Deliverable 3.2.

Standardized flexibility products and attributes

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Executive Summary

The current European landscape of flexibility services is versatile. Services for balancing, congestion management (CM) and intraday (ID) markets differ based on their degree of harmonization, the technical challenge they are meant to solve, the need owner and their specific product characteristics. As the number of flexible technologies and their availability at different network levels are evolving, so do – to an extent – the attributes of flexibility products and the requirements to flexibility service providers (FSPs). Overall, however, country implementation and product requirements remain largely heterogeneous.

To enable interoperability of flexibility use for different services, flexibility attributes are identified and ways in which heterogenous flexibility products could potentially be standardized are analyzed. The standardization of requirements for flexibility products is aimed at enabling a more efficient use of flexibility for multiple use cases, balancing and CM but also the ID market promising an increase in market liquidity and – in the best case – lower overall system costs. The goal of increasing liquidity in the flexibility market(s) must be balanced against the difficulties of meeting more specific system needs, accounting for technology-specific attributes and implementation efforts. Product standardization in fact represents a scale, on which the trade-offs between liquidity, system efficiency, ease of participation and implementation effort characterize potential solutions.

The identified attributes of flexibility are first classified along the technical and trading dimensions. Then ways in which flexibility products can be standardized are analyzed. In order to compare and analyse different flexibility product requirements in a structured manner, we lean on the stepwise approach proposed by [1]. The main focus is on two types of flexibility services, balancing and CM. The analysed system services in this deliverable cover frequency containment reserve (FCR), automatic and manual frequency restoration reserves (aFRR and mFRR) and redispatch. Further, integrated wholesale electricity markets, day-ahead (DA) and ID, are taken into account as FSPs providing balancing or CM services are likely to participate in them as well. This affects their bidding strategies to varying degrees.

The analysis of the potential for standardization is conducted on two levels: 1) product-wise standardization on the international level., and 2) cross-product integration on the national level. The former is aimed at advancing the integrated European energy market and cross-border flexibility exchanges, competition and joint procurement of flexibility services by multiple parties. Regarding the second, it is argued that there is still a lot of untapped potential for increasing the efficiency of flexibility procurement and identify the main issues that need to be addressed, such as the use of locational information for multiple services or harmonization of pricing rules. Therefore, advanced bid forwarding and linking approaches are presented to facilitate integration or full-scale product harmonization of product attributes on a national level.

We find that different degrees of product standardization are conceivable, both on the international product-wise and national cross-product levels. However, the benefits of full standardization should be evaluated against the background of potential trade-offs such as the risk of excluding some of the valuable flexibility potential or the implementation costs. Thus, in the short to medium term, full-fledged harmonization of several products is not considered very likely due to the barriers on organizational, technical and regulatory levels. Furthermore, it is not considered very likely that the vast majority of redispatch volume will be procured very close to real-time for system security reasons. Therefore, to maximize the use of available and new flexibility resources, full exploitation of the potential of international product-wise standardization, on the one hand, and cross-product integration using bid forwarding and linking concepts on the other hand seems most beneficial. In this regard, the most crucial

points that remain to be addressed include the use of locational information for multiple markets, harmonization of pricing rules for different products to avoid distorted incentives and defining new rules for portfolio aggregation that are compatible with redispatch provision.

Kurzfassung

Die derzeitige europäische Flexibilitätsdienstleistungslandschaft ist vielfältig. Dienstleistungen für Regelenergie, Engpassmanagement und Intraday (ID) Märkte unterscheiden sich stark hinsichtlich ihres Harmonisierungsgrades, der zu bewältigenden technischen Herausforderungen, sowie ihrer Bedarfsträger und produktspezifischen Merkmale. Da sich die Anzahl der flexiblen Technologien und ihrer Verfügbarkeit auf den verschiedenen Netzebenen weiterentwickelt, ändern sich auch die Eigenschaften der Flexibilitätsprodukte und die Anforderungen and die Anbieter von Flexibilitätsdienstleistungen. Insgesamt bleiben die länderspezifischen Umsetzungs- und Produktanforderungen jedoch weitgehend heterogen.

