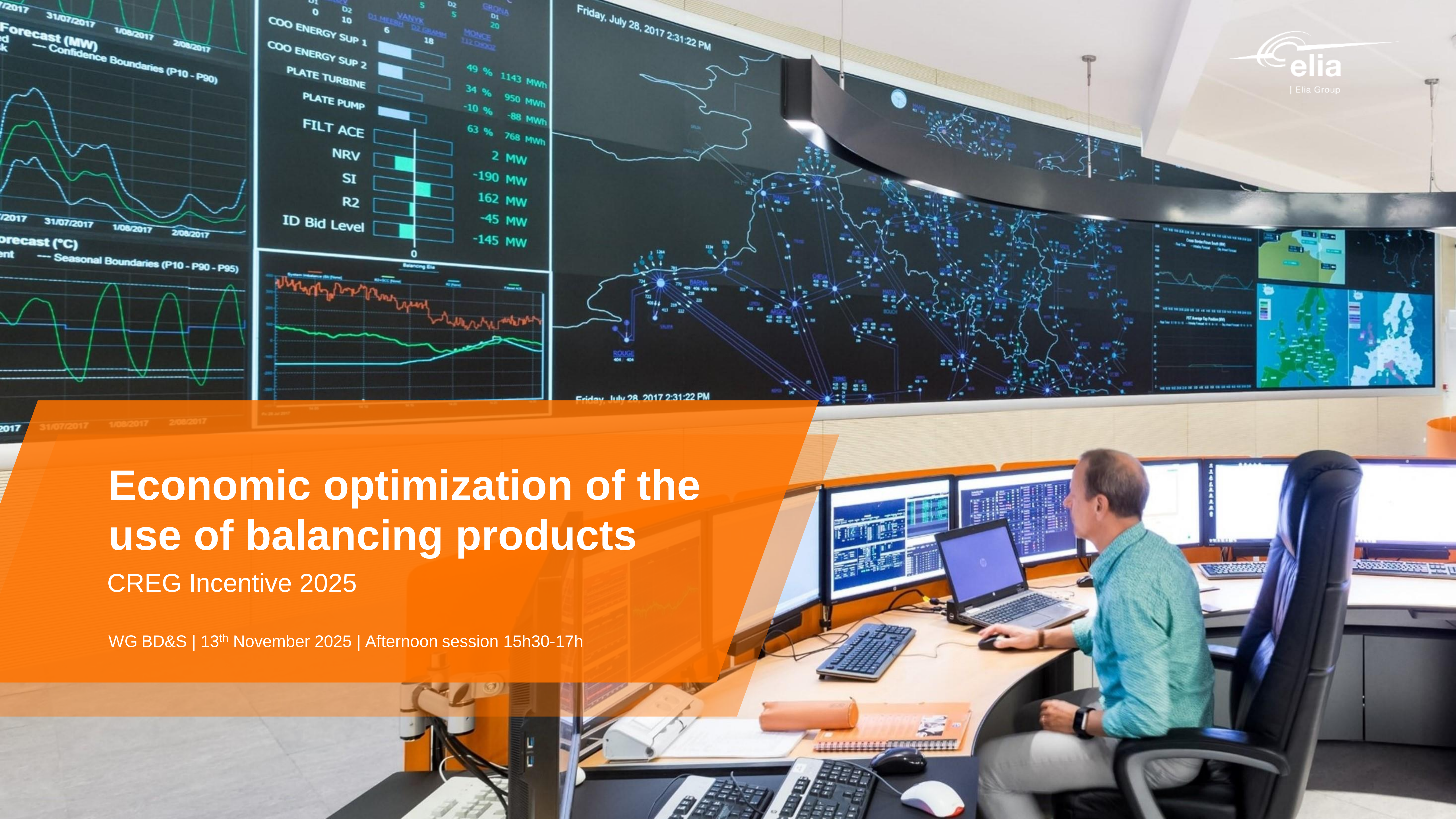
elia
| Elia Group

Economic optimization of the use of balancing products

CREG Incentive 2025

WG BD&S | 13th November 2025 | Afternoon session 15h30-17h



Agenda

1. Executive summary & implementation plan (15min)
2. Incentive objective & scope (10min)
3. Work approach (15min)
4. Implemented forecasting methodologies & outcomes (50min)
5. Appendix

Collection of stakeholder feedback after today's work session

The incentive that is discussed today will **not be subject to public consultation**

Elia invites market participants to organize **bilateral calls** with Elia before the **end of November 2025**, if desired by market participants. In that case, market participants are invited **to contact their KAMs**

1. Executive summary & implementation plan

Executive summary

The aim of the incentive is to assess if a methodology can be developed to **economically optimize the use of balancing energy products** to cover the System Imbalance (SI) for the next quarter hour (QH). More precisely, it aims to optimize the mFRR volume that is proactively activated by Elia

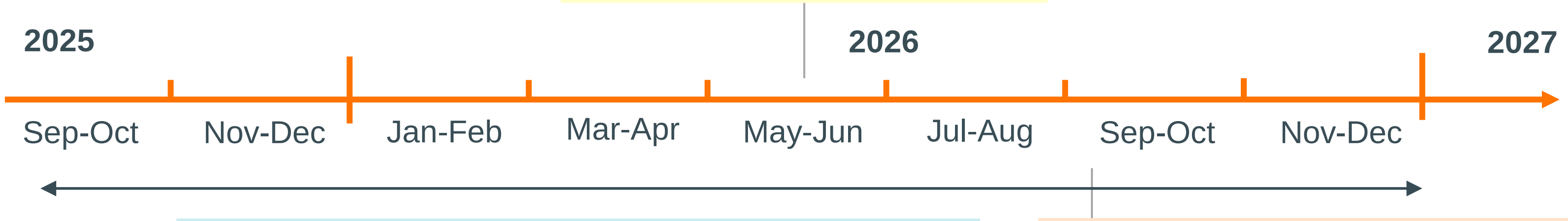
In the context of this incentive, different methodologies have been tested for the long-term, while a simple activation rule to optimize the use of balancing energy products at the short-term has already been implemented (after update of Balancing Rules)

The assessment of different methodologies resulted in following **final recommendations of the incentive**:

1. As none of the tested methodologies resulted in a better performance than currently implemented simple activation rules, **keep using simple activation rules** upon **further market evolutions**. Elia will monitor markets continuously & modify rules (currently based on aFRR as aFRR is most of the time cheaper than mFRR) when deemed necessary/logical with regards to a new situation (in particular when RTE will connect to MARI – Q2 2026)
2. Propose to implement **mFRR elastic demand** as a no regret measure, with a simple rule to use it (VoAA price threshold / aFRR CBMP at decision making)
3. In case further market evolutions (RTE connection to MARI, or other important change) **increase opportunities with mFRR**:
    - Re-evaluate the savings potential, assuming that we can predict when mFRR will be cheaper and make frequently use of it instead of aFRR
    - If potential savings justify restudying the testing of a more robust tool, **re-evaluate the performance of the most promising methodologies** that have been developed in the frame of this incentive and potentially consider industrialization of the most promising methodology

Proposed implementation plan

RTE connection to MARI currently expected in Q2 2026



1. Use of simple rules (PoC) until at least beg. 2027 (Elia will monitor markets continuously & modify current rules when deemed necessary/logical with regards to a new situation)

3. After stabilization of RTE connection to MARI (3 months after connection), **test again methodologies** based on spread of CBMPs & aFRR CBMP forecasting tool (to increase benefits in mFRR elastic demand) and assess their added-value compared to simple rules, for a maximum period of 4 months after stabilization of RTE connection to MARI. If the added value is confirmed, it could lead to an industrialization of the tool(s) in beg. 2027

2. Proposition to implement mFRR elastic demand in 2026 as a no-regret initiative (and independently of the development of any other parallel initiative). A dedicated Proof-of-Concept could be launched, during which the performance of a mFRR elastic demand strategy could be tested and monitored continuously

Legend

Measure already in place	External market event	Measure to be implemented

2. Incentive objective & scope

Incentive objective & scope (CREG decision (B) 658E/89)

The aim of the incentive is to assess if a methodology can be developed to **economically optimize the use of balancing energy products** to cover the System Imbalance (SI) for the next quarter hour (QH). More precisely, it aims to **optimize the mFRR volume** that is proactively activated by Elia.

INPUTS

Estimation of:
- **cross-border merit-order lists (CMOL) & prices (CBMPs) for mFRR and aFRR** on European platforms
- **15-min average system imbalance forecasts**

Identification of **operational constraints** that could have an impact on the optimization objective

METHODOLOGY ANALYSIS

Development of one or more methodologies for optimization of the use of FRR balancing products.

OUTPUT

Preliminary **evaluation** of the effectiveness of the different methodologies

Series of one or more **recommendations**:

- Scope of a Proof-of-concept (POC) in 2026 (if appropriate)
- To extend the test period of the different methodologies (if applicable)
- To extend the development of one or more methodologies (if applicable)
- To stop the initiative if no methodology can be developed (if applicable)

Note

Since our MARI connection (21st May), Elia has access **to less information than in the past** at activation decision moment

- mFRR demand decision needs to be taken at T-12min before the QH, which is 5 minutes earlier than in the past
- aFRR & mFRR CMOLs are not available before mFRR demand decision anymore

For 2025, the scope was initially on assessing the situation and making various analyses, without concrete implementation changes for 2025. However, Elia already implemented a new activation strategy using a simple rule since 23rd July 2025.

