STUDY ON PAID-AS-CLEARED SETTLEMENT FOR AFRR & MFRR ACTIVATED ENERGY

FINAL VERSION

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EXECUTIVE SUMMARY

In this report, we study the possible shift from the current FRR pricing schemes towards paid-as-cleared settlement of activated energy. In a context where such changes are more than encouraged by the European Balancing Guidelines and will therefore most probably be ultimately implemented, the focus has been to assess whether an earlier implementation on a local basis is valuable and desirable.

We first provide a theoretical analysis to differentiate the pros and cons of the two settlement schemes in general, and conclude that – generally speaking - a paid-as-cleared methodology facilitates competition, improves price formation and attracts liquidity, and is therefore worth to be considered further. Key findings are among others that paid-as-cleared – in conjunction with a single marginal imbalance pricing scheme - provides stronger incentives to (1) offer available flexibility in FRR markets and to (2) price it at marginal costs.

Then, after a description of the current balancing mechanism applicable in Belgium, we compare it with the neighboring European markets and observe that – while the Belgian design has some similarities with these markets – there are always quite significant nuances or differences that necessitate further harmonization. Besides we observe also that currently only in a limited number of countries a paid-as-cleared settlement is applied.

After that, we highlight some key elements in the current Belgian balancing arrangements that **require adaptations prior to the migration towards a paid-as-cleared settlement approach**:

- Firstly, it is highly desirable that the so-called "**Transfer of Energy"** is resolved in order to allow all resources that are willing to participate to FRR services to obtain a remuneration for the activated energy.
    - For mFRR, current expectations are that such a development will be fully implemented by the end of 2018.
    - Elia is currently investigating the feasibility to transfer the Transfer of Energy principles - as developed for mFRR - to aFRR in the framework of a pilot project called 'R2 non CIPU". The fact that for aFRR power is activated via signals per seconds – in contrast to mFRR which is a quarter-hourly energy product – requires a detailed assessment. A detailed implementation plan is not expected to be available before the end of 2018.
- Secondly, to be efficient, a paid-as-cleared mechanism necessitates a **merit order activation** of bids.
    - For mFRR, a full merit order activation infers some legal and technical changes – for which a process has already started upon impulse of the Elia User Group. It is also necessary to integrating the start-up costs of idle CIPU assets participating to R3 directly in the merit order. Because of these changes, and the dependency with the resolution of the Transfer of Energy issue, the implementation of a **merit order activation of mFRR for Free and Standard bids is expected around the end of 2018. In addition** it needs also to account for possible implementation dependencies with other important foreseen product/market developments, notably the project aiming at a review

of the mFRR product design (including the opportunity or not to keep 2 distinct products) within the framework of a possible shift towards a daily procurement of mFRR reserves, design phase of which will be undertaken in the course of 2018; **Consequently an effective implementation of a paid-as-cleared settlement for mFRR activated energy could be envisaged at the earliest in the second half of** 2019 on condition of having at least the same level of liquidity as today.

- For aFRR, the implementation of merit-order activation implies, on top of the typical legal and technical aspects, very significant modifications of the IT systems which are **not possible before end-2019 at earliest**. **Paid-as-cleared settlement of aFRR activated energy can therefore not realistically be expected before 2020.** Further, we also deduct from data observations and simulations that the level of liquidity of aFRR is currently insufficient for a proper implementation of paid-as-cleared aFRR activations. The actual implementation of marginal pricing in aFRR is thus also dependent on a significant improvement of liquidity (a.o. expected as a consequence of the other planned aFRR improvements)

The document then explores more in details the practicalities of a paid-as-cleared mechanism for mFRR and aFRR in isolation, and browses different design aspects (such as product definitions, price boundaries, activation timings, interactions with cross-border initiatives, etc.). **This analysis is demonstrating that the implementation of a paid-as-cleared is not straightforward as different design choices need to be made**. A precise price formation heuristic is presented for mFRR (notably to address acceptance tolerance and indivisibilities) while two alternative mechanisms are suggested and discussed for aFRR. For each design element, an implementation recommendation is discussed. Considering the implementation implications, the final choice between both options can only be taken after discussions with stakeholders.

The analysis continues by exploring the possible interactions that could be set between the different FRR pricing schemes (i.e. “cross-product pricing”). Roughly speaking, the conclusion is that artificially equalizing the prices of different products to the most extreme ones leads to a number of difficulties for little added value (although there are possibly some exceptions that deserve further considerations). We also did not find reasons for a fundamental change in the imbalance price setting mechanisms, nor could we identify significant reasons to suspect a deterioration of the functioning of the intraday market as a consequence of marginal FRR pricing.

We then finish the study by presenting the results of some financial simulations. Such simulations have been based on historical bids, which have been used to estimate the financial impact of the implementation of paid-as-cleared in FRR. As the historical bids have been used without any modification, the implied assumption is that the bidding and pricing strategies under paid-as-bid (with the current schemes or with full merit order activation) and under paid-as-cleared are identical. Such strong assumptions are obviously highly questionable, as they by construction only provide worst-case scenarios. The numerical results are thus to be interpreted with great caution.

Simulations show a contained impact of changing towards paid-as-cleared settlement in mFRR. The current liquidity in mFRR is therefore considered as sufficient for such a change. BSPs will be remunerated (for the assessed worst case scenario) around 1 M€ extra per year in case paid-as-cleared is implemented. However it is likely that this increase in costs could be compensated by lower capacity costs due to a better liquidity in the market. Based on these results, we conclude that **for mFRR it is appropriate to implement a paid-as-cleared settlement scheme** on condition that the liquidity level remains at least at the same level**.**

The simulated cost impact on aFRR on historical data is more problematic: total aFRR activation costs are likely to significantly increase upon implementation of paid-as-cleared settlement (up to 4,5-7 M€ per year). **This is due to the level of liquidity in aFRR, which is insufficient.** It is not clear whether this increase in costs could be compensated by lower capacity costs due to better liquidity in the market. **Hence the implementation of a paid-as-cleared settlement in the current conditions is not expected to deliver its benefits.** However, we expect that the numerous aFRR improvements which are planned in the next 2 years will alleviate this concern.

Our main conclusions are that an early implementation of paid-as-cleared settlement for activated FRR energy – i.e. prior to the deadline as prescribed by European legislation - is a desirable improvement in general. Unfortunately, such changes are not straightforward, and are subject to multiple dependencies, so that their implementation cannot be expected immediately. Though, we determine that there are in fact little interactions between the implementation of paid-as-cleared in the aFRR and mFRR mechanisms, so that both implementation projects can be treated independently and go-live at different moments. In particular, go-live in mFRR is not made dependent on the technical and improved liquidity conditions which are specific to aFRR.

A very high-level preliminary assessment leads to possible go-live at the earliest in the second half of 2019 for mFRR and at earliest during 2020 for aFRR on condition of having sufficient liquidity in this market. **This is obviously subject to a refined analysis and detailed project plans, notably taking into account the detailed design elements as well as the other priorities set by ELIA, CREG and other stakeholders.** Elia would like to stress that before mentioned timelines are very first high-level estimates that depend on the timely completion of a set of important pre-requisites and/or are based on design/implementation studies of related product/market developments that have yet to be performed. As a result, the timelines and dates presented in this document are to be considered only as very indicative. In no case does ELIA commit formally to any implementation plan in this document. Rather, this study is meant to serve as a basis for a discussion with the stakeholders of ELIA.

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1 Introduction

1.1 Scope of the study

Every high-voltage Transmission System Operator (TSO) in Continental Europe is responsible for maintaining the residual balances in its control area which are not resolved by the Balancing Responsible Parties (BRPs). TSOs manage the imbalance in the system via the activation of contracted and non-contracted power reserves supplied by Balancing Service Providers (BSPs).

The table below (see *Figure 1*) is giving an overview of the different types of balancing processes and the corresponding reserve products which are currently used by Elia to perform this task. For the Frequency Restoration Processes Elia is making use of contracted and non-contracted reserves. Currently there is only an energy settlement for the exchanged imbalance netting energy and for the activated balancing energy via the frequency restoration process.

As imbalance netting energy and balancing energy from automatic Frequency Restoration Reserves (aFRR) and manual Frequency Restoration Reserves (mFRR) are used to restore the imbalances of the Belgian control area, the settlement prices of these products are used as an input for the determination of the imbalance prices.

Balancing processes	Current terminology	Description	Procurement	Energy settlement	Current existing Balancing Products
Imbalance netting process	IGCC	Technical netting of opposed imbalances between TSOs of different balancing areas	N/A	TSO-TSO	IGCC
Frequency Containment Process (FCR)	Primary reserves (R1)	Very fast reserves with as objective to stabilize the European frequency in case of deviations after an incident.	Contracted reserves	No	R1 200MHz, R1 100MHz Up, R1 100MHz Down, R1 100 MHz
Automatic Frequency Restoration Process (aFRR)	Secondary reserves (R2)	Fast reserves activated automatically and on a continuous basis to handle sudden disruptions in the area managed by Elia	Contracted & non-contracted reserves	Yes, Paid-as-bid	R2 reserves & bids (Up & down)
Manual Frequency Restoration Process (mFRR)	Tertiary reserves (R3)	Activated manually at request of Elia to address a major imbalance in the Belgian Control Area	Contracted & non-contracted reserves	Yes, Paid-as-bid[1]	R3 Standard, R3 flex, ICH, CIPU Bids, Bids Bidladder

Figure 1: Schematic overview of the different balancing processes

Besides balancing energy, Elia occasionally also performs redispatching of power plants in order to resolve local system constraints. Currently this is done via bids which can also be used for balancing.

[1] Not applicable for the balancing energy activated via Non-CIPU contracts in case of absence of Transfer of Energy or an opt-out agreement (cfr. Infra)

Present document is studying the potential evolution to a paid-as-cleared mechanism for the settlement of activated balancing energy from aFRR and mFRR products (see red square in Figure 1). This study is assessing the following questions:

- What are the key differences from a theoretical perspective between paid-as-bid and paid-as-cleared settlement?
- What is the current implementation in Belgian and in other European countries?
- What are the missing market design elements to implement an efficient paid-as-cleared FRR settlement scheme in Belgium?
- What are the important aspects which needs to be considered when dealing with the topic of marginal pricing?
- What are the different design options for the determination of marginal price and which ones are recommended?
- What are the interdependencies with energy activated for redispatching purposes and energy exchanged with other TSOs in the framework of imbalance netting?
- What are the links to imbalance prices?
- What are the costs and benefits of such an evolution?
- What is the recommendation regarding an evolution to marginal pricing?
- What is the implementation timeline of such a pricing mechanism?

For sake of clarity, present study is not studying the evolution to paid-as-cleared for the capacity remuneration of contracted reserves. Although the basic principles of pricing for contracted reserves are the same, other aspects need to be considered in a study for this distinct topic than those considered in present study. Therefore, **the conclusions of this study are exclusively applicable for a shift to paid-as-cleared for the settlement of activated balancing energy.**

1.2 Legal & regulatory context

Currently the Belgian Federal Grid Code is having no concrete requirements regarding the pricing mechanism to be used for the settlement of balancing energy. Article 159 §1er of the Grid Code is stipulating that the CREG is approving the proposals of the System Operator regarding the "*Règles de fonctionnement du marché relative à la compensation des déséquilibres quart-horaires*". Currently chapter 7 "*Activation de puissance pour le réglage de l'équilibre de la zone de réglage belge*" of those functioning rules is describing that settlement of activated balancing energy is done based on the paid-as-bid principle.

The European legislation is quite prescriptive on this matter: The Electricity Balancing Guidelines[2], in its Article 30, discusses the pricing for balancing energy and cross-zonal capacity used for exchange of balancing energy or for operating the imbalance netting process.

[2] See [8]

<u>Extract Guideline on Electricity Balancing Version 1.03.2017</u>

Article 30

Pricing for balancing energy and cross-zonal capacity used for exchange of balancing energy or for operating the imbalance netting process

1. *By one year after the entry into force of this Regulation, all TSOs shall develop a proposal for a methodology to determine prices for the balancing energy that results from the activation of balancing energy bids for the frequency restoration process pursuant to Articles 143 and 147 of Commission Regulation (EU) 2017/000 [SO], and the reserve replacement process pursuant to Articles 144 and 148 of Commission Regulation (EU) 2017/000 [SO]. Such methodology shall:*

   (a) be based on marginal pricing (pay-as-cleared);

   (b) define how the activation of balancing energy bids activated for purposes other than balancing affects the balancing energy price, while also ensuring that at least balancing energy bids activated for internal congestion management shall not set the marginal price of balancing energy;

   (c) establish at least one price of balancing energy for each imbalance settlement period;

   (d) give correct price signals and incentives to market participants;

   (e) take into account the pricing method in the day-ahead and intraday timeframes.

2. *In case TSOs identify that technical price limits are needed for efficient functioning of the market, they may jointly develop as part of the proposal pursuant to paragraph 1 a proposal for harmonised maximum and minimum balancing energy prices, including bidding and clearing prices, to be applied in all scheduling areas. In such a case, harmonised maximum and minimum balancing energy prices shall take into account the maximum and minimum clearing price for day-ahead and intraday timeframes pursuant to Commission Regulation (EU) 2015/1222.*

3. *The proposal pursuant to paragraph 1 shall also define a methodology for pricing of cross-zonal capacity used for exchange of balancing energy or for operating the imbalance netting process. Such methodology shall be consistent with the requirements established under Commission Regulation (EU) 2015/1222, and:*

   (f) reflect market congestion;

   (g) be based on the prices for balancing energy from activated balancing energy bids, determined in accordance either with the pricing method pursuant to paragraph 1(a), or if applicable, the pricing method pursuant to paragraph 5;

   (h) not apply any additional charges for the exchange of balancing energy or for operating the imbalance netting process, except a charge to compensate losses if this charge is also taken into account in other timeframes.

4. *The harmonised pricing method defined in paragraph 1 shall apply to balancing energy from all standard and specific products pursuant to Article 26(3)(a). For specific products pursuant to Article 26(3)(b), the concerned TSO may propose a different pricing method in the proposal for specific products pursuant to Article 26.*

5. *Where all TSOs identify inefficiencies in the application of the methodology proposed pursuant to paragraph 1(a), they may request an amendment and propose a pricing method alternative to the pricing method in paragraph 1(a). In such case, all TSOs shall perform a detailed analysis demonstrating that the alternative pricing method is more efficient.*

In summary, this article of the Electricity Balancing Guidelines is stating that all **TSOs should develop a proposal regarding the settlement pricing methodology for activated energy** that obeys to the following principles:

Paragraph 1

- **Based on marginal pricing / Paid-as-cleared,**
- In case the same bids are used for balancing and congestion, the bids activated for congestion may not set the marginal price
- There should be at least one activation price per imbalance settlement period,
- Prices are consistent with pricing in day-ahead and intraday timeframes,
- Prices give the correct price signals and incentives to market participants,

Paragraph 2

- Prices can possibly be bound by technical price limits considering the limits applicable for day ahead and intraday markets.

Paragraph 3

- There should be also a pricing mechanism for the use of the cross zonal capacity (not relevant for present study – see §1.3)

Paragraph 4

- The harmonized pricing method is applicable for standard balancing energy products to be proposed by ENTSOE one year after the Guideline on Electricity Balancing is entering into force. Other approaches are possible for specific products.

Paragraph 5

- All TSOs may jointly develop an alternative to "paid-as-cleared" in case they are able to demonstrate, based on the observed inefficiencies after implementation of paid-as-cleared, that the alternative is more efficient.

In practical terms, **the Guideline on Electricity Balancing is requiring the use of harmonized pricing mechanism for the settlement of balancing energy for standard balancing products as soon as a TSO is joining the common European platform.** Regarding the usage of existing local products before joining the platforms, the guideline is silent. Hence there are no pricing requirements applying to them.

Within this study, we explore the local implementation of a paid-as-cleared settlement scheme for (automatic and manual) FRR activation. This is done locally, in anticipation of a harmonized pricing methodology following the above-mentioned principles that will be mandatorily applicable for all the standard products defined under the Electricity Balancing Guidelines.

1.3 Considered time horizon

The Electricity Balancing Guidelines [8] provides some deadlines for the implementation of European balancing platforms. Article 20 (respectively Article 21) stipulates that for Frequency Restoration Reserves with manual activation (resp. with automatic activation), all TSOs shall develop a proposal for the implementation framework of a European platform by one year after entry into force of the Regulation. This proposal shall include a description of the algorithm for activation optimization which shall respect the pricing method for balancing energy pursuant to Article 30 (i.e. use paid-as-bid principle, see above). The platform should be operational within 30 months after the approval of the implementation framework. Assuming that EBGL enters into force end 2017 and assuming a 6-month approval period, the **harmonized European FRR platforms should be operational at the end of 2021** approximatively. The expectation is thus that the settlement of activated FRR energy will be paid-as-cleared from end of 2021 onwards. **We investigate in this study the opportunity for an earlier implementation of this settlement principle, on a local basis.**

On the other side, we discuss in Chapter 5 some important preconditions for a proper implementation of marginal pricing of FRR activated energy in Belgium. We describe among others as key prerequisites (1) the activation of aFRR and mFRR products based on the economical merit order (expected around end-2019 and end-2018 respectively), and (2) the implementation of a so-called "Transfer of Energy" solution (gradually implemented in the course of 2018-19). Our assumption is that paid-as-cleared settlement is expected to be fairly inefficient as long as these key pre-conditions are not met.

The discussion held in this document therefore targets the period between the implementation of these key prerequisites (in the course of 2018-19) and the mandatory implementation of harmonized European solutions (end 2021). Figure 2 illustrates this indicative timeline. A more detailed implementation roadmap is presented in §5.6.

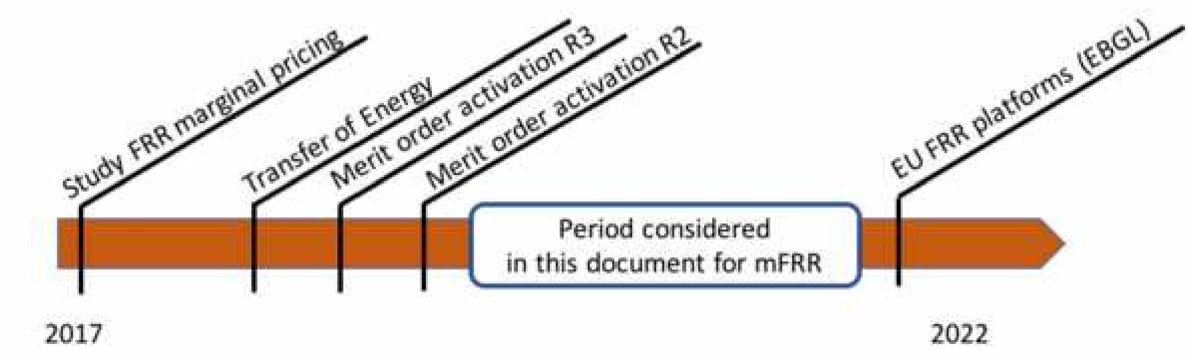

Figure 2: Indicative time horizon considered in this study

Note that the implementation of a marginal pricing settlement on a local basis is also intended to prepare and facilitate the transition towards a harmonized European solution. On the one hand, ELIA will gain the appropriate knowledge and experience for a well-prepared engagement into European implementation. On the other hand, European (or regional) implementation projects will also feed the local Belgian settlement design. This observation also applies as an important disclaimer: **the views expressed in this document are to be considered as preliminary and subject to evolution and further changes, notably based on European FRR design discussions.**

2 Paid-as-Cleared vs. Paid-as-Bid

The choice between paid-as-cleared vs. paid-as-bid in the power market has been largely discussed in the scientific and industry literature. Though, most studies focused more generally on wholesale power prices than specifically on balancing services. In this chapter, we compare both approaches from a theoretical perspective.

2.1 Definitions

Let us first start with definitions of both options:

2.1.1 Paid-as-cleared / Marginal pricing

Paid-as-cleared (also called marginal pricing) is a uniform pricing mechanism that offers the same price to all transactions of a given product at a certain point in time based on the marginally accepted order. The settlement price is fixed at the intersect of offer and demand curves and represents the marginal market value of an increment or decrement of 1 product unit.

From a theoretical point of view[3], suppliers in an effectively competitive market under marginal pricing have every reason to bid approximately their short run marginal opportunity costs for energy in each of the blocks of power that they offer.

By doing so, they know that if any of those bids is rejected, it is because there are other bids at better prices in sufficient quantity to satisfy the demand. Non-selected bids are therefore better off, as their bidders have not committed themselves to transactions at prices that fail to cover their avoidable costs. More importantly, bidders know also that, on their accepted bids, they will receive the uniform settlement price, which will at least recover avoidable costs, and for which any additional income can serve as a contribution towards recovery of fixed charges and profits, regardless of the level of their own bids.

For mathematicians, a marginal settlement price is equal to the shadow price of the balance constraint (i.e. the one which equalizes offer and demand quantities) in a cost minimization/welfare maximization problem. For economists, a marginal settlement price is a natural economic equilibrium in the Pareto sense to which markets naturally gravitates.

Paid-as-cleared is the pricing mechanism in use for the Day-Ahead Electricity market.