Um die Interoperabilität der Flexibilitätsnutzung für verschiedene Dienste zu ermöglichen, werden in einem ersten Schritt Flexibilitätsattribute identifiziert und in weiterer Folge Möglichkeiten analysiert, wie heterogene Flexibilitätsprodukte standardisiert werden könnten. Die Standardisierung von Anforderungen an Flexibilitätsprodukte soll, eine effizientere Nutzung von Flexibilität für mehrere Anwendungsfälle, sowohl für Balancing und Engpassmanagement als auch auf den Intraday-Märkten ermöglichen. Daraus erwartet man eine Erhöhung der Marktliquidität und damit niedrigere Gesamtsystemkosten. Die Erhöhung der Liquidität auf dem/den Flexibilitätsmarkt/-märkten, muss gegen die Schwierigkeiten abgewogen werden, die sich aus der Erfüllung spezifischer Systemanforderungen, der Berücksichtigung technologiespezifischer Eigenschaften und dem Implementierungsaufwand ergeben. Daraus lässt sich eine Skala für die Produktstandardisierung ableiten, auf der die Kompromisse zwischen Liquidität, Systemeffizienz, einfacher Teilnahme und Implementierungsaufwand mögliche Lösungen abgebildet werden.

Die identifizierten Flexibilitätsattribute werden zunächst entlang der Technischen- und der Handelsdimension klassifiziert. Anschließend wird analysiert, wie Flexibilitätsprodukte standardisiert werden können. Um verschiedene Anforderungen an Flexibilitätsprodukte strukturiert vergleichen und analysieren zu können, stützen wir uns auf den von [1] vorgeschlagenen Ansatz. Das Hauptaugenmerk liegt dabei auf zwei Arten von Flexibilitätsdienstleistungen, nämlich Balancing und Engpassmanagement. Die in diesem Deliverable analysierten Systemdienstleistungen umfassen Primärregelreserven (FCR), Sekundärregelreserve, Tertiärregelreserve (aFRR und mFRR) und Redispatch (RD). Darüber hinaus werden die integrierten Stromgroßhandelsmärkte, Day-ahead (DA) und ID, berücksichtigt, da die Anbieter von Flexibilitätsdienstleistungen, welche Balancing- oder Engpassmanagement-Dienstleistungen erbringen, wahrscheinlich auch an diesen Märkten teilnehmen werden. Dies wirkt sich in unterschiedlichem Maße auf deren Gebotsstrategien aus.

Die Analyse des Standardisierungspotenzials wird auf zwei Ebenen durchgeführt: 1) produktbezogene Standardisierung auf internationaler Ebene und 2) produktübergreifende Integration auf nationaler Ebene. Erstere zielt darauf ab, den integrierten europäischen Energiemarkt und den grenzüberschreitenden Flexibilitätsaustausch, den Wettbewerb und die gemeinsame Beschaffung von Flexibilitätsdienstleistungen voranzutreiben. In Bezug auf die zweite Ebene wird argumentiert, dass es noch viel ungenutztes Potenzial für die Steigerung der Effizienz der Flexibilitätsbeschaffung gibt, und es werden die wichtigsten Probleme identifiziert, wie z. B. die Nutzung von Standortinformationen für mehrere Dienstleistungen oder die Harmonisierung von Preisbildungsregeln. Es werden fortschrittliche Ansätze für die

Weiterleitung von Geboten und die Verknüpfung von Geboten vorgestellt, um die Integration von Produktattributen auf nationaler Ebene zu erleichtern.