Objective function:

1) The first priority remains to ensure operational safety
2) Optimizing FRR costs comes as second priority

1. Ensuring operational safety

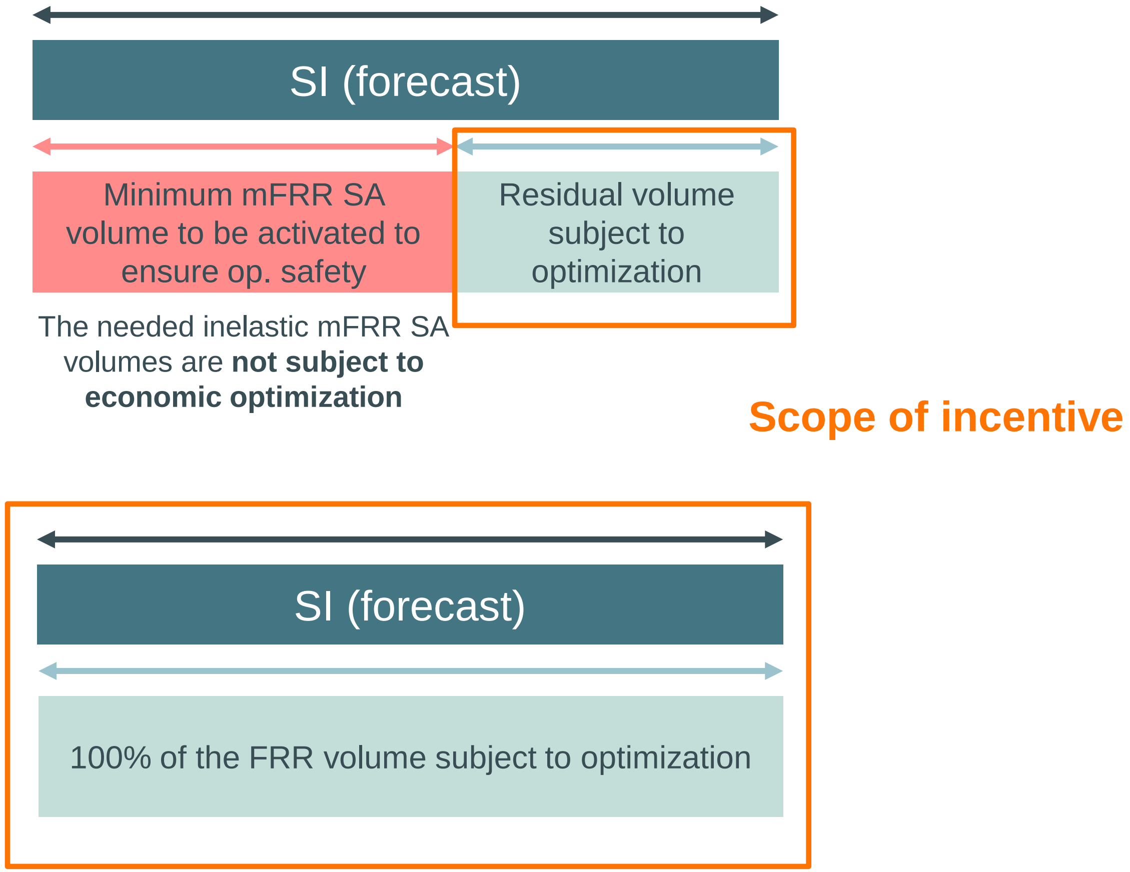
When aFRR is not sufficient to reasonably cover the full SI, **inelastic mFRR SA** needs to be pro-actively activated

Currently corresponds to ~ **10% of the QH**
(as monitored in the Proof-of-concept)

2. Optimizing FRR costs

In other situations, activating inelastic mFRR SA **is not needed** for operational safety as we could reasonably cover it with aFRR.
The objective is then **to fully optimize FRR activation costs** (aFRR, mFRR SA), without degrading FRCE*

Currently corresponds to ~ **90% of the QH**
(as monitored in the Proof-of-concept)



*FRCE = Frequency restoration control error

3. Work approach

Work approach

Defining the objective function

→

Assessing **potential savings** and the **situations** in which these savings **could occur**

→

Developing long-term methodologies

Section 4

The objective function : minimize balancing energy costs under constraints

Minimize

$$\textbf{\textit{Balancing energy costs}}$$
$$= Remuneration\ of\ local\ balancing\ activations + remuneration\ of\ neighboring\ TSOs\ for\ CB\ balancing\ exchanges$$

by adapting the **volume of mFRR** to be activated in the mFRR Scheduled Activation (mFRR SA) process *
and considering the use of mFRR elastic demand with a price threshold

Subject to operational constraints with three main objectives :

- Limiting the (negative) impact on FRCE** quality
- Limiting the amount of activated FRR volumes
- Avoid transferring mFRR inelastic demand as aFRR elastic demand

None of the operational constraints are currently strictly implemented in the Proof-of-Concept.
The approach followed by Elia is to continuously monitor the FRCE** & adapt its strategy if needed

* every residual imbalance that is not covered by the activated mFRR volume will be considered by the aFRR controller to activate aFRR accordingly. Assumption is made that the parametrization of the aFRR controller (and its objective function) is kept as it is today (considered out of scope of this incentive)
** FRCE = Frequency restoration control error

The savings analysis

1) significant mFRR activation cost savings in case large ATCs are identified and are already captured thanks to the Proof-of-Concept

Methodology to compute high-level benefits

1

Assumption on activation occurrences:

When forecasted |SI| is low & ATCs are large, mFRR SA would have been activated at a **similar frequency** and **similar volumes** than the **2 months before the PoC**

2

Assumption on activation prices:

New activation prices are calculated with the **QH aFRR price kept constant** (price-taker assumption) and **average mFRR price** calculated for **different volume levels** since the PoC *

Results

Savings of ~ **1.5 to 2 MEUR** over 23/07/25–28/10/25 (3 months) → savings of **~ 6 to 7 MEUR** extrapolated to a full year

Disclaimers

- This KPI shall be considered as a proxy with large uncertainty
- Assumptions made to allow the computation of such proxy are strong
- Market conditions affect importantly the KPI. It is not excluded that the current value changes importantly due to changing market conditions in the coming months

* Disclaimer: calculations made with imbalance price formula components. The mFRR CBMP assumption is obviously not accurate at QH level.

The savings analysis
2) savings are currently impossible to capture in case of limited ATCs

For QHs with **limited ATCs**, savings are **currently impossible to capture** due to:

- The limited locally available aFRR volume
- The SI forecast uncertainty*

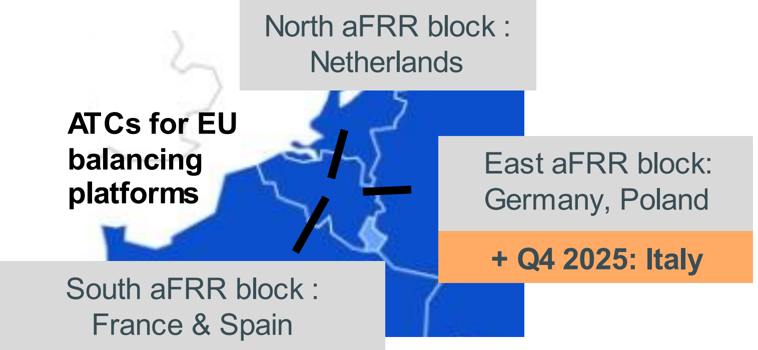
Consequence:

If limited ATCs are expected, there is a need to ensure that a **sufficient volume of local aFRR remains available** to cover **intra-QH SI variations** → a certain volume of **mFRR SA** needs to be **activated pro-actively**

* Both the average SI & the intra-QH SI need to be forecasted precisely to achieve savings in local situation

However, the context is evolving fast with upcoming connections to EU balancing platforms

PICASSO connections (aFRR)



Italy

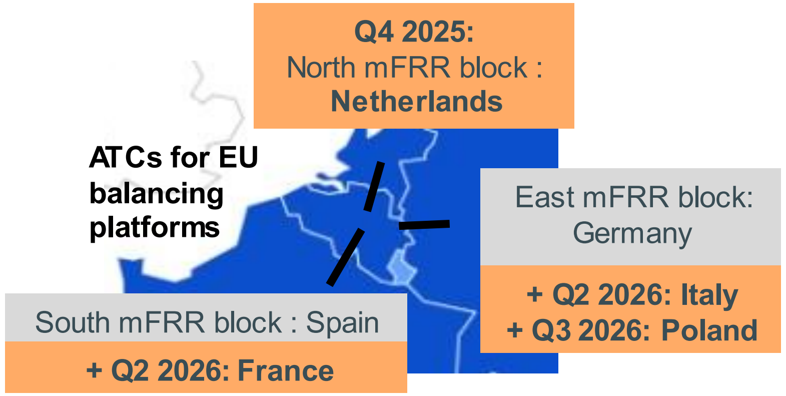
(connections expected to be impactful)

Sep-Oct | Nov-Dec | Jan-Feb | Mar-Apr | May-Jun | Jul-Aug | Sep-Oct | Nov-Dec

2025 **2026** **2027**

Netherlands France Italy

MARI connections (mFRR)



France & potentially Italy & Poland could share **large mFRR volumes** (a few GWs) **at low prices**

Based on available information, it is expected that the main game-changer for the economic use of FRR will be the connection of RTE to MARI

4. Long-term methodology results & recommendations

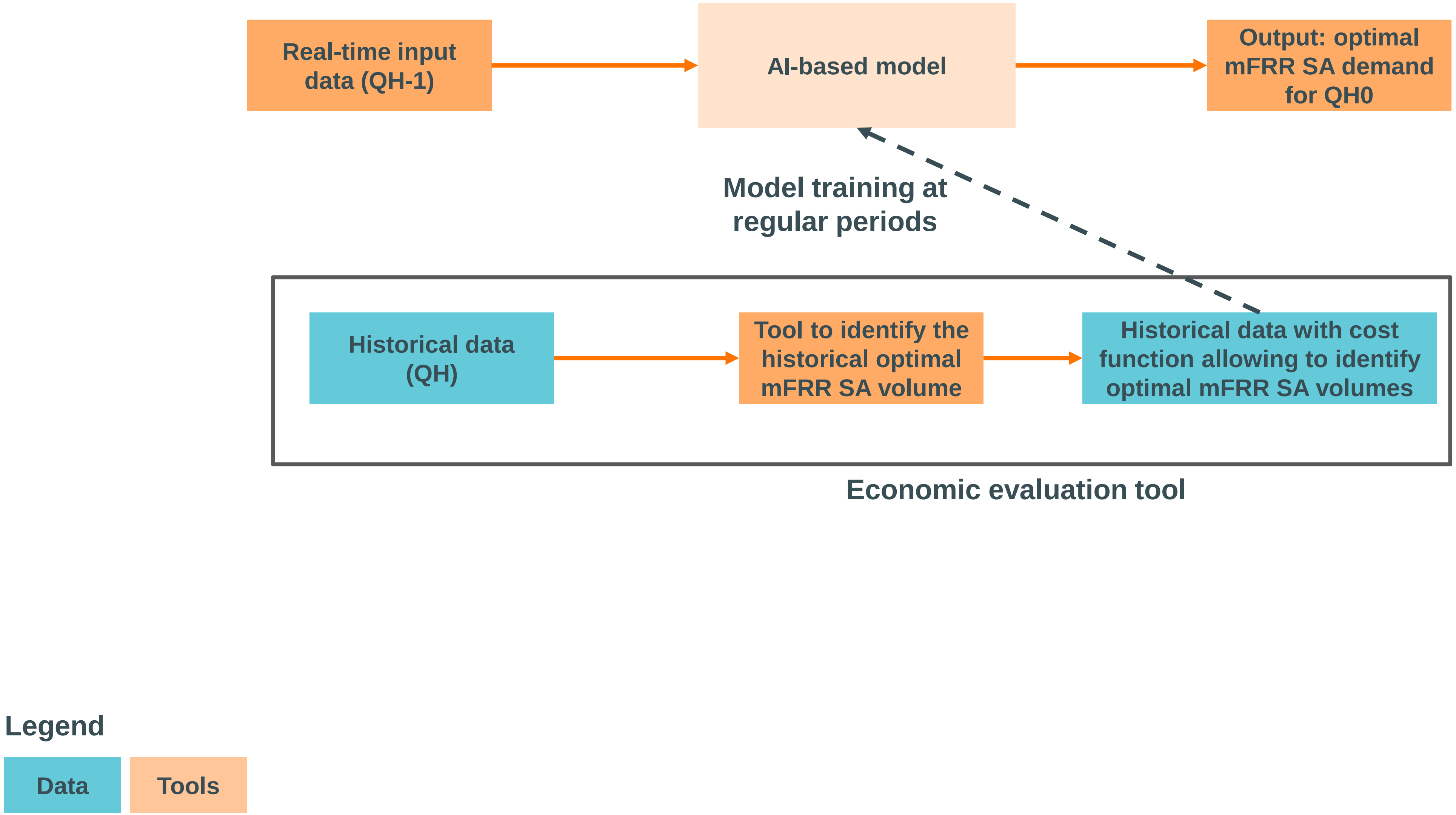
4.1. Methodology based on optimal mFRR SA volume