2.1.2 Paid-as-bid

Paid-as-bid is a pricing mechanism that enables a different price for each transaction, i.e. each transaction price is determined by the price set in the accepted bid. Bidders therefore have every good reason to include in the price of their bid – on top of their short run marginal cost – a profit margin to cover fixed charges and profits. Such a margin is naturally set to be as large as possible, though with the constraint that the offer is retained if profitable. In other words, under paid-as-bid, bidders will price their bids above their short run marginal cost, as the approach implies that the bid price should also contribute towards recovery of their fixed charges and profits.

Paid-as-bid is the pricing mechanism in use for the Intraday Electricity market.

2.2 Basic theory

From economic theory, paid-as-cleared and paid-as-bid provide the same results under perfect competition assumptions. These perfect competition assumptions are:

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[3] Source [3]

1. atomistic market structure (I.e. many independently owned market parties with no market power)
2. homogeneity of the product (i.e. all products within a market are identical, divisible and substitutable to each other)
3. No entry or exit barriers (i.e. market parties can freely enter or exit the market)
4. Perfect information (i.e. all parties have perfect information about the market and the products, including the quantities of products offered and demanded).

Under such assumptions, bidders can perfectly predict the demand and offer curves and consequently the system marginal cost. Under paid-as-bid, they will set the price of their bids at the level of (their expectations of) the system marginal cost, as this provides the largest possible contribution to fixed costs. Under paid-as-cleared, they will set the price of their bids at their own short run marginal cost, but will be remunerated the price of the last accepted bid, i.e. the system marginal cost. Consequently, the same dispatch and welfare repartition should occur under paid-as-cleared and paid-as-bid (see Figure 3).

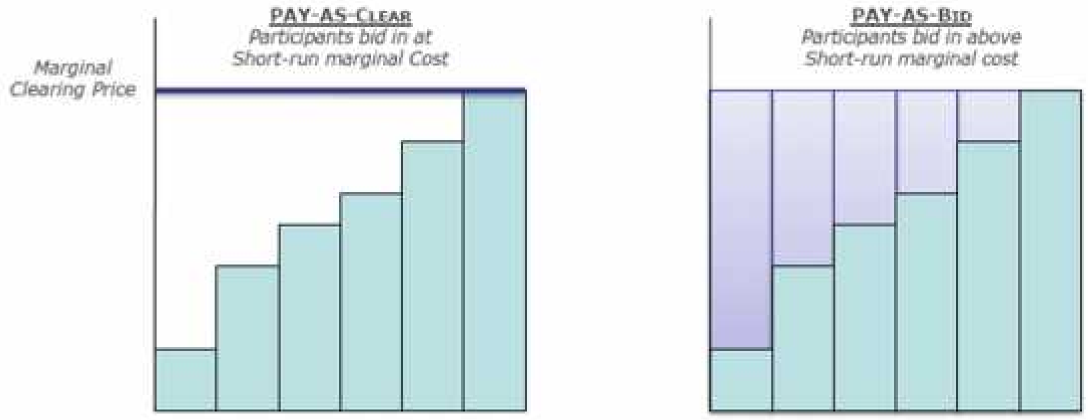

Figure 3 : Paid-as-cleared and paid-as-bid provide same results in case of perfect competition[4]

In practice though, perfect competition conditions never perfectly hold in any practical case. For the particular case of ancillary FRR services, such conditions are clearly questionable.

1. Firstly, balancing markets are typically – mainly due to historical reasons – dominated by one or a few incumbents. Consequently, market power is very often suspected or alleged. It is surely reasonable to say that the market under scrutiny is not “atomistic” in any European market.
2. Secondly, although electricity is in principle a very homogeneous and divisible commodity, the underlying assets that generate or consume the commodity have a wide range of characteristics (flexibility, location, …), so that tradable products are heterogeneous to at least some extent.
3. Thirdly, there exist multiple entry (or exit) barriers in the power market in general, and in ancillary services in particular. These can be financial (e.g. collateralization, scaling effects), legal/regulatory (e.g. DSO/TSO interface) or technical (e.g. flexibilization of assets). It is thus fair to say that ancillary services suffer from some entry or exit barriers.
4. Finally, although transparency and predictability have drastically improved in the last years, it can’t be stated that information is perfectly known and/or predictable. This is particularly the case for balancing services, where by definition there will always remain a part of unpredictability due to the very aim of the products at stake.

[4] Source [2]

We thus easily showed that the perfect competition assumptions do not hold in the studied context. Consequently, economic theory does not perfectly hold either, so that it is unlikely that paid-as-cleared and paid-as-bid provide equal output.

The question debated further in this study is the added value of an early adoption in the Belgian market of a paid-as-cleared settlement mechanism (as opposed to using a paid-as-bid approach) for the given practical application of FRR activation energy settlement.

2.3 Theoretical advantages of paid-as-cleared

2.3.1 Dispatch efficiency under imperfect information

A key observation for our theoretical comparison is that the market structure is in practice quite diverse, ranging from very small to very large players, and that treatment of information (and related uncertainties) is far from easy and perfect. Small bidders are in practice disadvantaged under paid-as-bid compared to paid-as-cleared, since their output does not only depend on their relative technical efficiency but also on their successful forecasting[5]. Indeed, under paid-as-bid, any forecasting error of the system marginal cost of some bids can lead to an alternative sequence in the merit order, and consequently a non-optimal selection of the resources.

Figure 4 illustrates such a possibility of non-optimal usage of resources: for a given set of 5 assets (labelled A, B, C, D, E), under marginal pricing we can assume that the activation sequence always selects the bids according to their economic efficiency – because of the clear incentive to bid at marginal cost. Under paid-as-bid settlement, a contribution to fixed cost and profit (colored in red in the figure) needs to be estimated based on the expectation of the market outcome. In the example depicted in the figure, these contributions have been misestimated, which leads to a suboptimal dispatch (i.e. the efficient asset B is not dispatched because of a too high required profit margin).

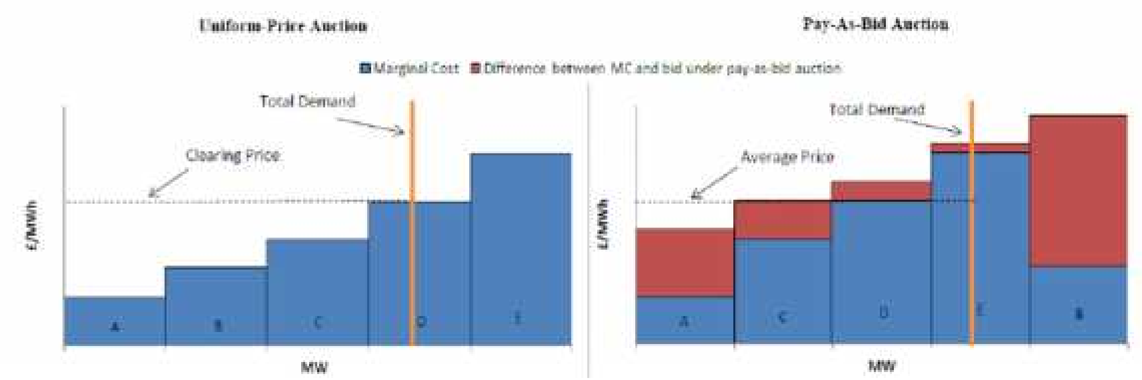

Figure 4 : Non-optimal dispatch in case of paid-as-bid, compared to paid-as-cleared[6]

Paid-as-cleared pricing is therefore often cited as preferable to accommodate a market with players of heterogeneous sizes with different access to information, and more generally facilitates economically efficient dispatches.

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[5] which is a rather fixed effort so relatively more expensive for smaller players, not to mention availability of information.

[6] Picture from [2]

2.3.2 Competition, market power and liquidity

As marginal pricing provides clear incentives for participants to bid at short run marginal cost, they also make the markets applying such a scheme easier to monitor, as **supervision agents (i.e. regulators) can more objectively verify the coherence between individual bids and the marginal costs of the corresponding assets.**

In case a market player with a dominant position abuses from his position and, by bidding largely above its marginal cost, increases the settlement prices, some argue that paid-as-bid is preferred because market parties without such a dominant position do not benefit from the artificially high prices and consequently that the total cost for consumers is lower. However, others argue that – even if this may be true in the short-run – such a reasoning does not hold in the long-run because it fails to address the primary issue of market power: on the contrary, it largely impedes stronger competition to emerge since players abusing from their dominant position genuinely obtain larger revenues than those who cannot or do not abuse. This latter reasoning supports the fundamental assumption, on which deregulation itself was predicated, that the wholesale electricity market is - or at least can become - effectively competitive, and that **bidding competition is notably facilitated by homogeneous remunerations for homogeneous services, as is the case in a marginal pricing scheme**. However obviously in order to enable trigger bidding competition first a sufficient number of participants need to be present in the market.

Irrespective of market power, **a decent level of liquidity still remains a genuine prerequisite to implement marginal pricing.** This is the case because the absence of a minimal market depth may imply “evitable price spikes” (i.e. spikes not cause by actual shortages but by lack of liquidity in the market). In addition, attention should be paid on the arrival in the FRR market of a limited volume of new flexible resources with inherently high marginal costs (due to either their underlying cost structure or to subsidy schemes). The added value of marginal pricing in such a case might not be so straightforward.

2.3.3 Bidding incentives

Another important aspect to consider when designing the settlement approaches for activated balancing energy is the overall coherence and set of incentives provided to market players.

A key question is whether market participants with flexible capacity are adequately incentivized to bid on FRR markets whenever they can, or whether they are better off the balancing market to keep left-over flexibility for their own use. This is for example the case if the remunerations for frequency restoration services are low, and imbalance prices are high: a potential bidder could then face imbalance risks on its own portfolio which are not financially compensated by FRR servicing. It can thus be a perfectly rational and fair behavior to keep flexibilities for self-balancing, rather than offering them as ancillary services.

Such an argumentation pleads for a relatively high FRR remuneration compared to imbalance prices. Assuming imbalance prices are set based on the most extreme between activation prices of FRR (or of any other ancillary servicing)**, paid-as-cleared is therefore superior to paid-as-bid, since the remuneration of FRR servicing is equal for all activated energy, and tend to be closer to imbalance prices.**

2.4 Theoretical advantages of paid-as-bid

2.4.1 Simplicity

The key perceived advantage of paid-as-bid resides in its conceptual simplicity: bidders are simply paid what they ask for.

However, on the other side, the alleged simplicity of a paid-as-bid mechanism is very often challenged as it may be more complicated to set optimal prices of bids that form an expected remuneration (must be as high as possible to maximize profit, but low enough to be selected – in practice close to the marginal cost of the entire system), compared to calculating the minimal acceptable income – i.e. the individual marginal costs of assets – and leaning on a uniform pricing mechanism to obtain the appropriate remuneration.

Therefore, paid-as-bid remains particularly valuable when the determination of a marginal cost is complex for some reason. In a "new electric world" with big portfolios of small units, it is not so clear if setting bid prices is easier with marginal pricing than with paid-as-bid, if when placing the bid, the portfolio supplier doesn't know which unit(s) will deliver the requested balancing energy[7].

2.4.2 Alleged cost-based pricing

Similarly, because by construction paid-as-bid never pays more than the bid price, one may allege – based on intuitive thinking - that the total acquisition cost is lower compared to the alternative. This reasoning is unfortunately biased as it ignores that the bid prices in the two models will necessarily be different. It is though reasonable to state that – even if mark-ups are lower under paid-as-cleared compared to paid-as-bid, they will not fully disappear (certainly not in a balancing market with dominant positions and potential scarcity situations). **It therefore remains quite unknown which settlement principle will deliver the lowest societal cost**, as from a pure theoretical point of view they deliver the same results providing some (fairly unrealistic) assumptions are holding. Rather, the question studied in this document focuses on the well-functioning and the attractiveness of the market, because **a liquid market is in our view the best way to strive for a good service level at a fair societal cost.**

2.4.3 Heterogeneity

A key advantage of paid-as-bid is that it is a convenient way to remunerate heterogeneous products, with the reasoning that products with different characteristics don't necessarily deserve the same price. This is particularly relevant in this study as the assets providing balancing services typically have distinct characteristics, in particular for what relates to:

- Their flexibility / speed of response / ramping capabilities (e.g. some assets are not enough flexible to participate to aFRR while being fit for mFRR purposes, etc.)
- Their minimal (and maximal) output, and related indivisibilities (i.e. indivisibilities are not supported in aFRR, while they complicate mFRR activation scheme – cfr. infra)
- Their constraints on duration and number of activations (cfr. the distinction between Standard and Flex R3 products)
- Their start-up costs
- The way they are activated and controlled remotely
- …

Products are also likely to be somehow heterogeneous from a contractual perspective, especially when considering

- Local exemptions and subsidies (support to renewable energy sources in particular)
- Cross-border aspects, where it is very probable that some contractual differences will remain in the foreseeable future.

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[7] see [10]

2.4.4 Volatility

One may also argue that paid-as-bid reduces volatility of prices/costs, because of the natural incentive to bid close to the expected system marginal system cost, i.e. multiple bids priced at similar price levels even though they have significantly different marginal costs. Reduced volatility implies better predictability of prices, which is typically seen as positive.

Seen from another angle, in case the balancing markets are not sufficiently liquid, price spikes which are neither directly linked to scarcity nor to market power (but rather to (in) efficient market functioning) may occur especially under uniform pricing. Such price spikes are deemed unnecessary and inefficient, and are largely mitigated in case of paid-as-bid since high-prices are only cashed out to the last activated bids (and not to all transactions as would be the case under uniform paid-as-cleared principle).

2.4.5 Delivery incentives

Another directly related question is how the delivery of balancing energy is monitored and penalized in case of non-delivery. A typical approach (i.e. the one currently implemented in Belgium) is that requested balancing energy is accounted in the participant's portfolio, so that non-delivery is accounted as an imbalance. In case FRR energy and imbalance energy are settled at more or less the same prices, the incentive to deliver is lower: the reward and the penalty almost net out each other.

From this point of view, assuming imbalance prices are set to the most extreme activation price (from FRR or any other mechanism), **paid-as-bid is relatively superior as the FRR remuneration approaches the imbalance penalty for the last accepted bids only.**

Though, in a well-designed market, non-delivery should always lead to a risk of loss. For balancing, this is typically done via penalty schemes (as is for example the case with the "alpha component" currently applicable in the Belgian imbalance pricing – cfr infra). **It might therefore be necessary to review the penalty scheme in light of the application of marginal pricing.**

On the other hand, the European integration of FRR suggests that FRR products are activated in some countries to resolve imbalances in other countries, so that national imbalance prices based on local FRR activations will no longer always provide suitable incentives for local delivery of FRR energy.

Consequently, while in the short run and with the current setup, paid-as-bid appears to provide suitable incentives to deliver the requested energy, in the long run such an advantage will disappear and **a new penalty/incentive scheme will have to be implemented anyway**.

2.5 Settlement mechanism for balancing energy

Hereafter we compare the two envisaged combinations of pricing mechanisms which might be applied for the settlement of balancing energy:

1. Paid-as-bid in combination with single marginal imbalance pricing

- In case of non-delivery, most BSPs will have a loss as the imbalance price is most often[8] higher than the settlement price for balancing energy.
- In case of delivery, BSPs which are also the BRP source are having an incentive to deliver more than the requested energy, as over-reactions will be settled at the marginal imbalance price

[8] i.e. except for the marginal bids

- BSPs will bid-in flexibility which is an estimation of the potential strike price; hence the bid price will not reflect the marginal cost of the offered flexibility
- BSPs will have a lower incentive for bidding-in flexibility as it is interesting to activate in real time flexibility and receive a marginal imbalance price as compensation or to avoid extreme imbalance prices

2. Paid-as-cleared in combination with single marginal imbalance pricing

- In case of non-delivery, the BSPs will have no loss or profit (except in case a penalty scheme applies)
- In case of delivery, BSPs which are also the BRP source are having an incentive to deliver more than the requested energy as over-reactions will be settled at a the marginal imbalance price
- In theory BSPs will bid in flexibility at the marginal cost of the offered flexibility
- BSPs will have an incentive for bidding-in flexibility as it is interesting to activate in real-time flexibility and receive a marginal imbalance price as compensation.

The overview table below is showing that a pay-as-cleared mechanism in combination with single marginal imbalance pricing is giving incentives to bid correct prices and all available volumes. With the same imbalance settlement however a pay-as-bid mechanism is giving better delivery incentives.

	Paid-as-bid Single Marginal Imbalance pricing	Paid-as-Cleared Single Marginal Imbalance pricing
Delivery	++	--
Over-Delivery	+	+
Bidding price	--	++
Incentive for bidding	+/-	++

2.6 Intermediate conclusion

From the high-level qualitative assessment presented in this chapter, it is not obvious to determine that, between paid-as-bid or paid-as-cleared, one model is clearly superior.

However, it is a fact that marginal pricing is recommended as the harmonized pricing methodology for standard FRR products upon application of the European Balancing Guidelines [8]. Further, **the argument that paid-as-cleared can facilitate competition and increase liquidity appears as very appealing. We therefore tentatively conclude that paid-as-cleared is worth a full assessment**, although the possible reduced delivery incentive under Paid-as-cleared deserves more attention (such as a mitigation via a reviewed penalty scheme).

We will show in the rest of this study that implementing marginal pricing is not easy, as it comes with a set of complex interactions and issues. There indeed exists no off-the-shelves solution readily available for settling at marginal price the activated FRR energy in the Belgian context.

Nevertheless, despite the inherent complexity of the exercise, we believe that the concrete proposal expressed in the document will provide added value to the market and contribute to the discussion related to the European harmonized pricing methodology.

3 Description of FRR functioning in Belgium (as of 1/1/18)

This chapter describes the existing market mechanisms in Belgium for IGCC, aFRR and mFRR, including surrounding mechanisms and developments already validated and being implemented in 2017. It thus explains the market functioning as will be on 1st January 2018 assuming all developments foreseen in 2017 are completed. Frequency Containment Reserves (FCR) – also called primary reserves or R1 - are not discussed at all in this study as no energy settlement is happening for this product.

The purpose of this chapter is to describe the "as-is" situation in order to better understand the context and rules in which the possible change towards marginal pricing would apply, and get a view on all the key surrounding mechanisms that are possibly affected by the introduction of marginal pricing for reserve activation.

3.1 IGCC/Imbalance netting

Prior to the activation of secondary reserves, TSOs participating in IGCC (International Grid Control Cooperation, which includes ELIA) exchange imbalances. Indeed, secondary control reserve is activated automatically and in accordance with the source of imbalances. Within a region with several control areas, for a given point in time, a counteracting deployment of reserves is possible and not unusual. IGCC therefore aims to prevent these counteracting deployments of reserves by exchanging in a continuous way opposing imbalances between TSOs. This leads to a more efficient activation of ancillary services and improves the quality of the regulation. The netting of opposite imbalances should therefore primarily be seen as a technical optimization, which has indirect economic benefits (without being directly an economical optimization)

Operationally, the IGCC TSOs compare in real time the imbalances of their respective zones and net them out when possible. The remaining imbalance of a zone will be corrected by the responsible Transmission System Operator with his own means.

In order not to hamper the grid security or influence the interconnection capacity made available for the market, the exchanges are limited to the remaining available transfer capacity after closure of the market. Currently, the exchanges are further limited to the available secondary control power reserves (around 140MW), although such a limit might be relaxed over time.

This cross-border cooperation primarily impacts the volumes of activated secondary reserve, and therefore impacts the local prices indirectly (i.e. by modifying the need for activation). The TSO-TSO settlement to compensate for this mechanism is computed ex-post based opportunity price principle[9]. Hence, no real-time prices for IGCC activation are available[10].

For more information on IGCC, see http://www.elia.be/en/products-and-services/ancillary-services/IGCC.

[9] See all details https://www.entsoe.eu/Documents/Network%20codes%20documents/Implementation/IGCC/20161020_IGCC_Opportunity_Prices.pdf

[10] As explained below, imbalance prices are currently calculated based on aFRR pro-rata prices, so as to make sure that BRPs are provided with the correct incentives to be balanced, even if IGCC is resolving all the imbalance.

3.2 Secondary reserves/R2/aFRR

3.2.1 aFRR principles

Secondary reserves are one among the resources ELIA can use to balance the Belgian zone. The secondary reserves are reserves for upward or downward regulation that are activated automatically based on imbalances of the Belgian zone (after IGCC netting). Elia transmits a dynamic and continuous set point (in practice every 4 seconds) from its control center to the participating suppliers, who alter their production automatically based on this set point. This alteration will help to restore the instantaneous balance in the Belgian zone. Secondary reserve is also often referred to as R2 or aFRR (Automatic Frequency Restoration Reserve), which are synonyms in this document.

Currently aFRR is only possible for assets under CIPU[11] (which de facto belong to BRPs). The access to aFRR to a broader set of assets is currently being investigated (notably via dedicated R2 non-CIPU pilot projects), in line with the requirement of EBGL to enable technology neutral access to these service offering.

3.2.2 Reservation and selection scheme

In order to guarantee a good regulation, Elia requires a certain capacity of upwards and downwards secondary reserves to be available at all times. To do this, Elia contracts this capacity on a weekly basis with different Balancing Service Providers (BSPs) who must have signed a CIPU contract and must make this capacity available at all times during the given period[12].

