria, but do have an impact (other criteria like DfD, 5' interval fluctuations,… are still considered)
  - Sudden or extreme variations of the aFRR needs are avoided which may hamper market stability while ensuring a fair contribution to the European frequency stability
    - ENTSO-E recommends to not use current FRCE target parameters as dimensioning criteria (as such these are included in the method as an automatic correction rather than a dimensioning criterion)
    - The calculation of the FRCE target parameters is currently under discussion withing and ENTSO-E and expected to be gradually tightened, with a first revision foreseen as from May 2023
    - Following evolution of the FRCE quality and FRCE target parameters, the caps and floors can be re-assessed (after assessing evolution of the intra-15' FRCE, and Elia's contribution to frequency deviations)

Implementation



- Elia proposes an implementation towards 1.10.2024
  - IT implementation can be ready as from 30.06.2024, the latest
  - Launch parallel run on 01.07.2024 until 30.09.2024 to gain experience on the results
  - Effective implementation of the method by 01.10.2024

- Projections on the probabilistic result of the aFRR needs dimensioning reveal that these can increase up to average needs of 170 MW in 2024 (with variations from day-to day between 160 MW and 210 MW)
  - The implementation of a feedback loop based on FRCE quality is expected to bring back these average aFRR needs to 119 MW, with minima up to 109 MW and maxima up to 163 MW.
  - Following daily variations, these can not exceed an absolute interval of [109 MW; 245 MW), resulting from the caps and floor
  - Elia expects that aFRR volumes will increase over time (towards 2026) to the probabilistic result when FRCE target parameters are tightened by ENTSO-E given issues with frequency quality. In such case the feedback loop will lead to lower decrease (or potentially even an increase) of the volumes.
  - Note that the aFRR needs are currently fixed at 117 MW. This volume will be maintained until the implementation of the new method (foreseen on 1.10.2024, the latest)

Re-cap of the conclusions of the aFRR dimensioning study

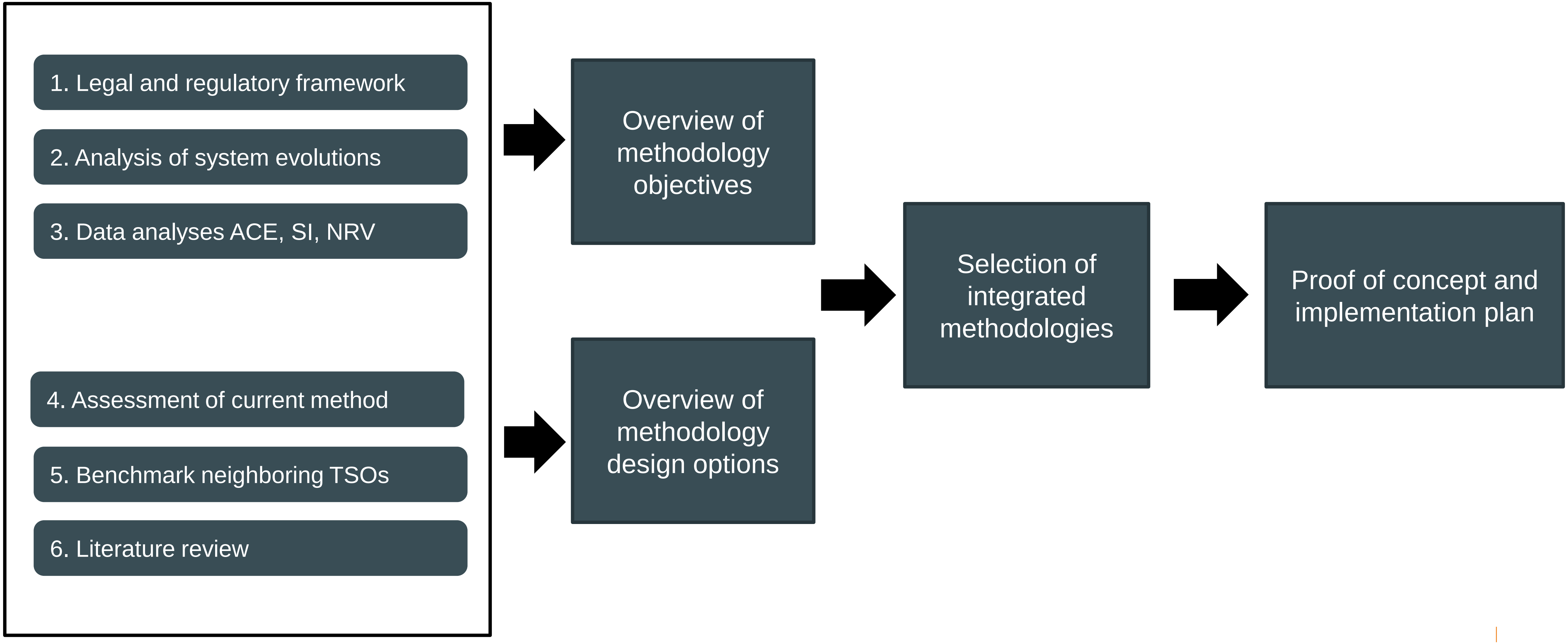
Subject to a public consultation in June 2020 (link consultation page)

Objectives of aFRR dimensioning methodology

- **Meet the legal L1 & L2 criteria in line with SOGL Article 128 and shall endeavor to restore the ACE / FRCE (ACE = 0) within 15 minutes in line with SOGL Article 152(9)**
  - Temporary deviations are netted or resolved by FCR
  - The L1 & L2 criteria are minimum thresholds which are legally imposed which are largely met by most TSOs (including Belgium)
- **Cover FRCE and LFC block imbalance variations within 5.0 – 7.5 minutes (FAT of aFRR)**
  - Note that forced outages are typically covered by FCR and mFRR (after 15 minutes)
- **Consistent with a tender design of the aFRR product** (daily dimensioning with 4-hour resolution)
- **Robust towards future system evolutions** (2nd wave of offshore wind power, further balancing market integration)
- **Avoid disruptive aFRR volume evolutions upon introduction of a new methodology**

Although there are no specific legal requirements for aFRR dimensioning (such as exist for mFRR), the dimensioning should at the same time respect minimum legal requirements (FRCE target parameters) and ensure a fair contribution of Elia LFC block to the European frequency quality.

Analyses to find a new aFRR dimensioning methodology



Recommended methodology

The aFRR needs are dimensioned to cover 99% of simulated aFRR activations based on historic LFC block imbalances (SI), iGCC activations and simulated mFRR activations.

$$\text{Simulated aFRR activations}_t = SI_t - \text{Simulated mFRR activations}_t - IGCC_t$$

Input data

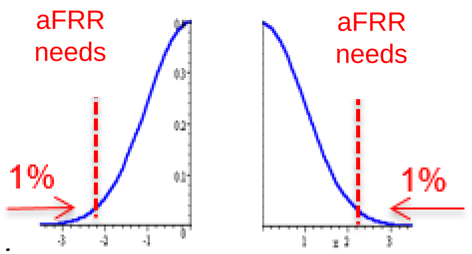
- 5' averaged LFC block imbalances for a period of 2 years before the calculation
- 5' iGCC activations for a period of 2 years before the calculation

Calculations

- *Filter out all periods with forced outages of large units*
- Simulate mFRR activations per bloc of 15 minutes based on perfect LFC block forecasts*

Results

- Simulate aFRR activations 5 minutes by correcting for simulated mFRR and iGCC activations



*Various implementation options were tested and assessed towards result, robustness and alignment with dispatch operations

Dynamic aFRR dimensioning method

- It is investigated if the aFRR needs can be dimensioned based on day-ahead predicted system conditions, similar to the FRR dimensioning process. Machine learning algorithms are trained to capture relations between the features (predicted system conditions) and the dependent variable (aFRR simulations) :

Features

The machine learning methodologies rely on the following features :	
5’ Renewable generation and load forecasts	The day-ahead forecast (in MW) of onshore, offshore, solar photovoltaic and total load (where needed interpolated from 15’ resolution data)
5’ Renewable generation and load forecast variations	The gradients (in MW) of solar and total load calculated as the difference between two quarter-hour day-ahead predictions
5’ Scheduled leaps	The difference between the hourly averaged predicted residual load (total load minus renewable generation) and the 15’ values. Also the absolute value of the scheduled leaps is included as separate feature
15’ Weather predictions	The day-ahead predicted temperature (in °C) and solar irradiation (where needed interpolated from 5’ resolution data)
Time features	Month of year, day of week and hour of day (in h)

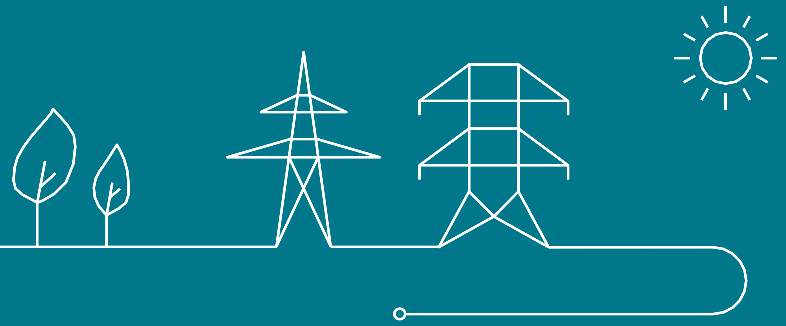
Dependent variable

To predict one sizing variable representing the aFRR needs :	
5’ aFRR simulations	Based on averaging 1’ LFC block imbalances and iGCC activations

Machine learning **best practices are followed**

- Data gathering, data cleaning
- Split train/test set and cross validation
- Simple model analysis
- Complex model analysis
- Comparative study with adapted KPIs

Implementation of the probabilistic aFRR dimensioning methodology



The dynamic probabilistic methodology remains the engine of the methodology

- The method used is one where the aFRR needs are dimensioned to cover 99% of simulated aFRR activations based on historic LFC block imbalances, iGCC and mFRR activations.

$$\text{Simulated aFRR activations}_t = SI_t - \text{Simulated mFRR activations}_t - IGCC_t$$

- After quantitative analysis, a resolution of 5' (aligned with foreseen aFRR FAT)
- Time series are filtered to remove forced outages (no objective of aFRR dimensioning)

- An oracle-based method has been put forward assuming activations on 'perfect' foresight
- A dispatch-based method resulted in higher complexity, intertwines dispatch and dimensioning discussions and resulted in elevated aFRR needs

- iGCC shall be taken into account via observed activated iGCC volumes during same periods (more accurate / straightforward as simulations for a dynamic method)

- The aFRR needs can be dimensioned based on day-ahead predicted system conditions, similar to the FRR dimensioning process. Machine learning algorithms are trained to capture relations between the features (predicted system conditions) and the dependent variable (aFRR simulations)

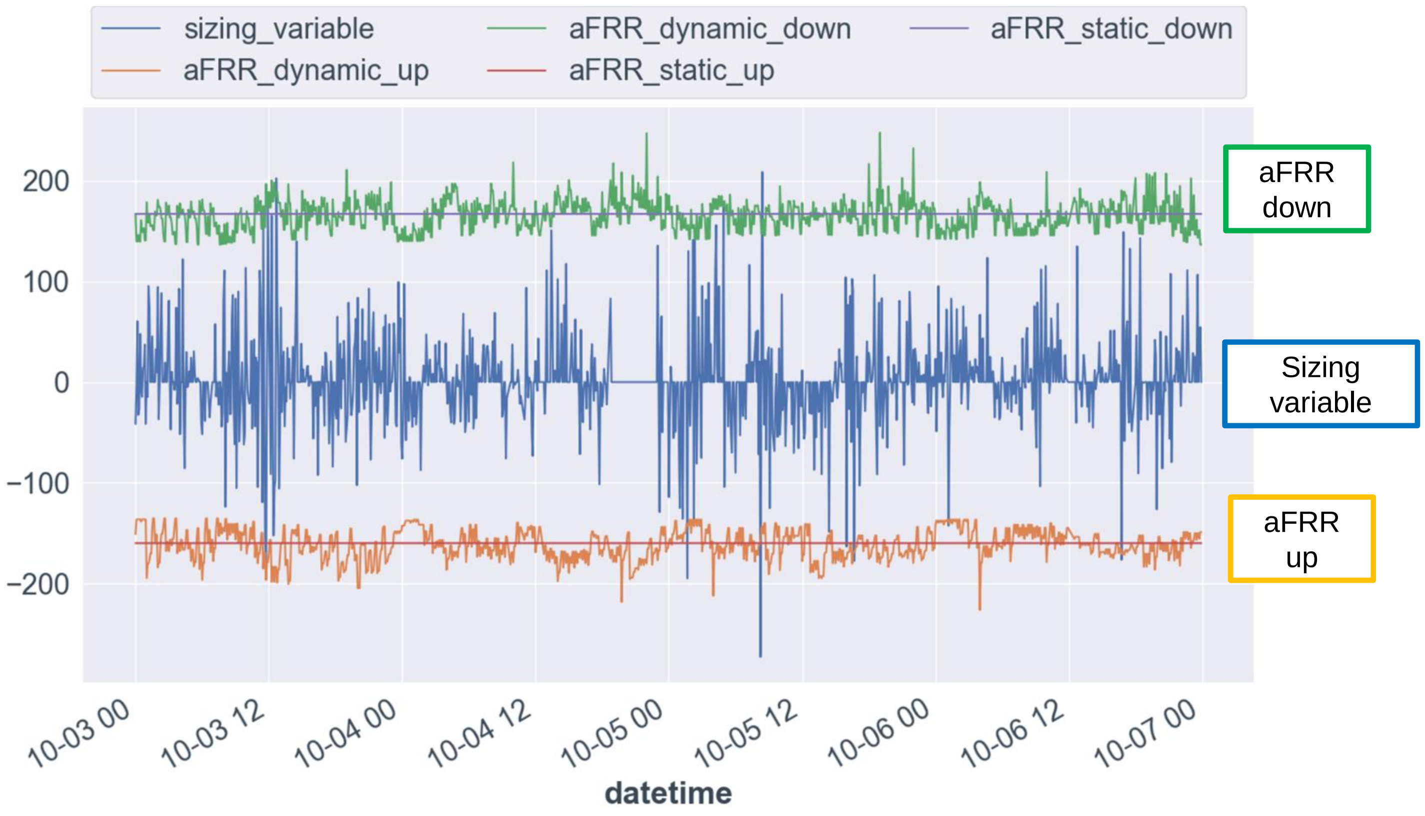
Back casting of historic aFRR needs trough the dynamic probabilistic methodology