4.2. Methodology based on CBMP spread

4.3. mFRR elastic demand

4.1. Methodology based on optimal mFRR SA volume

Elia investigated whether a methodology to identify the historical optimal mFRR SA volume could be developed



Building the economic evaluation tool requires access to additional data, as well as to a MARI prototype, that are not available today

	1	2	3
Initially envisaged approach	**Computing precisely historical mFRR CBMPs**	**If step 1 successful, implement the what-if analysis (changing the mFRR demand) to assess impact on mFRR CBMPs**	**Model training to forecast optimal mFRR SA demand for QH0**
Conclusion on feasibility	Elia demonstrated that this task isn't feasible with a simplified approach → **requires a prototype of MARI AOF**	Important data to evaluate CBMPs for a different mFRR SA demand is currently not made available by MARI platform. → **requires data that is currently unavailable**	Relevant only if steps 1 & 2 are reliable.

- Additionally, it is impossible to **assess** the **exact potential of such approach** without a MARI prototype & missing data (to identify the mFRR optimal volume). And even if available, it would remain impossible to verify with 100% certainty the calculated mFRR CBMP for another mFRR demand
- The implementation of **mFRR elastic demand** would capture part of this added-value already (especially when RTE connects to MARI)

Conclusion on the feasibility of a model able to predict the optimal volume of mFRR to be activated

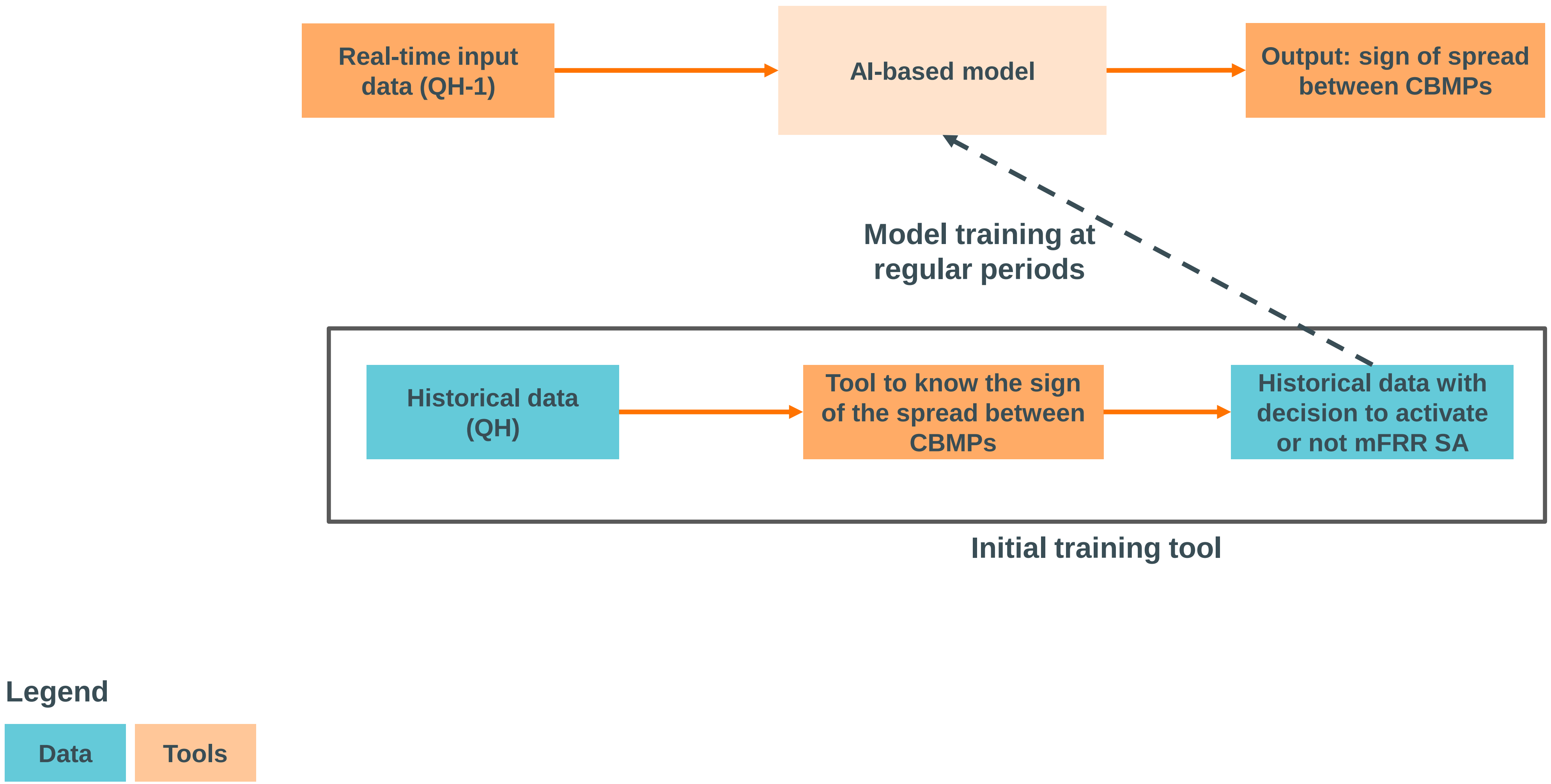
- Developing a model able to predict the **optimal volume of mFRR** to be activated requires access to **additional data**, as well as to a **MARI prototype** that are not available today. The performance of such a model could therefore **not be tested** in the context of the incentive

- If the **required data is made available**, **and residual opportunities for savings in mFRR** would justify it, Elia would **advocate for the release of a mFRR prototype at EU level** and could potentially investigate again the feasibility & added value of such tool if such prototype would become available

- To enable grasping potential benefits in the short term, Elia **explored alternatives** that could be applied in the **short term**, including methodologies based on CBMP spread (see section 4.2), heuristic rules (PoC) and the use of mFRR elastic demand (see section 4.3)

4.2. Methodology based on CBMP spread

Elia implemented & tested a simplified methodology based on the spread between historical CBMPs



Elia tested 3 different methodologies focusing on the sign of the spread between CBMPs for the "real" mFRR & aFRR demands, with different levels of interpretability

1. Separate forecast of **aFRR & mFRR CBMPs** for the past-observed level of demands, using an **"interpretable" methodology with an AI-based decision-tree**

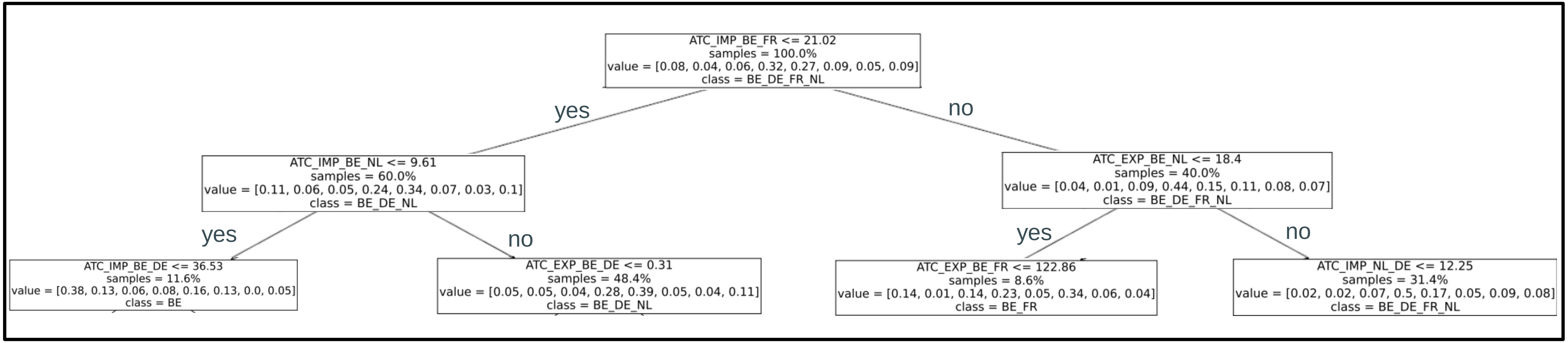
2. Separate forecast of **aFRR & mFRR CBMPs** for the past-observed level of demands, using calibrated **AI-based** algorithms (less interpretable)

3. **Direct forecast of spread of CBMPs** for the past-observed level of demands, using calibrated **AI-based** algorithms (less interpretable)

The methodologies have in common that they:

- Take real-time data and try to compare with historical data, to find a similar past situation
- **Focus on the sign of the spread between CBMPs** for the "real" mFRR & aFRR demands
- Work with a simple cost function (the aim is to compare activation costs between the mFRR volume activated historically, or no mFRR activation at all)

In the first methodology, Elia built a tree-based model to train it relatively quickly with a simplified historical evaluation tool