In addition to such contracted reserves, all parties that have signed a contract for the provision of secondary reserves with Elia (even with a reserved capacity equal to 0MW) can voluntarily offer, day-ahead, a (extra) volume of secondary reserves for the next day, i.e. “free bids” for aFRR.

Both contracted and free bids for aFRR must comply with certain technical requirements (such as a minimum ramp up or ramp down capability). All secondary reserve bids are divisible.

The day ahead of delivery, all suppliers provide Elia with prices for the activation of R2 bids for every quarter hour. Suppliers which have contracted capacity must submit the volumes that will be made available and their corresponding activation price. These bids are called “R2 pre-contracted bids”. Suppliers which have a contract for secondary reserves and which voluntarily offer additional volumes also set a corresponding activation price. These bids are called “R2 free-bids”.

Note that, currently, boundaries are imposed on such activation prices, which cannot be below 0€/MWh for downwards regulation and not above the generic fuel cost[13] plus 40 €/MWh for upward regulation.

Elia then selects the best bids based on economical ranking, until the total capacity required for upwards and downwards regulation is achieved (typically 140MW in Belgium). The selection is done separately for

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[11] The contract for Coordination of Injection by the Production Units - commonly known as the CIPU contract – is the contract that governs the relation between ELIA and the large production assets influencing the high-voltage system (i.e. assets producing >75 MW).

[12] When a balancing service provider is not able to make the contracted capacity available for a certain amount of quarter hours, he has the possibility to transfer his obligation to another party who has a contract for secondary reserves with Elia - via the daily secondary market. This aspect is neglected in this document as it is independent of the studied topic.

[13] Generic Fuel Cost: the fuel cost for producing 1MWh of energy of a typical CCGT with 50% efficiency.

upwards and downwards volumes, for every quarter hour. The bids with lowest prices for upwards regulation (Elia buys energy and pays money to the supplier) and highest prices for downwards regulation (Elia sells energy and receives money from the supplier) are retained.

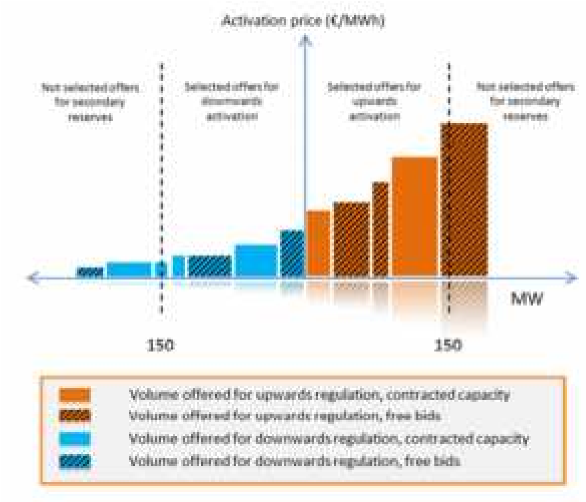

Figure 5: R2 bid selection (current scheme)

Bids not selected by Elia in the secondary-reserve activation process can be used as free-bids in tertiary reserve.

3.2.3 Activation scheme

During real time, all retained bids for upward and downward secondary regulation are automatically and continuously activated in parallel. They kick in quickly (between 30 seconds and 7.5 minutes) and remain active as long as needed. Grid users that provide secondary reserves must have the appropriate facilities for communicating in real time with Elia's national control center, and their production units must comply with certain technical requirements.

All retained bids of secondary regulation (whether pre-contracted or free-bids) are activated simultaneously on a pro rata basis (see Figure 6). This has the advantage of providing fast regulation - as multiple assets are ramping up simultaneously - but is not necessarily optimal from an economic perspective (since the most attractive bids from an economical perspective are not activated first). We discuss later - cfr. §5.2 - the required evolution from such a pro-rata activation towards a merit order activation sequence, in order to take full benefit of marginal pricing.

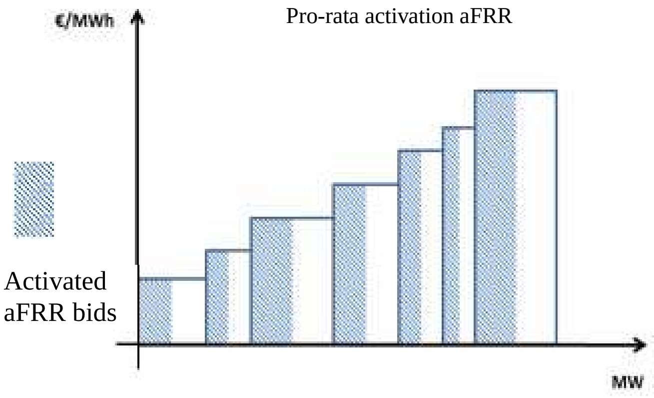

Figure 6: Pro-rata activation aFRR

For the activation, Elia transmits a dynamic and continuous set point from its control center to the participating suppliers, who alter their production automatically based on this set point. The dynamic set point, which takes into account the capabilities of the concerned unit, represents the volume with which the supplier must increase/decrease its production. The supplier is required to keep the activated reserves equal to this signal.

3.2.4 Remuneration scheme

To remunerate the contracted capacity, Elia pays the supplier a reservation fee (per MW per hour for the entire period that the capacity is made available) equal to the price of its offer if retained (i.e. paid-as-bid). Recall that this concerns the remuneration for the reservation and is therefore not the point studied in this document.

Concerning the activation, when a supplier is selected for a quarter hour, he can be activated continuously and he will be remunerated proportionally to the energy supplied based on the price of his offer (i.e. paid-as-bid principle). **The point specifically studied in this document is precisely the change from such a paid-as-bid mechanism – where regulation energy is remunerated based on the price of the related bid – towards a paid-as-cleared mechanism – where all regulation energy is remunerated the same marginal price.**

The different pricing patterns and related cash flow directions are as follows:

- Upwards regulation: Elia requests the supplier to produce more electricity than planned. Elia buys the extra energy produced from the supplier at the prices offered the day before.
- Downwards regulation: Elia requests the supplier to produce less electricity than planned. Elia sells[14] energy to the Supplier of secondary reserve at the prices offered the day before.

Note that upward and downward activations are settled separately (i.e. gross settlement) on a quarter-hourly basis since the activation prices are different for each direction, while the R2 set point is only possible in one direction for a given moment. A model where the netted delivered volume (incremental minus decremental energy over a given ISP) would indeed not always remunerate appropriately the two services.

[14] Since activation prices for downwards regulation cannot be below 0€/MWh, the prices cannot become negative

3.3 **Tertiary reserve/R3/mFRR**[15]

Similarly as for R2, we here describe the tertiary reserve principles applicable in Belgium. Though, since 2017 is rich in terms of new developments and improvements, the description considers the situation as it is planned to be on 1/1/2018 (e.g. Bid Ladder, no ICH, Standard & Flex products, …)

3.3.1 mFRR principles

Unlike primary and secondary reserves, tertiary balancing products are activated manually. They are also often named R3 or mFRR (manual Frequency Restoration Reserve), which are used as synonyms in this document. The general activation purpose of mFRR is to relieve secondary reserve in case of large or persistent imbalances, with products that are standardized "block"-products[16] for energy delivery during 15 minutes with a minimum activation time of 15 minutes. This provides the adequate conditions for a well-functioning balancing market as well as a step to facilitate international harmonization.

R3 balancing products are composed by pre-contracted reserves and free-bids.

There are two categories of R3 pre-contracted products: standard and flex products[17], which are both contracted short term and can be offered by CIPU or non-CIPU units.

- R3 standard products allow for an unlimited number of activations per contractual period, with up to 8 hours of activation per day.
- R3 flex product allow for limited number of activations per contractual period[18], for a maximum duration of 2 hours per activation and a minimum standstill period between 2 activations of 12 hours.

CIPU units are obliged – conform to the applicable rules – to offer all their left-over availabilities in the form of free bids. In other words, any CIPU unit capacity that is not scheduled by the market participant within its ARP portfolio, must be made available as tertiary balancing product.

Non-CIPU units connected to the ELIA grid can also offer non-reserved upwards and downwards free-bids, although this is not mandatory. Offers relative to non-CIPU units require either that the Balancing Service Provider is both its own ARP and the ARP supplying all the grid points at stake; or that the Balancing Service Provider has an explicit agreement with all the concerned parties (i.e. its own ARP, and the supplier(s) and ARP(s) of the concerned grid users). In case of non-CIPU units connected to the distribution grid, an agreement with the concerned Distribution System Operators is also required. A state of play of the evolution of this intricate arrangement, generally referred to as "Transfer of Energy" is provided in §5.1.

Tertiary reserve products sourced from large power plants (CIPU) are mandatorily linked to a specific grid location, and can also be used to resolve congestion problems (see below).

In case national R3 products are insufficient, ELIA can further make use – under some conditions – of inter-TSO emergency contracts, which are mutual assistance contracts between ELIA and its neighboring TSOs (see §3.3.6).

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[15] Sources [11], [13] & [4].

[16] In case such a block representation does not exactly reflect the physical constraints of resources, the differences between the product and physical reality are not explicitly accounted in the product and need to be considered in the price when offering to Elia.

[17] Interruptible products (i.e. ICH) are not considered in this report as they will not be continued after 1/1/2018.

[18] i.e. 8 activations in case of a reserves contracted monthly.

3.3.2 Reservation scheme

The selection of tertiary standard and flex reserves is based on technico-economical optimization and aims at minimizing the total reservation cost while respecting the required reservation volumes as determined by ELIA (following art. 233 of the grid code) as well as the constraints expressed in the orders. This aspect is not further discussed in this document, which focuses on marginal pricing of activated energy.

3.3.3 Activation scheme[19]

The current order of activation of mFRR products is as follows (see Figure 7)

1. Firstly, incremental or decremental free-bids (or bids non-selected from secondary reserve) are activated in the merit order sequence.
2. Secondly, once all free bids are exhausted, pre-contracted R3 CIPU standard products – which have an unlimited number of activations – are activated according to their merit order, followed by the R3 non-CIPU standard products[20].
3. Thirdly, pre-contracted R3 flex products, with limited number of activations per period, are activated.

Within each category, stopped CIPU production units able to start and deliver their power within 15 minutes are activated at the end of the merit orders. For such stopped units, the activation sequence currently only takes into account the costs of the delivered energy, while the startup cost – although it will be cashed out in case ELIA commands a start-up – is not considered in the activation sequence. This will be corrected in the future upon the uniformization of merit order activation.

In addition, since activation of non-CIPU R3 Standard and Flex products are not remunerated, they cannot be activated in economic order. Instead, ELIA uses them after all CIPU bids are exhausted, and seeks to activate each of these products more or less the same number of times and/or for the same volumes over the contracted period.

[19] Source [4] §6 p 33

[20] Which have no activation prices as long as the Transfer of Energy is not resolved. See §5.1.

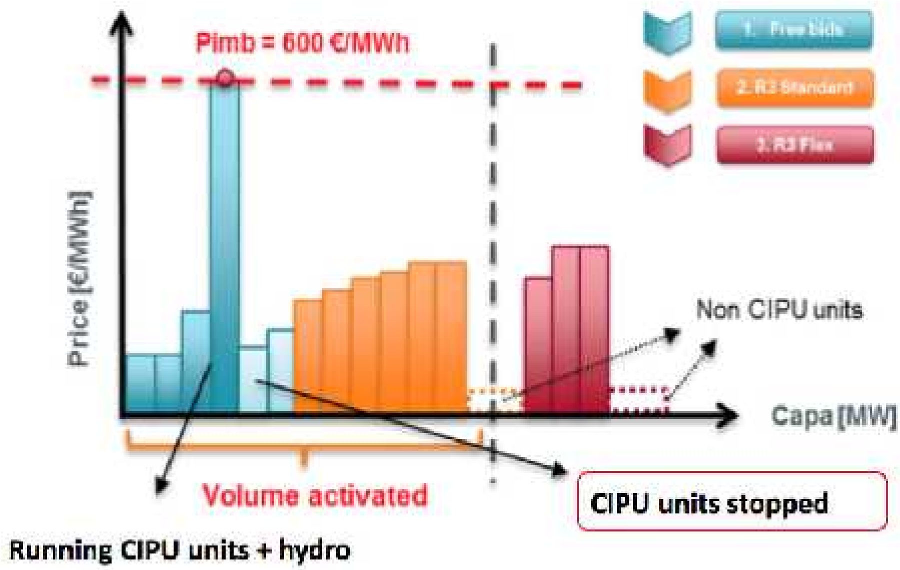

Figure 7: Current activation order of mFRR products

In case these mFRR products are still insufficient, emergency reserves stemming from bilateral contracts with neighboring TSOs are activated (see §3.3.6).

3.3.4 Remuneration scheme for activated balancing energy

For remunerated activations, Elia's payments for activating the reserve comprises two distinct components:

- payment for the energy supplied to Elia: If Elia requests activation of the tertiary power reserve, the supplier will be paid for activation by the volume requested by ELIA (standard block profile concept). Activated energy is currently paid-as-bid, i.e. paid the price that is specified in the bid. However, currently, the balancing energy activated from BSPs which are not BRP and do not have an opt out (and as long as "Transfer of Energy" is not applicable) will not receive any activation price (while instead the corresponding BRP will receive an imbalance payment for the delivered energy since its portfolio will not be adjusted)
- payment to cover start-up costs (only CIPU units): A payment for starting up units is only made if Elia explicitly orders the production unit to be started up. The amount of the payment is calculated using the formula found in the CIPU contract. This formula takes into account the specifications of the production unit, the cost of the fuel used and the management costs incurred. Importantly, such a start-up cost is currently not included in the merit order used to determine the activation sequence (although this will be changed upon full merit order activation of R3 – see below).

The point on the remuneration of activated energy is precisely the point for which a modification towards paid-as-cleared is studied in this document.

Note that activation of the tertiary CIPU production reserve is *in fine* neutral on the ARP's balancing perimeter. Indeed, the balancing perimeters are adjusted to incorporate the energy requested by ELIA. Consequently, in case the delivered energy does not correspond exactly to the request made by Elia, any deviation is penalized via the balancing mechanism. This is however not the case for activated non-CIPU mFRR, which are neither remunerated for the activation, nor is the corresponding ARP balance perimeter corrected (so that consequently the delivered energy is remunerated via the induced imbalance – cfr. §5.1). Unlike for CIPU units, the net effect of an activation on the ARP's balancing perimeter is thus not neutral.

3.3.5 Congestion management

Generally speaking, any CIPU unit (i.e. even those which do not satisfy the minimum requirement to participate to R3 or which are idle) can be used for congestion management purposes.

In such cases, activations are not necessarily purely based on the merit order, but rather on the location of the assets and their impacts over grid bottlenecks. The settlement mechanism to remunerate such activations is nevertheless the same as the one explained in the previous section.

3.3.6 Cross-border inter-TSO emergency contracts

ELIA has contracted with neighboring TSOs the possibility to call emergency power to ensure balancing extreme situations. The activation of such mechanisms is a last resort one, i.e. they are activated only if all other alternatives are exhausted.

In case ELIA supports a neighboring TSO, the exchanged energy is remunerated paid-as-bid to the BSP, and the exported energy does not influence the national imbalance prices. In case ELIA requests supports from a neighboring TSO and imports or exports energy, the exchanged energy is remunerated based on a price formula fixed in the inter-TSO contract.

3.4 Imbalance settlement[21]

In order to provide a full picture of the concerned ancillary services pricing mechanism, a description of the imbalance settlement mechanism and underlying price formation is also relevant. The imbalance pricing approach is fully based on marginal pricing rules. In short, Belgium applies a single price scheme (i.e. same price to settle positive and negative imbalances) that is equal to the price of the most extreme regulation cost used in the direction of the Net Regulation Volume (NRV) of a given Imbalance Settlement Period (ISP). On top of this, an additional incentive component is added to the imbalance price in ISPs for imbalances which are in the same direction as the system imbalance when the system imbalance exceeds 140 MW (which corresponds more or less to the available volume of aFRR). This incentive is referred to as “the alpha component”.

The NRV is defined on a quarterly basis and is the difference between:

- on one hand, the sum of the gross volume of upward regulation as ordered by Elia, for the considered quarter/ISP, for maintaining the balance in the Belgian control area (composed by IGCC, secondary and tertiary products as well as inter-TSO support), and the strategic reserve volume injected in the balancing control area for the same quarter if applicable;
- and on the other hand, gross volume of downward regulation as ordered by Elia, for the considered quarter, for maintaining the balance in the Belgian control area, expressed in MW.
- In what follows, a positive value of the NRV is referred to as a « net upward regulation » and a negative value of the NRV is referred to as « net downward regulation ».

The marginal price for upward regulation (MIP) is, for a given ISP/quarter, the highest price of all upward activations ordered by Elia for maintaining the balance in the Belgian control area. The marginal price for

[21] Source [15].

downward regulation (MDP) is, for a given quarter, the lowest price of all downward activations ordered by Elia for maintaining the balance in the Belgian control area[22].

The tariff for maintaining and restoring the individual balance of access responsible parties is established based on the formulas in the table below. These formulas relate to the quarterly imbalance of one given access/balance responsible party (BRP), for one given quarter.

		Net Regulation Volume (NRV)	
		Negative (net downward regulation)	Positive (net upward regulation)
ARP imbalance	Positive	MDP - α1	MIP
	Negative	MDP	MIP + α2

Where:

- If the absolute value of the System Imbalance is smaller than or equal to 140 MW:
  - α1 (€/MWh) = 0
  - α2 (€/MWh) = 0
- If the absolute value of the System Imbalance is bigger than 140 MW:
  - α1 (€/MWh) = average {(System Imbalance QH-7)^2, …, (System Imbalance QH)^2} / 15.000
  - α2 (€/MWh) = average {(System Imbalance QH-7)^2, …, (System Imbalance QH)^2} / 15.000
- NB: The value of the tariff for maintaining and restoring the residual balance of the access responsible parties, while activation of the strategic reserves, is fixed at 4.500 €/MWh. The application terms of this tariff are defined in the functioning rules for strategic reserves.

Prices for positive imbalance (injection exceeds offtake) can either be positive or negative. A positive price for positive imbalance means a payment from Elia to the BRP and a negative price for positive imbalance means a payment from the BRP to Elia.

Prices for negative imbalance (offtake exceeds injection) can either be positive or negative. A positive price for negative imbalance means a payment from BRP to Elia and a negative price for negative imbalance means a payment from Elia to the BRP.

Let us illustrate this by a couple of examples:

- In case only IGCC is activated, the aFRR weighted average price in the NRV direction is arbitrarily used to set the imbalance price (the same opportunity price is considered in the IGCC TSO-TSO settlement).
- In case aFRR is activated (whether in complement of IGCC or not), the weighted average of the selected aFRR bids in the NRV direction sets the imbalance price.

[22] This price takes also into account the additional incentives applicable on the marginal price for downward regulation if the mutual emergency power between grid operators has been activated.

- In case mFRR and aFRR are activated (whether in complement of IGCC or not), the most extreme between (1) the weighted average of the selected aFRR bids and (2) the price of the last activated mFRR bid in the NRV direction sets the imbalance price.
- In case of strategic reserves activation, the imbalance price is set to 4500 euros/MWh.

Importantly, the imbalance settlement scheme is thus already largely based on marginal pricing principles[23]. Therefore, **our preliminary assessment is that the current imbalance settlement principles remain suitable in case of paid-as-cleared settlement of activated FRR energy. However, the details of the imbalance pricing mechanism might need some adaptations to reflect the new FRR design. This is for example the case for the penalty scheme, or for cross-pricing with aFRR (especially for the M2 model, see §7.1). Such changes can however only be envisaged in light of a complete and final FRR settlement design.**

3.5 Statistics of activated balancing volumes

We present in this section some statistics about the usage of balancing products in Belgium which can be found in [6].

Figure 8 shows the evolution of the energy activated annually in upward and downward direction (when it exists) for each balancing product type. Most relevant product types include R2 (in red), "free" R3 ID bids (in blue) and IGCC (in orange).

Additionally, this figures also shows the total balancing energy activated annually for both upwards and downwards activations, the total energy activated (black line) and the sum of the total energy activated and the energy exchanged through IGCC (blue line).

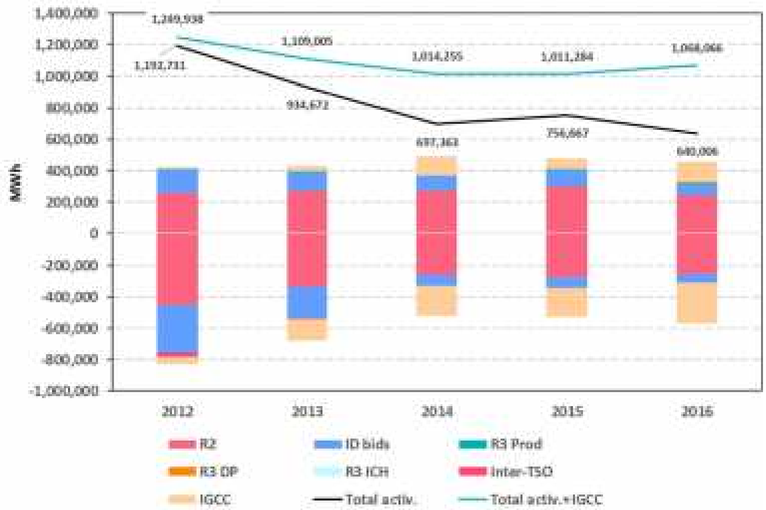

Figure 8 : Balancing energy activated by product type (Source CREG [6])

Figure 9 below shows the evolution of shares of the energy activated annually, aggregating upward and downward activations when relevant, for each balancing product type. Most relevant product types include IGCC (in orange), aFRR (in red) and "free" mFRR ID bids (in blue).