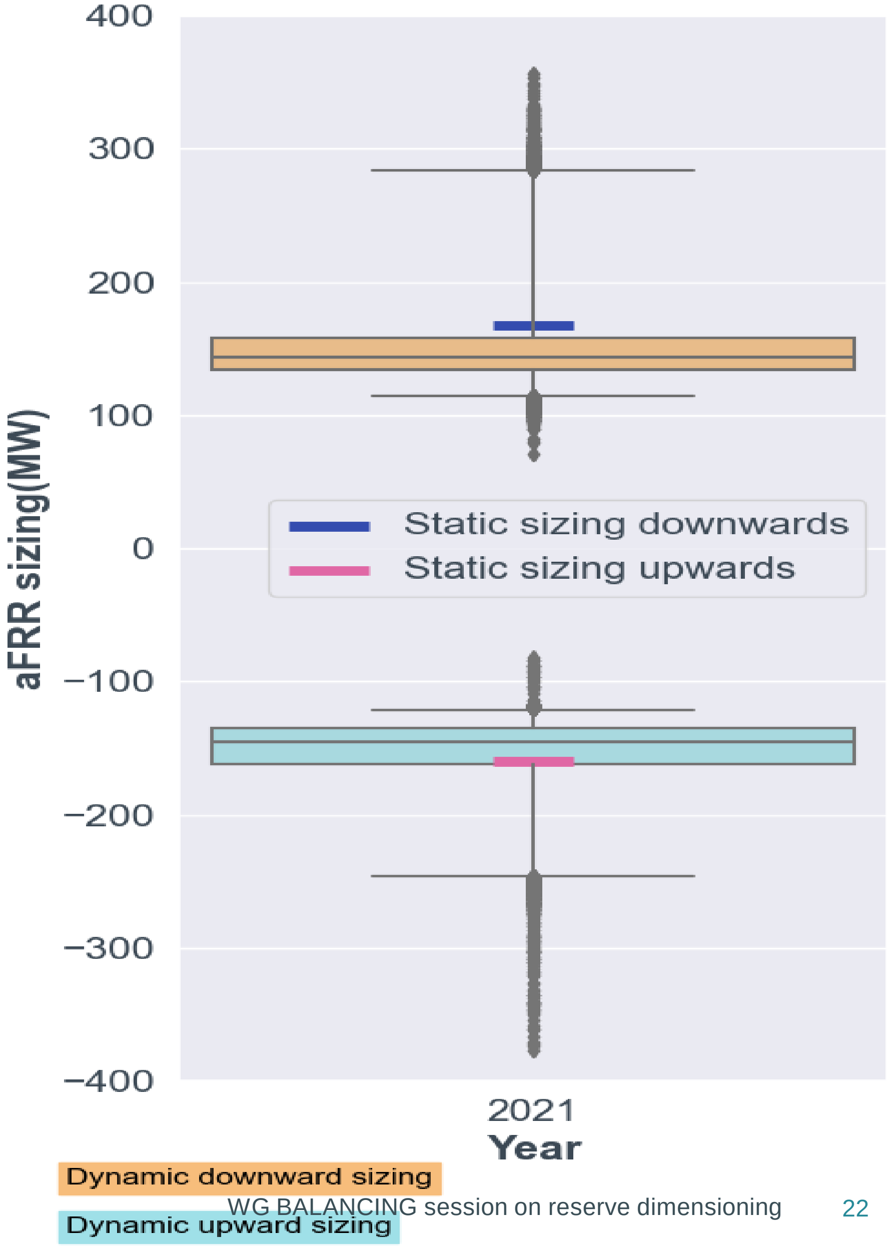
- Calculations of the aFRR dimensioning study (based on data 2018-19) are updated for 2020-21
- Based on the machine learning algorithm presented in 2020 study (random forests algorithm)
- Results represent average FRR needs based on a 5' minute resolution

Static	aFRR dimensioning study 2018-19	Update 2020-21
aFRR needs up	151	160
aFRR needs down	145	167

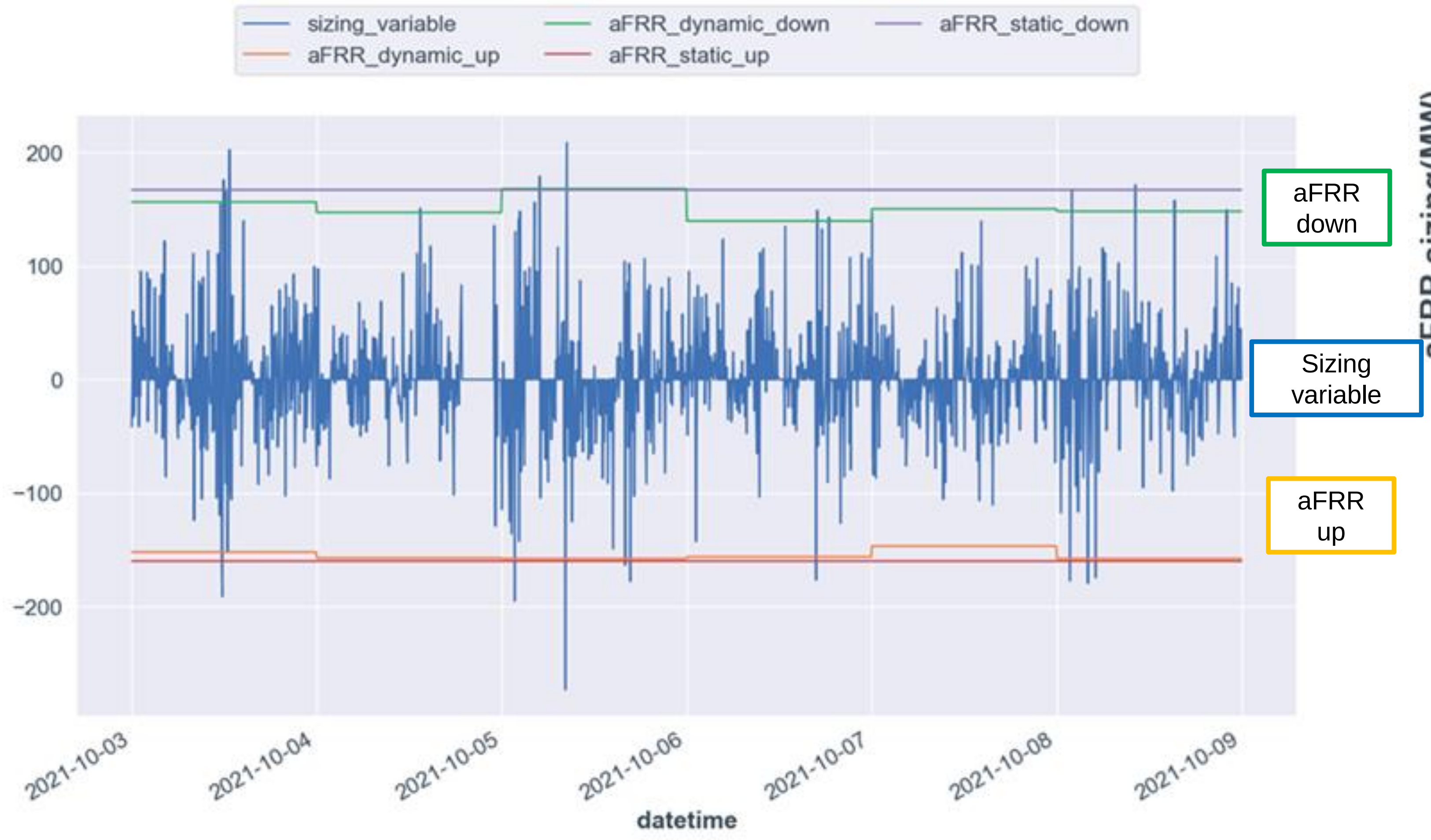
Dynamic	2018-19	2020-21
aFRR needs up	143	153
aFRR needs down	153	158

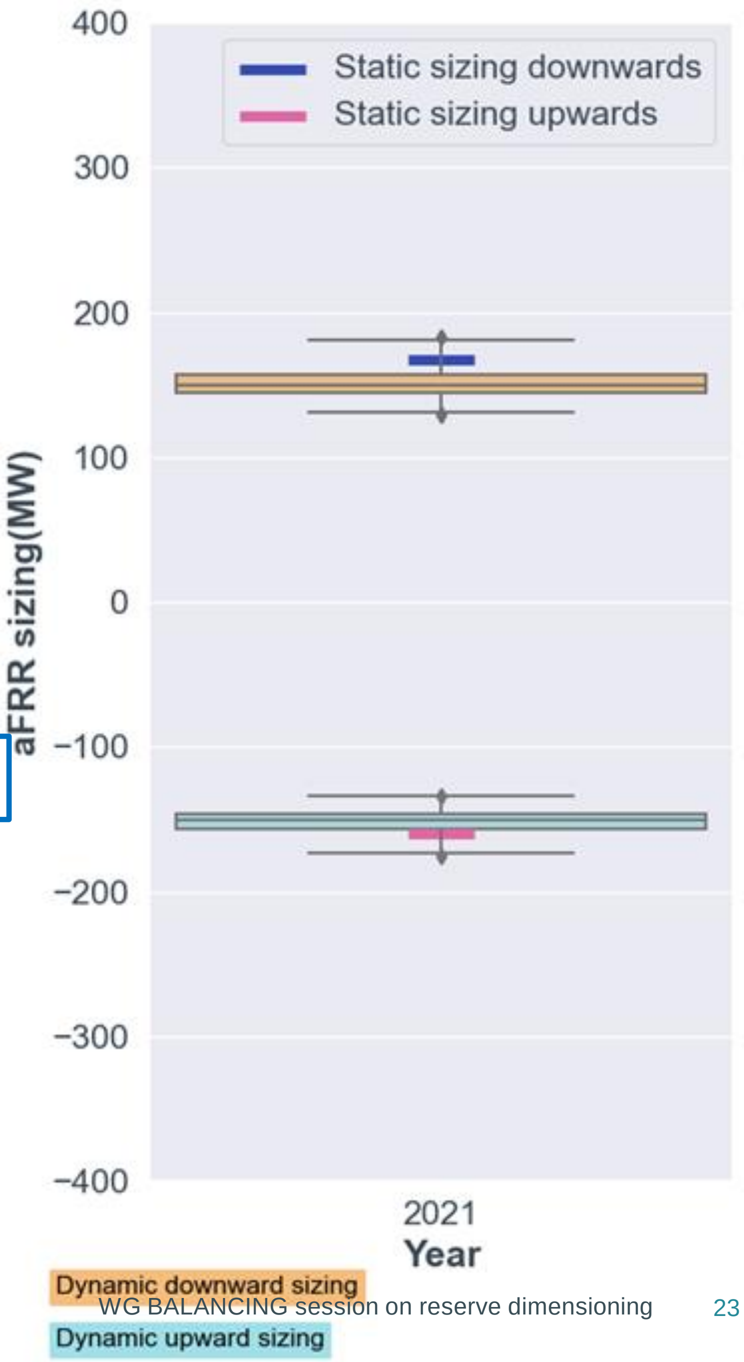
Example of the dynamic approach in two different days (2021), with one output per 5-minute





Example of the dynamic approach in two different days (2021), with one output per day





Further specifications

- The calculation will be integrated in the FRR dimensioning process, i.e. the results of the FRR, aFRR and mFRR needs, as well as the aFRR and upward mFRR balancing capacity for the next day will be **published before 7 AM D-1 on Elia's website**

- In line with the auction design of aFRR, Elia will determine **one separate value for the aFRR upward, and one value for downward for the next day**. This value will be determined by the average over all periods of 5 minutes for the corresponding period (daily basis following current mFRR tender design)

- The specifications of the machine learning algorithm will be specified in the **LFC block operational agreement** (subject to consultation, and approval)

Introduction of the feedback loop based on FRCE target parameters

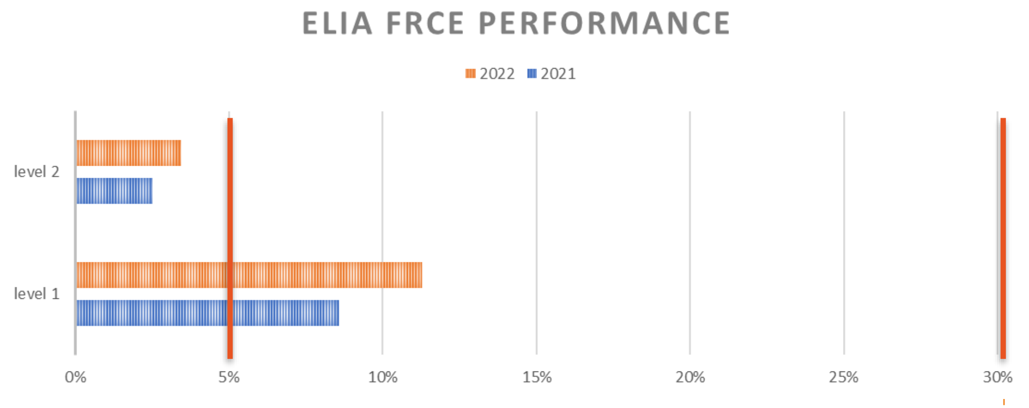
Introduction of the FRCE feedback loop

- In 2020, Elia recommended a **dynamic probabilistic method** in its aFRR dimensioning study..
  - The method was designed to cover 99% of the expected aFRR activations (based on 5’ system imbalances, imbalance netting and simulated mFRR activations)
  - The method determines the aFRR needs for the next day with help of machine learning algorithms based on the aFRR activation risk
  - The method dimensions the aFRR needs in order to maintain the FRCE close to zero and minimize Elia’s contribution to European frequency deviations

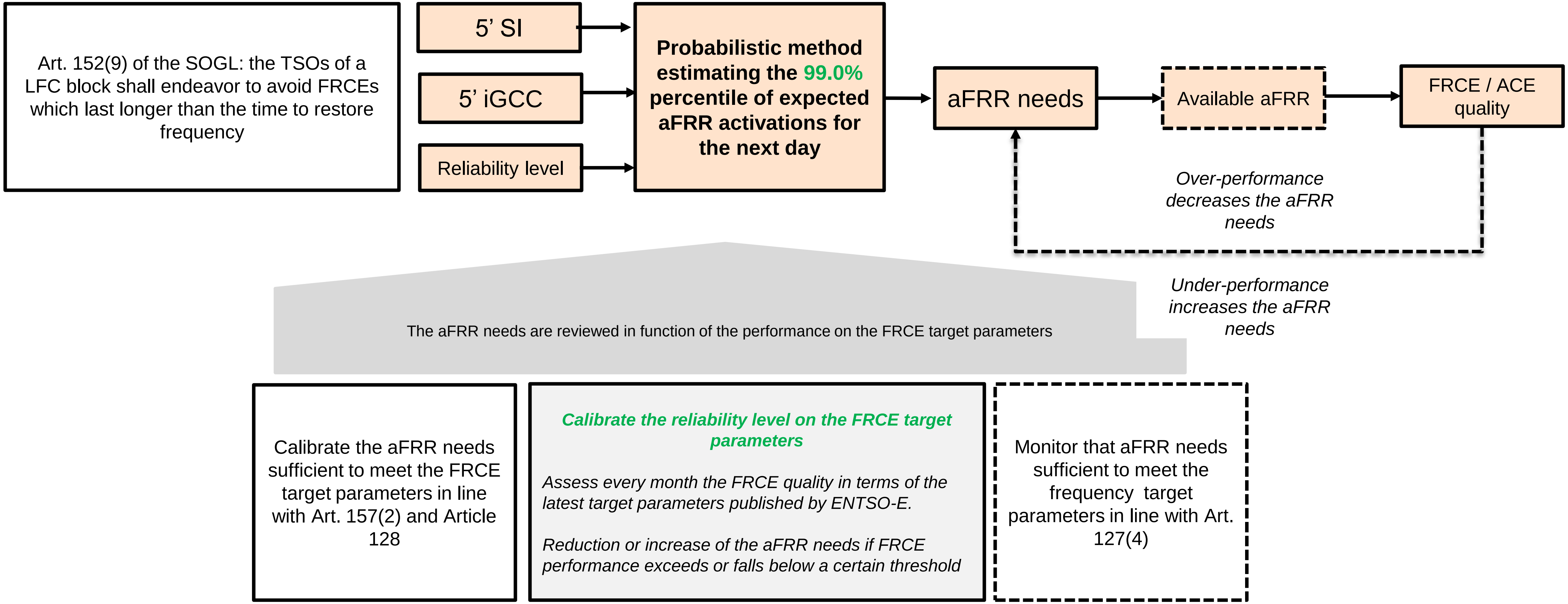
- Following discussions with CREG on the role of the FRCE target parameters in aFRR dimensioning, considered to be the legal minimum requirements, Elia proposes to complement the method with an **FRCE feedback loop** based on Elia’s performance in the previous month and year. This enables to achieve :
  - Absolute aFRR needs reductions when facing structural over-performance on these legal minimum requirements (or vice versa) ➔ Elia is currently over-performing
  - Seasonal aFRR needs reductions when facing over-performance in certain months or seasons (or vice versa) ➔ Elia observes higher performance during Summer than Winter