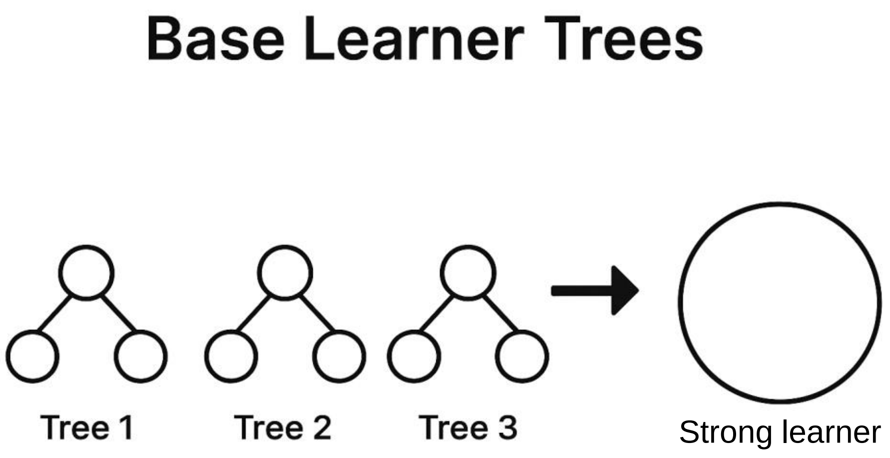


Legend : value = ['BE', 'BE_DE', 'BE_DE_FR', 'BE_DE_FR_NL', 'BE_DE_NL', 'BE_FR', 'BE_FR_NL', 'BE_NL']

The tree-based model seems adapted to the ATC-availability and subsequent CMOL access, which are key drivers of the CBMPs

The second & third methodologies using calibrated AI-models involve "Base learner trees"

- **Base learner trees** are individual decision trees that are combined to create a single, more accurate "strong learner" that **improves the overall predictive performance** beyond that **of individual trees**



- However, the **resulting strong learner** is not based on a decision-tree anymore → the approach is **less interpretable**

The performance of the different methodologies based on CBMP spread is close to the one of a simple rule

Test period : 15/06/25 – 07/09/25	Correct forecast rate & aFRR vs. mFRR activation rate	Estimated activation cost differences (representative set of QHs with mFRR SA demand that could be replaced by aFRR without compromising operational safety*)
Cheapest option between mFRR volume activated historically or no mFRR activation	Correct forecast : 100% aFRR activation : 85%	Reference
Simple rule based on aFRR (similar to current PoC)	Correct forecast : 85% aFRR activation : 100%	Ref + 0.98 MEUR/y
Decision-tree methodology	Correct forecast : 81% aFRR activation : 82%	Ref + 1.57 MEUR/y
Base-learner tree methodology "both CBMPs forecasted separately"	Correct forecast : 86% aFRR activation : 94%	Ref + 0.99 MEUR/y
Base-learner tree methodology "direct CBMP spread forecasted"	Correct forecast : 87% aFRR activation : 95%	Ref + 0.96 MEUR/y

For comparison:
- FRR activation costs represent ~60 MEUR/y
- PoC savings are estimated at ~6 MEUR/y

Difference of ~20kEUR/year estimated between the simple rule & the most performant model

- The **performance of both base-learner tree methodologies is close** to the one of a simple rule
- Currently, **market conditions** are characterized by largely imbalanced aFRR & mFRR CBMPs (aFRR ~85% of time cheaper than mFRR + when mFRR is cheaper, the CBMP spread is in average not large), thus a tool is **not necessarily required**
- Even though there does not seem to be a business case for our tool today, the **connection of RTE to MARI** or **other market events** (such as the increase of the Spain – France cross-border capacity limit) **might change the situation**
- Elia recommends to stop further developments of simple methodologies based on the spread of CBMPs, but to **test them again once RTE is connected to MARI** (testing tool is already developed → should be quick to test on a new dataset)
- The tool robustness to context changes could not be properly evaluated → to be tested when RTE connects to MARI
- The implementation of mFRR elastic demand constitutes an alternative option

* Disclaimers : Note that a aFRR CBMP price-taker assumption is used (aFRR volumes could replace mFRR volumes without any aFRR price increase)
Additionally, the presented results should be appreciated with caution. These aim to compare the performance of different methods, but should not be seen as targets or realistically achievable results

4.3. mFRR elastic demand assessment

Note that mFRR elastic demand can be implemented independently of the outcomes of the long-term methodology

mFRR SA elastic demand definition & principles of use

Definition:

- mFRR SA elastic demand corresponds to a mFRR SA demand for which **price** and **volume thresholds** are defined by the TSO when submitting the demand to the mFRR-platform

Principles of use:

- When submitting such demand, the intention is to **lower FRR prices**
- In case this demand cannot be covered due to unavailable mFRR SA within requested thresholds, **alternative means** (aFRR and/or mFRR DA) should be available to cover it

Objective function:

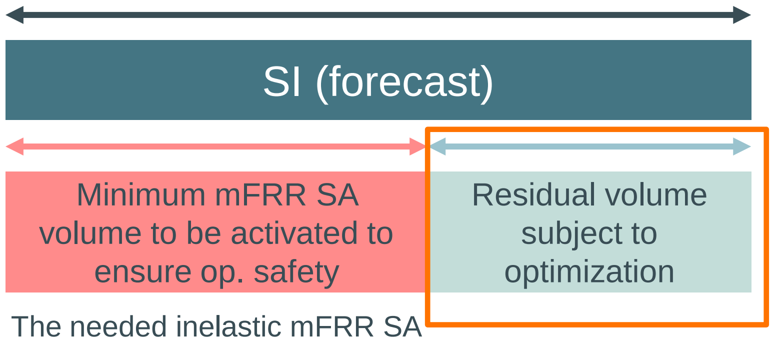
1) The first priority remains to ensure operational safety
2) Optimizing FRR costs comes as second priority

1. Ensuring operational safety

When aFRR is not sufficient to reasonably cover the full SI, **inelastic mFRR SA** needs to be pro-actively activated:

- When ATCs are limited (but could evolve in future)
- Situations with large ATCs but large SI as well

Currently corresponds to ~ **10% of the QH**
(as monitored in the Proof-of-concept)



The needed inelastic mFRR SA volumes are **not subject to economic optimization**

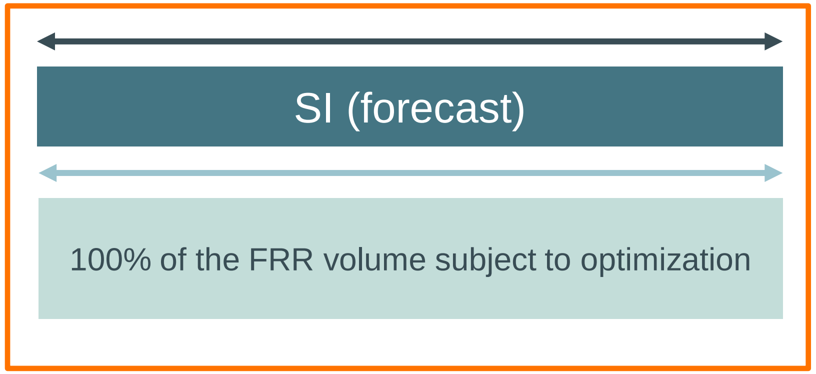
In a first step, mFRR SA could be submitted in inelastic form only for QH with a need to ensure operational safety. Residual volumes could be covered by aFRR only. The opportunity to use elastic mFRR for those QH could be introduced progressively

2. Optimizing FRR costs

In other situations, activating inelastic mFRR SA **is not needed** for operational safety as we could reasonably cover it with aFRR.

The objective is then **to fully optimize FRR activation costs** (aFRR, mFRR SA), without degrading FRCE*

Currently corresponds to ~ **90% of the QH**
(as monitored in the Proof-of-concept)



The use of mFRR SA elastic demand as an alternative to aFRR could apply to QH where 100% of the FRR volume is subject to optimization

*FRCE = Frequency restoration control error

mFRR SA elastic demand regulatory attention points

Regulatory limits & thresholds
(mFRR Implementation Framework (IF) & ACER's 2020 decision on point 70 of mFRR IF)

- TSOs should have **local alternative means** (aFRR and/or mFRR DA) at time of elastic demand submission
- **Volume threshold** set at the volume of the locally available alternative ways
- **Price of mFRR SA elastic demand** should reflect the local alternatives
  - in up direction: not cheaper than the cheapest local alternative
  - in down direction: not more expensive than the most expensive local alternative

An analysis by CREG is ongoing to clarify whether mFRR DA could be considered as an additional alternative to aFRR

Reporting & publication (mFRR Implementation Framework)

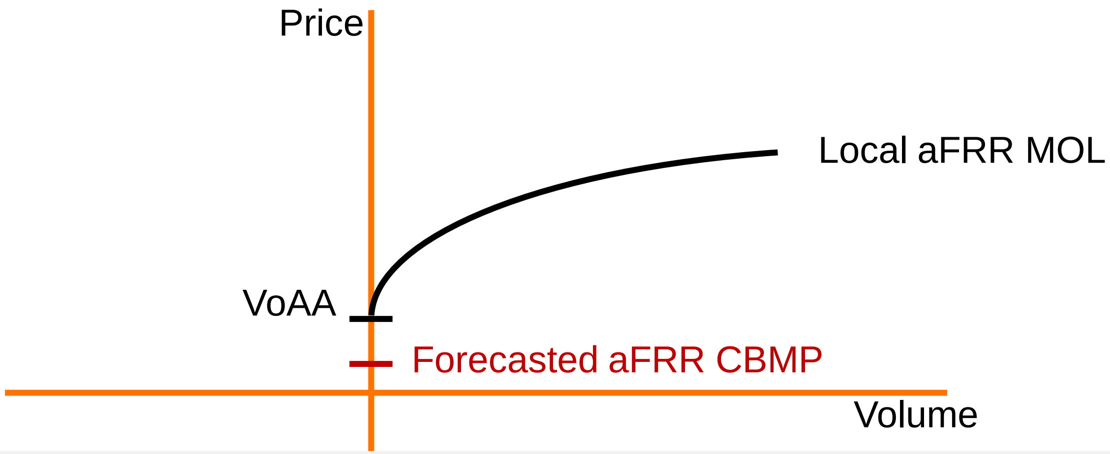
- Mandatory reporting requirements
- Mandatory publication of **"elastic demand curves"** by the TSO

No need to update neither Balancing Rules nor T&C BSP mFRR before such implementation

mFRR elastic demand illustration (in up direction)