[23] Since MIP and MDP, i.e. the most extreme prices ordered by ELIA to maintain the balance, are the key parameters for the imbalance price setting

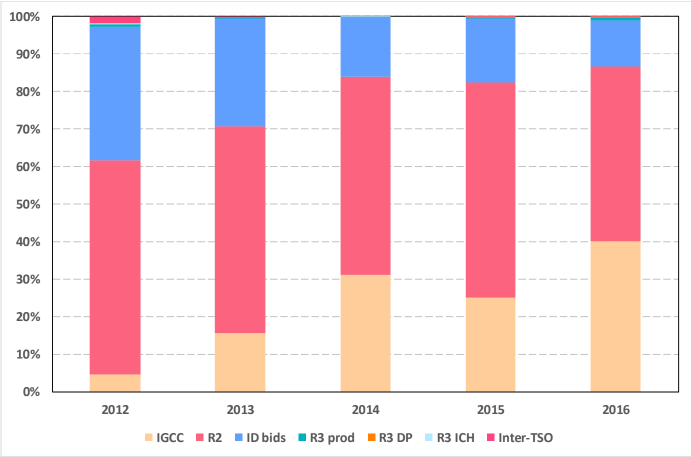

Figure 9 : Shares of balancing energy activated by product type (Source [6])

Several observations can be done on that figure:

- Free mFRR bids, aFRR and IGCC shares cover most of activation needs of balancing energy. In 2016, their sum equals 98.9%.
- Excluding for 2015, the sum of the shares of IGCC and aFRR increases every year, reaching 87% in 2016.
- The part of IGCC activations in sum of aFRR activations and IGCC exchanges increases, raising up to 47 % in 2016.

4 High-level comparison of FRR functioning in Europe

4.1 Overview FRR activation and settlement in Europe

Before exploring more de depth a few key specific European market designs, we start by presenting a general overview about where merit order activation on paid-as-cleared remuneration is currently implemented Europe-wide. All these data are extracted from source [19].

Note that such summarized information is only giving a high-level idea. When looking into to the details of local market designs, it appears that there exist many different kinds of merit order and pro-rata systems. Moreover, some systems perform a merit-order activation while applying a pro-rata kind of system for the settlement.

Figure 10 displays the countries where pro-rata and merit order activation of aFRR was implemented (in 2016). It shows that continental Europe is essentially split into blocks using the two options (some countries are not performing (themselves) the aFRR process).

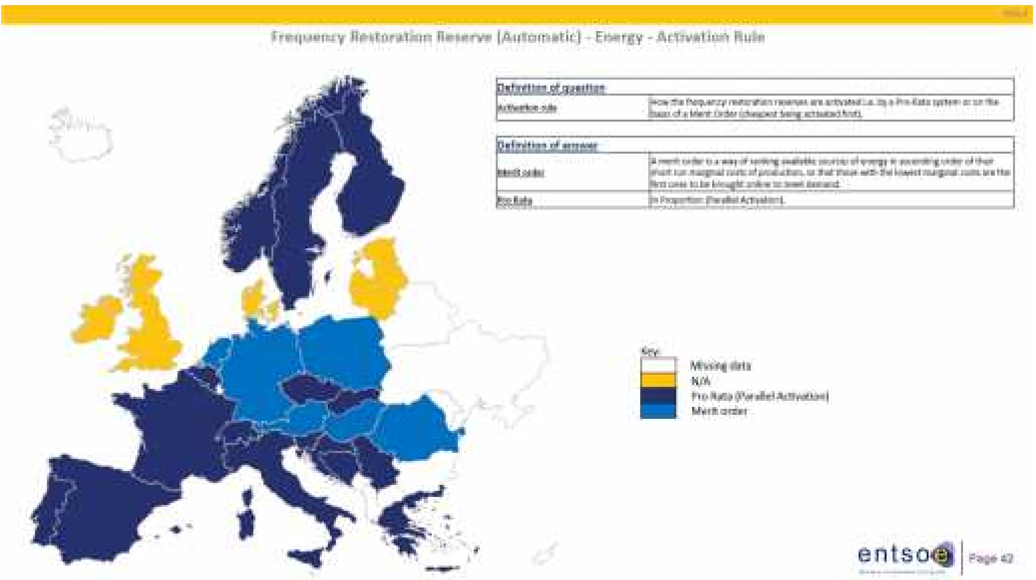

Figure 10: overview of aFRR activation rules per country

Figure 11 provides the aFRR remuneration schemes for the same period. As can be observed, while Belgium uses a pro-rata activation scheme remunerated paid-as-bid, none of its surrounding countries uses the same approach. France activates pro-rata but remunerates based on regulated prices, Germany remunerates paid-as-bid but activates based on merit-order, and the Netherlands activate based on merit-order and remunerate paid-as-cleared.

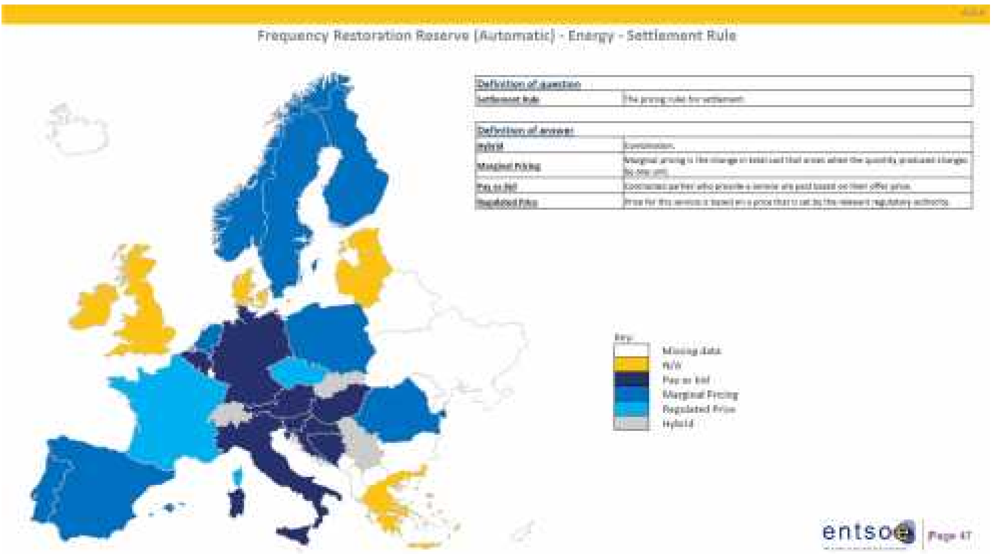

Figure 11: overview of aFRR settlement rule per country

Figure 12 and Figure 13 provide the same information for mFRR. They show a less heterogeneous pattern at least for what concerns the region of Central Western Europe, where all countries apply a merit order activation and a paid-as-bid remuneration, except for the Netherlands where paid-as-cleared settlement is already applied.

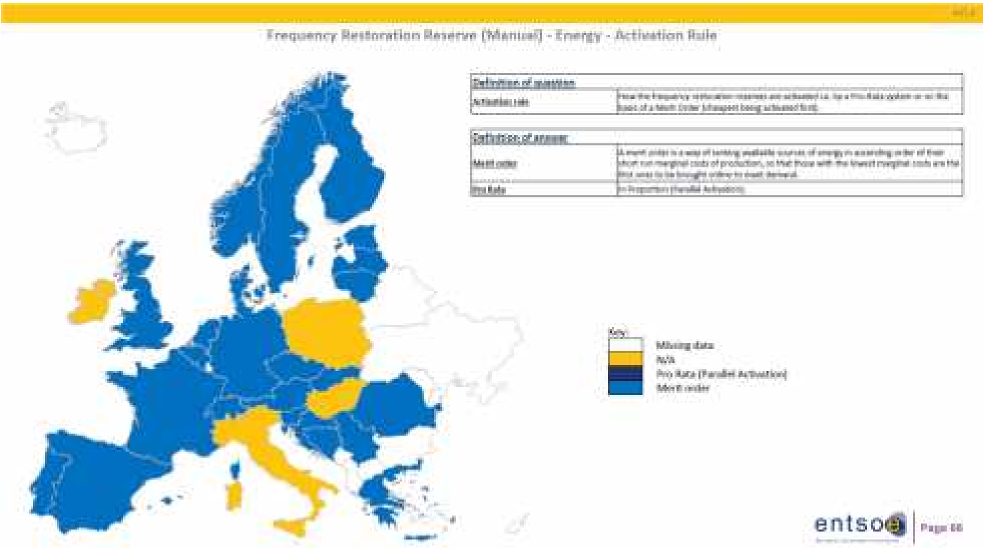

Figure 12: overview of mFRR activation rules per country

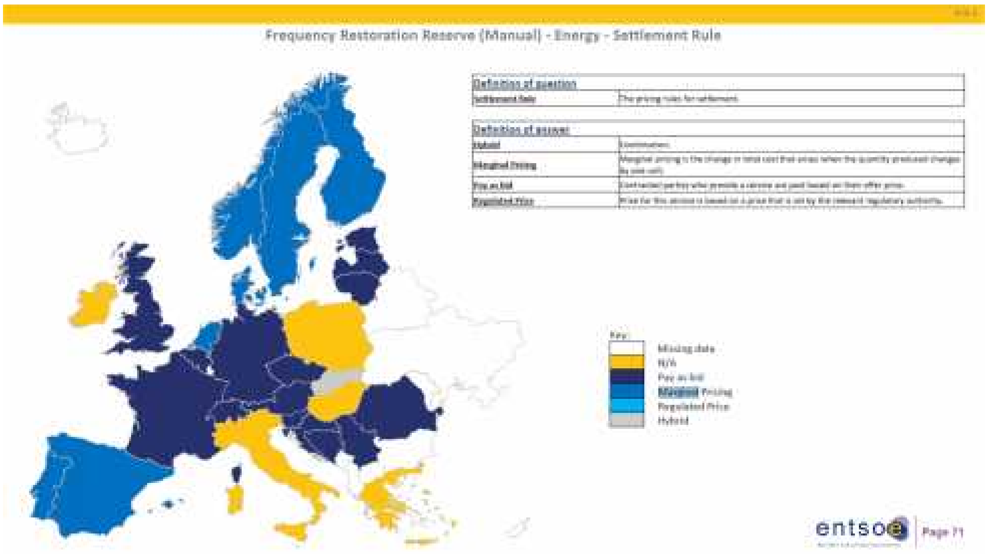

Figure 13: overview of mFRR settlement rule per country

Note though that such synthetic figures do not consider any implementation detail, and may misleadingly suggest that the settlement schemes in these countries are close from being harmonized. Despite similar high-level concepts being implemented, this is though very far from the current reality.

4.2 FRR in the Netherlands

4.2.1 General FRR activation principles[24]

A comparison of the present arrangements shows that the Netherlands and Belgium share a lot of similarities with regards to the procurement and use of operating reserves and real-time balancing. Elia and TenneT rely on a similar set of products and processes, and strive to rely on market-based mechanisms where possible. Moreover, the balancing mechanisms in both countries are based on a “reactive” balancing philosophy, which aims at providing clear and effective incentives for self-balancing by BPRs. In line with this approach, the time horizon of balancing services used by ELIA and TenneT is principally limited to the current and the next consecutive ISP, whereas BRPs always remain responsible for balancing themselves. Both TSOs try to incentivize BRPs to react immediately and reduce their imbalances in advance, for instance by means of self-balancing or through the intra-day market, in order to reduce the deviations which finally have to be resolved by the TSO.

Similarly to ELIA, TenneT is also participating to IGCC imbalance netting initiative, and TenneT and ELIA have signed a reserve sharing agreement (i.e. the most obvious benefits of cross-border initiatives have already been achieved).

The Netherlands already have implemented the merit order activation of aFRR, although with an add-on to address cases of severe and rapid disturbances, in which case multiple aFRR bids can be activated in parallel.

[24] Sources [17] & [18]

4.2.2 Remuneration of activated FRR - Marginal pricing

Only bid prices from bids that are actually activated are included in the determination of the activation settlement price. The activation price is the basic element for the determination of the imbalance price.

Balancing energy is remunerated at marginal price of combined aFRR & mFRR activation in each ISP in the Netherlands (i.e. full aFRR and mFRR cross-pricing). For pre-contracted aFRR, offer prices must remain within a certain range around the hourly market price in the DAM (i.e. with +/- 1000€/MWh). Due to the principle of marginal pricing, however, this restriction appears to be of limited relevance in practice

Any activated reserve is able to set the price, irrespective of the duration of this activation. In other words, an aFRR bid that is activated only for a few seconds possibly sets the marginal FRR activation price for the entire ISP.

4.2.3 Imbalance settlement

Similarly as in Belgium, Dutch imbalance prices are set equal to the marginal price of balancing actions, i.e. the activation of both automatic and manual FRR. However, whilst both countries try to reflect the system status as good as possible, they have chosen different structural options in terms of pricing.

The Netherlands use a hybrid pricing scheme, which changes between single and dual pricing, depending on the balancing actions taken by the TSO in each ISP. Whenever TenneT has taken balancing actions into one direction only, i.e. either upward or downward regulation, there is a single imbalance price, which is set equal to combined marginal price of all balancing energy activated from aFRR and mFRR in that ISP. However, under some specific conditions (such as changes of the system imbalance or changes in the activated FRR directions), dual imbalance prices are published. In the latter case, the prices for positive and negative imbalances are set equal to the marginal price of all balancing actions for upward and downward regulation, respectively, in that ISP.

In both cases, the resulting imbalance price(s) in the Netherlands may be adjusted by adding or subtracting an additional incentive component. This incentive is based on system performance over the last week and is adjusted weekly. Conceptually, it serves similar purposes as the "alpha component" applied by ELIA.

4.2.4 Congestion management

In both countries, it is possible to use mFRR resources to manage local congestions. The practical application modalities appear to be slightly different. However, in the context of this study, such differences are considered as minor.

4.3 FRR in Germany[25]

4.3.1 Key differences for aFRR

aFRR is jointly procured weekly[26] by all German TSOs (vs. monthly in Belgium), though each TSO may define a technically required minimum share of aFRR that has to be procured exclusively within its area. A significant difference with Belgium (and the Netherlands) is that, in Germany, prices for aFRR balancing capacity and balancing energy are provided altogether: the bids for aFRR volume contain both a price for

[25] Source [30]

[26] Evolution to daily procurement is foreseen mid-2018.

the capacity and a price for the balancing energy. The former is used to select the balancing capacity to be reserved, while the latter is used to select the bids that are to be activated.

Free-bids in R2 are not allowed, therefore there is no ISP specific process that selects the bids to be activated during a given ISP, since the activation prices – which are known for peak and off-peak products since the reservation phase – are constant over the entire period. The pre-reserved bids are then activated sequentially, based on their merit-order (while they are activated pro-rata in Belgium).

The activations are remunerated at (a variant of) paid-as-bid, where the TSO settles at an average price-volume of each BSP. Also, contrary to Belgium where the volumes are settled according to the requested volume (and delivery deviations are accounted as imbalances), BSPs are directly remunerated for the delivered volume in Germany.

There are also several differences in the product specifications, for example for what relates to ramping up and time-to-delivery of activated energy. Those are however not relevant in our context.

4.3.2 Key differences mFRR

Similar to aFRR, German TSOs procure balancing capacity and balancing energy in a combined auction selecting the successful bids according to their balancing capacity price only. Balancing energy is then activated in the economic order based on the provided activation prices, and is remunerated the price of the bid (i.e. paid-as-bid). Free-bids are not allowed in the German mFRR market.

mFRR products are procured daily (vs. monthly in Belgium) for periods of 4 hours, for upward and downward regulation (vs. only upward at the moment in Belgium, although this is about to change).

There also exist a separate market for interruptible load in German (broadly comparable to the ICH in Belgium).

4.3.3 Congestion management

Unlike in Belgium, congestion management in Germany is operated via a completely distinct market, not using the same bids as FRR.

4.3.4 Key differences Imbalance settlement

Germany also has a so-called “reactive balancing philosophy”, although with some principle and practical differences. In particular, German BRPs are contractually obliged to be balanced for every ISP and any predicable deviation is seen as an infringement of duties. In particular, in case of unplanned outages of generation, BRPs are legally obliged to be in balance at the latest at the end of the consecutive three ISPs (i.e. after 45-60 minutes).

Further, the imbalance prices are only published 20 working days after delivery month, as opposed to very shortly after the actual delivery in Belgium. This incentivizes BRPs to make the best possible prognosis in order to minimize the risk of being exposed to unfavorable imbalances prices. On the other hand, the calculation method of imbalance settlement prices leads to lower imbalance prices compared to the “highest activated mean” approach as applied in Belgium (and in the Netherlands).

Similarly as with the “alpha-component” in Belgium, Germany also has a penalty scheme that kicks in in case of major imbalances: in case more than 80% of the contracted positive/negative FRR were activated in Germany, the imbalance tariff (i.e. the Average control Energy Price – see [30]) is increased/reduced by 50% - and in any case by no less than 100€.

4.4 FRR in France[27]

4.4.1 Key difference in balancing philosophy

Let us first highlight the most important principle difference in the balancing approaches of France and Belgium.

While ELIA has clearly favored a so-called "corrective/reactive balancing approach" (where market parties are incentivized until real-time to be balanced and where ELIA only acts very close to real-time to absorb left-over imbalances), RTE has opted for a more proactive balancing management where imbalances are primarily solved by the TSO.

The consequences of this key difference in approach are essentially twofold. On the one hand, while in Belgium (or in the Netherlands/Germany), a decentralized approach is proposed (and largely incentivized), with market players taking voluntary actions to self-balance until real-time, RTE is the only stakeholder in France that is allowed to act to restore the system balance in the last 2 hours before real-time. The reasoning is that it allows RTE to rely on a larger spectrum of balancing means, and to thereby reduce the total cost of reserves that need to be secured in advance, by reserving a relatively smaller amount of fast and expensive reserves but a much larger volume of slow and cheap reserves. The French market uses a dynamic "margin" approach (as opposed to a "reserve" approach as for Belgium) where the security margin is constantly monitored and adapted within the day. "Margins" are typically adjusted via so-called Replacement Reserves, which is a product category that is not used in Belgium.

Another notable difference is that the Imbalance Settlement Period (ISP) in France is 30 minutes, while it is 15 minutes in Belgium (and the Netherlands/Germany).

4.4.2 Similarities between France and Belgium

However, there are also a lot of similarities between the French and Belgian approaches. Let us underline the most important ones:

- As in Belgium, free bids (i.e. not pre-contracted) are allowed, and any spare production capacity on large production units must mandatorily be offered in mFRR.
- Currently, French secondary reserve (aFRR) is activated pro-rata (although the settlement price is essentially regulated - while it is paid-as-bid with regulated caps and floors in Belgium).
- RTE participates to IGCC.
- Tertiary reserve products (mFRR)[28] are activated based on a combination of technical capabilities and economic efficiency
- As is the case for Belgium – FRR products still need further harmonization and better economic optimization, notably for what relates to merit order activation, in preparation of EU integration.

[27] Source [25]

[28] As well as replacement reserves (RR)

4.4.3 Ongoing developments

As is the case in all European countries, there are multiple ongoing developments in France to align with the Electricity Balancing Guidelines [8]. The most significant developments concern the merit order activation of aFRR[29], the standardization of (mFRR & RR) products wherever applicable and move towards a single price for imbalance settlement.

In addition, marginal pricing for balancing energy settlement is also part of the upcoming roadmap. Though, there seems to be a caveat that marginal pricing could only apply to standardized products, while specific and/or local products could remain remunerated Paid-as-Bid.

[29] See [25] p.18

5 Required elements to apply marginal pricing in Belgium

We describe in this section some key prerequisites to apply an efficient marginal pricing scheme for the settlement of FRR products, which are not yet implemented in Belgium but which are planned for the future. Such changes in the market design are not only fundamental enhancements to foster competition among all possible assets and market players, but more importantly – in the context of this study – the absence of such improvements questions the fundamental principles of a paid-as-cleared settlement.

5.1 Transfer of energy[30]

The "Transfer of Energy" issue currently occurs[31] in case of activation of mFRR from non-CIPU units implying two distinct BRPs – one for the supplier of the non-CIPU unit and one for its FSP. It relates to how the energy quantity and price is compensated between these two parties.

Currently, as long as the Transfer of Energy rules are not effective, the activated energy of reserved mFRR from non-CIPU bids provided by BSPs is not remunerated. This is because there is no implemented solution yet to compensate for the energy that is offered for balancing purposes by the FSP but initially sourced from another BRP.

In practice, in case a reserved mFRR bid is activated, the BRP perimeter of the source BRP (i.e. the BRP of energy supplier of the asset providing flexibility) is not adjusted so that the change of infeed induced by the FSP provides a financial remuneration to the source BRP via the imbalance mechanism. E.g. a reduction in offtake implies a positive imbalance towards the source BRP, assuming the later was in a balanced position. The BSP receives a reservation payment for the capacity but no activation price. The source BRP is financially compensated for the imbalance via a positive imbalance price.