Wir stellen fest, dass verschiedene Grade der Produktstandardisierung denkbar sind, und zwar sowohl auf internationaler Produktebene als auch auf nationaler, produktübergreifender Ebene. Wie bereits erwähnt, sollten die Vorteile einer vollständigen Standardisierung jedoch vor dem Hintergrund potenzieller Risiken, wie z.B., dass Teile des wertvollen Flexibilitätspotenzials ausgeschlossen werden, oder den Implementierungskosten, bewertet werden. Daher wird kurz- bis mittelfristig eine vollständige Harmonisierung mehrerer Produkte aufgrund der Hindernisse auf organisatorischer, technischer und regulatorischer Ebene als nicht sehr wahrscheinlich bewertet. Darüber hinaus wird es als unwahrscheinlich angesehen, dass der überwiegende Teil des Redispatch-Volumens, aus Gründen der Systemsicherheit, sehr nah an Echtzeit beschafft werden wird. Um die vorhandenen und neuen Flexibilitätsressourcen bestmöglich zu nutzen, erscheint daher die volle Ausschöpfung des Potenzials der internationalen produktbezogenen Standardisierung einerseits und der produktübergreifenden Integration mittels Gebot Weiterleitung und Verknüpfungs-Konzepten andererseits am sinnvollsten. Zu den wichtigsten Punkten, die in diesem Zusammenhang noch angegangen werden müssen, gehören die Nutzung von Standortinformationen für mehrere Märkte, die Harmonisierung der Preisbildungsregeln für verschiedene Produkte, um verzerrte Anreize zu vermeiden, und die Festlegung neuer Regeln für die Portfolioaggregation, die mit der Redispatch-Bereitstellung vereinbar sind.

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List of abbreviations

aFRR *automatic frequency restoration reserve*
ALPACA *Allocation of Cross-zonal Capacity and Procurement of aFRR Cooperation Agreement*
APG *Austrian Power Grid*
BDEW *Bundesverband der Energie- und Wasserwirtschaft*
CACM regulatory framework for capacity allocation and congestion management
CBA *cost benefit analysis*
CBMP *Cross Border Marginal Price*
CHP *combined heat and power*
CM *congestion management*
DA *day ahead*
DACF *Day-Ahead Congestion Forecast*
DR *demand response, demand response*
DSO *distribution system operator*
EB GL *Electricity Balancing Guideline*
EIV *Einsatzverantwortliche*
ElWOG *Elektrizitätswirtschafts- und -organisationsgesetz*
EnWG *Energiewirtschaftsgesetz / German law for electricity and gas supply*
EU *European Union*
FAT *Full activation time*
FG *framework guideline*
FG DR *Framework Guideline on Demand Response*
FSP *Flexibility Service Provider*
GCT *gate closure time*
GOT *gate opening time*
ID *intraday*
IDCF *Intraday Congestion Forecast*
IDM *intraday market*
IGCC *International Grid Control Cooperation*
LFC *load flow calculation*
MARI *Manually Activated Reserves Initiative*
mFRR *manual frequency restoration reserve*
NEMO Nominated Electricity Market Operator
NRA *national regulatory authority*
PICASSO *Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation*
RD redispatch
RES *renewable energy sources, renewable energy sources*
SA *schedule activation*
SDAC *single day ahead coupling*
SGU *Significant Grid Users*
SIDC *Single Intraday Coupling*
SO *system operator*
SO Gl *System Operator Guideline*
SP *service provider*
ToE *table of equivalences*
TSO *transmission system operator*
VC *voltage control*
WAPP *Week-Ahead Planning Processes*

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1 Introduction

The current European landscape of flexibility services is versatile. The services differ based on their degree of harmonization, the technical challenge they are meant to solve, the need owner and their specific characteristics. As the number of flexible technologies and their availability at different network levels evolved, so did – to an extent – the attributes of flexibility products and the requirements to flexibility service providers (FSPs). Overall, however, they remain largely heterogeneous.

To enable interoperability of flexibility use for different services, in this Deliverable, 1) the attributes of flexibility are identified and classified in Chapter 1, 2) the attributes of flexibility services are summarized and compared and other relevant regulatory developments addressed in Chapter 2 and 3) the analysis of ways in which flexibility products can be standardized is conducted in Chapter 3.

Project DigIPlat considers two dimensions of interoperability:

1) Interoperability of flexibility platforms
2) Interoperability of flexibility itself.