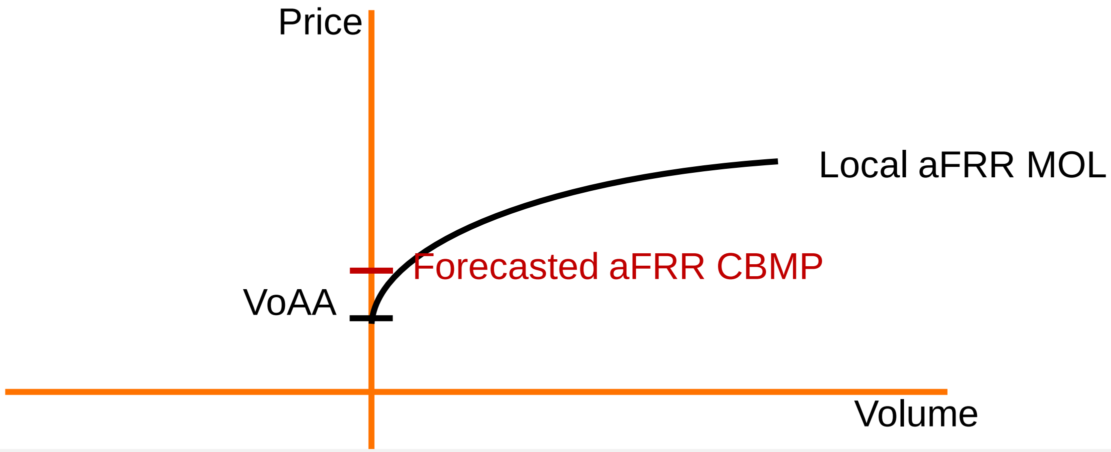
considering only aFRR as alternative (and not mFRR DA)

Case 1: Forecasted aFRR CBMP cheaper than cheapest local alternative (aFRR VoAA)



In this case, to comply with regulation, Elia would need to send mFRR elastic demand **at aFRR VoAA price at minimum.** However, it would be cheaper to activate that demand as aFRR, thus Elia shouldn't submit mFRR elastic demand in this situation

Case 2: Forecasted aFRR CBMP more expensive than cheapest local alternative (aFRR VoAA)



In this case, Elia can send mFRR elastic demand at **forecasted aFRR CBMP**, since it is above the regulation limit.
In this situation, Elia should send mFRR elastic demand to capture additional benefits in case mFRR CBMP is cheaper (for instance in case of netting).

Note that the quality of aFRR CBMP forecast therefore plays a key role. It could trigger additional costs if forecast is often wrong

mFRR elastic demand possible scenarios / uses

Example 1:

- Large ATCs
- Forecasted SI at decision making (T-12min) = -200 MW
- aFRR CBMP forecast **above** local aFRR VoAA (regulatory price threshold for sending mFRR elastic demand)

Example of activation rules before introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 0 MW (not needed for operational safety as ATCs are large)
2. aFRR will cover residual SI

Introduction of mFRR elastic demand

Example of activation rules after introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 0 MW (not needed for operational safety as ATCs are large)
2. mFRR SA elastic demand : x<200MW (*)
3. aFRR will cover residual SI

SI (forecast)	-200 MW
Residual volume subject to optimization	Covered by aFRR

SI (forecast)	-200 MW
Residual volume subject to optimization	Covered by mFRR elastic + aFRR

With the introduction of mFRR elastic demand, Elia could send an mFRR elastic demand to capture additional benefits in case mFRR CBMP is cheaper (and if available)

* In this example, the full SI doesn't aim to be covered by mFRR SA to limit the risk of counter-activation

mFRR elastic demand possible scenarios / uses

Example 2:

- Large ATCs
- Forecasted SI at decision making (T-12min) = -300 MW
- aFRR CBMP forecast **above** local aFRR VoAA (regulatory price threshold for sending mFRR elastic demand)
- Locally available alternative means : 150 MW

Example of activation rules before introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 0 MW (not needed for operational safety as ATCs are large)
2. aFRR will cover residual SI

Introduction of mFRR elastic demand

Example of activation rules after introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 0 MW (not needed for operational safety as ATCs are large)
2. mFRR SA elastic demand : 150 MW (*)
3. aFRR will cover residual SI

Before:

SI (forecast) — -300 MW

Residual volume subject to optimization — Covered by aFRR

After:

SI (forecast) — -300 MW

Residual volume subject to optimization — Covered by mFRR SA elastic + aFRR

With the introduction of mFRR elastic demand, Elia could send an mFRR elastic demand to capture additional benefits in case mFRR CBMP is cheaper (and if available). However, **economic optimization is limited** by mFRR elastic demand regulatory **volume threshold**

* In this example, there are locally available alternative means of only 150 MW, mFRR SA elastic demand volume is therefore limited by the regulatory volume threshold

mFRR elastic demand possible scenarios / uses

Example 3 (use case with simple activation rule currently in place):

- Large ATCs
- Forecasted SI at decision making (T-12min) = -200 MW
- aFRR CBMP forecast **below** local aFRR VoAA (regulatory price threshold for sending mFRR elastic demand)

Example of activation rules before introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 0 MW (not needed for operational safety as ATCs are large)
2. aFRR will cover residual SI

SI (forecast) — -200 MW

Residual volume subject to optimization — Covered by aFRR

Introduction of mFRR elastic demand →

Example of activation rules after introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 0 MW (not needed for operational safety as ATCs are large)
2. mFRR SA elastic demand : 0 MW (since regulatory price thresholds prevent to use it in an economic way)
3. aFRR will cover residual SI

SI (forecast) — -200 MW

Residual volume subject to optimization — Covered by aFRR

Even with the introduction of mFRR elastic demand, **economic optimization is limited** by mFRR elastic demand regulatory **price threshold**. Note that such cases are **very frequent** and highly limit the potential of mFRR elastic demand

mFRR elastic demand possible scenarios / uses

Example 3 (use case if activation rule evolves to include mFRR arbitrage opportunities):

- Large ATCs
- Forecasted SI at decision making (T-12min) = -200 MW
- aFRR CBMP forecast **below** local aFRR VoAA (regulatory price threshold for sending mFRR elastic demand) **but above mFRR CBMP forecast**

Example of activation rules before introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 100 MW (not needed for operational safety as ATCs are large but forecasted cheaper as aFRR)
2. aFRR will cover residual SI

SI (forecast) -200 MW

Residual volume subject to optimization — Covered by mFRR SA inelastic + aFRR

Introduction of mFRR elastic demand →

Example of activation rules after introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 100 MW (not needed for operational safety as ATCs are large but forecasted cheaper as aFRR)
2. mFRR SA elastic demand : 0 MW (since regulatory price thresholds prevent to use it in an economic way)
3. aFRR will cover residual SI

SI (forecast) -200 MW

Residual volume subject to optimization — Covered by mFRR SA inelastic + aFRR

Even with the introduction of mFRR elastic demand, **economic optimization is limited** by mFRR elastic demand regulatory **price threshold**. In the future, if economic opportunities increase with mFRR (for instance when RTE connects to MARI), it could be worth adapting activation rules to allow economic arbitrage with mFRR SA in **inelastic form** (when mFRR SA cannot be sent in elastic form due to regulatory price threshold **and** when it is forecasted to be cheaper than aFRR)

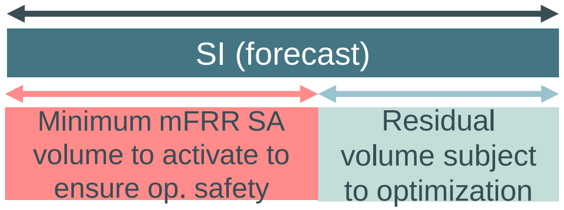
mFRR elastic demand possible scenarios / uses

Example 4:

- Large ATCs
- Forecasted SI at decision making (T-12min) = -800 MW
- aFRR CBMP forecast **above** local aFRR VoAA (regulatory price threshold for sending mFRR elastic demand)

Example of activation rules before introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 500 MW (needed for operational safety*)
2. aFRR will cover residual SI



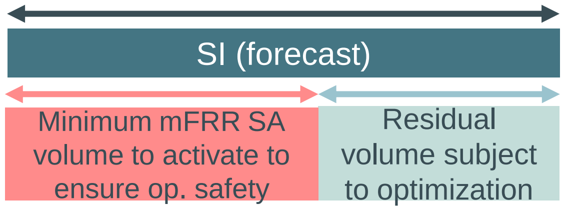
-800 MW

Covered by mFRR SA inelastic + aFRR

Introduction of mFRR elastic demand

Example of activation rules after introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 500 MW (needed for operational safety*)
2. mFRR SA elastic demand : 0 MW (**)
3. aFRR will cover residual SI



-800 MW

Covered by mFRR SA inelastic + aFRR

Inelastic mFRR demand would still fully be determined by operational safety risk (minimum mFRR need).
Elia would not activate mFRR elastic as mFRR inelastic is already activated

* In this example, the mFRR SA demand would be deducted from the maximum aFRR target volume that can be activated (and considering locally available aFRR means / to ensure op. safety)

** In this example, we do not activate mFRR elastic as mFRR inelastic is already activated

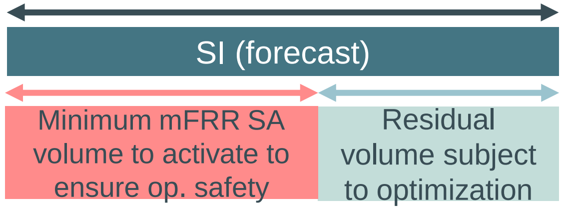
mFRR elastic demand possible scenarios / uses

Example 5:

- Limited ATCs
- Forecasted SI at decision making (T-12min) = -150 MW
- aFRR CBMP forecast **above** local aFRR VoAA (regulatory price threshold for sending mFRR elastic demand)

Example of activation rules before introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 75 MW (needed for operational safety*)
2. aFRR will cover residual SI



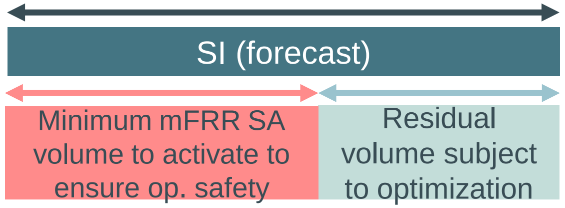
-150 MW

Covered by mFRR SA inelastic + aFRR

Introduction of mFRR elastic demand

Example of activation rules after introduction of mFRR elastic demand

1. mFRR SA inelastic demand : 75 MW (needed for operational safety*)
2. mFRR SA elastic demand : 0 MW (**)
3. aFRR will cover residual SI



-150 MW

Covered by mFRR SA inelastic + aFRR

When ATCs are limited, inelastic mFRR SA demand is to be activated to ensure that a sufficient volume of local aFRR remains available to cover intra-QH SI variations demand.
Elia would not activate mFRR elastic as mFRR inelastic is already activated.