The number of time intervals per year outside the Level 1 FRCE range (Level 2 FRCE) range within a time interval equal to the time to restore frequency shall be less than 30 % (5%) of the time intervals of the year

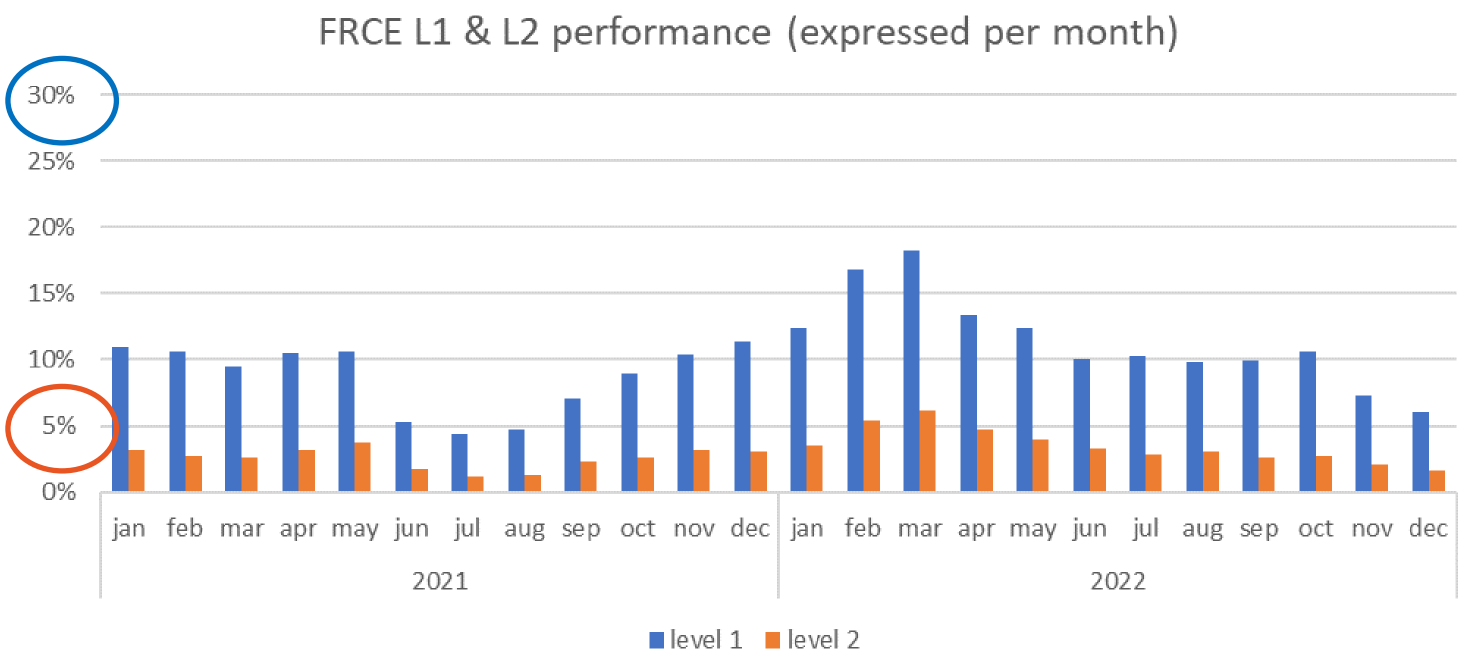
- Time interval is currently set at 15 minutes
- The current FRCE range for Belgium is determined by ENTSO-E at
  - 98 MW (level 1) and 186 MW (level 2), until May 2023
  - 85 MW (level 1) and 160 MW (level 2), as from May 2023



The feedback loop complements the probabilistic method to adapt the aFRR needs in function of the performance on the FRCE target parameters



Objectives of the feedback loop



**percentages assuming 30 days per month*
**performance calculated based on L1 & L2 targets as from May 2023 (85 MW, 160 MW)*

1. **Capture absolute performance on legal FRCE target parameters**
   - Based on the performance on the legal FRCE target parameters in the previous year
   - Used to determine a correction factor which increases / decreases aFRR needs for the upcoming year
   - Note that the Elia LFC block FRCE quality is below the annual FRCE target parameters in 2021 and 2022 (but shows a deteriorating trend)

2. **Capture relative performance variations on FRCE control quality within the year**
   - Based on the performance on the FRCE target parameters in the previous month
   - Used to determine a correction factor which increases / decreases aFRR needs for the upcoming month
   - Note that the Elia LFC block FRCE quality seems to show higher FRCE quality during Summer than Winter

Caps and floors to ensure market stability and Elia's contribution to European frequency stability

- By means of implementing **<u>caps and floors on the correction of the probabilistic aFRR needs</u>** brought by the FRCE feedback loop:
  - The method recognizes that 15' FRCE target parameters are not the unique dimensioning criteria, but do have an impact (other criteria like Deterministic Frequency Deviations, 5' interval fluctuations,… are still considered)
  - Sudden or extreme variations of the aFRR needs are avoided which may hamper market stability while ensuring a fair contribution to the European frequency stability
    - ENTSO-E recommends to not use current FRCE target parameters as dimensioning criteria (as such these are included in the method as an automatic correction rather than a dimensioning criterion)
    - The calculation of the FRCE target parameters is currently under discussion withing and ENTSO-E and expected to be gradually tightened, with a first revision foreseen as from May 2023
    - Following evolution of the FRCE quality and FRCE target parameters, the caps and floors can be re-assessed (after assessing evolution of the intra-15' FRCE, and Elia's contribution to frequency deviations)

Implementation of the feedback loop

- **Step 1:** calculate the y-1 and m-1 performance
  - Calculate percentage of time L1 (e.g. 160 MW) and L2 (e.g. 85 MW) range are exceeded
  - Express as percentage of target parameters (L1 5%; L2 30%), corrected with a margin of 20%
    - *The margin avoids undesired FRCE quality evolutions following the lag of one month / year*

- **Step 2 :** calculate the final correction factor
  - Cap / floor the y-1 and m-1 performance to 80% / 120% of the probabilistic result
  - Multiply the maximum of the L1 & L2 y-1 performance with the maximum of the L1 & L2 m-1 performance
    - *Cap / floor of aFRR needs increase / decrease of the probabilistic aFRR needs to avoid extreme variations and maintain market stability (in view of future evolutions of the FRCE target parameters, dynamic probabilistic results, FRCE quality evolutions*

- **Step 3 :** calculate the corrected aFRR needs
  - Multiply the daily probabilistic result with the final correction factor
  - Cap / floor the final result to 64 / 144 % of the rolling average of the probabilistic result over 12 months

Impact assessment (for 2024)

- Projections of the probabilistic dynamic result foresee an average aFRR needs of 170 MW in 2024 for Elia's realistic optimistic scenario
  - More information on the scenarios and projection in the next part of this session on reserve dimensioning
  - Variations of the aFRR needs from day-to day are expected between 160 MW and 210 MW)

- The feedback loop is applied on historic 15' FRCE data for 2021 (to assess y-1 performance) and 2022 (m-1 performance)
  - The implementation of a feedback loop based on FRCE quality is expected to bring back these average aFRR needs to 119 MW, with minima up to 109 MW and maxima up to 163 MW.
  - The daily variations cannot exceed an absolute interval of [109 MW; 245 MW), resulting from the caps and floor
  - Elia expects that aFRR volumes will increase over time (towards 2026) to the probabilistic result when FRCE target parameters are tightened by ENTSO-E given issues with frequency quality. In such case the feedback loop will lead to lower decrease (or potentially even an increase) of the volumes.

- *A deterioration of the performance compared to the previous month when facing structural over-performance in the previous year will brake potential aFRR increases (cap is 96%, i.e. 80% * 120%)*
- *A deterioration of the performance compared to the previous month when facing structural over-performance will not result in a further decrease of the aFRR needs*

month	performance l1	performance l2	yearly correction	monthly correction	final correction	aFRR [MW]
2021	36%	63%		[redacted]	[redacted]	[redacted]
Jan-22	47%	76%		80%	64%	109
Feb-22	52%	87%		87%	69%	118
Mar-22	70%	135%		120%	96%	163
Apr-22	76%	155%		120%	96%	163
May-22	56%	119%		119%	95%	162
Jun-22	52%	98%	80%	98%	78%	133
Jul-22	42%	82%		82%	66%	112
Aug-22	43%	71%		80%	64%	109
Sep-22	41%	78%		80%	64%	109
Oct-22	42%	65%		80%	64%	109
Nov-22	44%	69%		80%	64%	109
Dec-22	30%	52%		80%	64%	109

- *L1 and L2 range as from May 2023 (communicated by ENTSO-E)*
- *Monthly performance L1 and L2 expresses performance of previous month on 80% of the level 1 and level 2 FRCE target parameters (data 2022)*
- *Yearly performance L1 and L2 expresses performance of previous year on 80% of the level 1 and level 2 FRCE target parameters (data 2021)*
- *Monthly and yearly correction are floored / capped at 80% / 120%.*
- *The final correction is calculated as the multiplication of both corrections factors and applied on the estimated average probabilistic result of 170 MW (2024)*
- *Additional caps of 64% / 144 % are put on the average dynamic probabilistic (after feedback loop) result over the last 12 months*

Next steps

- Launch consultation is foreseen on 24.02.2023
  - Consultation until 21.03.2023 (4 weeks)
  - Submission proposal to CREG the latest on April 19, 2023
- Implementation foreseen on 1.10.2024
  - IT implementation ready as from 30.06.2024, the latest
  - Launch parallel run on 01.07.2024 until 30.09.2024 to gain experience on the results
  - Effective implementation of the method by 01.10.2024

Until that date, aFRR needs will remain at 117 MW (symmetric)

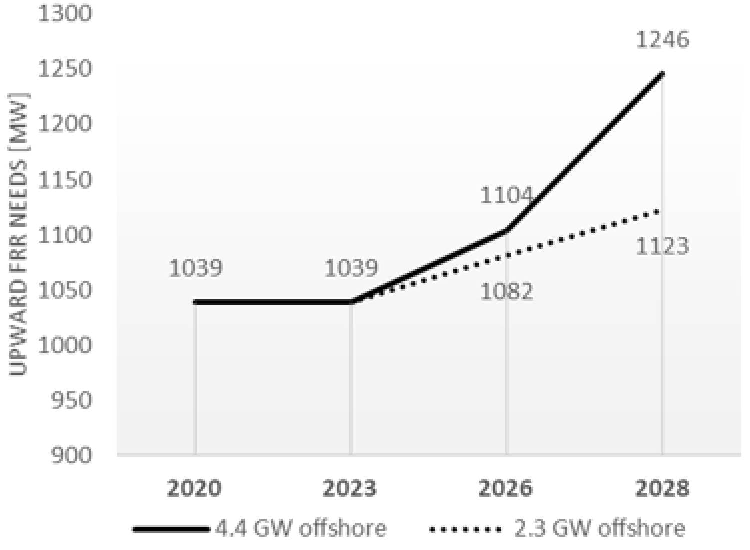
PART 2 – Reserve needs and balancing capacity projections

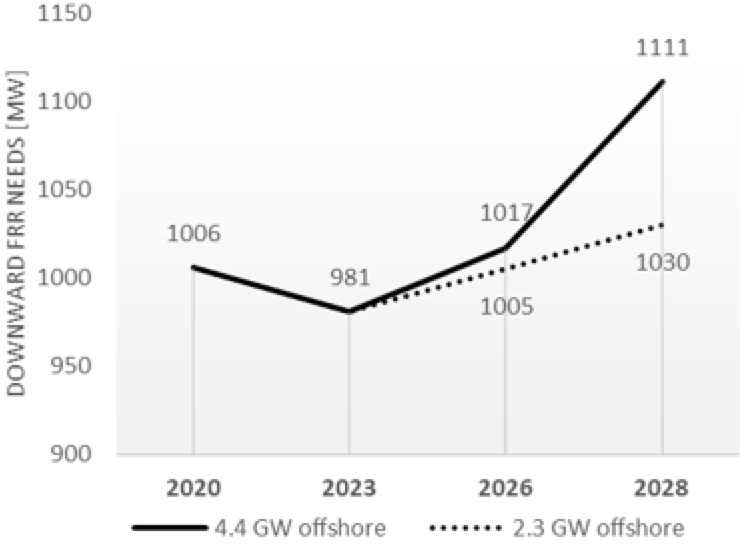
Introduction and reminder study 2020

- **In view of its responsibility to maintain system security and balance the system, Elia dimensions and procures reserve capacity to manage residual imbalances which are not covered by the market**
  - As with the integration of other variable renewable generation such as onshore wind and solar power, the integration of offshore wind power is expected to increase Elia's reserve requirements due to its variability and limited predictability
- **The MOG 2 study (2020) investigated the effect of offshore wind power on the FRR reserve needs :**
  - It concluded that Elia's **reserve capacity requirements are expected to face an increasing trend** following the integration of additional offshore wind power capacity, as well as the increasing capacity of other renewables.
  - It is found that the **market performance** (i.e. the ability of BRPs to balance their portfolio) can substantially impact the future FRR needs
  - A **dynamic dimensioning methodology** will help managing the impact of these increasing needs, taking into account the observed market performance
  - Note that **no specific mitigation measures to limit the effect of offshore wind power on reserves** were proposed except for general measures strengthening the ability and incentive for market players to balance their portfolio.