Note that this deliverable is concerned with the latter. Specifically, it refers to *use-case interoperability* or the use of flexibility for multiple purposes or services based on the technical and product requirements for FSPs.

Concerning flexibility services, we focus on two system services, balancing and congestion management (CM). The flexibility products covered in this Deliverable include frequency containment reserve (FCR), automatic and manual frequency restoration reserves (aFRR and mFRR) and redispatch (RD). We further include integrated wholesale electricity markets, day-ahead (DA) and intraday (ID), as FSPs providing balancing or CM services are expected to participate in them as well, which to different degrees would affect their bidding strategies. Flexibility services may be needed or provided on different network levels, which makes it important to take the distribution network level into account, in particular from the point of view of cooperation of transmission and distribution system operators (TSOs and DSOs).

1.1 Classification of flexibility attributes

Flexibility is a broad term that tends to be interpreted differently depending on the context, stakeholder or use case. In this project, **"flexibility" is understood as the umbrella term for the change of the generation, load or storage profile to deliver a service to the system.** In this sense, system services encompass both those on the level of the transmission and that of the distribution grid.

Here and in the remainder of the text, flexibility attributes are understood as characteristics of a flexible resource (unit or group) that is of relevance for the provision of a flexibility service.

To analyze the attributes of flexibility, it is useful to consider its different dimensions (based on [2]):

1) Spatiality / spatial specification – refers to the locational component of flexibility, i.e. its position in the transmission or distribution grid, which is relevant for some services, redispatch and voltage control.
2) Time /temporal specification– refers to how fast and for how long flexibility can be provided. It includes, among others, activation time, ramp-up/ramp-down speed or duration of activation. This also includes a possible direction of activation (Figure 1).

3) Resource – refers to the groups of flexibility providers on the supply side (conventional and variables renewable generation), demand side (industry, households, aggregated DR assets) and storage.

FSPs have to fulfil service-specific communication and technical requirements as well as product requirements, i.e. requirements related to their procurement by the system operator.

Flexibility services may be required by the TSO, the DSO or, potentially, by both. At different points in time, the same flexibility resource could be used for several TSO/DSO services or might be needed by both TSO and the relevant DSO, requiring a coordinated approach.

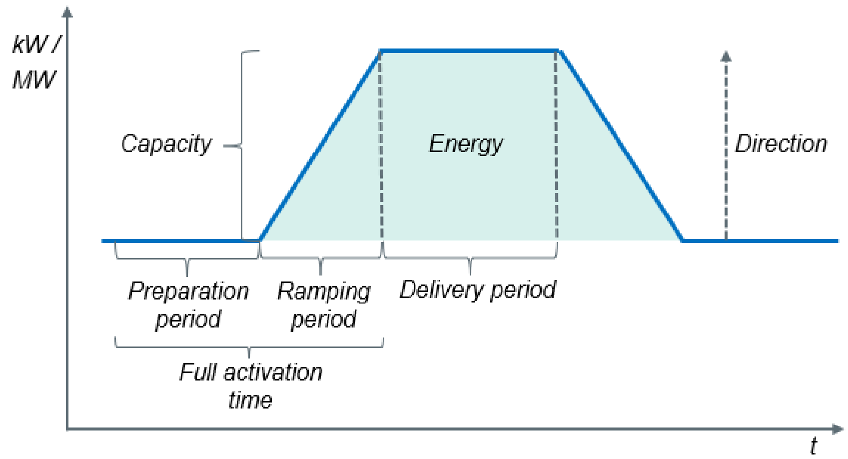


Figure 1 Temporal specification of flexibility (based on [3])

To compare and analyze different product requirements by flexibility attributes in a structured manner, we lean on the stepwise metric proposed by [1] and organize the review of flexibility attributes in two major dimensions, the technical and the trading one. The latter is further subdivided into three categories, timing, product and auction/procurement rules, as illustrated in Figure 2. The flexibility attributes were selected based on the requirements stipulated in Art. 25 of the Electricity Balancing Guideline (EB GL) and on the attributes identified in previous research [4], [1].