* In this example, mFRR SA demand is activated to ensure that a sufficient volume of local aFRR remains available to cover intra-QH SI variations
** In this example, we do not activate mFRR elastic as mFRR inelastic is already activated

As illustrated in previous examples, in the current context, some principles need to be respected to make use of mFRR elastic demand efficiently

1) Compliance with regulatory thresholds

- Forecasted aFRR CBMP must be above local aFRR VoAA in up direction, and opposite in down direction
- mFRR elastic demand is limited by the regulatory volume threshold

2) ATCs must be large (but this principle could evolve in the future)

3) Limiting the risk of counter-activation

Currently, the frequency of QH for which those principles take place simultaneously **is only ~10%**, limiting the overall mFRR elastic demand potential

Using these principles, a methodology to assess benefits of mFRR elastic demand is implemented

mFRR inelastic demand is determined independently

1 **mFRR inelastic demand fully determined by operational safety needs (as today in PoC situation)**

Then, elastic demand is determined via following criteria / formula

2 **Sending mFRR elastic demand only if**:
- Compliance with reg. thresholds is ensured
- ATCs are large
- Forecasted |SI| is sufficiently large (otherwise risk of counter-activation)

→ If all criteria in step 2 are fulfilled, determination of volume threshold in step 3

3 **mFRR elastic demand volume threshold** considering
- Regulatory thresholds
- Risk of counter-activation

→ Once volume threshold is determined, average activated volumes & prices are estimated

4 **mFRR elastic demand activation estimated using historical average mFRR volumes and CBMP** when netting through MARI exchanges are observed

Disclaimer:
Rules defined on this slide are defined to assess a high-level mFRR elastic demand potential. These rules are currently being reviewed and may be adapted by Elia before implementation. Additionally, operational feasibility is currently being assessed

Evaluated benefits of mFRR elastic demand suggest to go for implementation

1. Estimation of yearly potential : $mFRR\ elastic\ demand\ volume\ x\ (real\ aFRR\ CBMP\ -\ price\ for\ elastic\ demand\ (VoAA))$
(supposing at this stage that at all moments, 100% of elastic demand covered at the requested price)

- “aFRR forecasting mistakes” (aFRR cheaper than mFRR during QH) **~30-40% of time & incorporated** (cost deducted from potential)
- **Maximum** potential is estimated around **1 MEUR** per year (75% in down direction)

2. Estimation of conversion rate : based on historic observation of netting between BE and ES demand (market-sensitive)

- Conversion rate of this maximum potential currently estimated at ~20%
- Leading to mFRR elastic demand benefits currently estimated around **200 kEUR** per year
- There is a business case for mFRR elastic demand as implementation complexity / budget seems very limited
- Once RTE will be connected to MARI, the maximum potential might not significantly change, however the **conversion rate will likely increase as additional netting opportunities with France will appear,** leading to higher annual benefits
- Those benefits add up to the ones of simple / heuristic rules

Disclaimers:

- Results need to be taken with caution as strong assumptions on mFRR elastic demand activation prices and volumes are taken. Results also highly depend on market conditions (assumptions used here are for the summer period as there is only historical data available for summer 2025 since Elia’s connection to MARI)
- Before going to implementation, some IT developments are required

mFRR elastic demand advantages & conclusion

Advantages of mFRR elastic demand

1. Could be implemented **without forecasting tool** (using aFRR VoAA or aFRR CBMP at decision-making as price threshold) in a first step, with limited implementation costs (**no-regret**), to capture a significant part of the “netting potential”
2. To increase further the benefits (from potentially inexpensive mFRR prices), a **forecast of the aFRR CBMP** could be implemented
3. There is **no need to have a mFRR CBMP forecast**
4. Implementing mFRR elastic demand would provide Elia with more options for improved activation strategies in the future. A concrete proposition of activation rules and possible implementation will be discussed in a next WG

Conclusion

- mFRR elastic demand could be seen as a no-regret implementation measure
- Elia proposes that implementation could be launched in 2026

Openings:

1) Sensitivity analysis on aFRR contracting volume
2) Arbitrage between platforms

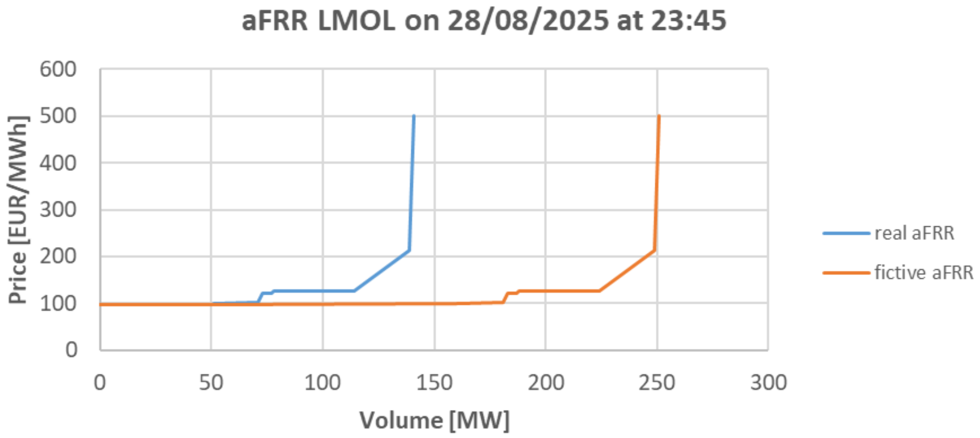
CREG suggested Elia to conduct a sensitivity analysis to assess to which extent a higher volume of contracted aFRR may increase the potential of economic optimization locally

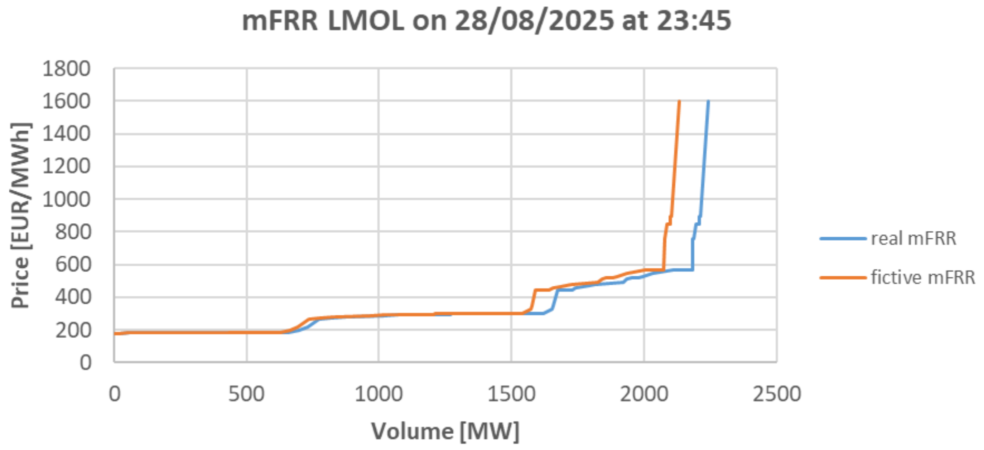
Context

- When assessing the FRR optimization potential (see savings analysis in section 3), Elia concluded that, **when ATCs are limited**, **savings are currently impossible to capture** due to the limited locally available aFRR volume & to SI forecast uncertainty*
- As agreed with CREG, Elia conducted a sensitivity analysis to assess if the **theoretical optimization potential in local situation** could increase by procuring a higher volume of aFRR

Assumptions agreed with CREG for this sensitivity analysis

- aFRR procurement volume **to be increased until formation of an optimization potential in local situation** (instead of 110MW typically in 2025), extending the typical current merit-order by adding flexibility at an average bidding price of aFRR VoAA (ambitious assumptions which could correspond to a “potential upper limit”)
- Respective decrease of the mFRR contracted volume is considered, by “shrinking” the typical current merit-order while keeping its same “shape”





* Both the average SI & the intra-QH SI need to be forecasted precisely to achieve savings in local situation

Elia concluded that* an increase of the aFRR contracted volume could lead to the formation of an optimization potential in local situation

Sensitivity case: aFRR contracted volume increased to 160MW

- Activation costs for QHs with limited ATCs could be reduced by **approximately 1% (~200 to 400 kEUR per year),** leading to the **formation of an optimization potential in local situation**

Disclaimers:

- These calculations consider **ambitious price assumptions** in the aFRR MOL and a similar SI forecast performance as today
- A recommendation on the future volume of aFRR to be contracted however requires a more robust methodology & more extensive analyses (consideration of additional procurement costs in the balance, various scenarios and sensitivities on key parameters such as prices and MOL shapes, etc.) which are out of the scope of this incentive
- In 2026, a study will be executed on FRR procurement optimization, including such extensive analyses, to recommend an optimal aFRR volume to be procured in the future

Way forward:

In case the available aFRR volume would increase in the future (as an outcome of the FRR procurement optimization study results or other market evolutions), and the formation of an optimization potential in local situation would be confirmed, the current activation strategy in local situation (relying on mFRR to cover the SI magnitude) could be adapted

* Please note that ambitious price assumptions have been made in this scenario (see previous slide)

Discussion on arbitrage between platforms

Elia is not in favor of deliberate activation of mFRR in opposite direction (or leading to overshoot) to make benefits from mFRR-aFRR price difference

- We believe, as a TSO, that **it is not our role to arbitrate between aFRR & mFRR prices outside the flexibility volume needed to cover our own imbalance**

- Our reserves are not dimensioned to be used for cross-platform arbitrage. Allowing such arbitrage would thus be inconsistent with our dimensioning and present risks of saturation

- In 2019, NRAs could not agree on counter-activations in MARI SA and ACER had to make a decision. Stakeholders were also either prudent in allowing counter activations, or against it as referred to in ACER's decision 03-2020 (20)(b)
    - *"Whereas some stakeholders could support scheduled counter-activations only for optimizing balancing needs, another group completely opposes the principle, arguing that trading, some call scheduled counter-activations trading, should not be done by mFRR-Platform but facilitated by the (cross-zonal) intraday markets;"*

- Elia considers those concerns to also apply to cross-platforms counter-activations

- Elia therefore doesn't intend to analyze the impact of such arbitrage between aFRR and mFRR in the context of the incentive