The basic principles to properly address the transfer of energy issue are the following:

The BSP activation cannot be done to the detriment of other parties.
This implies:

1. **the necessity to correct the balance perimeter of the source BRP, and**
2. **the necessity to compensate financially the supplier of the final grid user**

Conform with the principle 1, Elia must correct the balance perimeter of the source BRP (i.e. imbalance adjustment), with the delivered energy in order to neutralize the impact of the activation of flexibility. Such an adjustment is made at portfolio level to guarantee anonymity (the source BRP doesn't receive specific information about the delivery points that have been activated).

Conform with the principle 2, a financial compensation must occur between the BSP and the supplier of the final grid user. Such a compensation is either done based on a bilateral agreement between the supplier

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[30] Source [23]

[31] Application domain of ToE is described in ToE Law of 19/7/2017. ToE applies to balancing market, strategic reserves market, DA & ID market with exception of FCR-market. The ToE-law foresees a phased implementation. Proposal in forthcoming ToE-rules is to open ToE as from mid-April 2018 to non-reserved mFRR from non-CIPU units. In Q4 2018, ToE shall be opened to reserved mFRR from non-CIPU units. Later onwards, opening aFRR-market to ToE is foreseen.

and the FSP, or – in absence of such a bilateral agreement between the two parties – at a "default price" set by the CREG.

A more detailed discussion on Transfer of Energy can for example be found in [23]. The key benefit of the integration of non-CIPU bids is to improve the level of competition in FRR markets. The assumption made in this study is that, since the Transfer of Energy needs to be resolved to enable an activation price for non-CIPU FRR bids, its implementation is a pre-requisite for a full merit order activation of FRR bids (see below). And since, as explained in the two following sections, merit order activation is required for an efficient marginal pricing, the implementation of **"Transfer of Energy" becomes a highly desirable milestone to be achieved prior to implement marginal price of FRR activated energy**.

The tentative implementation plan for mFRR – which remains indicative and still largely depends on several external factors (e.g. regulatory process, IT implementation, …) – foresees a two-step deployment: "Transfer of Energy for non-reserved mFRR will be firstly implemented during the second quarter of 2018, followed by "Transfer of Energy for reserved mFRR bids" by the end of 2018.

Currently the aFRR energy product can only be delivery by BRPs. As a result the Transfer of Energy issue is currently not applicable for aFRR. Nevertheless Elia is currently investigating how the aFRR product can be opened to new types of technology via a R2 non CIPU Pilot project. In particular the fact that aFRR is a power product with a cycle of 10 seconds might potentially affect the technical feasibility of the implementation of ToE solutions. In the framework of the pilot project Elia is currently performing an impact assessment. Therefore a detailed implementation plan is not expected to be available before the end of 2018.

5.2 Merit order activation R2

As explained above (cfr. §3.2.3), the current activation mechanism of secondary reserve is based on a two-step approach: in a first step, offers for secondary reserve are selected for each 15-minutes period, based on merit order ranking, up to a volume predetermined by ELIA; in a second step, when imbalances occur on the Belgian grid in real-time, all the selected offers are activated on a pro-rata basis.

It is obviously debatable whether a paid-as-cleared approach is compatible and/or desirable with this pro-rata activation methodology. Two interpretations are in principles possible:

- If the marginal price is interpreted narrowly – as in pure economic theory – as the extra cost required to produce or consume one additional unit, then, given the existing pro-rata scheme, the weighted average of the activated bids is the marginal activation cost.
- However, another common interpretation is that the marginal price is the price of the last accepted bid. It is then in principle possible to accommodate a sort of paid-as-cleared approach and to remunerate all the activated bids with the highest price among these bids.

The added value of changing towards marginal pricing while keeping the pro-rata activation is however questionable. Our point of view is rather **that full merit order activation of R2 is an important pre-requisite to change towards paid-as-cleared settlement pricing**, and is more in general a very valuable improvement from a market perspective.

Under merit order activation, the cheapest bids are activated first, which thus provides a higher economic efficiency, possibly at the expense of regulation performance. The activation cost then becomes progressive (see Figure 14, to be compared with Figure 6 on page 16) and enables both paid-as-bid or paid-as-cleared remuneration schemes.

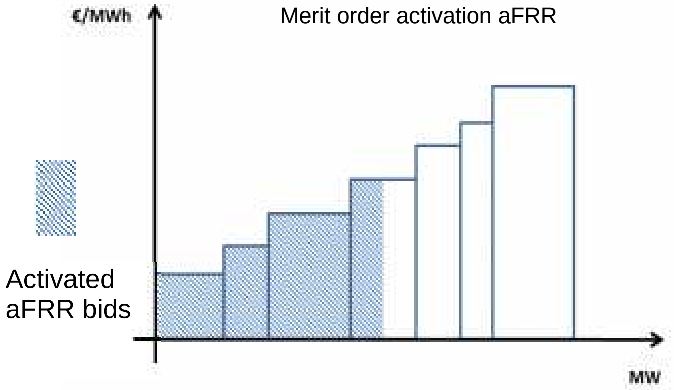

Figure 14 : merit order activation of aFRR

Under merit order activation of aFRR, all the bids (whether pre-contracted bids or free-bids) are retained and can be activated in real-time. Their activations priority is ranked by increasing price for incremental regulation and by decreasing price of decremental regulation.

The main expected benefit of Merit Order aFRR activation is the more favorable market environment to attract liquidity, and thus obtain larger volumes at fair prices. It also is a pre-requisite for the various emerging cross-border cooperation's related to aFRR which all rely on this concept (notably, Germany and the Netherlands already have such an activation mechanism in place, while France is planning to implement it - see above).

Merit order activation of R2 is not expected to be operational earlier than end-2019, as it requires a number of important steps to be successfully conducted, such as interactions with the relevant stakeholders and fundamental IT system adaptations – in particular to the SCADA/EMS systems of Elia.

Changing the R2 activation rule from a pro-rata to a merit order principle indeed appears to be far from trivial from an IT perspective: while currently the settlement price per R2 provider and per ISP is fixed for the back-office system (and equal the weighted average of all the selected bids of the provider), the only variable is the requested volume. A merit order activation implies a variable settlement price, which is either attached to the selected bid (in case of paid-as-bid) or which depends on the total activated volume (in case of paid-as-cleared). This appears to be a rather fundamental change to the IT logic. Past experience on IT projects of similar magnitude proved that the complexity should be adequately considered. **Elia is currently negotiating the implementation of a merit order activation with the provider of the related systems, which appears not possible before End-2019 at best.**

As explained, one of the key rationale of merit order activation of R2 is to attract liquidity on the free-bids part, to supplement pre-contracted reserves. Indeed, only a limited number of market participants and assets are currently bidding for pre-contracted aFRR, and even less for aFRR free-bids. **On top of the technical pre-requisite of having aFRR merit order activation to change towards a paid-as-cleared settlement scheme, a minimal level of liquidity in the aFRR market is also required.** Reaching such a sufficient level of liquidity is an external factor which needs to be taken into account.

A directly related question is whether the price caps and floors that are currently applicable to R2 bids should be kept. Arguably, price limits are helpful in case of low liquidity and/or suspicions of market power. At this stage, it can be said that the level of liquidity in aFRR is low. Our recommendation is therefore to link the need of price limits with the liquidity of the market, and to consequently progressively loosen these constraints as the liquidity improves. Implementation of paid-as-cleared settlement can only be done once an adequate liquidity is reached.

5.3 Adjusted R2 & R3 activation strategy

A consequence of merit order activations of R2 is that the bid stack that can be activated is likely to become larger. Indeed, while nowadays around 140MW of R2 reserves are pre-contracted, and quite the same volume is selected for pro-rata activation, it is likely that the same R2 pre-contracted volume will be complemented with potentially larger additional volumes. Following our reasoning in §5.2, price limits might no longer be imposed on R2 free-bids once liquidity improves. It therefore becomes likely that the triggers to activate R3 should be reviewed. Indeed, it will no longer be possible to simply decide to activate tertiary reserves once secondary reserves are nearly exhausted, since the secondary reserves merit order might be more liquid, but ending up with very unattractive prices.

Although this topic deserves an entire study on its own, it is possible that the need to adjust the FRR activation strategy impacts the implementation of a paid-as-cleared settlement approach.

5.4 Merit Order activation R3

The activation scheme for tertiary reserve is currently also not yet fully based on merit order. Rather, activation of bids is prioritized: free bids > R3 standard > R3 flex. Further, start-up costs of stopped CIPU units are not included in this merit order, so that bids stemming from stopped CIPU units are activated after all bids from spinning CIPU units. Lastly, within each category, non-CIPU bids are activated at the end of each category (as no activation price exist for these bids). See (see Figure 7 on page 19)

It is obvious that, prior to considering a paid-as-cleared remuneration scheme, economic efficiency gains can be obtained by improving this activation sequence, as by construction the current activation sequence does not necessarily select the cheapest orders first. Obviously, in case mFRR bids are not activated in the merit order but that marginal pricing is nevertheless applied, it can clearly happen that a deep in-the-money bid – or a bid stemming from an asset with very attractive marginal costs - remains non-activated. This would largely impede the expected gains that can be obtained by implementing marginal pricing, which is precisely based on the principle that all infra-marginal bids are activated and remunerated equally, and is therefore judged inappropriate. **As a result, we estimate that a full Merit Order activation of R3 products is a prerequisite to implement marginal prices of mFRR**.

The point of view of ELIA and its Users'Group (see [20]) is to propose to modify the activation sequence in order to benefit from higher economic efficiency. In particular, contracted reserves and Free bids will be activated based on a single merit order. Such a change implies a modification of Article 157 of the Federal Grid code, and the ELIA Users'Group proposes to make such a modification in a "fast-track mode", i.e. separate and before a more global modification change of the grid code expected end of 2018, early 2019 at earliest. The implementation time of this legal change is however yet unknown.

As already announced in the Task Force Balancing, the technical implementation of a merit order activation for Free bids and Standard R3 bids is not possibly before end of 2018.

With such a modification, it is expected that the imbalance settlement will gain in economic efficiency (i.e. avoid the occurrence of non-market reflective imbalance price spikes), and that market liquidity will improve as it will facilitate market parties to bid all available flexibility on balancing energy and balancing reserve markets (i.e. no – or at least more limited – flexibility withholding for hedging against price spikes). Merit order activation of mFRR is further a pre-condition for establishing a cross-border balancing market.

In addition, part of the plan is also to also include the start-up costs of stopped CIPU units in the single merit order, in order to better reflect the economic ranking (see next sub-section).

Finally, the treatment of R3 Flex products remains yet unsettled. Firstly, for merit order activation, R3 Flex products need to allow for an activation price, which is only possible upon resolution of the "transfer of energy" issue (see § 5.1). Secondly, even with an activation price, R3 Flex will most likely remain excluded from the single merit order, and kept for activation after all other R3 products are exhausted. This is because of the limitations of this product in terms of number of activations for a given period, the reasoning being that such products should be kept available for the most severe incidents, and therefore not "consumed" solely based on their activation prices. A shift towards a full, single merit order may be implemented in a second stage (not before second half 2019), depending on the outcome a project aiming at a review of the mFRR product design (including the opportunity or not to keep 2 distinct products) within the framework of a possible shift towards a daily procurement of mFRR reserves which will be undertaking in the course of 2018.

Note that, all in all, the specific treatment of R3 Flex products does not fundamentally change the design, and therefore the theoretical discussion at stake in this document, even if it possibly impacts the overall roadmap as the absence of a clear design (and related decisions) is likely to delay the implementation. In case it is decided to include R3 Flex products in a single merit order together with free and standard bids, such an implementation will not occur before end of 2019. In the absence of such a decision, or prior to its implementation, R3 Flex products will be activated after all other mFRR products. In this case, marginal pricing means that all mFRR energy will be remunerated at the price of the activated bid with the most extreme price. Figure 15 provides the merit activation sequence in such a case (to be compared with the current set up as shown in Figure 7 on page 19)

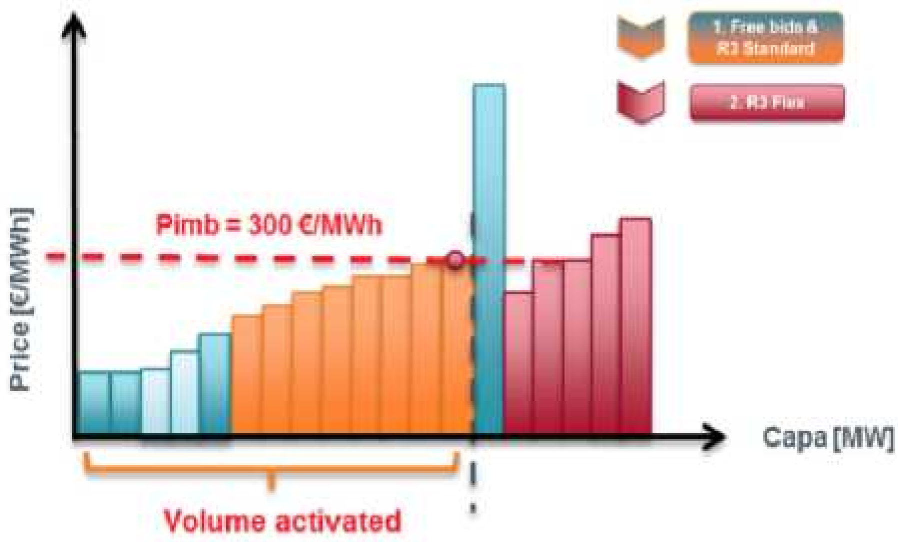

Figure 15 : possible activation sequence of mFRR

5.5 Startup costs in R3 Merit Order

We discuss in this section how start-up costs could be integrated in the merit order of mFRR products, the main difficulty being that the start-up costs should in principle be spread over all the periods during which the asset is running.

Let us focus on the case of activations for balancing purposes. In the case of balancing activations, three aspects need to be considered:

- Firstly, the basic principle of merit order activation is that orders should always be activated based on their economic ranking.

- Secondly, it is not known at the moment the activation is committed for how long the activation will last (an activation can at worst last for a single ISP, possibly longer).

- Lastly, a high-level of real-time transparency – in particular in terms of activated volumes and expected settlement prices – is a fundamental cornerstone of the reactive balancing philosophy.

With these three aspects in mind, **the only possible way forward to fully integrate start-up costs in the merit order is to add these costs to the price of the first energy unit that is activated.** This implies that the start-up costs will only be settled and recovered during the first ISP it has been activated (as opposed to being spread over the period during which the asset has been activated).

Despite the observation that startup costs should in principle be included in the price of the activation of the first energy unit, several detailed design elements need to be clarified prior to integrating the startup costs in the merit order activation sequence (notably related to activations for other purposes than balancing). The finalization of the design may have an impact on the implementation roadmap. **Realistically, the integration of startup costs in the merit order is not possible before end-2018.**

5.6 Overview of preconditions and related timing

Figure 16 summarizes the different design elements presented above, that need to be implemented prior to the implementation of a marginal pricing scheme. Indicative timings are also provided so as to provide a rough idea of the expected implementation timeline.

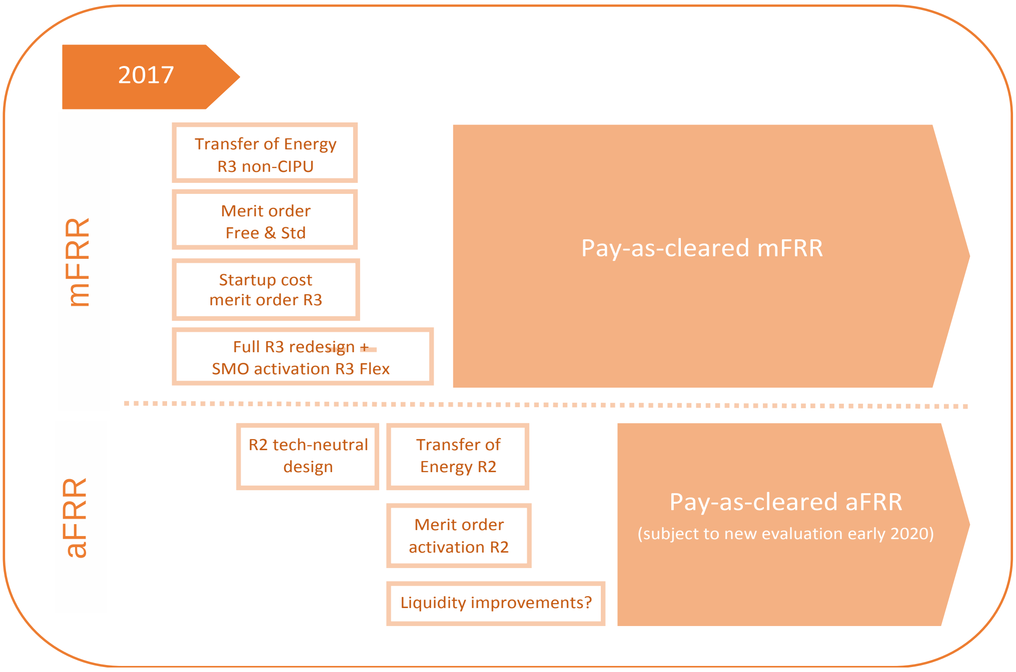

Figure 16 : dependencies with key design elements and tentative timeline

Implementation of mFRR paid-as-cleared is in any case not possible before 2019:

- As it requires a number of steps that will be implemented during 2018 (such as transfer of energy and merit order activation of free and Standard bids) and which are seen as prerequisites

- As it needs to account for possible implementation dependencies with other important foreseen product/market developments, notably the project aiming at a review of the mFRR product design (including the opportunity or not to keep 2 distinct products) within the framework of a possible shift towards a daily procurement of mFRR reserves which will be undertaking in the course of 2018 (design phase – hence implementation likely not before second half of 2019);

For what concerns aFRR, it is currently only possible to give an indicative timing as the assessment of the design elements required to enable pay-as-cleared aFRR still need to be further investigated. We expect that the proposed design to make participation to R2 neutral for all technologies together with elaborated rules for the R2 Transfer of Energy will be available by the end of 2018. Hence the implementation will then start in 2019. The merit order activation of R2 cannot be implemented before end of 2019 at the very earliest from an IT perspective. An implementation of marginal pricing for aFRR during the course of 2020 is therefore in principle possible, but will also highly depend on the R2 liquidity level that results from the above-mentioned improvements.

6 Paid-as-cleared pricing proposal for mFRR in isolation

In order to describe a potential design for paid-as-cleared settlement of FRR activation in a comprehensible way, we have split the discussion as follows: first, we discuss in this chapter paid-as-cleared settlement for R3 products in isolation; the next chapter is dedicated to paid-as-cleared settlement for R2 in isolation; while the following one discusses the options to combine and/or align the settlement prices of R2 & R3 (as well as other products like IGCC & inter-TSO emergency contracts).

As explained in the previous chapter, from now on we assume that the various pre-required elements described in the previous chapter are implemented.

6.1 Basic model

If mFRR settlement is considered in isolation, the basics of marginal pricing can easily be considered as a starting point. Let us consider two standard products for each ISP – one for upward and another for downward regulation. Within each product, each bid is composed by a price volume pair. The price of a bid for upward regulation (respectively for downward regulation) expresses the minimum income (resp. the maximal expense) that the participant agrees to receive (resp. to pay) to be activated, for at most the volume expressed in the bid. All participating assets satisfy the same set of minimal conditions to make them substitutable/homogeneous.

For each category, bids can be stacked according to their merit order (increasing price for upward regulation and decreasing price for downward regulation). Then, for a given activated volume, the marginal price of each category is equal to the price of the partially activated bid (i.e. the marginal bid). This price is deemed fair since all *in the money* bids (i.e. bids which precede the marginal order in the merit order) are accepted, and all *out of the money* bids (i.e. bids which follow the marginal order in the merit order) are rejected. Marginal bids / partially accepted bids are always a*t the money*.

Graphically, the marginal price is set at the level of the bid curve which corresponds to the requested activation demand (see Figure 17).