This structure is used to analyze each flexibility product in Section 2 and to compare their individual attributes for the standardization proposal in Section 3.

1.2 Technical dimension

The attributes included in the technical dimension are:

Type of flexibility – active or reactive power; upward or downward direction (increase of generation/reduction of demand or reduction of generation/increase of demand, respectively)

Mode of activation – either manual or automatic activation model

Portfolio/Unit-based prequalification – the requirement to prequalify assets separately on a per-unit basis or as a single portfolio of multiple assets

Preparation period – a period required in preparation for activation for a flexibility service Note that the requirements for the preparation period vary across Europe as it depends on the mode of activation in use and the local generation structure [5].

Ramping period - a period required for a unit to ramp up to the full required production level.

Full activation time (FAT) – the total time required for the unit's activation, which consists of the preparation period and a ramping period. The maximum allowed duration for the full activation or deactivation of a standard energy bid after the activation request is called full activation time [5].

Deactivation period - the total time required for the unit's de-activation.

Location / Spatial specification – specification of the geographical location of a flexibility-providing unit or group

Communication criteria – criteria for the communication between the TSO and the FSP.

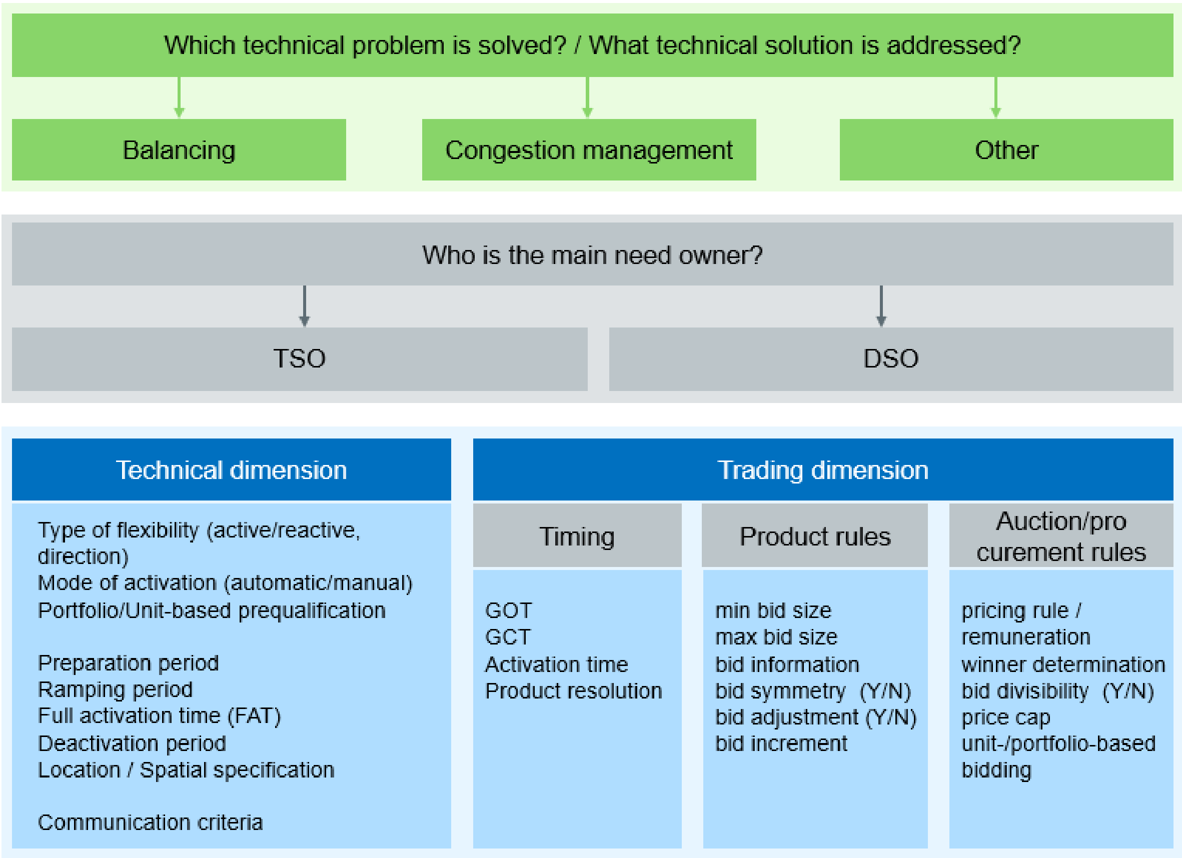


Figure 2 Definition of flexibility attributes according to its technical and trading dimensions