5. Appendix

List of operational constraints

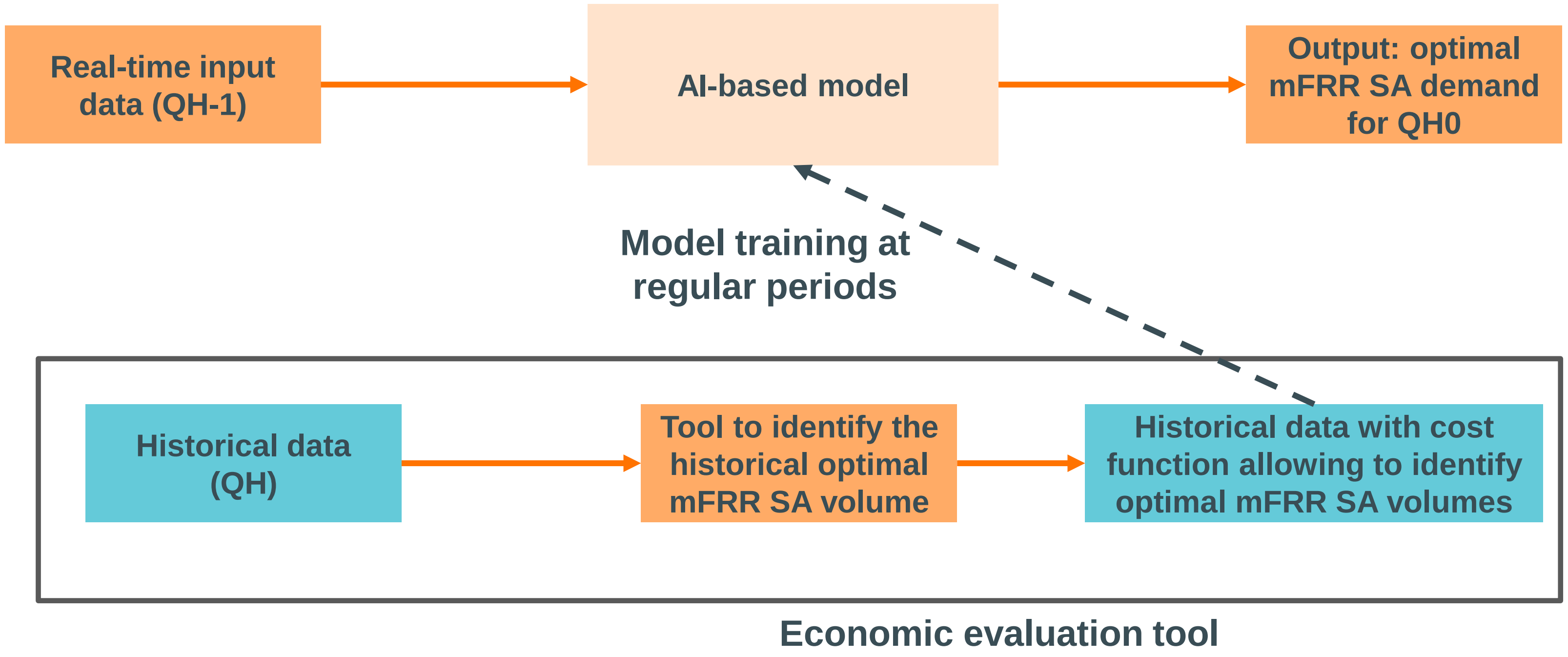
A list of operational constraints impacting the objective function has been defined

Constraint objective	Operational constraint title
Limit the (negative) impact on FRCE* quality	Ensuring access to sufficient local aFRR to cover intra-QH SI fluctuations
	Avoid depleting the EU aFRR reserves to cover structural imbalances
	FRCE* quality should continue respecting the targets set at EU level
	FRCE* quality should remain in a range that ensures no impact on aFRR dimensioning
	Avoiding frequent alert/emergency states (considering potential Picasso disconnection, loss of ATCs)
Limit amount of activated FRR volumes	Avoiding activating more FRR balancing energy volumes than strictly required (e.g., avoiding mFRR activations in opposite direction of the average QH SI and/or activations of higher mFRR volumes as the average QH SI)
Avoid transfer of mFRR inelastic demand to aFRR elastic	Avoid transferring mFRR inelastic demand from MARI as elastic demand to PICASSO

*FRCE = Frequency restoration control error

4.1. Methodology based on optimal mFRR SA volume

Elia investigated whether a methodology to identify the historical optimal mFRR SA volume could be developed



Legend

Data | Tools

Some inputs are available in real-time to the forecasting model, while others are only available ex-post

Real-time input data (QH-1) → **AI-based model (based on AI)** → **Output: optimal mFRR SA demand for QH0**

Inputs

Available in real-time	Unavailable in real-time
• aFRR CMOLs (for QH-1) • aFRR CBMPs and demands (for QH-1) • Local aFRR & mFRR MOLs (for QH0) • ATCs with neighboring countries (for QH0) • Different forecasts for the BE system: SI forecast, solar, wind and load forecasts (for QH0)	• mFRR CMOLs, CBMPs and demands (only known ex-post)* • Detailed ATCs between all European countries *As soon as available ex-post (a few QH later), those data are used (but not the real-time ones for the considered QH)

Outputs

- Optimal mFRR SA demand for QH0
- Visualization of aFRR CMOLs and estimation of mFRR CMOL for the activation decision

The economic evaluation tool relies on different tools & assumptions

Historical data (QH) → Tool to identify the historical optimal mFRR SA volume → Historical data with cost function allowing to identify optimal mFRR SA volumes

Economic evaluation tool

Tools

Prototype of Picasso aFRR algorithm

Allows to change the aFRR demand on 4 seconds timestep and re-calculate the aFRR CBMPs

Simplification of MARI AOF

- There isn’t any prototype of the MARI algorithm
- Therefore, **this tool is the most challenging to build**. Elia investigated whether a simplified version of MARI AOF could be built (see next slides)

Assumption

- At this early stage, Elia doesn’t consider the impact of a change of the FRR activation strategy on the implicit reaction, but the aim is to harmonize with other functions / tools of the smart balancing controller initiative at a later stage

Elia investigated whether a simplified version of MARI AOF could be built

Picture source : MARI activation optimization function (AOF) public description

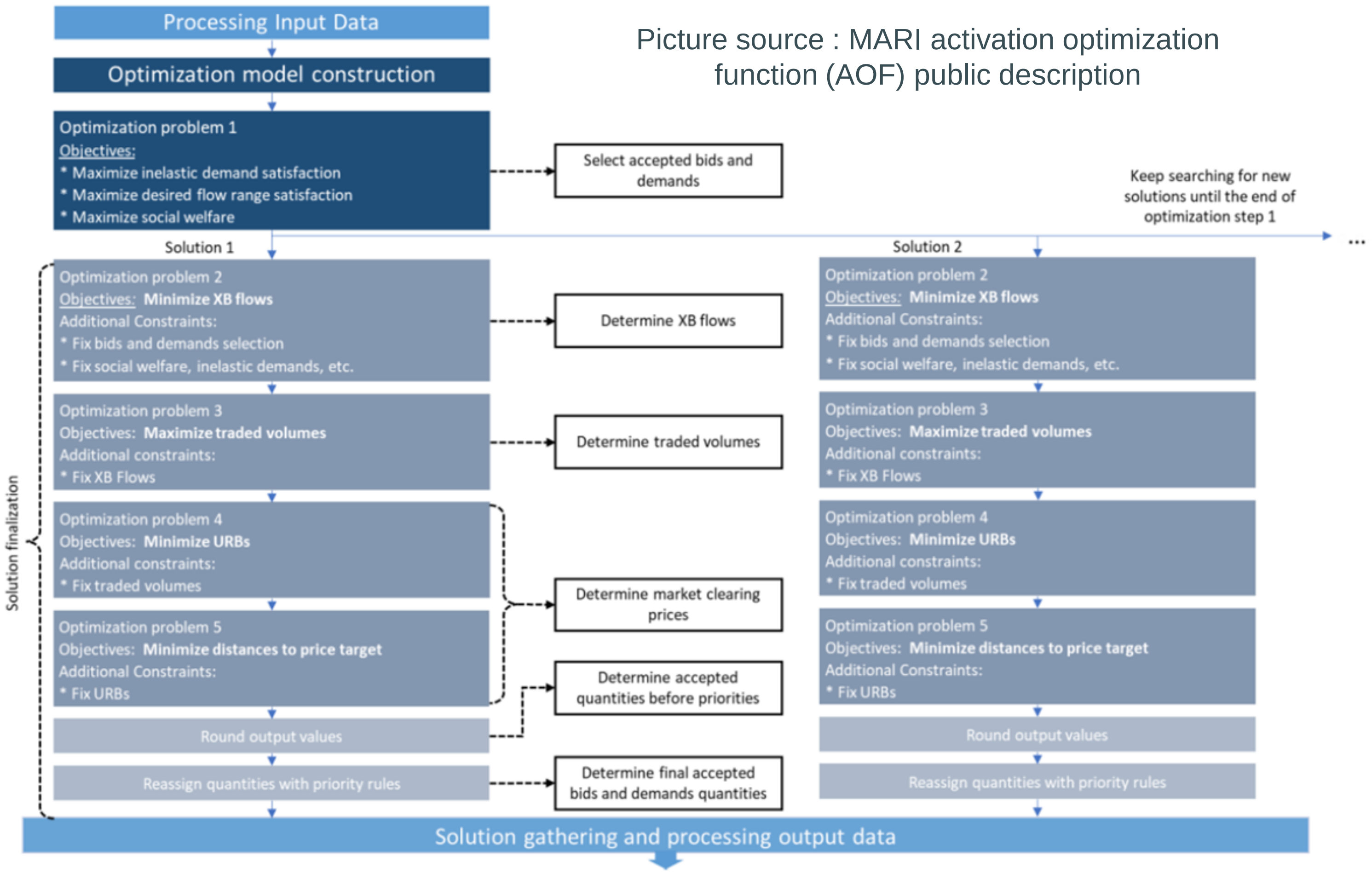
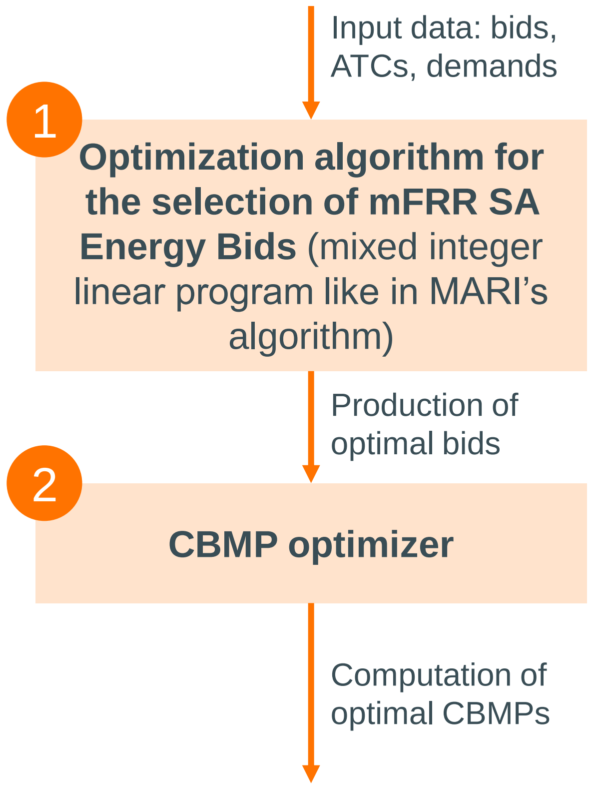