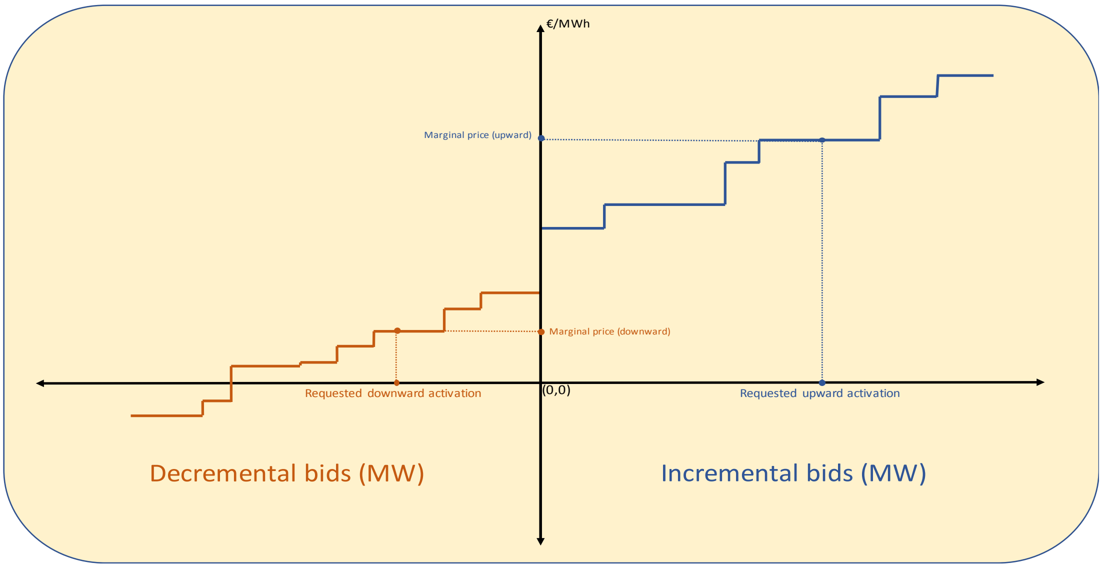

Figure 17: standard merit order curves for incremental and decremental mFRR

Some specificities need though to be considered:

- In case the last accepted bid is entirely activated, there is a theoretical indeterminacy in the price setting: reducing by 1 unit doesn't lead to the same cost as increasing by 1 unit, so that there exist a range of feasible prices between these two limits. Graphically, the intersection of the product curve and the activation demand appears on a vertical part of the merit order (see Figure 18). Consequently, any settlement price between these two limits are in principle acceptable (as they all respect the principle that *in the money* bids are accepted and *out of the money* bids are rejected). For the sake of simplicity, the proposal is to always take the lowest feasible price for upward regulation and the highest feasible price downwards regulation. In other words, the considered design is that **the settlement price always equals to the price of the last activated bid, whether entirely or partially**.

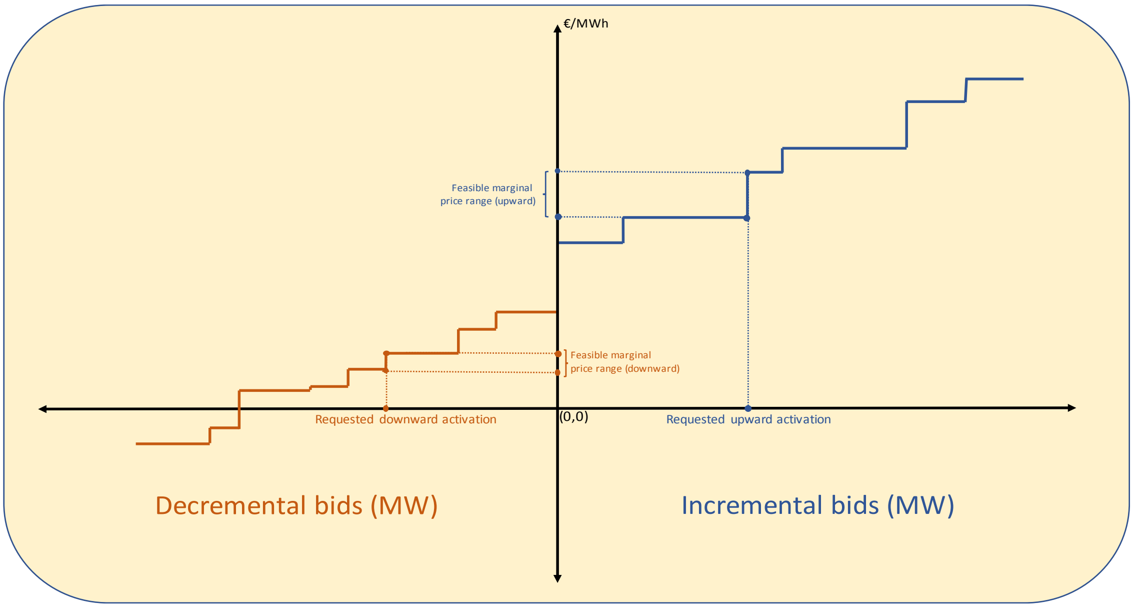

Figure 18: Price indeterminacies

- In any case, mFRR is composed by two distinct sets of products: one for incremental, the other for decremental activation. The two sets are treated completely independently, so that incremental and decremental activations can coexist and lead to distinct settlement prices.
- In case several bids are priced equally, the merit order is insufficient to univocally set the activated bids. Suppose for example a simplified example where only two incremental bids are available, both being priced at 76 €/MW and having the same volume of 100MW. The question is which bids shall be activated in case of an activation request of e.g. 80 MW. There are two classical approaches for such cases. Either a pro-rata activation – i.e. all the bids at the same price are activated simultaneously and proportionally, which provides a fair and non-discriminatory approach but may lead to operational inefficiencies when it comes to partial activation of a large set of equally priced bids. Or, alternatively, bids are activated in sequence, based on an arbitrary rule. The proposal is to take FCFS (first-come-first-served) as arbitrary rule and therefore **activate – in case there are several bids at the same price – firstly the one with the oldest timestamp.** In the simplified example of this paragraph, this means that – out of the two identical bids – the one with the oldest timestamp will be activated for 80 MW, while the other will be totally rejected. Any other arbitrary rule would lead to a similar outcome. The main reason why pro-rata is not retained is that it doesn't work for indivisible bids.
- **In case no R3 activation takes place during a given period in a given direction, no settlement price is applicable as no transaction occurred.** In terms of computation and/or reporting, the proposal is – in case no mFRR is activated in a direction during a ISP – to leave the price blank and inexistent.

- As we assume the Transfer of Energy discussion (cfr. §5.1) is satisfactorily concluded, and that consequently R3 Flex & R3 Standard Non-CIPU bids are remunerated for their activation – there remains two options for the activation sequence of R3 Flex:
  - Either it is considered that R3 Flex is a sufficiently substitutable product[32], and that its activation can be fully based on the activation cost. R3 Flex bids therefore are integrated in the single merit order. This product is then settled similarly to the other ones.
  - Or R3 Flex product remains a "not-fully-substitutable product" because of its limits on the number and duration of activations, and a willingness to keep this volume for potential worst-case situations that can happen in the future. The activation of R3 Flex is therefore set to occur after the activation of R3 standard and free-bids. In this latter case, the mFRR settlement price is set at the most extreme between the activation price with the "free bids and R3 standard merit order" on the one hand and "R3 Flex merit order" on the other hand.
  - **The choice to integrate R3 Flex products in the single merit order largely** are exogenous for this study. Note that, for the discussion at stake in this study, leaving this point open is rather considered as an implementation detail, given the expected low activation occurrences.

6.2 Sophisticated products

The standard harmonized product definition[33] for mFRR in Europe (as a consequence of the European Balancing Guidelines – see [8]) is not yet set. However, it already seems clear that – most of the reasons applicable to the other timeframes applying also in this context – standard divisible bids will most likely not been deemed sufficient to cover all the European market needs, and that sophisticated products will be required. Likely at a certain stage indivisible balancing bids will need to be implemented.

On the other hand, only simple divisible bids are currently in use in Belgium. It is thus yet unclear whether new product categories will need to be developed in the scope of this early implementation of FRR marginal pricing in Belgium.

We don't discuss in this paper whether "indivisibilities" are required. Instead, we present in this section how "indivisible bids" (as an illustration of sophisticated bids in general) can possibly be implemented. Surely, the integration of sophisticated products in mFRR will have a significant – yet unknown – planning impact.

[32] Depends for example on the procurement schedule (e.g. daily procurement) or on the product definition (e.g. unique daily 4-hours products)

[33] Standard mFRR product definition notably comprises parameters such as: duration of preparation period, duration of ramping period, full activation time, deactivation period, validity period, etc… see for example [26] for an overview of the discussion points.

An indivisible bid is like any other bid as described above and is defined for a given ISP and direction by a price and volume pair. However, unlike standard bids, indivisible bids cannot be activated partially.

Let us consider an example with 4 incremental bids as depicted in the table below. Orders A to E are ranked according to their prices which are of 30, 40, 50 and 60 €/MWh for volumes of 15, 20, 50 and 60 MWh respectively. Orders A and C are indivisible. The demand for activation is 75 MWh.

Given that there are 2 indivisible bids, and that each can be either fully activated or fully rejected, we can list 2² = 4 possible solutions, where indivisible bids acceptance is fixed ex-ante and where divisible bids are accepted based on merit order. These 4 solutions are depicted in the table below:

Bid	Price	Volume	Indivisible	Solution 1	Solution 2	Solution 3	Solution 4
A	30 €/MWh	15 MWh	yes	15 MWh		15 MWh	
B	40 €/MWh	20 MWh	no	10 MWh	20 MWh	20 MWh	20 MWh
C	50 €/MWh	50 MWh	yes	50 MWh	50 MWh		
D	60 €/MWh	60 MWh	no	0 MWh	5 MWh	40 MWh	55 MWh
			Negative welfare term	€ -3.350	€ -3.600	€ -3.650	€ -4.100
			Price of last activated bid	50€/MWh	60€/MWh	60€/MWh	60€/MWh

All solutions satisfy the requested activation of 75 MWh, but none fully respects the merit order rule. Indeed, in solution 1, order B is partially accepted while it is fully in the money, whereas for solutions 2, 3 and 4, there is always at least one indivisible bid which is paradoxically rejected (i.e. rejected although in the money). This clearly shows a need to tolerate deviation from a pure merit order principle.

Solution 1 is deemed unacceptable: with a marginal price of 50 €/MWh, the partial activation of the deep *in-the-money* divisible bid B provides undesirable incentives (i.e. discourages the use of divisible bids).

Solution 2 leads to a marginal price of 60€/MWh, and is the solution that minimizes the total activation cost. However, bid A is deeply in the money (i.e. by 30€) and is nevertheless rejected, which may trigger complains (cfr. The discussions in the Day-Ahead market). Further, identifying such a solution requires a complex optimization algorithm. This is therefore not the preferred solution.

Solution 3 is the solution that would be returned with the procedure presented at the end of this chapter. It activates bids in the merit order sequence: firstly bid A for 15MWh, then bid B for a cumulative volume of 35MWh in total. The acceptance of bid C would lead to a cumulative accepted volume of 85MW, and over-satisfy the demand. Bid C is therefore skipped, and the demand of 75MWh is fulfilled with the next bid D.

Solution 4 is a solution where all the indivisible bids are rejected, and is therefore the least efficient one (highest provision cost / lowest welfare). Algorithms that identify such solutions would completely discourage the use of indivisible bids.

The direct consequence of indivisibilities is that they largely complexify price determination as they question theoretical marginal pricing principles: indeed, by definition, an indivisible bid cannot be marginal (i.e. cannot be augmented or reduced by one unit). From a pure theoretical perspective, a true uniform pricing where execution is fully compatible with the settlement price is actually not always possible in the presence of non-convexities such as indivisibilities. Graphically, the intersection between the merit order curve and the demand for activation curve might happen on an infeasible point (in case this intersect takes place on an indivisible bid).

Since by definition, indivisible bids cannot be accepted partially, they are either fully accepted or fully rejected, with the possible consequence that – irrespective of pure merit order rule – price-compatible bids can be rejected or price-incompatible bids can be accepted.

There are three key elements to be considered to find a way to cope with indivisibilities:

- Simplicity: the selection procedure should be sufficiently simple to output results that are expectable and understandable. Notably, as is the case in the day-ahead market, divisible in the money orders are expected to be always accepted and divisible out of the money orders must always be rejected.

- Incentives to use divisible bids: although it is well understood that indivisible bids are required in general, there is a genuine preference for divisible bids, which are the most flexible bids that can be obtained.

- No bid can be loss-making: the price of the bid represents a minimum income for incremental products (respectively a maximum payment for decremental products), and the remuneration should comply with such boundaries.

While the typical approach to resolve problems with binary variables is to use mixed integer optimization techniques[34], the proposed simplified approach (see the heuristic described at the end of this chapter) is likely to provide similar economic efficiency (i.e. no significant welfare differences), higher robustness (e.g. no issues with computation performance), and better predictability (i.e. no deep-in-the-money rejected bids). Further, such an approach incentivizes the use of divisible bids.

Roughly speaking, **the proposed heuristic that would be used in presence of indivisible bids in mFRR is to sequentially accept the bids in the merit order, except that if the acceptance of an indivisible bids provides a (much – see below) larger volume than the activation request, then this bid is ignored (i.e. rejected paradoxically) and the next bid is considered**.

6.3 Activation volume tolerances

Generally speaking, as mFRR is activated manually to relieve aFRR very close to real-time, operators activate mFRR mostly using standardized volumes: typically, mFRR is activated by multiples of 10MW or 25 MW.

On the other hand, mFRR bids are dimensioned according to the assets' specificities so that the offered volumes do not necessarily coincide with the requested activation volumes.

In presence of indivisibilities, ELIA would in practice be able to tolerate that the activated volume exceeds by a small tolerance the actual request. For example, if ELIA requests 25 MW and that the first order in the merit order is an indivisible bid of 30 MW, ELIA can probably accept to activate this bid.

So far, ELIA estimates as rule of thumb that a tolerance of between 10 MW and 30 MW for over activations can be permitted. However, for practical reasons, under activations will not allowed. At the latest when moving to a European platform, this rule of thumb will have to be made explicit in order to be included in the cross-border Activation Optimization Function.

[34] Although combinatorial, this problem is much simpler than other typical power auctions (i.e. the day-ahead market) because no grid constraints or multi-period horizons are considered. Further, the proposed approach addresses by construction the so-called "deltaP issue" and avoids by construction that deep in the money indivisible bids are paradoxically rejected.

6.4 Dummy energy

Let us define "Dummy energy" as energy delivered in relation to an activation but that does not correspond to the settled energy. The typical example relates to delivery deviations due to ramp up or ramp down phases preceding or succeeding the ISP for which the product has been activated.

The general principle is that dummy energy is not valorized specifically, i.e. the standard block approach prevails: only the requested energy is accounted for and settled at the marginal price during the corresponding ISP.

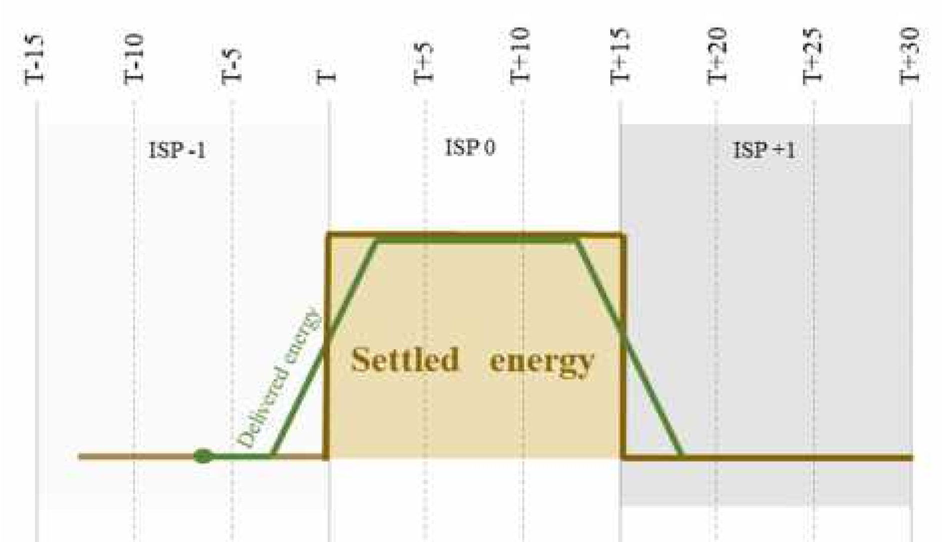

Figure 19: The difference between delivered energy and settled energy is not accounted and settled separately (i.e. dummy energy)

In case dummy energy influences the balance perimeter of the preceding or succeeding ISP, and consequently the direct or indirect imbalance cost of a market player, this needs to be integrated in the bid price[35].

Similarly, if dummy energy influences the total balance, ELIA will compensate via other ancillary services, which in turn can influence the balancing cost and imbalance prices. In any case, ELIA's approach is that **dummy energy is considered as a regular deviation and not treated specifically**. As a consequence, dummy energy has no influence over the marginal price of adjacent ISPs, or, in other words, the activated bids only influence the marginal price in the corresponding ISP.

6.5 Scheduled activations and direct activations

There exist two ways mFRR bids can be activated:

- Either, for a given ISP, bids are activated at a fixed point in time preceding the ISP to enable preparation and ramping up so as to deliver the requested energy during the corresponding ISP. This is referred to as "scheduled activation" (SA), and is favored by some market participants as it sets fixed moments when activation is triggered.

[35] Note that in practice such imbalances are expected to be mostly in the "right direction"

- or bids are activated at any other moment, typically in case of sudden significant grid incidents. This latter activation mode is named "Direct Activation" (DA). The possibility to activate mFRR bids continuously is required by TSOs as it enables to restore the imbalance within 15 minutes (conform to the requirements in the European Guideline on System operations [7]).

Currently Elia is performing a selection per ISP in case there is a need to perform a direct activation of mFRR reserves (see figure 20). This implies that in theory it is possible that a bid activated during ISP-1 is different than the bid activated during ISP 0 and that the bid activated during ISP-1 is only activated during a very short period and hence remunerated for a limited amount of energy.

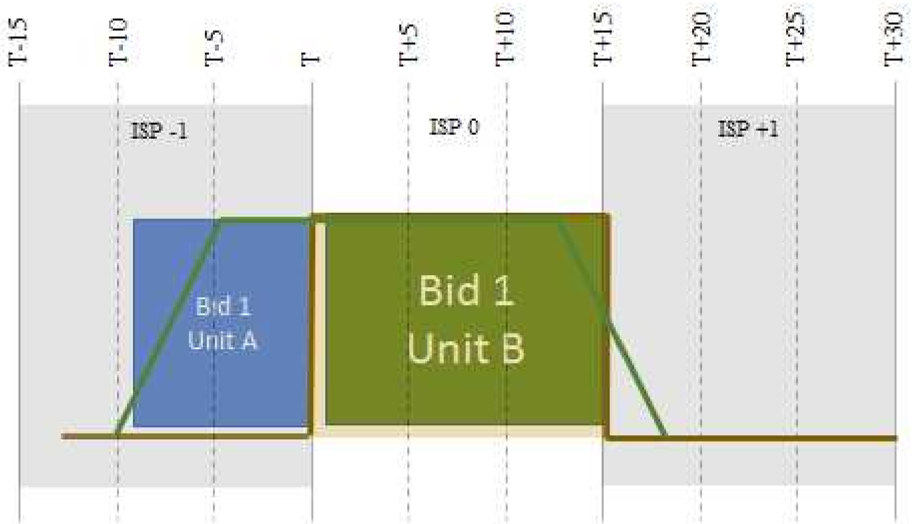

Figure 20 : Current direct activation process

However in practice today such short activations almost never occur as the merit order lists are not substantially changing between consecutive ISPs. In this mechanism it is fairly easy to apply paid-as-cleared as the standard rule just need to be applied per ISP.

As soon as merit order lists are getting more dynamic and the minimum energy settlement time of 15 minutes need to be guaranteed for market parties, the design will become more complex. Indeed, since DA does not coincide with the SA timing, they imply the delivery of energy outside the ISP for which the bid was offered, which opens a question on the price at which this energy outside the main ISP should be remunerated in case of paid-as-cleared settlement. There are in theory three possible combinations (see figure 20) of DA and SA for a given ISP: either DA is only possible during a 15-minutes period prior to the SA activations time, or DA is only possible during a 15-minutes period after the SA activations, or a DA can be activated during a 15-minutes period spread before and after the SA activations. This might lead to different choices of influence – or not – of the marginal price of one ISP to other ISP. The choice between one of these setup is currently under discussion at EU level, and is far beyond the scope of this study.

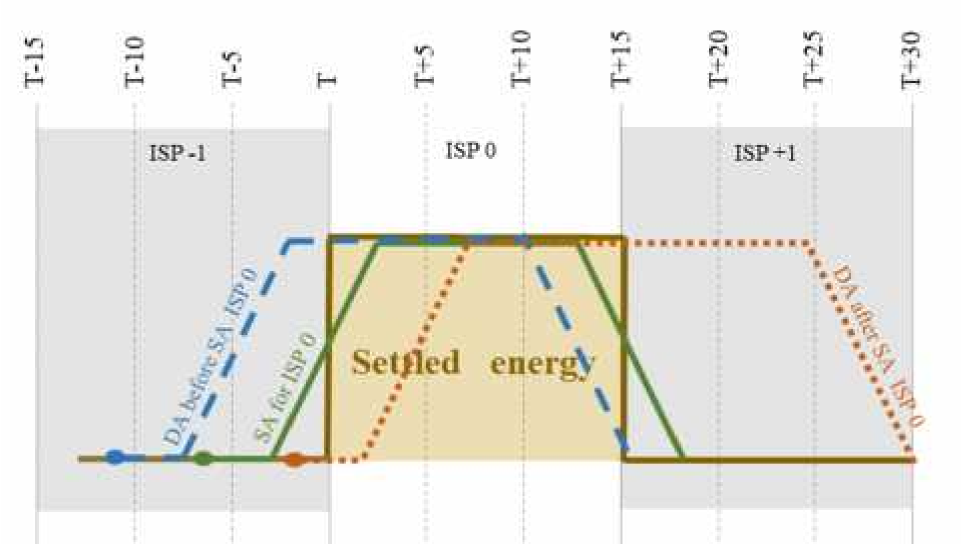

Figure 21: Example of Direct Activation (DA) before or after scheduled activation (SA)

6.6 Inversal Pricing

We refer to “inversal pricing” when the cheapest incremental bid has a lower price than the most expensive decremental bid. See for example Figure 22.