These figures were used to provide transparency and visibility to stakeholders but remain Elia's best estimations based on expected system evolutions. ***Final reserve needs and balancing capacity procurements are determined close to real-time following the methodologies consulted and approved in the LFC block operational agreement and LFC Means.***

MOG 2 study (2020)
3.0 GW offshore wind in 2026, 4.4 GW in 2028





Executive Summary

- The method and assumptions to extrapolate imbalances used in the projections were improved and updated to the latest available observations (forecast data, system imbalances) and latest expected system evolutions (renewable projections, installed generation fleet and grid topology)

Note that this exercise is not exclusively related to the integration of offshore wind power in the system, but also accounts the effect of onshore wind and solar power

- In general, the results confirm the previous trends and conclusions :
  - The FRR needs are expected to increase with additional renewable energy installed
  - The facilitation of delivery of flexibility by existing and new (cf. electrification) assets trough CCMD is expected to have a strong mitigating effect on this FRR needs increase
  - Under assumptions of having a consumer-centric market design, together with the implementation of key enablers (electrification, smart metering…) it is expected that despite high RES integration :
    - Upward mFRR balancing capacity procurement can be gradually reduced after 2027 compared to today’s levels and might even approach zero for most of the time after 2032.
    - Downward mFRR balancing capacity procurement can continue to be avoided

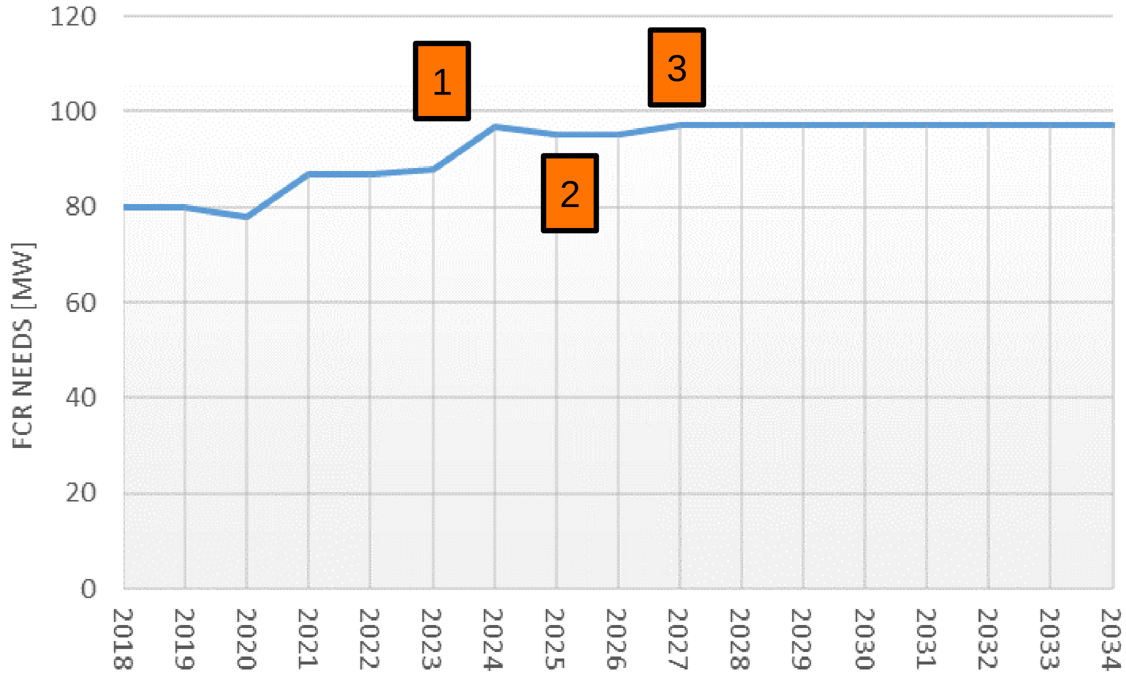
FCR projections

- Dimensioned by ENTSO-E for Continental-Europe Synchronous Area
  - Deterministic method (3000 MW)
  - Probabilistic method (as from 2024)

- Allocated to each LFC block based on its share in total generation and demand withing Continental Europe

- Expected evolution :
  1. Slightly increasing volumes expected though probabilistic method (+ 10% as from 2024)
  2. Slightly reduction after 2024 following nuclear unit phase out in 2022-23
  3. Generation and demand profiles of ERAA 2021 simulations for 2027 indicate stabilization around 95 MW

Expected FCR needs for the Belgian LFC block



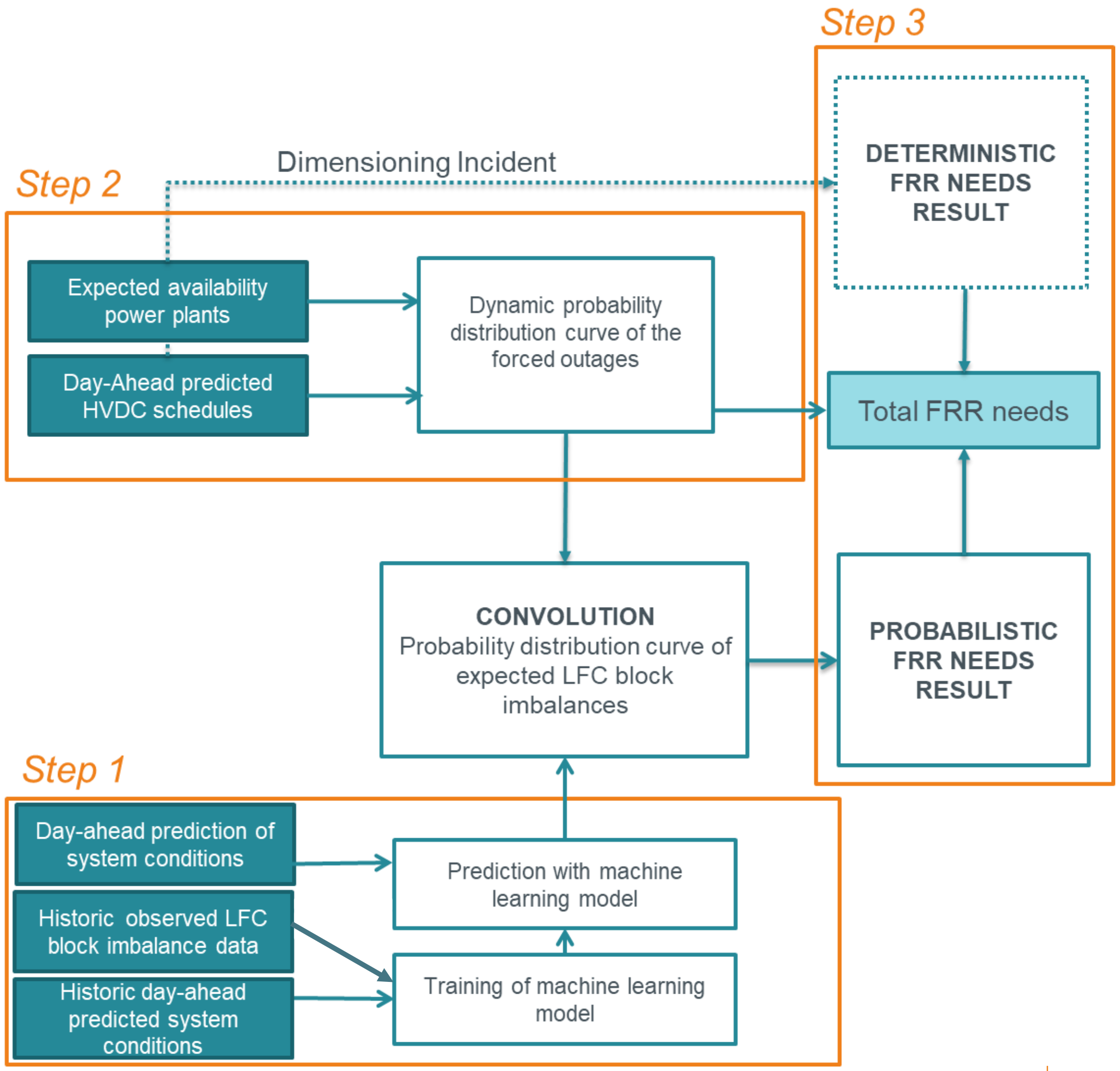
The reminder of the presentation focuses on FRR dimensioning

Methodology and improvements compared to the MOG 2 2020 study

FRR dimensioning method (in depth)

The FRR needs for every period of the next day are calculated by means of three steps :

- **Step 1: calculation of the prediction risk**
- **Step 2: calculation of the outage risk**
- **Step 3: calculation of the FRR needs**



Overview of the methodology to make projections of future FRR needs

Scenarios on future BRP ability to balance portfolios

- Assumptions on **ability of BRPs** to balance forecast errors of additional renewable capacity
- Assumptions on **general evolutions of the Elia's LFC block** system imbalances
- Assumptions on **forecast tool improvements**

Projections of future system imbalances

- **Upscaling of historic LFC block** imbalances in view of expected forecast errors of renewable capacity
  - *Based on projections on the installed wind and solar power*
  - *Based on time series of historic forecast errors*
- Accounting **evolutions on forced outages** of conventional generation units and relevant transmission assets

Estimations of future balancing capacity needs

- **Estimations** on future **FRR/aFRR/mFRR needs**
- **Estimation** on **balancing capacity requirements** (to be procured)

Improved methodology for making projections of system imbalances

Based on improvement factors determine for each target year

Recurrent formula (iteration): for all imbalance settlement periods (15min) in a year

Expected system imbalances SI in target year T	=	Expected evolution of system imbalances following balancing performance of BRP portfolios compared to year T-1		Contribution of forecast errors (FE_i) of incremental capacity installed (ΔIC) to the system imbalance of new renewable generation for technology i (PV, Onshore, Offshore) installed between year T-1 and T		
SI_T	=	$X_T * SI_{T-1}$	+	$\Delta IC_{T,T-1} * FE_{0,i} * Y_{T,i}$	x	$Z_{T,i}$

T= 1,2,…

SI_0 = Observed system imbalances in year 0
FE_0 = Observed forecast errors in year 0

$$FE_{0,i} = \frac{\text{Real-time generation}_{0,i} - \text{Day-ahead-forecast}_{0,i}}{\text{Installed capacity}_{0,i}}$$

X_T	General improvement of the general LFC block quality (existing BRP portfolio). An improvement / deterioration of the system imbalances with 1% translates to a factor X of 99% / 101%
$Y_{T,i}$	Improvement factor representing the improvement of the day-ahead forecast error of a renewable technology. An improvement / deterioration of the forecast quality with 1% translates to a factor Y of 99% / 101%
$Z_{T,i}$	Factor representing the share of the forecast errors on the incremental capacity installed of a renewable technology will not be covered by the market players and therefore contributes to the system imbalance

Scenarios, evolution and target years overview

elia | Elia Group

Scenarios presented in the MOG 2 study 2020

Worst Case
- *0%/y forecast improvement*
- *0%/y SI improvement*
- *35% BRP coverage*

Reference case
- *1%/y forecast improvement*
- *1%/y SI improvement*
- *50% BRP coverage*

Best case
- *1%/y forecast improvement*
- *1%/y SI improvement*
- *65% BRP coverage*

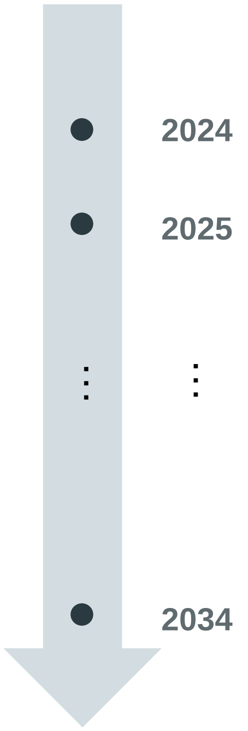
New evolutions compared to the MOG 2 study 2020

1. Update of the historic observations / data (observations 2020-21)
2. Update of the simulated offshore wind generation profiles (DTU simulations)
3. **Revision of the projections on installed renewable capacity (Adeqflex ’23 consultation)**
4. Update of the projections on the conventional generation fleet (Adeqflex ’23 consultation)
5. Revision of the direction schedule projections of Nemo Link (latest estimations)
6. Revision of generator outage probabilities (Adeqflex ’23 consultation)
7. **Integration of MOG 2 grid design (Federal Development Plan)**
8. **Revision of the market performance indicators (latest estimations)**
9. **Expected impact of an offshore bidding zone (high level analysis)**

Presented in MOG 2 report (items 1, 2, 4, 5, 6)

Presented in next slides (items 3, 7, 8, 9)

Projections



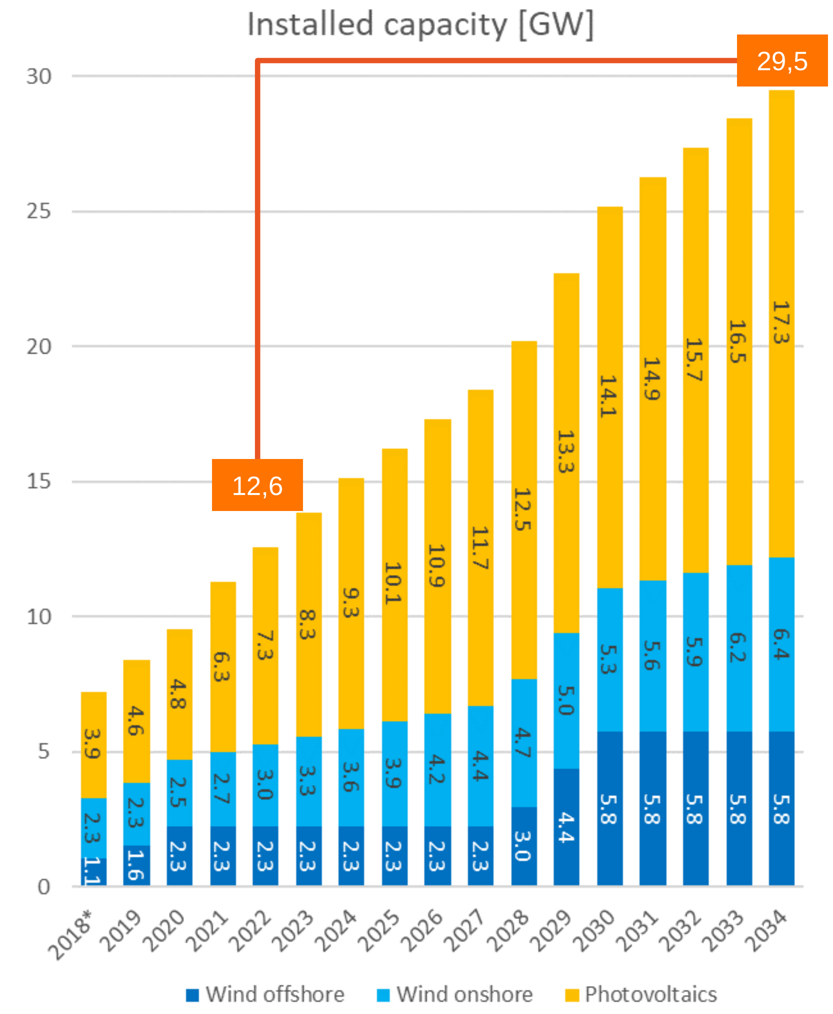
Scenarios and assumptions

Update - revision of the projections on installed renewable capacity

Projections on installed renewable capacity is based on latest available data (consultation on the Adequacy and Flexibility study 2023) including :