Figure 24: MARI AOF algorithm workflow

Different consecutive optimization problems and objectives & iterative process to find the final optimum of each QH



Looking at the **complexity** of the MARI optimization algorithm, Elia built a **2-step simplified approach.** Priority given to implement a replication of the "coupled mode" (to consider XB exchanges between countries and determine CBMPs) as described in the MARI AOF

URB = unforeseeable rejected bids, XB = crossborder

Assumptions were made for this simplified version of MARI AOF

1. ATCs available to the balancing platforms are only available between Elia & neighboring countries. For other ATCs, a proxy of ATCs (continuous allocation of ATC in ID, available on ENTSO-e Transparency) is used*

2. Details about linkings and complex mFRR SA bids aren't available for other countries than Belgium. The historical status of mFRR SA bids (available / or not) is used, however it is impossible to calculate the mFRR SA CBMP precisely for another mFRR demand

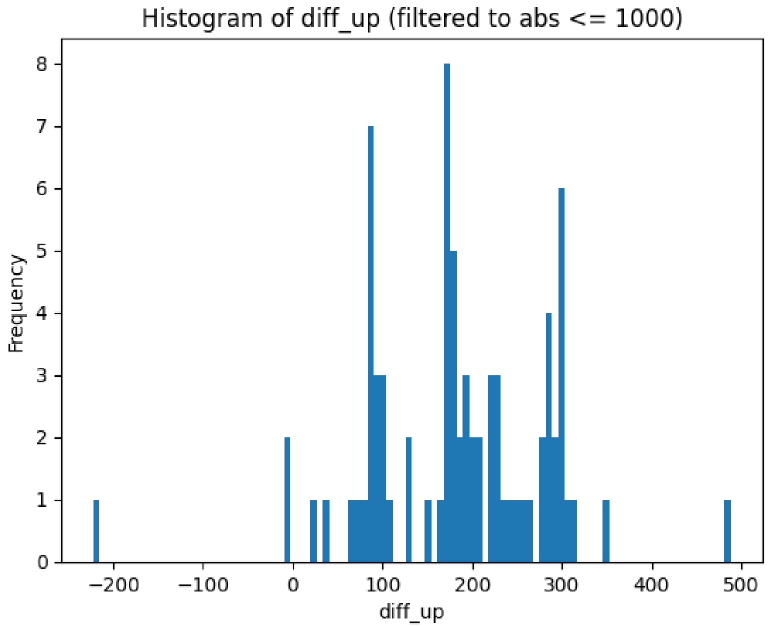
3. Consideration of neighboring countries & areas with highest mFRR demands only: BE, DE, FR (ATC-sharing), ES, PT but the areas could be further extended**

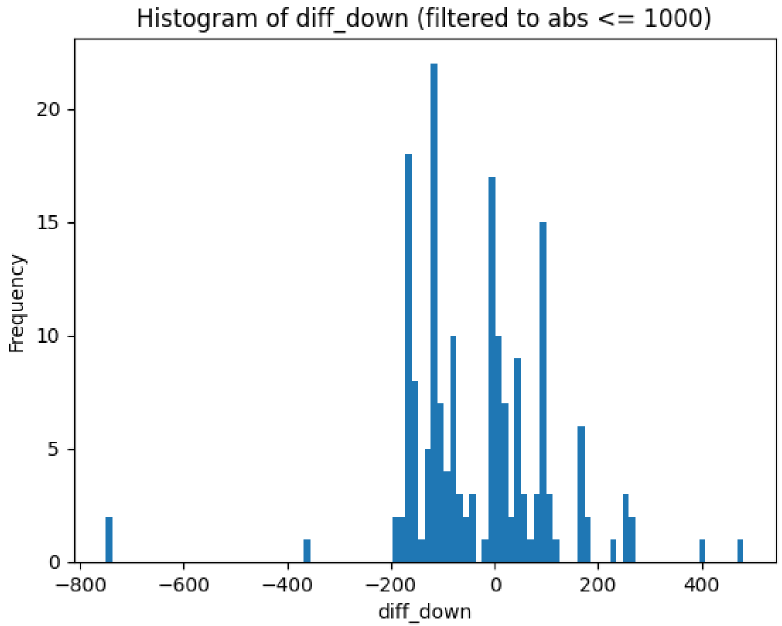
* Currently, it is not possible to have access to ATCs communicated by TSOs to the balancing platforms, except the ones Elia has with its neighboring countries. A data extraction tool is currently being developed by the MARI-platform. At this stage, it remains unclear if this possibility will be implemented, allowing to have access to this data

** Due to the uncertainty on ATC values, it is not considered relevant to include the 6 other countries (CZ, AT, SK and 3 Baltic countries) that are currently connected to MARI. More specifically, CZ, AT and SK almost do not activate mFRR (around 1% of time) & the 3 Baltic countries are currently quite isolated as Poland is not yet connected to MARI (and not ATC-sharing)

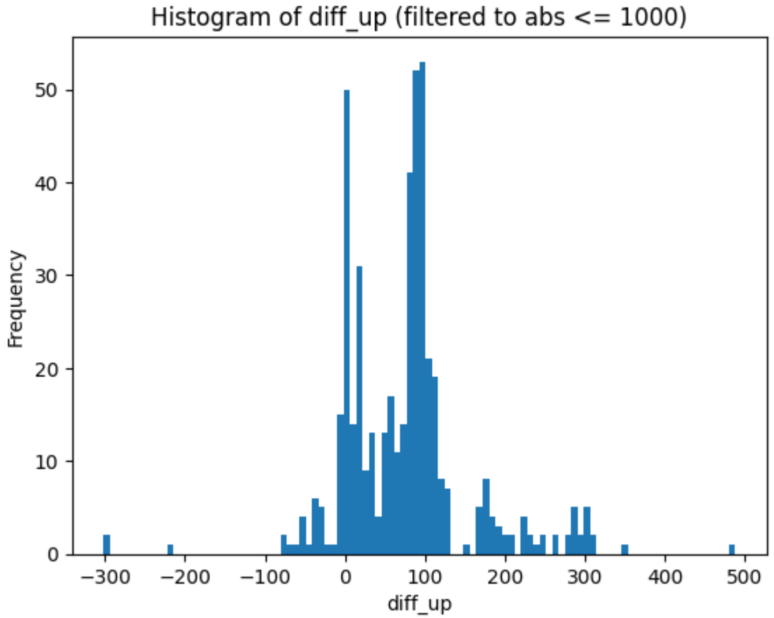
mFRR CBMP errors are of different levels

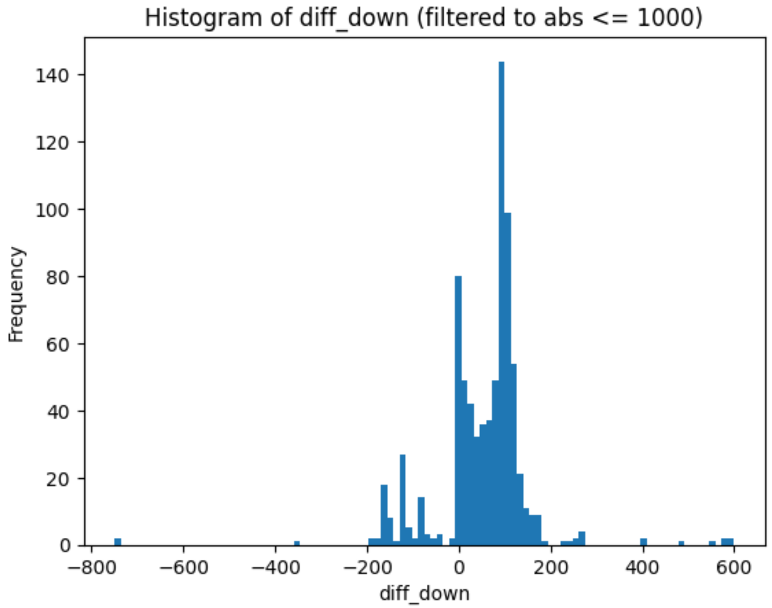
Belgium





All areas
(neighboring countries & areas with highest mFRR demands: BE, DE, FR (ATC-sharing), ES, PT)





The convention of the errors is actual CBMP minus estimated CBMP

- Errors are of both signs, which indicates that the optimizer both under and overestimates mFRR SA CBMPs
- Errors could be due to the simplification of the approach in 2-steps, which does not consider all complex objective functions of the MARI AOF, but also to complexities, ATCs or other factors
- Overestimations indicate that, sometimes, it accepts more expensive bids than those accepted in reality

Building the economic evaluation tool requires access to additional data, as well as to a MARI prototype, that are not available today

	1	2	3
Initially envisaged approach	**Computing precisely historical mFRR CBMPs**	**If step 1 successful, implement the what-if analysis (changing the mFRR demand) to assess impact on mFRR CBMPs**	**Model training to forecast optimal mFRR SA demand for QH0**
Conclusion on feasibility	Elia demonstrated that this task isn't feasible with a simplified approach → **requires a prototype of MARI AOF**	Important data to evaluate CBMPs for a different mFRR SA demand is currently not made available by MARI platform. → **requires data that is currently unavailable**	Relevant only if steps 1 & 2 are reliable. A similar training has already been implemented for the "CBMP spread" approach (see further slides)

- Additionally, it is impossible to **assess** the **exact potential of such approach** without a MARI prototype & missing data (to identify the mFRR optimal volume). And even if available, it would remain impossible to verify with 100% certainty the calculated mFRR CBMP for another mFRR demand
- The implementation of **mFRR elastic demand** would capture part of this added-value already (especially when RTE connects to MARI)

Conclusion on the feasibility of a model able to predict the optimal volume of mFRR to be activated

- Developing a model able to predict the **optimal volume of mFRR** to be activated requires access to **additional data**, as well as to a **MARI prototype** that are not available today. The performance of such a model could therefore **not be tested** in the context of the incentive

- If the **required data is made available**, **and residual opportunities for savings in mFRR** would justify it, Elia would **advocate for the release of a mFRR prototype at EU level** and could potentially investigate again the feasibility & added value of such tool if such prototype would become available

- To enable grasping potential benefits in the short term, Elia **explored alternatives** that could be applied in the **short term**, including methodologies based on CBMP spread (see section 4.2), heuristic rules (PoC) and the use of mFRR elastic demand (see section 4.3)