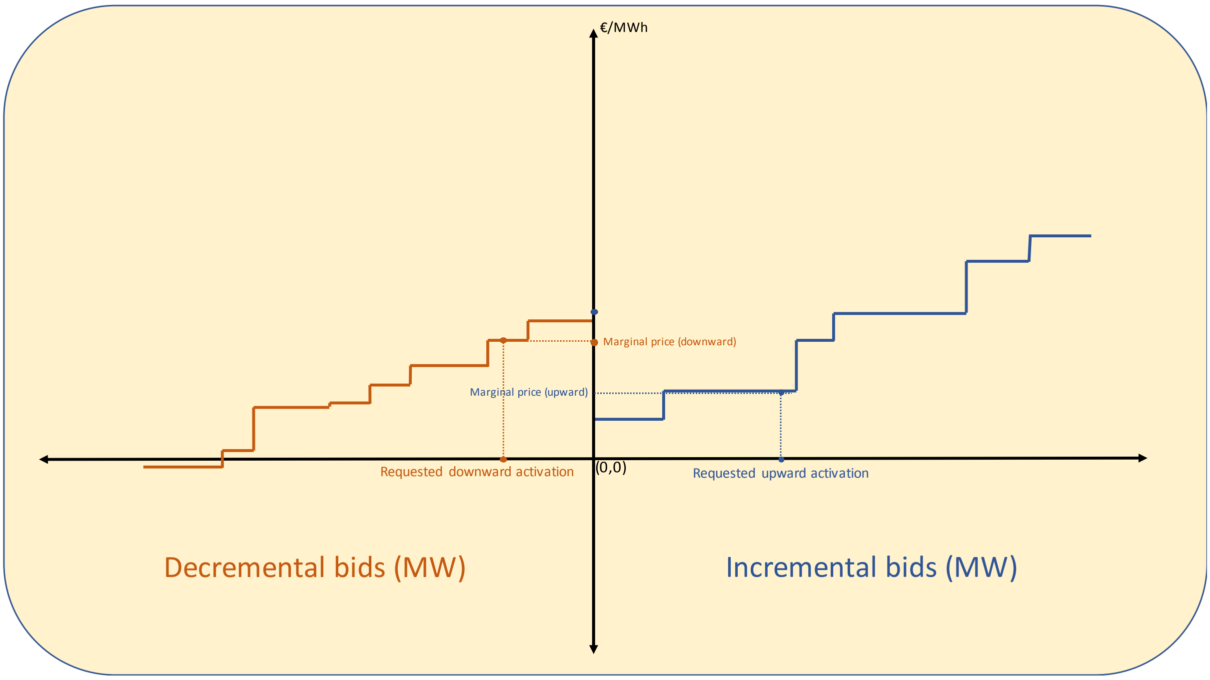

Figure 22 : example of inversal pricing

Such situations are possible, although they are not expected to occur frequently, since Incremental and Decremental bids are treated as distinct products.

The option to clear all these crossed-priced orders, so that the merit orders for upward and downwards regulation no longer cross each other, has logically been discarded. The main reason is that, if price-compatible mFRR products in opposite directions (whether pre-contracted or not) are cleared, they disappear from the order stack and it thereby reduces the total amount of available reserves. Another argument is that this would have implied that ELIA's balancing market act as a peer-to-peer market venue, which is not in line with the views of ELIA to incentive trading on market venues (intraday, OTC, etc.)

Our view is thus to ignore inversal prices and to allow marginal prices of upward tertiary regulation to be equal or below the marginal prices for tertiary downwards regulation.

6.7 Use of bids for other purposes than national balancing

Another important aspect that influences the settlement scheme of tertiary reserve products – and possibly questions the concept of marginal pricing – relates to the use of bids for other purposes than (national) balancing.

Currently bids received from CIPU units are used for balancing and local congestion purposes. Besides flexibility from CIPU units can also be used to deliver energy to neighboring TSOs through inter-TSO contracts. Note that in the future – in the framework of the iCAROS project – Elia proposes to develop a separate mechanism for congestion and balancing. Once implemented this section is not relevant anymore.

Usage for congestion management purposes triggers a fundamental question on the homogeneity of mFRR products, which is a mandatory requirement for efficient marginal pricing. Indeed, it is well possible that a bid which is in the middle of the merit order appears as the most efficient (or possibly even the only) solution to e.g. alleviate a local congestion. In this case, it is questionable whether the general merit order principle – on which marginal pricing is based on – still applies.

Moreover, Article 30 of EBGL [8] clearly states that *"at least balancing energy bids activated for internal congestion management shall not set the marginal price of balancing energy"*.

It is also valuable to note that congestion management actions are typically done more ahead of real-time than the envisaged timing applicable to usage of bids for balancing. The settlement for congestion management actions ahead of real-time can thus use a different pricing scheme, while the marginal settlement principles described in this chapter – i.e. the price applicable to all activated bids is equal to the price of the last activated bid in the merit order – applies for any Direct or Scheduled activation.

In practice, the distinction can be based on the timing or purpose of the activation. FSPs thus benefit from two distinct markets: a **first to account for congestion management based on a paid-as-bid or regulated principle[36], and a second – very shortly before real-time – to offer balancing services based on a paid-as-cleared principle**. Only bids which have not been activated for congestion management purposes remain active for balancing purposes, so as to avoid that the same flexibility is considered twice.

We must also bear in mind that congestion management actions – sometimes also called (local or cross-border) redispatching - in principle always comprise two legs: one to alleviate a local congestion, and another to compensate the first and maintain the balance. The locational specificity of bids for congestion management only applies to the first leg. In order to keep FRR capacity for balancing purposes, ELIA proposes to compensate the redispatching actions (i.e. activate the second leg) with other mechanisms, such as sourcing on the intraday market, whenever this is possible.

[36] Note that the approach seems to be compatible with CACM [28], notably its article 35 (§5 & §6) which strives to provide TSOs with the necessary information to calculate redispatch and counter-trading costs ex-ante.

6.8 Price boundaries

Let us distinguish technical boundaries from market influencing boundaries. The first ones are often required for some technical reasons, but they are not intended to restrict bidding behavior. We thus don't discuss them, and leave this point open until the implementation phase. The second ones are precisely intended to put constraints on prices, and should therefore be addressed.

In essence, price boundaries are typical remedies for defaulting market situations with liquidity or competition issues. On the contrary, if the considered market is sufficiently liquid and competitive, price boundaries are neither required nor suitable. At the extreme, narrow price boundaries are equivalent to regulated prices, which is in contradiction with the free markets paradigm underlying the discussion of this study.

In practice, the question therefore boils down to how competitive the mFRR market is or will be. Our assumption is that a merit order activation of R3 of standard products, coupled with the existence of free bids and the bid ladder, should ultimately lead to a sufficiently liquid and competitive environment in which price caps and floors are not required. **We therefore recommend keeping the current practice and not to apply price boundaries to mFRR settlement prices.** However, such situation should be revaluated – in consultation with the CREG.

6.9 Proposed heuristic

The activation heuristic resulting from the discussion above reads as follows:

Proposed price calculation and activation procedure mFRR

Parameters: (separate for incremental and for decremental activations)

- A is the total requested activation volume, A>=0
- P_i is the price of bid i
- Q_i is the volume of bid i
- D_i equals 1 if bid i is divisible, equals 0 if bid i is indivisible
- TOL is the tolerance margin for over-activations

Variables:

- q_tot is the total activated volume
- P is the settlement price
- v_i is the activated volume of bid i (v_i <= Q_i)

Initialization (only once per ISP prior to any DA or SCH activation):

- Order all bids {1,….,n} according to their economic efficiency (increasing price for incremental bids, decreasing price for decremental bids)
- Set activated volumes of all bids to zero (v_i := 0 for all i in {1,…n})
- Set total activated volume to zero (q_tot := 0)
- Set default price P:=P_1

Procedure (run at each DA or SCH activation request):

- Initialize with i = 0
- While the requested activation volume is not fully satisfied (while q_tot < A) do
    - i := i+1
    - If the bid is indivisible (If D_i= 1) then
        - If activating the entire volume of bid i satisfies less than the requested activation volume + the tolerance margin (If q_tot + Q_i <= A + TOL) then
            - Activate the bid (v_i := Q_i)
    - else
            - Activate the bid i (v_i := min (A - q_tot; Q_i)
    - Set the settlement price at the price of the last accepted bid (P := P_i)
    - Update the total activated volume: q_tot := q_tot + v_i

This procedure has the advantage to be extremely simple, and is therefore attractive as it allows to transparently generate acceptable prices which are easy to forecast, without risking any operational difficulty implied by a more complex price calculation algorithm. For the time being, we assume such a procedure is implemented.

Note that this procedure can be adapted in case other sophisticated products (such as those considering start-up costs) are to be integrated.

6.10 Cross-border arrangements

As explained in the introduction (see §1.3), the time horizon envisaged for the implementation of marginal FRR pricing in this study precedes the implementation of the transnational approaches as set in the Electricity Balancing Guidelines [8].

There are numerous projects and discussions related to cross-border implementation of FRR that are being or have been held at national, regional and European levels, in anticipation of the entry into force of the Electricity Balancing Guidelines. Marginal pricing of mFRR is one of the cornerstone of such European harmonized FRR implementation.

At this moment however, the maturity of these international discussions is insufficient to draw conclusions which are directly applicable to our context. Rather, studying the implementation of marginal balancing energy settlement in Belgium should be seen on the one hand as a "step in the right direction", and on the other hand as a source of experience to contribute to the European debates.

Meanwhile, at least the current cross-border arrangements (i.e. inter-TSOs emergency assistance) remain in place as is. In this respect, **the proposal[37] is that, whenever balancing energy is offered by ELIA to neighboring TSO, the energy of this transaction should be included in the marginal price formation for balancing energy (similarly as in day-ahead price coupling).** By doing so, we ensure that any activated mFRR energy is paid equally – whether it is to serve the national or another balancing area. Such a proposal appears suitable, in particular given very rare activation of such inter-TSO contracts.

Note that we discuss later (cfr. §8.3) the possible interactions of balancing services acquired from other TSOs, as well as of balancing services offered by ELIA to other TSOs, and the national imbalance pricing.

[37] Following the recent conclusions for the Nordic market [24]

7 Paid-as-cleared pricing proposal for aFRR in isolation

Let us first recall the **main differences of aFRR** compared to the discussion just held about mFRR.

Unlike mFRR, for which a "standardized block approach" enables to consider any bid activation as equivalent to a delivery for an entire ISP, aFRR products by construction are activated continuously with a **set point which by nature can constantly vary as the time of the ISP elapse**s.

For a given subperiod of an ISP, the system imbalance can only be in a single direction: either incremental, decremental or null (e.g. in case of IGCC netting). Hence for a given point in time, **counter-activations are in principle not possible**[38].

In any case, there remains two distinct merit orders for upward and downwards activations, hence a different settlement price is calculated for each direction. The entire reasoning applicable to inversal prices in mFRR (see §6.6) is therefore also equally applicable to aFRR, and **inversal prices for incremental and decremental aFRR activation during a single ISP are possible**.

Also, contrary to mFRR products, there is **only one type of simple bid per direction in aFRR** (no indivisibilities, no startup cost, etc.). As all orders satisfy a set of requirements (minimum ramp rate, etc.), they are treated as **fully homogeneous**.

We propose below two distinct approaches to fix a paid-as-cleared settlement price for aFRR. As explained, incremental and decremental activations are treated separately.

7.1 Two possible basic models

7.1.1 M1: Unique aFRR settlement price per ISP based on largest activation (w/o minimum duration)

In this model, **a single settlement price applicable to all activated energy in a given direction is computed for a given ISP based on the most extreme activated bid in the merit order**. More precisely, the aFRR set points define the requested volume that varies over the imbalance settlement period (ISP), and the aFRR balancing energy settlement price of this ISP in a given direction becomes the price of the bid in the merit order which corresponds to the absolute largest aFRR set point in this direction.

In case no activation is requested in a given direction, and a price is necessary for other purposes (such as setting an imbalance settlement price), the settlement price for this direction equals to the price of the first bid in the merit order.

One likely issue with this type of model is that an extremely short activation of expensive bids influences the settlement price of the entire ISP, despite a very limited amount of delivered energy. A theoretical option to avoid this concern could have been to force the TSO systems to mechanically/operationally avoid such extremely short activations. This is however deemed very impractical and therefore strongly disfavored by TSOs as it is technically overcomplicated (TSOs don't know in advance for how long a set point will be needed) and ultimately could lead to operational or grid stability issues (as this has a direct impact on ACE quality), not to mention the technical difficulty to set up the EMS to cope with such a feature. This would

[38] In practice, due to ramping and other operational constraints, it might be possible to trigger counter-activations in extreme situations. This is however irrelevant for the discussion at stake.

also be questionable in terms of compliance with SOGL as the principles of the automatic frequency restoration process would not be followed.

A credible alternative of this model therefore consists of – **instead of using the absolute largest aFRR set point to determine the uniform settlement price of the entire period – only set points for which the activation has in total lasted more than X seconds (say 30 seconds) are considered**. Bids activated less than X seconds are remunerated paid-as-bid.

The proposal M1 therefore consists of taking as aFRR settlement price in a given direction the price of the last bid in the merit order that has been activated by more than X seconds. Out of the money-bids (i.e. bids activated less than X seconds) are compensated and remunerated paid-as-bid.

We refer to such an approach in this document as the "M1 model", and provide a procedure to calculate prices under this model.

M1 method for aFRR pricing

Parameters (separate for incremental and decremental activations)

- SP_t is the aFRR set point at instant t (t in {1, …, T}), SP_t >=0
- P_i is the price of bid I (i in {1, …, I})
- Q_i, is the volume of bid I (i in {1, …, I})
- MinT is the minimum activation duration (in number of subperiods) required to influence the price. (E.g. 30 seconds).

Variables:

- p is the settlement price of the entire period
- count_i counts the activation duration of bid i

Initialization (once per ISP):

- Order all bids {1,….,n} according to their merit order (increasing for incremental bids, decreasing for decremental bids)
- n(X) is the function that returns order i corresponding to volume X in the merit order
- p:=P_1 (sets the default price in case of no activation)
- count_i := 0 for all i

Procedure:

- p := P_1
- for t=1 to T do (i.e. as time elapses)
  - o Identify most extreme activated bid (i = n(SP_t))
  - o Count the duration of the activation (count_i := count_i + 1)
  - o if P_i >p (incremental activation) // if P_i<p (decremental activation) then
    - if count_i >= MinT then p := P_i
  - o end if
- next

7.1.2 M2: Different aFRR settlement prices every X seconds

An alternative model can be built on the concept on sub-ISP periods. Such sub-periods would either be aligned with the frequency at which set points are updated by ELIA (i.e. every 4 seconds), or possible to a more manageable duration (e.g. 30 or 60 seconds). The exact duration can be decided during implementation, while we here discuss conceptually how the mechanism would work.

In such a model, which we name M2**, a different marginal settlement price is calculated for every sub-period,** based on the requested activation volume of this sub-period (from which a price is derived on the merit order curve). For each BSP, the activated volumes in each sub-period multiplied by the corresponding settlement prices are summed up to form the total remuneration of a given ISP.

M2 method for aFRR pricing

Parameters (separate for incremental and decremental activations):

- SP_t is the aFRR set point for subperiod t (t in {1, …, T})
- P_i is the price of bid I (i in {1, …, I})
- Q_i, is the volume of bid I (i in {1, …, I})

Variables:

- p_t is the settlement price for subperiod t

Initialization (once per ISP):

- Order all bids {1,….,n} according to their merit order (increasing for incremental bids, decreasing for decremental bids)
- n(X) is the function that returns order i corresponding to volume X in the merit order

Procedure:

- for t=1 to T do (as time elapses)
  - Identify last activated bid i = n(SP_t) // i = 1 if SP_t = 0
  - p_t = P_i
- next

7.2 Cross-border integration

Besides IGCC, there is currently no aFRR cross-border arrangement existing for Belgium. And, since the focus of this study is on the period that precedes the implementation of a European aFRR platform as prescribed in the Electricity Balancing guidelines [8] – we consider that this situation remains as is.

Nevertheless, the local implementation of marginal price for aFRR energy is both considered as (1) a preparatory step for European integration project such as PICASSO [9], as well as (2) a way to gain the necessary experience to actively participate to the design of such mechanisms and platforms.

It is thus to note that M2 model is likely to have multiple advantages when it comes cross-border price setting. Indeed, a key question related to aFRR cross-border pricing relates to how congestions are considered. Indeed, generally speaking, the common expectation is that marginal settlement prices are equal across a region with no internal congestion. Though, while for any other spot or balancing markets, the committed output always is assumed to be constant over a given ISP, this is not the case for aFRR. A key design element for cross-border aFRR pricing is then how are congestions defined. Indeed, it may be that a given network constraint is binding only during a sub-period of the ISP. Assuming that the "no-congestion ⇔ equal prices" rule remains a general requirement, M2 model straightforwardly copes with such situations, by considering the occurrence of congestions in a very accurate way (as that the granularity of the sub-period duration allows to consider congestions uniformly during each sub-period). Moreover, price convergence will increase with the method M2. Therefore, overall competition between suppliers will increase, which is identified as a key driver for the implementation of marginal pricing.

Other methods (such as M1) necessitate to define a new pricing method to cope on the one hand with a uniform price over the entire ISP and on the other hand with the requirement to equalize prices in areas with no binding grid constraints.**M2 therefore seems more appropriate in preparation of cross-border integration.**

7.3 Use of aFRR for other purposes than balancing

Unlike mFRR, aFRR are not used for active congestion management, but solely for balancing purposes.

The only possible discussion relates to how R2 bids which are creating or aggravating a constraint should be considered. Our proposal is to exclude such bids. However, before such an exclusion, the market participant will – whenever possible – be informed in due time about the risk of one of his bids being excluded due to a local congestion, so as to let him the possibility to update his bids and remove the problematic resources from the portfolio wherever possible.

Bids which are rejected due to local congestions do not affect the marginal price in either models M1 & M2.

7.4 Price boundaries and extreme prices

Currently, aFRR bid prices are bound by caps and floors. This is mainly due to the lack of competition on this market segment, correlated with the fact that the vast majority of selected aFRR bids are nowadays pre-contracted (which provides a separate revenue stream that could contribute to fixed costs and profit).

In M1 model, setting a minimum activation duration can be seen as a way to limit – at least to some extent – unnecessary extreme prices, since only extremely priced bids which are activated for a longer period than a given threshold are able to set the remuneration price. Similarly, under M2, obtaining an extreme average settlement price all along a given ISP implies that large set points have been necessary during a significant part of the ISP. **We did not identify any clear distinction between M1 & M2 models in terms of necessity to impose caps and floors on aFRR prices.**

The competitive situation in aFRR market is expected to improve upon the opening of aFRR to non-CIPU assets, as well as with the full merit order activation of aFRR, which will provide better incentives to bid competitively. Our view is that **the need of price caps and floors should be revaluated in light of these two major improvements. Importantly, the absence of a sufficient level of competition in aFRR could delay the implementation of a marginal pricing mechanism,** as such a system is likely to deliver poor results if most bids prices are artificially bound and that competition cannot emerge anyway.

Note that the cross-border integration will also significantly contribute to the enhancement of the competition.

7.5 Technical implementation

A technical assessment of the IT changes to implement either M1 or M2 model hasn't been performed in the scope of this study.

However, initial expectation is that M2 implies more significant IT changes than M1. Indeed, the core principle of the M2 approach implies a sub-ISP settlement. In order to ensure a transparent, verifiable and auditable process, data will therefore have to be stored on a more granular level than per ISP, both on the TSO side (notably to manage invoices towards FSPs) and on the FSP side (notably to be able to verify invoices). This is expected to be a significant additional complexity. Therefore the feasibility and acceptability for stakeholders need to be carefully examined when considering this solution.

7.6 Intermediate conclusion

As explained, the change towards paid-as-cleared settlement of R2 is in principle a desirable change in preparation of the European integration of aFRR. In this respect, the M2 model appears more convincing: as it is based on sub-ISP periods, it more accurately determines settlement prices and is more likely to be future-proof and cope with cross-border integration and congestion pricing, thereby inviting true European competition to emerge.

From a local pricing perspective, the choice between M1 and M2 boils down to a redistribution trade-off: while M1 provides a higher remuneration to BSPs – and consequently implies a higher cost for BRPs – M2, because it enables a more granular settlement, reduces the BSPs revenues and thereby the BRPs costs.

To conclude, on the one hand, ELIA intends to conform to the European standards once established, and – although no clear European model has emerged yet – M2 is an attractive model from this perspective. On the other hand however, ELIA also desires to implement a pragmatic solution, and M1 is likely to be more easy to implement. Therefore, the M1 vs M2 choice remains somewhat open for the moment.

8 Links between different products and markets

In the two previous chapters, we proposed possible settlement schemes for aFRR & mFRR in isolation. In this chapter, we discuss whether it makes sense to combine the settlement prices of these different products by analyzing “cross-pricing” options between pairs of products.