- **Additional offshore generation** as from 2030 (**+1.4 GW**)
- **Increase** speed of **photovoltaic power developments** (**+ 1.6 GW** in 2023 and even **+ 3.5 GW** in 2032)
- **Additional onshore wind** as from 2026 (**+ 0.6 GW** in 2030)

- **General upward pressure expected on reserve capacity requirements**
- **Effect of offshore wind comes later in time (as from 2028 instead of 2026)**



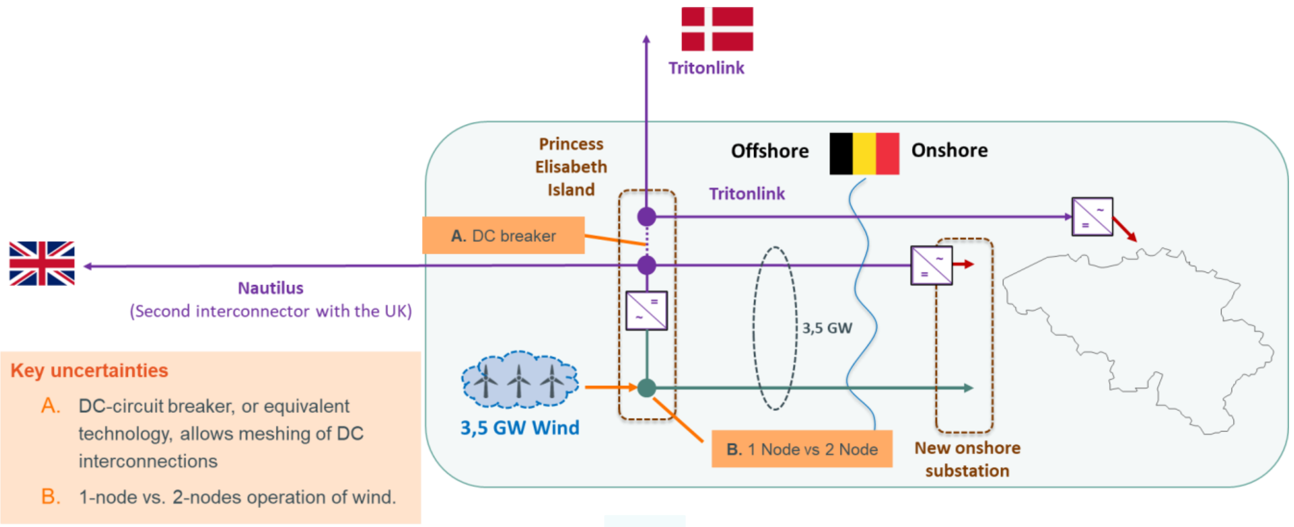
Source: adequacy and flexibility study 2023 – public consultation and latest planning of the offshore developments communicated by government in 2022

Update - Integration of MOG 2 grid design

- **Current design options for Nautilus / Triton*** ensure that probability of losing more than 1000 MW remains well under probability levels currently accounted as dimensioning incident
  - HVDC system will consist in a full bi-pole (i.e. a dedicated metallic return will be foreseen in the cable system). Doing so, a pole failure or a cable failure will only lead to the loss of half of the HVDC system.
- The **probability of losing more than 1000 MW** only becomes unacceptable when coupling both HVDC systems (MOG2/Nautilus & Triton link) on the island. By design the coupling will only be implemented in presence of a mean to automatically open the coupling after a fault (e.g. HVDC Circuit Breaker) and probability of a losing more than 1000 MW remains sufficiently low.
- **Under normal conditions****, no other grid elements related to MOG 2 (connection of the wind farms to the island, AC connection of the island to shore, onshore grid infrastructure) are expected to impact the dimensioning incident

By design, the forced outage probability* is expected to be far under what is currently accounted as dimensioning incident and allows to justify that the design options considered do **not substantially impact the dimensioning incident in Elia's LFC block**

As foreseen in the Federal Development Plan, Nautilus (as from 2030) and Triton (as from 2032) will be **included in the forced outage simulations in the probabilistic method of the dimensioning** (at potential impact of 50% of their installed capacity following the metallic return technology)



Note: figure shown is the anticipated configuration in the FDP 24-34 for the Interconnectors Nautilus and Triton.

*To be confirmed by the manufacturer

Revision of the market performance indicators

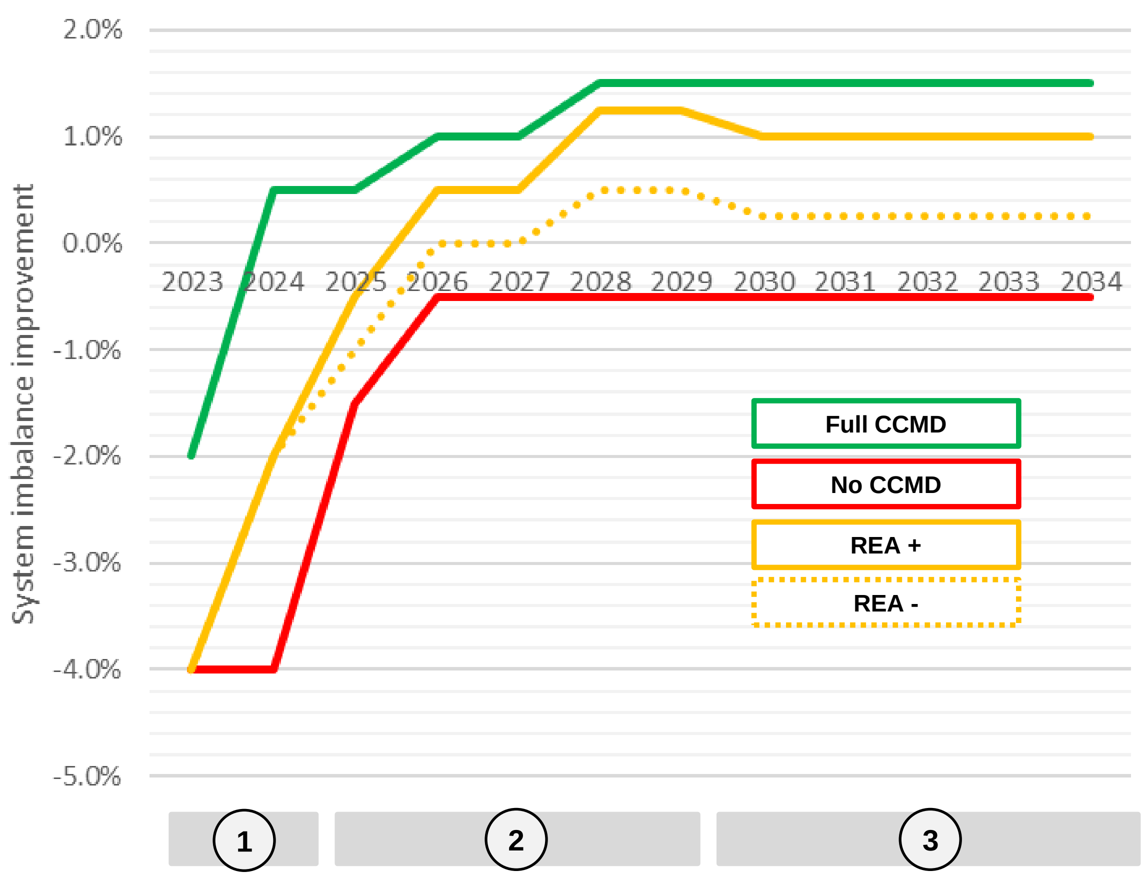
	Extreme scenarios (e.g. used for Elia's CCMD value calculations)		Best estimates scenarios (e.g. used for Elia's adequacy studies)	
	Worst case scenario (no CCMD)	**Best case scenario (full CCMD)**	**Reference Optimistic (REA +)**	**Reference Pessimistic (REA -)**
General description	No or limited participation of flexible appliances to the electricity markets due to lack of electrification / digitalization/implementation of CCMD. Market players will not be able to balance their portfolio well and the system will largely rely on Elia's balancing capacity procurement and activations	Optimal participation of flexible appliances to the electricity markets thanks to high electrification / digitalization and full implementation of CCMD. Market players will balance their portfolio and the Belgian balancing area to large extent and relieve Elia's balancing capacity requirements and activations	Most of the effect of electrification / digitalization and CCMD will eventually be in place but comes later in time and to slightly lower extent.	Not all effects of electrification / digitalization will be achieved and the effects achieved come later in time due to limited market reform and/or the deployment of key enablers
Status of CCMD developments (for a large part driven by regulator and stakeholder support)	No CCMD	Full CCMD	Medium (e.g. slight deviation from targeted real-time price / EoEB design, investments in data access management lower than ambitioned)	Low (e.g. inadequate real-time price design, use of EoEB limited to some specific use cases).
Status of key enablers (external factors with important impact on success of CCMD, e.g. smart meters uptake, distribution tariff design, integration of smart appliances)	Low development (e.g. natural electric vehicle charging only)	High development (e.g. smart electric vehicle charging only)	High development	Medium development

Scenario assumptions

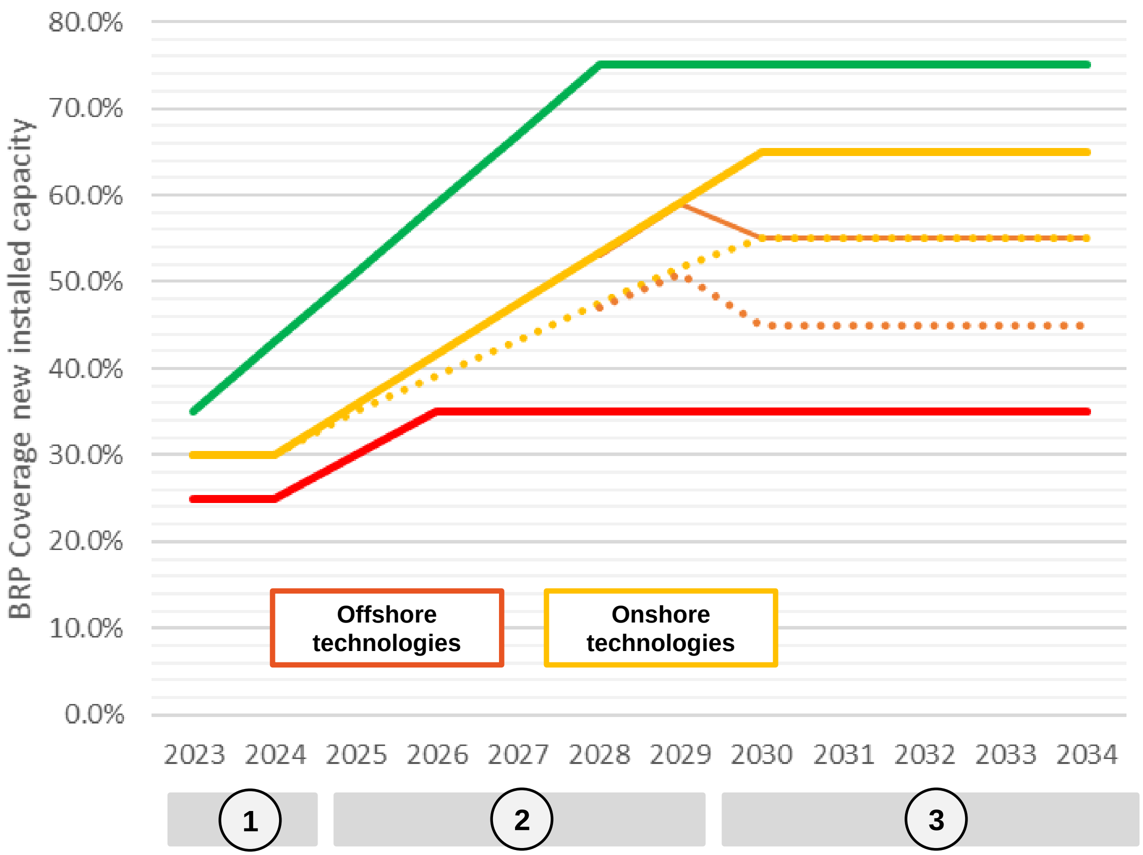
Requires minor updates in the assumptions

For info

SI improvement (X)



BRP coverage (Z)



1

- Large system imbalance observed in 2021 and 2022 (energy crisis). Assumptions are taken on slow / fast sector recovery after energy crisis
- Identified challenges to take up new variable generation following limited visibility. Assumptions are taken on solutions to enhance visibility and transparency

2

- Gradual recovery of the system imbalance and ability to take up new variable generation in portfolio as from 2024.
- Assumptions are taken on the speed of improvements based on progress CCMD realizations

3

- Market performance towards 2034 depends on CCMD vision realization.
- Reduction of market performance when assuming no solutions can be found for reduced reactive balancing possibilities in an offshore bidding zone)

Impact of an offshore bidding zone (high level)

Elia presented its first reflections on the implications of offshore bidding zone for balancing in a workshop on June 24, 2022. It concluded that "*beyond the legal obligations, defining a separate imbalance price area consistently with offshore bidding zone has clear advantage in terms of market and system efficiency.*"

Impact of potentially reduced reactive balancing capabilities

A risk is identified / confirmed of reduced reactive balancing possibilities for BRPs in an OBZ (after intra-day cross-zonal gate closure time)

It is not certain that solutions will be found which can completely mitigate this effect

The reference scenarios therefore take into account reduced reactive balancing capabilities following an OBZ

Note that a partial procurement strategy (foreseen as from 2027) should mitigate the effect on balancing capacity procurement when flexibility is available through EU balancing platforms

Impact on reserve dimensioning methodology

Most straightforward solution identified by Elia (cf. TF 24/6) is to maintain both bidding zones in one LFC block (e.g. with two imbalance price areas / LFC Areas)