We refer to “cross-product pricing” in case the settlement prices of two products (e.g. aFRR and mFRR) are equalized towards the most extreme of the individual prices (as opposed to “per product pricing” where the prices of two products remain distinct).

8.1 Cross-product pricing IGCC

IGCC TSO-TSO settlement price is based on a specific formula (that estimates the welfare gains of the mechanism for the given ISP) which doesn’t necessarily refer to the bid prices. The parameters of this formula (see §3.1) are only available ex-post, so that the settlement price is not available close to real-time. Further, the formula applies to TSO-TSO settlement, are therefore neither useful nor published to market participants. It is clearly out of the scope of the present study to reconsider this formula.

Consequently, applying cross-product pricing with IGCC is considered irrelevant.

8.2 Cross-product pricing aFRR vs. mFRR

Let us now discuss the possibilities to combine the settlement prices for aFRR and mFRR activated energy.

8.2.1 Cross-product pricing calculation

To start with, let us envisage the functioning of such a cross-pricing principle under the 2 proposed aFRR methods:

In case the M1 method (cfr. §7.1.1) is applied, the obvious cross-product pricing approach would be to take the most extreme (i.e. highest for upward activation and lowest for downwards activation) settlement prices among aFRR and mFRR settlement prices as computed in isolation for each direction, and to remunerate each unit of activated aFRR and mFRR energy of the given direction with this unique aligned price.

For the M2 aFRR pricing method (cfr. §7.1.2), a pure “aFRR-mFRR cross-product pricing” is not natively possible, since the M2 approach relies on sub-period settlement and that there is no single settlement price that applies to all the activated aFRR energy during an ISP (while the mFRR is settled per ISP). Though, it may be envisaged to combine the mFRR settlement price of a given ISP with the multiple aFRR settlement subperiod prices obtained with the M2 method. This can for example be done by:

- bounding, in each ISP subperiod, the M2 aFRR settlement prices with the mFRR price applicable to this ISP, and
- calculating the weighted average price of all aFRR energy of an ISP (as calculated under M2 principle) use this as a bound for the corresponding mFRR price.

The relevance of such a cross-pricing scheme is however uncertain.

8.2.2 Incentive & attractiveness

We consider here FRR attractiveness irrespective of the remunerations for reservation, which are out of scope of this study and which can be considered as “sunk” at the time the energy bid prices are set.

FRR attractiveness for activated energy are determined by the likelihood to be activated and by the remuneration level. We can thus discuss to what extent the fact that mFRR and aFRR prices are aligned (i.e. cross-product pricing) influences the bidding behavior and makes the FRR markets more attractive.

On one hand, one may argue (see for example [10]) that “cross-product pricing” has the advantage of consistency of pricing between the different means by which energy is injected and withdrawn from the system in the balancing timeframe (specifically in systems that allow BRPs to support the system balance in real time). Hence “cross-product pricing” may participate to make FRR products attractive for any spare capacity to be offered.

On the other hand however, R2 and R3 products are distinct products with distinct characteristics, in particular in terms of granularity: while R3 is defined to be delivered for a period equivalent to an ISP, R2 is by nature infra-ISP and consequently a much more flexible product. **Heterogeneity of products then suggests that different settlement prices should apply, and hence pleads for a “per product pricing” approach.**

8.2.3 Infra-marginal mFRR activation

In case of per product pricing, mFRR settlement prices are by construction compatible with activated orders: all infra-marginal bids (i.e. in the money bids) are activated[39]. This is a neat feature which is generally observed in auction-type markets such as in the day-ahead market and provides sound prices with appropriate incentives: a participant can expect that all his price-compatible orders are accepted, and all non-compatible bids are rejected.

In case of “full cross-product pricing”, since prices are modified, such a principle no longer holds, and non-activated mFRR bids might become in the money. This may lead to inefficiency and dissatisfaction, ultimately impacting the liquidity: participants have submitted price-compatible bids which have not been accepted, and are therefore no longer attracted by this market.

From this perspective, because of the coherence between clearing prices and acceptance/rejection of bids, we deduct that “per product pricing” is clearly superior.

8.2.4 Cross-border FRR initiatives

There are two important aspects to consider when discussing FRR cross-product pricing options. They relate to cross-border FRR deployment.

Firstly, and most importantly, it currently remains an open question whether a suitable mechanism of cross-product pricing that properly addresses congestion pricing exist. Indeed, the expected rule in case of cross-border pricing is that the price of a product exchanged within an area with no grid constraints should be equal. This is already a challenging question in general for aFRR products, for which we advocated the M2 model. Given that mFRR and aFRR are activated at different moments and for different durations, cross-product is hardly compatible with congestion pricing. It is for instance likely that one product is activated from another area without being limited by grid constraints (hence the settlement prices equalize) while congestions occur when the other is activated (which implies a price difference). **It might then be impossible to keep the appropriate congestion pricing, while equalizing also the aFRR and mFRR prices.**

[39] At the possible exception of sophisticated bids (see §6.2) due to their particular nature, but this is a different topic.

Secondly, there are currently multiple ongoing European TSOs initiatives to harmonize and integrate balancing markets in anticipation of EBGL. PICASSO [9] and MARI [29], the most promising aFRR and mFRR pilot projects for ELIA at this moment, are unfortunately not consistent with respect to the participating TSOs and geographical scope, and are also likely to go-live at different moments. A very practical concern about cross-product pricing is thus that it actually implies a very high-level of interactions between the aFRR and mFRR systems. In case such systems have different geographical scopes, stakeholders, and go-live dates, such a strong level of interactions might be unreachable in practice. The difference in geographical scope is likely to remain a long-standing reality since the requirements to implement each platform are not fully aligned. Therefore, for practical implementation reasons, **cross-product pricing appears very problematic in the context of transnational FRR pilot initiatives**. In addition, such a feature can actually only be discussed once aFRR and mFRR are exchanged cross-border, which is out of the scope of the present study.

8.2.5 Intermediate conclusion

From all the above-mentioned reasons, **we conclude that there is little added value to further consider aFRR vs. mFRR cross-pricing**. The proposal is thus not to artificially align the aFRR and mFRR prices, and to keep the price calculations for each product separated.

8.3 Cross-pricing mFRR vs. TSO-TSO support

Another possible cross-pricing discussion relates to the use of support via the inter-TSO contracts, and whether it is valuable is to link the FRR remuneration and the inter-TSO settlement prices.

Let us distinguish the case where the inter-TSO is called by ELIA or by a neighboring TSO.

In case ELIA requires support from neighboring TSOs, the envisaged design is that the cost of this support (as specified by the inter-TSO arrangements) serves as a bound for the mFRR remuneration. In other words, in case ELIA calls an inter-TSO contract to resolve an undersupply (respectively an oversupply), the price that ELIA pays to the other TSOs to acquire this energy (resp. that ELIA receives from other TSOs to sell this energy) becomes a lower bound for the upward mFRR settlement price (resp. an upper bound for downward mFRR settlement price). By doing so, we ensure that national mFRR resources are always remunerated as good as similar services acquired abroad.

From a technical perspective, the implementation of such a rule is straightforward, it consists of an ex-post adaptation of the mFRR remunerations. Clearly though, the effects of such a rule is expected to be very minor, since inter-TSO is triggered only once all other resources are exhausted. Relatively high mFRR marginal prices are thus anticipated anyway, so that such bounds will have limited effects, if at all.

On the other side, in case ELIA supports neighboring TSOs**, although we already concluded (see §6.10) that mFRR bids activated in this context should be included in the mFRR marginal price formation, we estimate that bids activated to support neighboring TSOs should not participate to the imbalance settlement price formation.** Indeed, the simple reasoning is that the fact ELIA supports neighboring TSOs should not lead to more extreme local imbalance prices, so as to keep the BRP incentives to self-balance intact.

Technically, the approach suggests that an alternative theoretical mFRR settlement price "without activation of cross-border support" is calculated for such rare cases, which may in turn lead to a situation where the mFRR settlement price is more extreme than the imbalance price, and where ELIA is potentially not able to cover all the ancillary services costs by the imbalance charges. Given the very low probability of such cases, and the fact that such arrangements are expected to disappear upon further cross-border harmonization (since projects like MARI [29] are precisely about implementing models where cross-border "support" is the general rule – not the exception), it is questionable whether this point is of importance.

Note that, once cross-border FRR platform are implemented, the pricing relation between the FRR activations and imbalance volumes per countries will need to be revaluated, as by design the volumes and directions will no longer necessarily correspond.

8.4 Interactions with the spot markets

Let us now briefly discuss if the application of a paid-as-cleared settlement pricing scheme for FRR energy is expected to influence the liquidity and prices of the intraday market.

On the one hand, one may consider that – as intraday is a continuous market that applies paid-as-bid settlement – bidding some spare capacity on the FRR market is more likely to provide a fair remuneration, while it reduces the trading effort. Indeed, while the intraday market requires active on-screen trading (i.e. provide prices and negotiate the bids continuously), a paid-as-cleared FRR market will guarantee that – on top of the marginal cost expressed in the bid price – the remuneration will always be equal to what the other market parties offering similar products also obtain.

However, on the other side, the activation of FRR only occurs at the very last moments, and execution remains very uncertain until very close to real-time. Therefore, to maximize profit, the fact that trades in the intraday market can occur at any time, and for a negotiated price, is a clear advantage for whoever has an open position ahead of real-time and wants to secure a revenue. Further, intraday already operates in a cross-border environment, and it is unlikely that the liquidity stemming from the neighboring countries is influenced by the Belgian balancing design.

Although it is clearly difficult to anticipate the impact on the intraday liquidity of a change towards paid-as-cleared settlement in FRR, the preliminary expectation is that such impact will not be very significant.

9 Costs and benefits of FRR paid-as-cleared settlement

From the above discussion, we can summarize the key expected benefits that would come as a consequence of a paid-as-cleared settlement of FRR as related to either an increase in liquidity (i.e. new flexibility is attracted, as it is guaranteed to benefit from a fair remuneration), or to an eased price formation (i.e. bids are expected to directly relate to marginal costs, which is more easy to price and monitor). This will in turn have a positive effect on reserve sourcing.

In order to provide a quantitative estimation of the impact of a change towards FRR paid-as-bid settlement, we performed simulations to compare the total FRR activation cost for ELIA under paid-as-cleared and paid-as-bid settlement. Prior to that, we have altered the historical dataset to replicate a situation under single merit order activation (aFRR and mFRR).

Bidding behavior will improve in the future, due to the implementation of market design improvements, competition… and marginal pricing. But this cannot be estimated by Elia. Further, simulating another usage of available bids appears as an intricate exercise, especially for “implicit free bids” where the offered volumes are computed by ELIA based on the nominations on one side and the assets characteristics on the other side (for example, it is far from trivial to recalculate the available volumes at any time of hydro-pumped storage assets). Therefore, we consider the available bids and assume the bidding behavior is unchanged. Consequently, we interpret the outcome of the simulations as worst-case results.

The simulations focus on the year 2016 and are based on the assumptions presented in the table below.

Working assumptions used for simulations (considered period: 2016):

- Set of bids.
    - Dataset used for the simulations are available aFRR and mFRR bids.
    - In general, no additional bids have been populated for the purpose of the simulations, hence the overall liquidity has not been artificially improved (despite several expected changes in the market mechanisms which are precisely intending to improve liquidity). On the contrary, because of technical reasons, some non-activated bids (for example non-activated bids related to hydro assets) could not be reconstructed and are therefore excluded from the simulated dataset.
    - All aFRR & mFRR bid prices are unchanged. Even if it is specifically a cornerstone of the marginal pricing concept that – while under pay-as-bid the bid prices are set to cover variable and fixed costs – bid prices under pay-as-cleared should tend to replicate only the marginal costs, modifying the bid prices would have had too arbitrary consequences on the simulation results.
    - In addition, startup costs remain excluded from the mFRR bid prices.
- Activated volumes
    - Activation requests granularity is per minute for aFRR activations and per 15 minutes for mFRR activations.
    - aFRR and mFRR bids become activated based on full merit order (as opposed to pro-rata and prioritized activation in the 2016 reference case).
    - The activated aFRR and mFRR volumes remain unchanged (while a full merit order activation of aFRR and mFRR is likely to imply a different a/mFRR activation strategy, hence another a/mFRR mix – see §5.3).
- Pricing
    - The activation and price calculation procedures as described in this document (see §7.1.1, §7.1.2 and §0) where implemented
    - For aFRR under M1 model, the minimal duration of an activation to influence the clearing price is set to 1 minute. For aFRR under M2 model, the duration of the ISP sub-periods is set to 1 minute. No sensitivities for these parameters could be calculated.

The following tables provide an overview of all the results obtained by such simulations, as well as a description of the key findings.

In the first table, the "Historical pro-rata activation" contains the reference data of 2016. In the "Simulated merit order activation PAB", we have modified the activation method to be sequential but keep the paid-as-bid pricing scheme. The two next lines provide the paid-as-cleared simulated results under the two proposed activation methods M1 & M2. The first column represents the cost for upward activations, and the second the cost for decremental activations (negative values mean an income). The last column gives the net cost.

The second table calculates the differences in cost between the simulations.

Summary of aFRR simulations

aFRR (total costs)	**Inc**	**Dec**	**Inc + Dec**
Historical pro-rata activation	12.878.938 €	-3.304.405 €	9.574.533 €
Simulated merit order activation PAB	11.734.581 €	-4.006.891 €	7.727.690 €
Simulated merit order activation PAC M1	16.274.010 €	-1.658.164 €	14.615.847 €
Simulated merit order activation PAC M2	14.657.933 €	-2.486.853 €	12.171.080 €

aFRR (variations)	**Inc**	**Dec**	**Inc + Dec**
From historical pro-rata activation to merit order PAB	-1.144.357 €	-702.486 €	-1.846.843 €
From merit order PAB to merit order PAC M1	4.539.429 €	2.348.727 €	6.888.157 €
From merit order PAB to merit order PAC M2	2.923.352 €	1.520.038 €	4.443.390 €
From historical pro-rata activation to merit order PAC M1	3.395.072 €	1.646.241 €	5.041.314 €
From historical pro-rata activation to merit order PAC M2	1.778.995 €	817.552 €	2.596.547 €

Lessons learned during the aFRR simulations:

Generally speaking, it is clear that aFRR is not a liquid and competitive market. This is notably observable by the limited number of bidders, and the limited amount of price steps in the bid curves.

On the one hand, for ISPs with small volumes of activated R2, the regulation cost is lower in the simulated data (PAC or PAB) compared to the historical one. This is because only the first bids are activated under merit order activation, while also more extreme orders are activated under the pro-rata scheme. Given the limited number of price steps, the results are very similar for merit order simulations under PAB, PAC_M1 & PAC_M2 when small volumes are activated.

On the other hand, when large volumes of R2 are activated, pro-rata activation and PAB merit order activation lead to similar costs, i.e. at the extreme, when all R2 energy is activated in one direction, pro-rata and PAB activation costs are identical. Though, PAC settlement becomes much more costly for such large activations because all bids are remunerated at the most extreme prices.

The net effect is that, while a change from the current pro-rata towards merit order activation reduces the total cost by less than 2M€ under PAB, the further switch towards PAC would increase the activation costs by 4,5 to 6,8M€ (for M2 and M1 respectively[40]). We believe that it is not certain that this increase in costs for

[40] NB: by construction M1 is always costlier than M2.

activation could be compensated by a reduction in costs for capacity reservations. Indeed the average capacity price for 140 MW aFRR would need to decrease with at least 3,6 to 5,6 €/MW/h (for M2 and M1 respectively) in order to compensate the increase in activation costs.

As a result of these simulations, **PAB merit order activation is a step in the right direction, as it prepares for European integration and is likely to attract liquidity, while it also reduces the overall activation costs. However, the current level of liquidity of aFRR is probably yet insufficient for a shift towards a paid-as-cleared activation. Our proposal is therefore to reevaluate the gains of such a change after having observed changes in the level of liquidity, i.e. once the currently ongoing or already planned improvements in R2 are implemented.**

Let us now have a look at the mFRR simulations.

The tables below compares the historical results, with (1) a scenario where full merit order activation is deployed under paid-as-bid settlement and with (2) a scenario under full merit order and paid-as-cleared mechanisms.

Summary of mFRR simulations

mFRR (total costs)	**Inc**	**Dec**	**Inc + Dec**
Historical prioritized activation	8.922.073 €	-167.174 €	8.754.898 €
Simulated merit order activation PAB	4.503.878 €	-357.884 €[41]	4.145.993 €
Simulated merit order activation PAC	5.167.830 €	36.133 €	5.203.963 €

mFRR (variations)	**Inc**	**Dec**	**Inc + Dec**
From historical prioritized activation to merit order PAB	-4.418.195 €	-190.710 €	-4.608.905 €
From merit order PAB to merit order PAC	663.952 €	394.018 €	1.057.970 €
From historical prioritized activation to merit order PAC	-3.754.243 €	203.308 €	-3.550.935 €

Lessons learned during the R3 simulations:

As expected, the mFRR activation based on a single merit order comprising all types products (Free-bids and Standard bids, from CIPU and non-CIPU assets) provides significant economic gains, as only the most economic bids are activated (as opposed to a prioritized scheme in the 2016). Such gains are estimated to be around 4.5 M€ per annum from the 2016 simulations. Based on this analysis we believe that that the current liquidity in mFRR is adequate.

Though, given the above-mentioned assumptions – and in particular that the bid prices are unchanged – the further shift towards a paid-as-cleared settlement can only lead to additional activation costs (simulated to be in the magnitude of 1 M€). We believe that it is likely that this increase in costs for activation could be compensated by a reduction in costs for capacity reservations. Indeed the average capacity prices for 750 MW mFRR would need to decrease with only 0,16 €/MW/h in order to compensate the increase in activation costs.

[41] While in principle "Simulated merit order activation PAB" should provide the same outcome as the "historical prioritized activation" for the decremental case – since there is only one category of products in mFRR DEC – the observed differences are due to the use of different data sources. Indeed, for some technical reasons, the list of available bids are not always completely coherent with the list of activated bids.

Importantly, given the assumptions used to perform the simulations, which do neither assimilate any of the improvements that are currently being implemented[42], nor any behavioral change following a change in the settlement scheme, the activation cost impact resulting from such simulations is to be interpreted as a worst-case analysis.

Given all these disclaimers, and the results of the worst-case simulations presented above, we estimate that the net cost impact of a change towards paid-as-cleared should be limited. As the liquidity concerns identified for aFRR are not applicable to mFRR, we conclude that a change towards a paid-as-cleared in such conditions is reasonable from a cost perspective.

[42] On the contrary, we ignore some aspects such as inclusion of startup costs

10 Recommendation for implementation

Based on the various elements presented above, the **findings of ELIA is that an implementation of marginal pricing for FRR activated energy is in general desirable in the current conditions (liquidity)**. This is particularly the case because paid-as-cleared is expected to facilitate the bidding process, and thereby provide an efficient resource allocation for a fair remuneration. This should in turn incentivize participation to FRR markets and attract further liquidity (see chapter 2).

There are a number of market design improvements – e.g. Transfer of Energy and Merit Order activation (see Chapter 5) – that are already planned or being implemented by ELIA. These changes are not only prerequisites for the implementation of a paid-as-cleared settlement mechanism. Rather, the implementation of paid-as-cleared appears as a further step in the same direction, and intends to foster competition with a robust, attractive and liquid market.

It also appears that marginal pricing will most likely become mandatory as a consequence of European integration and the Balancing Guidelines. An early adoption of the methodology therefore will position ELIA at best in the pilot initiatives to integrate FRR mechanisms.

A specific concern has been identified for aFRR, where the current level of liquidity is insufficient to implement paid-as-cleared settlement. Though, there are a number of foreseen improvements the upcoming years (R2 non-CIPU, techno-neutral, , merit order …) which are aiming at improving the aFRR liquidity. Our proposal is therefore to reassess the value of such a new mechanism in light of the level of liquidity observed once these improvements are implemented.

In practical terms, despite important identified prerequisites, we have identified limited interdependencies between the implementation of marginal pricing in aFRR and in mFRR. Therefore, the two implementation projects can be treated relatively separately, which will reduce the project risks and is likely to speed up the implementation.

In terms of implementation timeline, we have assessed (see §5.6) that an implementation of marginal pricing for mFRR could become possible somewhere in the second half of 2019. This is however subject to availability of resources and without taking into account other implementation priorities and requests from market parties and CREG. There is potentially an implementation dependency with the project aiming at a review of the mFRR product design (including the opportunity or not to keep 2 distinct products) within the framework of a possible shift towards a daily procurement of mFRR reserves which will be undertaking in the course of 2018.

An implementation of paid-as-cleared for mFRR would be based on the design presented in Chapter 6. Whenever relevant, evolutions of the European platforms' design will be taken on board.

Similarly, Chapter 7 presents a design proposal for the implementation of paid-as-cleared in aFRR. Such a project could be initiated in early 2020 at best, depending also on internal and external dependencies. The general design principles will be based on the description made in chapter 7, in conjunction with the specific IT and implementation constraints, as well as input stemming from European platforms (in particular for what concerns a choice between M1 and M2 models – see §7.1). As explained, the level of liquidity in aFRR may also remain a cause of concern and postpone implementation.

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