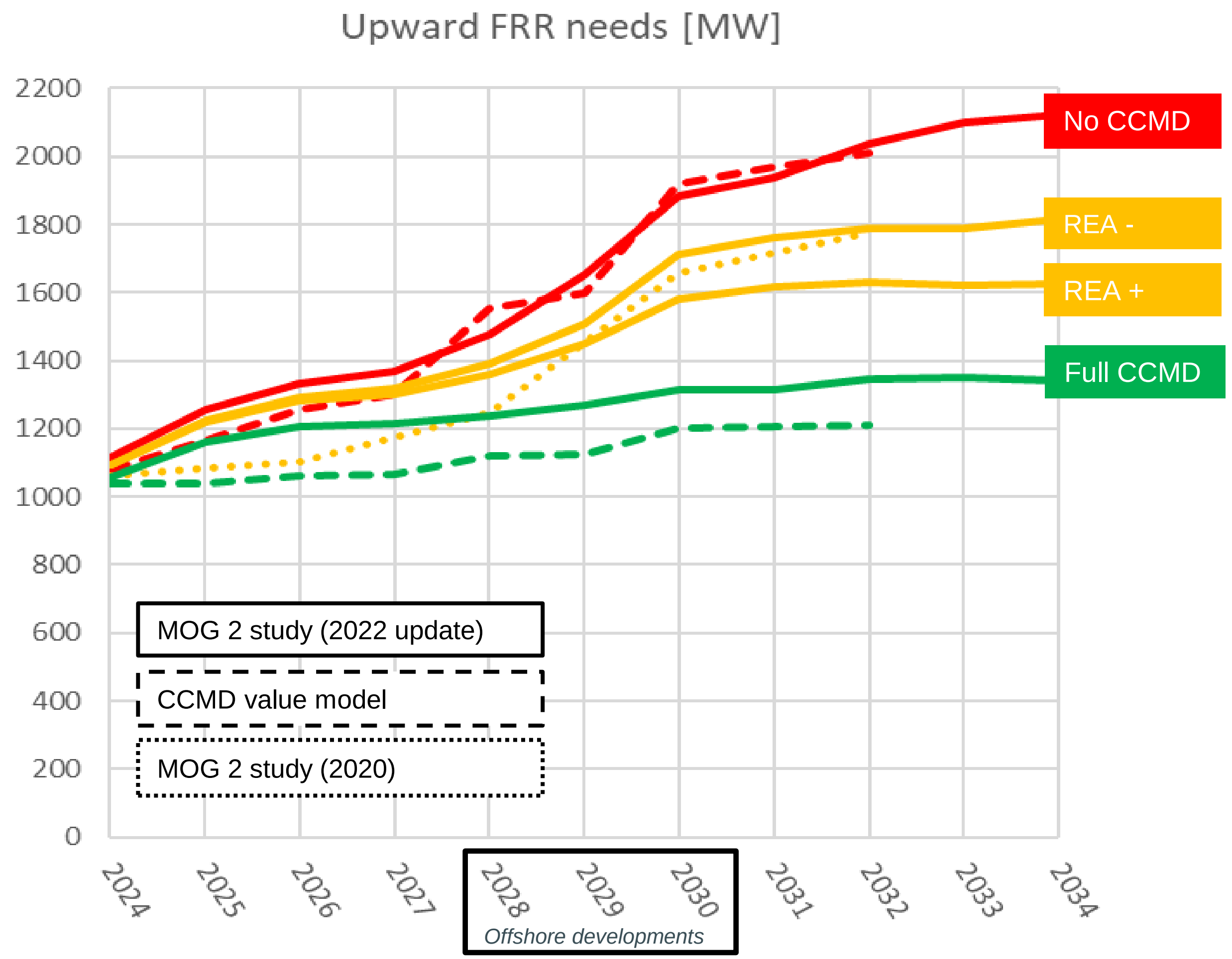
This allows to maintain a common dimensioning over the two bidding zones (maximizing benefit of aggregating prediction errors over larger geographical area)

But some **geographical constraints** (due to hybrid interconnector congestions) have to be taken into account in the dimensioning of the reserve needs or calculation of the balancing means, i.e. excess energy during high import conditions This is not expected to result in additional procurements (availability of downward regulation trough wind power)

Elia will continue discussions on the topic of balancing an offshore bidding zone with stakeholders in the workshop of TF MOG 2 workshop of 24.03.2023

Results

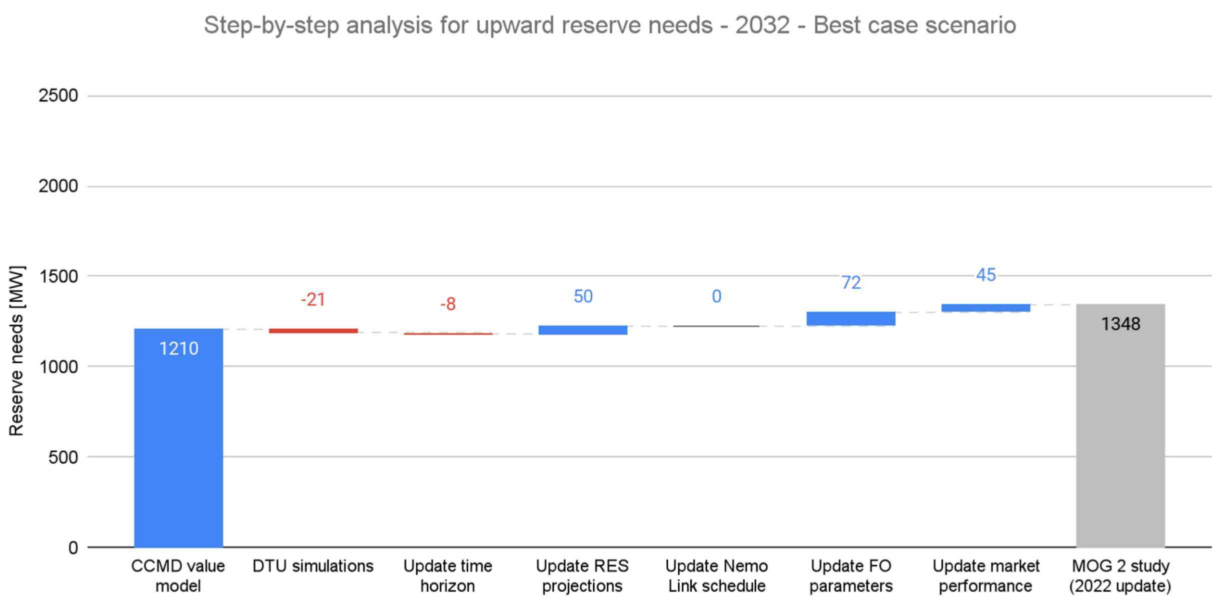
Upward FRR needs projections

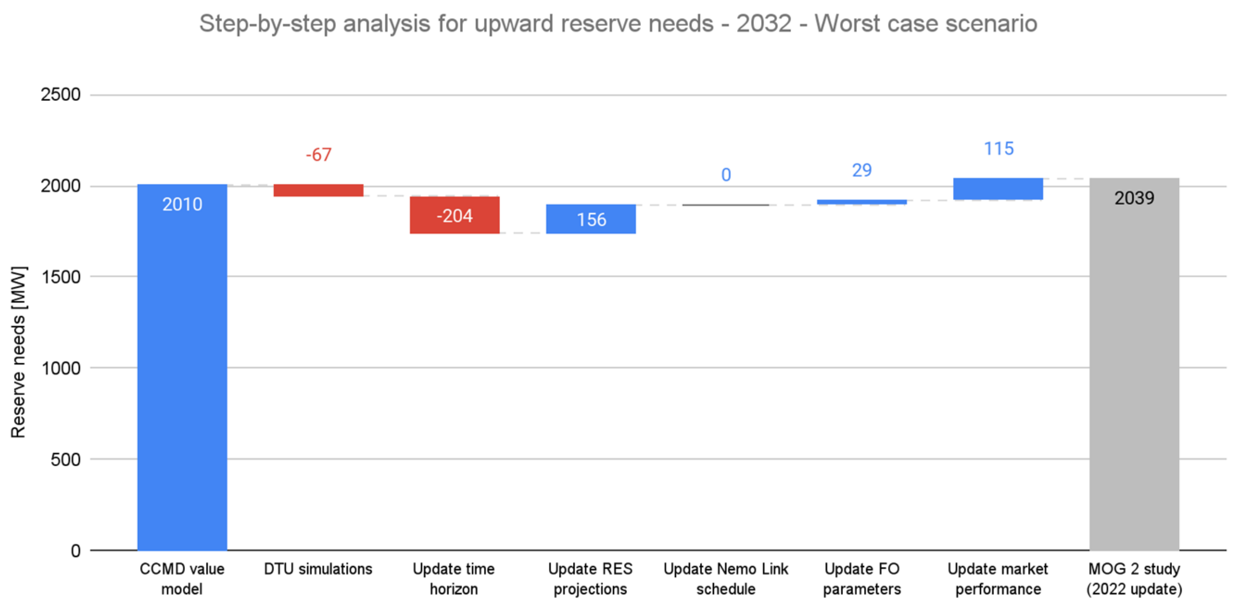


- New projections confirm that in a worst case “no CCMD” scenario, the **reserve needs are expected to more than double towards 2034** following penetration of variable renewable generation.
  - Projections show a prominent effect of the offshore wind developments between 2028 and 2030
  - It is also confirmed that in a best case ‘full CCMD’ scenario, this increase can be stabilized at an increase of a factor 1.3 towards 2034
- **Projections on the “No CCMD” and “Full CCMD” demonstrate similar trends** as the results presented by Elia in **March 2022 on its CCMD value model**
  - FRR needs increased slightly in a full CCMD scenario, mainly following the implementation of market performance evolutions over time (where largest reduction will come later in time)
- **Elia will consider an Optimistic Realistic (REA+) as a best estimate scenario**
  - FRR needs projections are assumed to be lower as the projections presented in the MOG 2 (2020) study.
  - Without CCMD, or enablers develop slower than expected, Elia will shift projections towards a Pessimistic Realistic (REA-) scenario, close to projections presented in MOG 2 (2020) study

AVERAGE UPWARD FRR NEEDS	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	1118	1258	1332	1371	1475	1655	1886	1937	2039	2102	2121
REA -	1093	1225	1291	1317	1391	1511	1710	1753	1791	1789	1814
REA +	1093	1222	1283	1303	1360	1450	1583	1607	1630	1620	1627
Full CCMD	1056	1162	1208	1215	1237	1271	1314	1315	1348	1352	1342

In depth (1) : evolutions of compared to latest projections



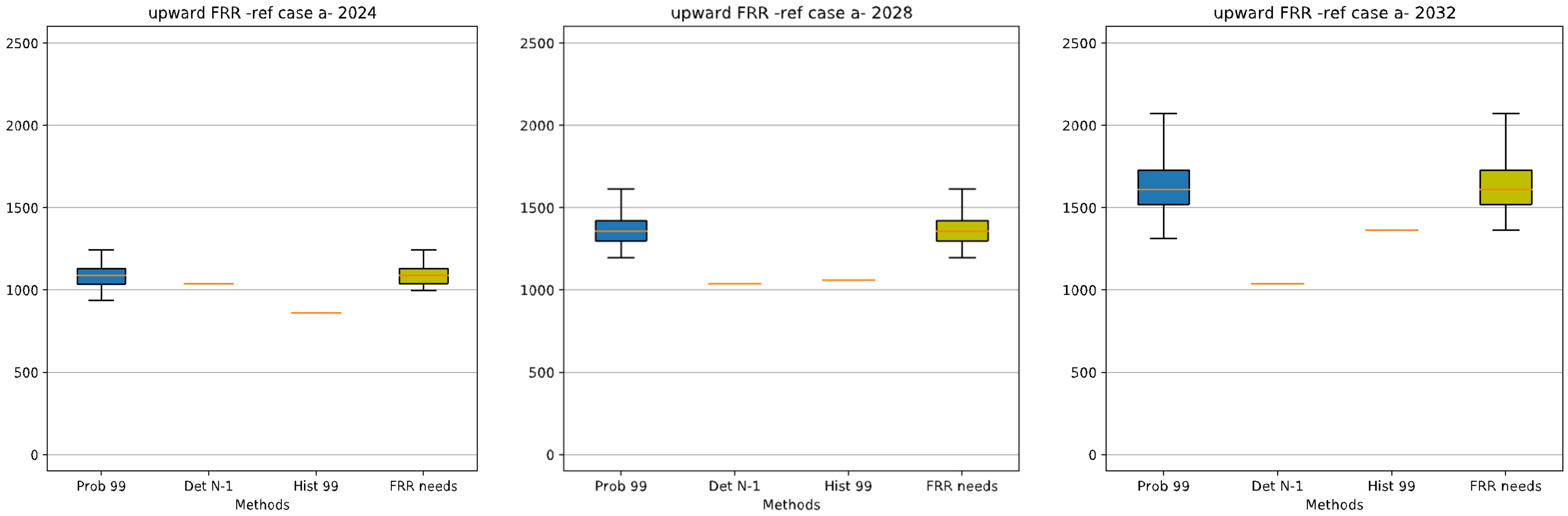


- The **upward pressure of higher renewable ambitions** on reserve capacity requirements is confirmed
- Updated **forced outage statistics** (higher forced outage probabilities assumed for CCGT, cf. consultation adequacy and flexibility study) and improvement **market performance assumptions** (with higher improvements coming later in time) explain higher reserve requirements
- Note that the **update of historic system imbalance observations** (post 2.3 GW offshore) reduce reserve capacity requirements which is explained by better performance as the initial worst case assumptions)

In depth (2): expected behavior of the dynamic dimensioning

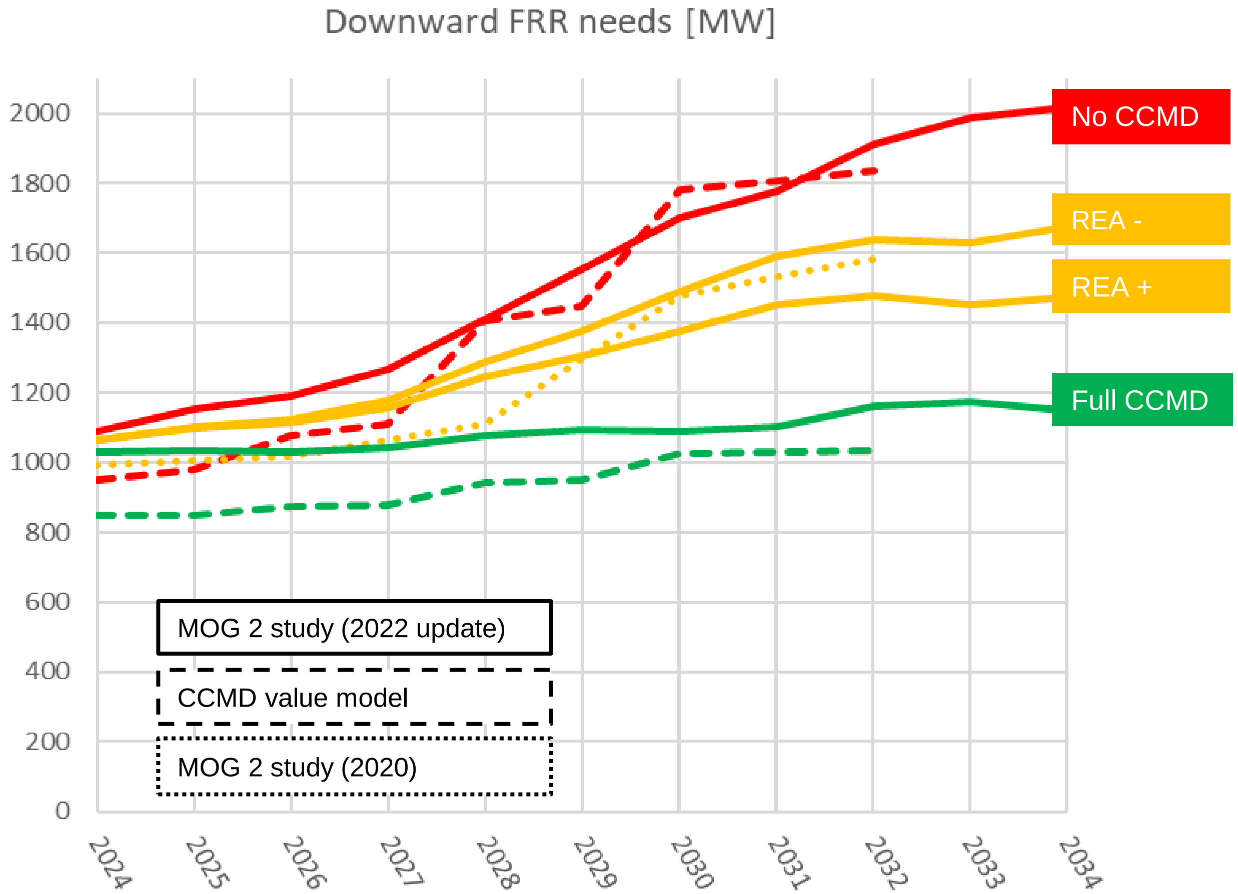
2024, 2028 and 2032 for the REA+ scenario

For info



- **Decreasing impact of the dimensioning incident** on the final FRR needs (and even no impact of dimensioning incident anymore as from 2028) in REA+ scenario
- As from 2028, final **FRR needs are generally driven by dynamic result of the probabilistic method** (demonstrating increasing variability)

Downward FRR needs projections

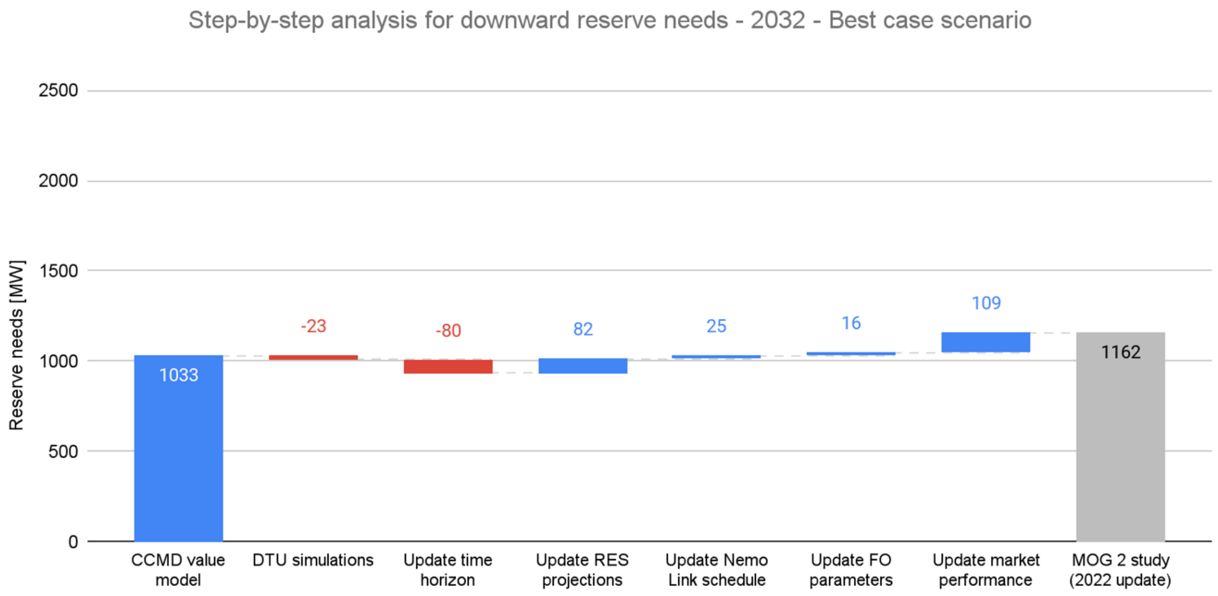


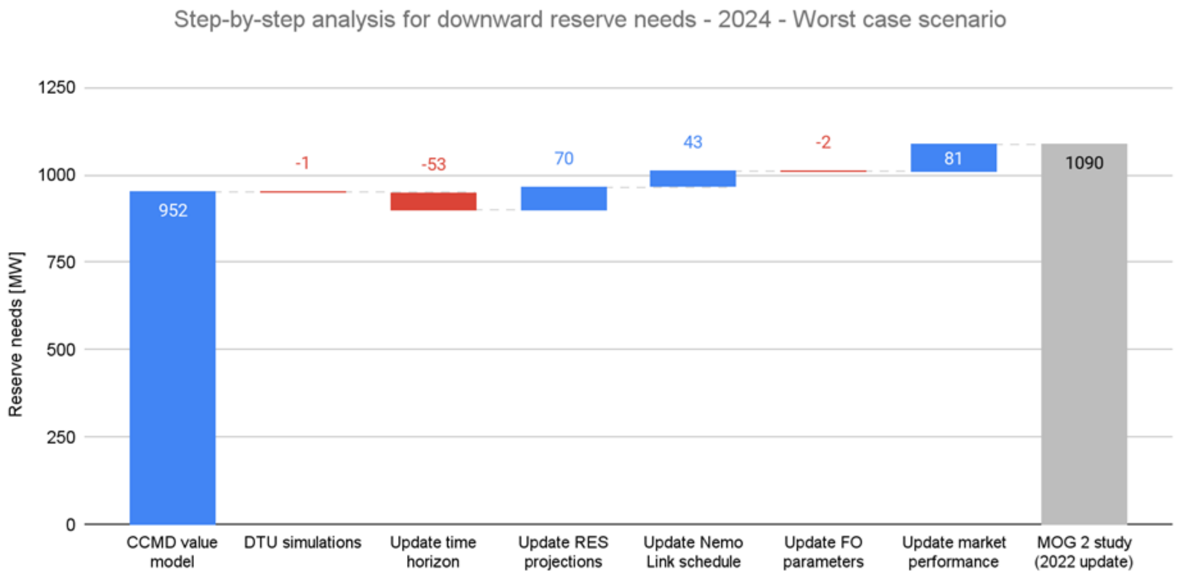
- **In a "no CCMD" scenario, the downward reserve needs projections towards 2034 behave rather symmetrically to the upward side**
  - In such a scenario, reserve needs are driven **by prediction risks of renewable generation** while forced outage risk have limited impact in both up- and downward side.
- **In a "full CCMD" scenario, reserve needs remain at lower level as on the upward side**
  - In such scenario, the **forced outage typically have a larger impact** on the results while these forced outage risk are lower on the downward side (limited to relevant HVDC-interconnectors)

AVERAGE DOWNWARD FRR NEEDS	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	1090	1151	1189	1267	1412	1552	1703	1776	1912	1990	2019
REA -	1062	1102	1123	1178	1287	1376	1491	1589	1639	1628	1674
REA +	1062	1098	1113	1155	1247	1306	1377	1447	1479	1453	1475
Full CCMD	1029	1036	1030	1043	1077	1092	1091	1100	1162	1175	1149

In depth (1) : evolutions of compared to previous projections

For info

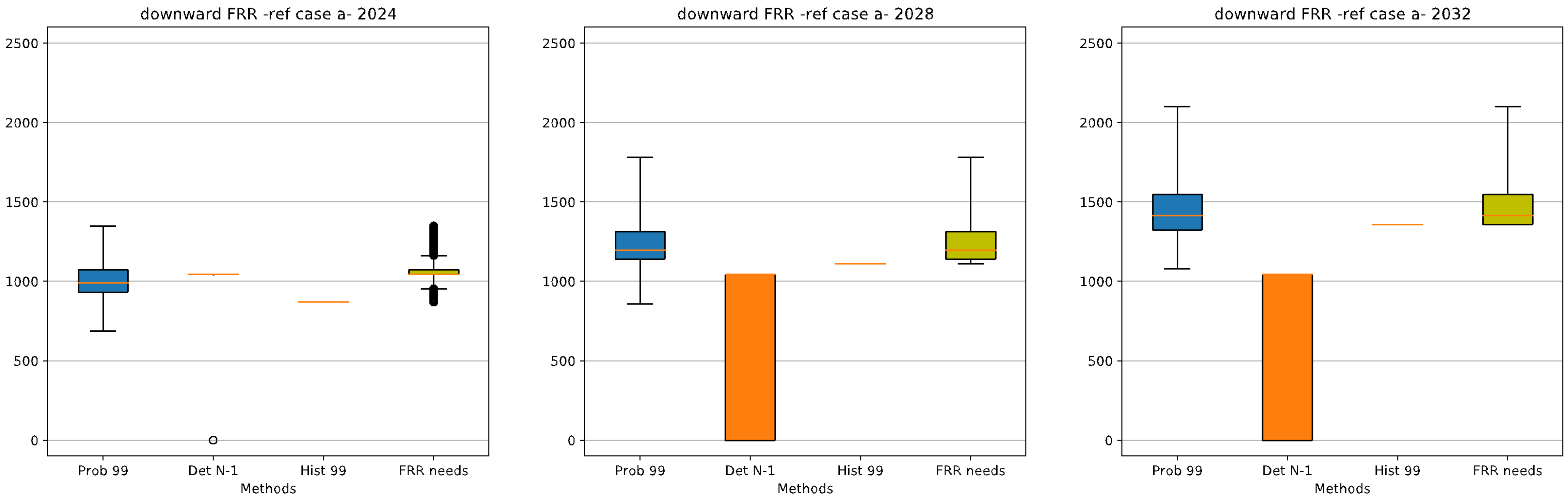




- Similar trends as for upward direction

In depth (2): behavior of the dynamic results

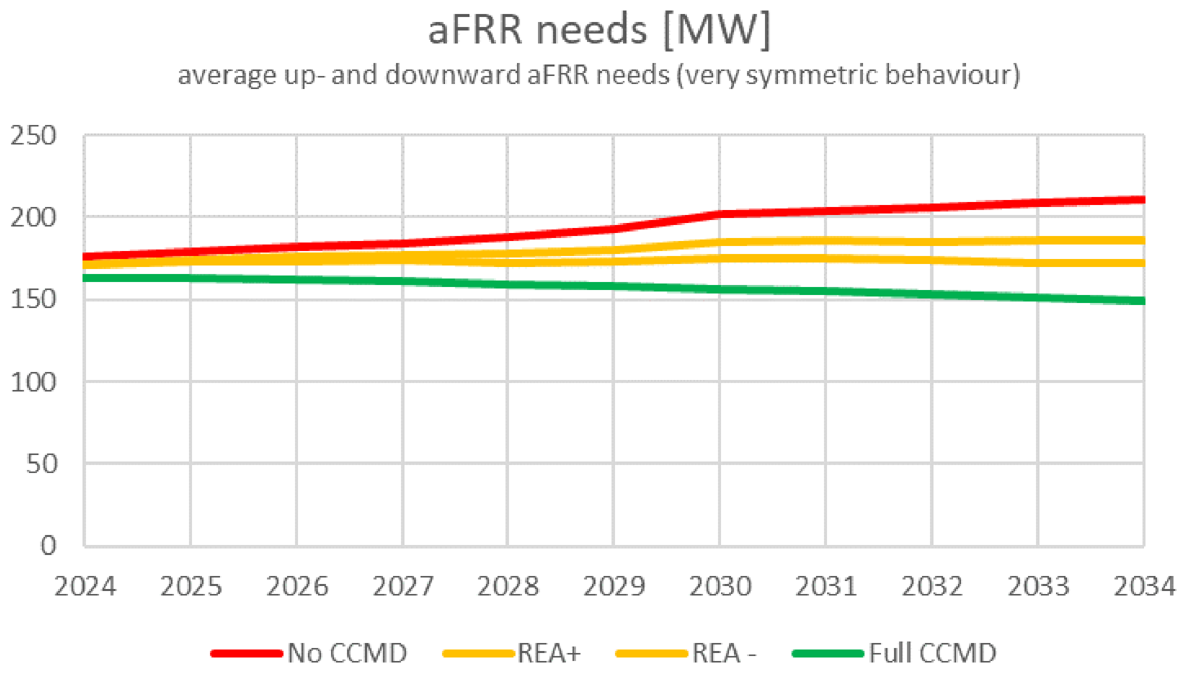
For info



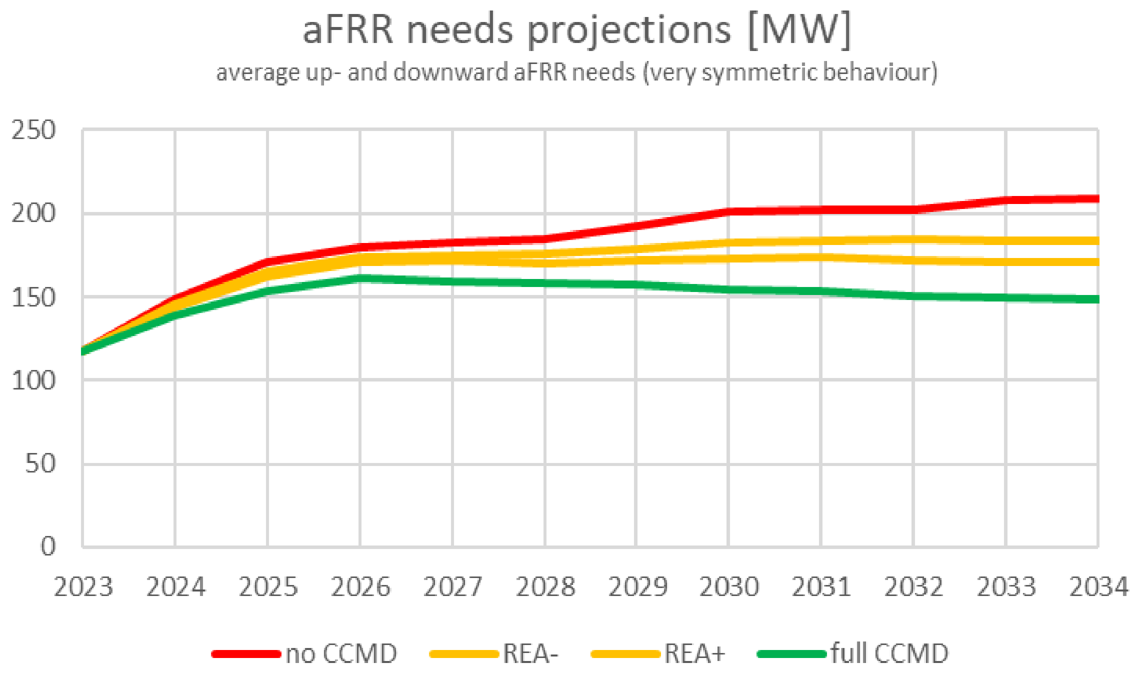
- **Decreasing impact of dimensioning incident** on the final FRR needs (but remaining impact until 2032) in REA+ scenario
- As from 2028, final **FRR needs are largely driven by dynamic behaviour of the probabilistic method** (demonstrating increasing variability)

aFRR needs projections

Result of the probabilistic method (before FRCE feedback loop)



Result of the probabilistic method (after FRCE feedback loop)

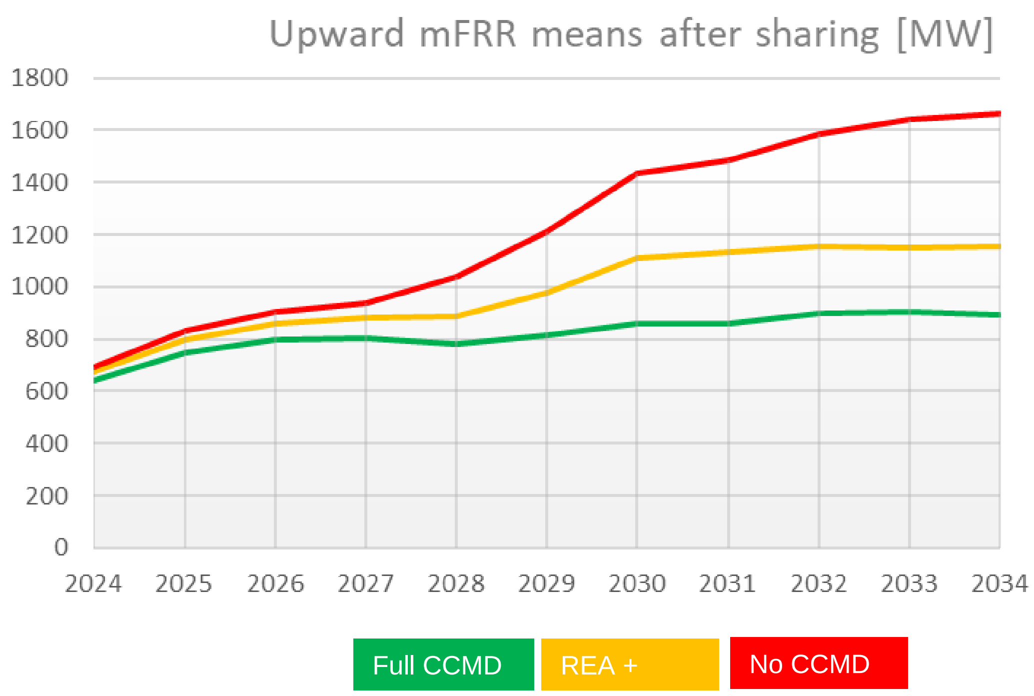


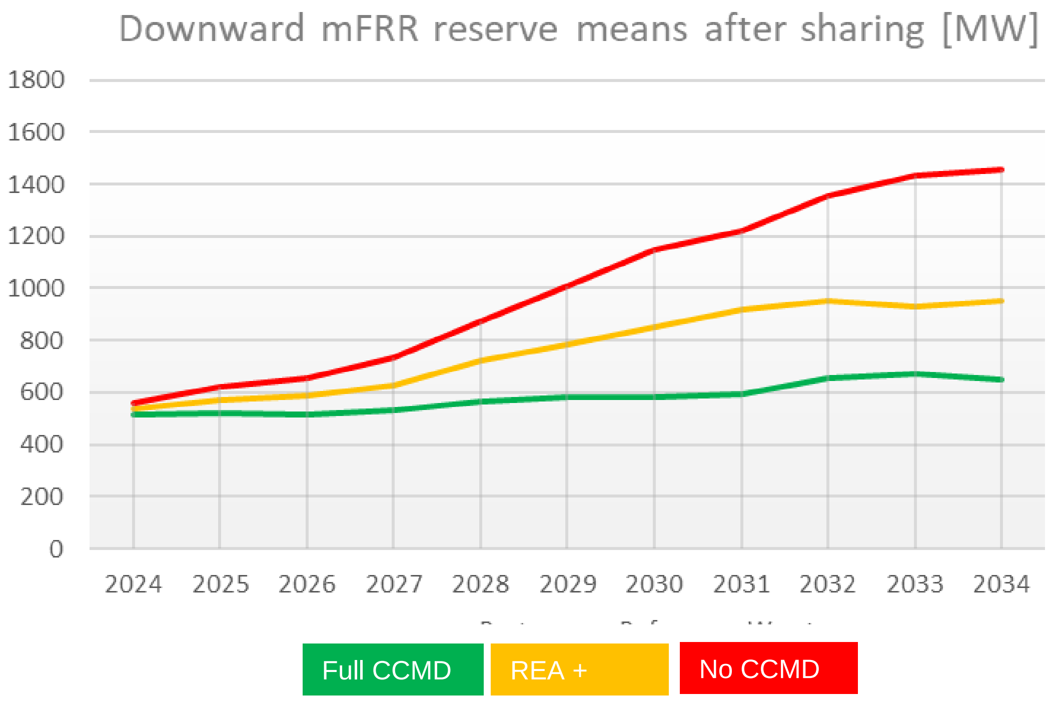
- In line with the system imbalance projections and general FRR needs evolutions, aFRR needs increase up to 160 - 170 MW in 2024
- Depending on the scenario, these volumes may remain stable in realistic scenarios (REA + and REA -), increase above 200 MW in the no CCMD scenario or even decrease to 150 MW in the full CCMD scenario

- The feedback loop is expected to play a substantial role in the first years as the effect will be gradually be phased out when the parameters are revised downwards by ENTSO-E.
- This effect is captured by a linear interpolation between the current volume (117 MW in 2023) towards the probabilistic result as from 2025

mFRR reserve means are expected to increase proportionally with the FRR needs

= Capacity that needs to be covered with contracted or non-contracted mFRR balancing energy bids





ASSUMPTIONS

mFRR needs = FRR needs – FRR sharing - aFRR needs

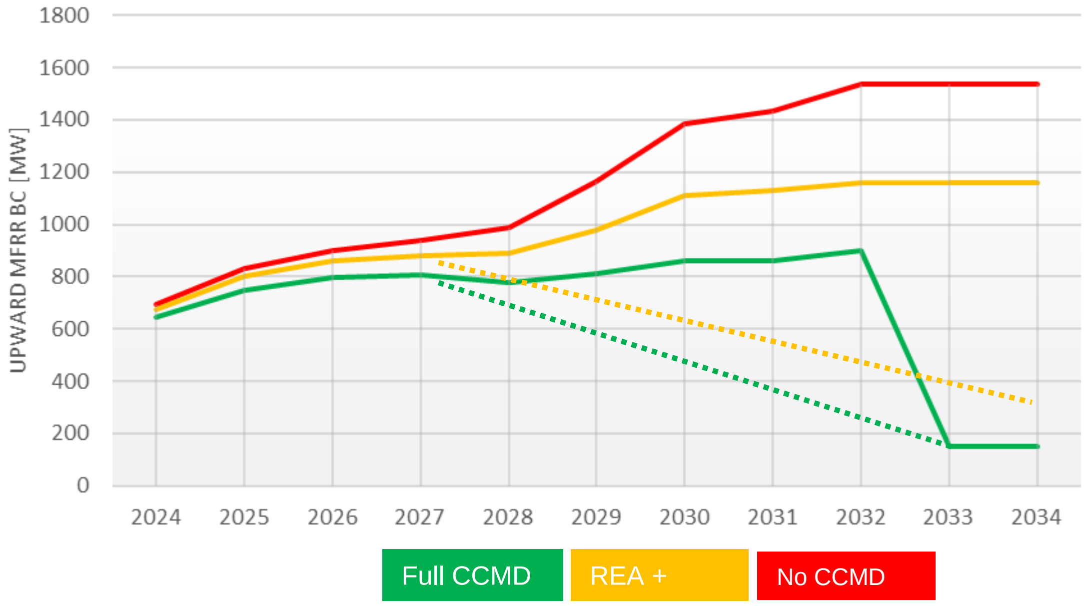
- Based on mFRR reserve sharing volumes up to 250 MW / 350 MW for up- downward capacity until 2027, increasing to 300 MW / 350 as from 2028 through the implementation of dynamic sharing together with partial procurement strategies in the Full CCMD and REA + scenario
- Updated of aFRR needs projections in line with FRR projections presented in the previous slide.

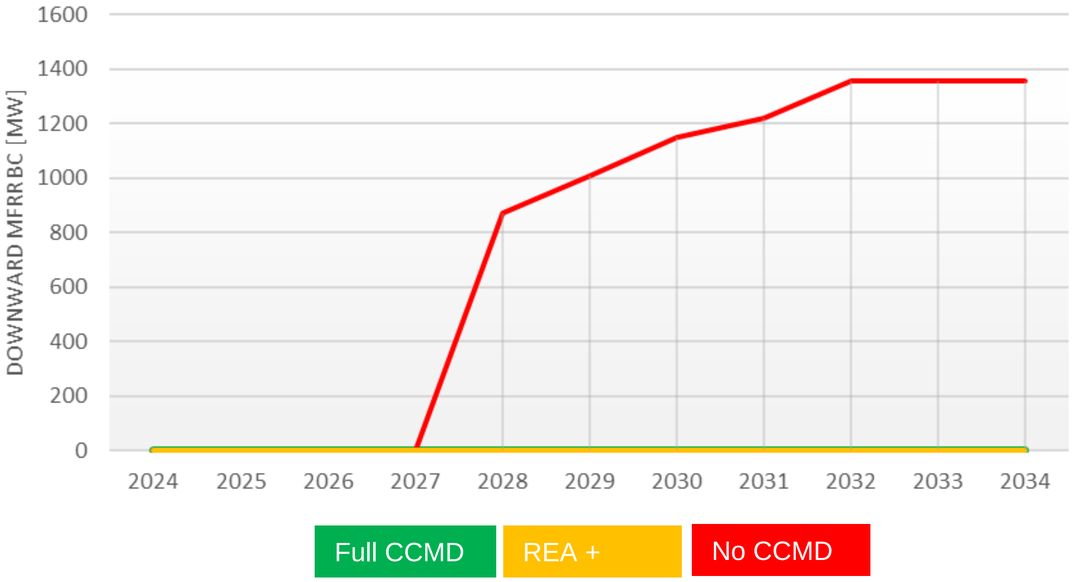
mFRR balancing capacity requirements can be reduced to zero when able to fully account non-contracted balancing energy bids*

Procurement close to zero (most of the time) after 2032 in Full CCMD scenarios

Elia's adequacy and flexibility study shows that in the reference scenario (including participation of some decentral capacity), upward flexibility needs are expected to be operationally covered up to 85% of the time in 2032. ***Elia's ambition is to target full coverage after 2032 and try to avoid upward mFRR procurements for most of the time****.*

Elia's adequacy and flexibility study shows that the downward flexibility needs are expected to be operationally covered for 96%. ***Elia's ambition is to continue to achieve full coverage and avoid downward mFRR procurements.***





Gradual reduction of procurement after 2027 in Full CCMD and REA+ scenario

- Partial procurement strategies allow to gradually reduce mFRR balancing capacity procurement (dotted line - rough estimations)
- Projections can be further refined following next flexibility study based on expected operational flexibility in the system

- No impact as downward mFRR balancing capacity procurement is expected to be avoided in Full CCMD and REA+ scenario

Annex- figures related to graphs in previous slides

Upward FRR Needs [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	1118	1258	1332	1371	1475	1655	1886	1937	2039	2102	2121
REA-	1093	1225	1291	1317	1391	1511	1710	1753	1791	1789	1814
REA+	1093	1222	1283	1303	1360	1450	1583	1607	1630	1620	1627
CCMD	1056	1162	1208	1215	1237	1271	1314	1315	1348	1352	1342

Upward aFRR Needs [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	149	171	180	183	185	192	201	202	203	209	209
REA-	146	165	174	175	176	179	182	184	185	184	184
REA+	144	162	171	172	170	172	173	174	172	171	171
CCMD	139	153	161	159	158	157	155	154	151	150	148

Upward mFRR Needs [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	969	1087	1152	1188	1290	1463	1685	1735	1836	1893	1912
REA-	947	1060	1117	1142	1215	1332	1528	1569	1606	1605	1630
REA+	949	1060	1112	1131	1190	1278	1410	1433	1458	1449	1456
CCMD	917	1009	1047	1056	1079	1114	1159	1161	1197	1202	1194

Upward mFRR Means [MW] after sharing	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	719	837	902	938	1040	1213	1435	1485	1586	1643	1662
REA+	699	810	862	881	890	978	1110	1133	1158	1149	1156
CCMD	667	759	797	806	779	814	859	861	897	902	894

Upward mFRR BC [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	719	837	902	938	1040	1213	1435	1485	1586	1643	1662
REA+	699	810	862	881	801	782	777	680	579	460	347
CCMD	667	759	797	806	701	651	601	431	179	135	134

Downward FRR Needs [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	1090	1151	1189	1267	1412	1552	1703	1776	1912	1990	2019
REA-	1062	1102	1123	1178	1287	1376	1491	1589	1639	1628	1674
REA+	1062	1098	1113	1155	1247	1306	1377	1447	1479	1453	1475
CCMD	1029	1036	1030	1043	1077	1092	1091	1100	1162	1175	1149

Downward aFRR Needs [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	150	173	183	185	190	194	203	206	208	209	214
REA-	146	166	175	176	174	174	177	176	175	173	173
REA+	150	173	183	185	190	194	203	206	208	209	214
CCMD	140	156	164	163	160	159	158	157	155	154	151

Downward mFRR Needs [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	940	978	1006	1082	1222	1358	1500	1570	1704	1781	1805
REA-	916	936	948	1002	1113	1202	1314	1413	1464	1455	1501
REA+	912	925	930	970	1057	1112	1174	1241	1271	1244	1261
CCMD	889	880	866	880	917	933	933	943	1007	1021	998

Downward mFRR Means [MW] after sharing	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	590	628	656	732	872	1008	1150	1220	1354	1431	1455
REA+	562	575	580	620	707	762	824	891	921	894	911
CCMD	539	530	516	530	567	583	583	593	657	671	648

Downward mFRR BC [MW]	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
No CCMD	590	628	656	732	872	1008	1150	1220	1354	1431	1455
REA+	0	0	0	0	0	0	0	0	0	0	0
CCMD	0	0	0	0	0	0	0	0	0	0	0

Conclusions

Conclusions and main take-aways

- **Latest reserve capacity needs projections were updated** (used in MOG 2 2020, CCMD Value Model 2022)
  - System imbalance and wind power forecasts 2020-21 (after full commissioning of the 2.3 GW offshore fleet)
  - Latest projections on evolutions of the Belgian generation fleet (Adeqflex 2023)
  - New assumptions on evolutions on market performance (with / without CCMD)
  - Including latest assumptions on MOG 2 (Nautilus, Triton and OBZ)

- By design, **none of the (offshore) grid evolutions is expected to fundamentally impact the reserve needs** through the dimensioning incident

- **Without action, upward reserve capacity needs are expected to almost double to 2 GW towards 2032** following the integration of renewable generation due to its variable nature (with limited predictability)
  - Prominent effect of offshore wind power is found between 2028-2030 in pessimistic scenarios
  - Most optimistic scenarios with electrification / digitalization / CCMD can stabilize increasing reserve needs around 1.3 GW

- **In optimistic scenarios (assuming implementation of Elia's CCMD)**, the system can be expected to operate after 2032 most of the time **with almost no mFRR procurement**. Gradual reductions of upward balancing capacity procurements are already foreseen after 2027 when implementing partial procurement strategies. In the same scenarios, **no downward mFRR procurement is expected to be needed,** even after the integration of the 2nd wave of offshore wind power.