1.3 Trading dimension

The attributes included in the trading dimension are:

Timing

GOT – the earliest point in time for FSPs to submit their bids

GCT - the latest point in time for FSPs to submit their bids

Activation time – the point in time when an awarded FSP is activated

Product resolution – bid granularity

Product rules

Minimum bid size – the minimum size of a single bid

Bid increment - the minimum size of the subsequent bid(s)

Maximum bid size - the maximum size of a single bid

Bid information – any information that is required as part of the bid (e.g. MW, MWh, €/MW, €/MWh, location tag)

Bid symmetry – whether a submitted bid must be able to be activated in both directions (symmetric) or a single direction (asymmetric)

Bid adjustment - whether a submitted bid may be adjusted at a later point (up to the GCT)

Auction/procurement rules

Pricing rule/remuneration – whether a bid is remunerated pay-as-bid (including cost-based) or pay-as-cleared (marginal pricing)

Winner determination – whether the bids are awarded based on a merit order, pro rata or other principles

Bid divisibility – whether only a share of the submitted bid volume may be awarded

Price cap – the maximum price that an FSP may bid in the market

Unit-/portfolio-based bidding - the requirement to place separate bids per unit or a portfolio/group of multiple assets

2 Flexibility products

The two main system services that flexibility required for include balancing and CM.

CM can be subdivided into reserved (e.g. grid reserve in Austria) and non-reserved (commonly, redispatch). Reserved CM is capacity-based and is commonly used to handle structural congestion or as a complementary measure to other remedial actions. Non-reserved CM is meant to solve less predictable deviations from the TSO's congestion forecast in a shorter timeframe and is energy-based [6].

As to balancing, this Deliverable covers all standard balancing products, FCR, aFRR and mFRR.

Wholesale electricity markets are included in this section for the sake of completeness since FSPs participate in the DA and ID markets irrespective of or as an alternative to the provision of flexibility services. In addition, it is conceivable that short-term flexibility from the ID market could be used for system services – provided there is an interface between the two – or unused flexibility could be forwarded to the ID market whose gate closure time is the closest to real-time (5 to 15 minutes in Germany, Austria and Switzerland) (see also Section 2.2.2).

In this Chapter, we briefly describe the procurement of these services and characterize them based on the technical and trading dimensions, following the classification in Chapter 1. Finally, in Section 2.4, we provide an overview other regulatory developments that are of relevance for the project. We focus on Redispatch 3.0 in Germany and the Draft Framework Guideline on Demand Response ([7]) and discuss its implications for the standardization proposal in Chapter 3.

2.1 Participation of flexible resources in the day-ahead and intraday markets

2.1.1 Single day ahead coupling

Single day ahead coupling (SDAC) is the pan-European, cross-border DA electricity market. It is a cooperation of TSOs and NEMOs of all EU countries with the aim of optimizing the Pan-European DA Spot market, taking into account cross-border capacities. 95 % of the electricity demand in the EU is covered by market coupling. It is planned to introduce products in 15-minute granularity throughout the entire SDAC until 2025. Day-ahead trading usually involves trading full hours, although, some standardized block bids such as the classic base or peak load or more unusual blocks such as the morning block are also offered. Block orders encompass several hours at the same price with flexible volume profiles [8].

2.1.2 Single Intraday Coupling

Single Intraday Coupling (SIDC, formerly XBID) is the European cross-border ID market which is in operation since June 2018. As Switzerland is not part of the European Union, it is not allowed to participate in the SIDC. The aim is to optimize the European intraday market under consideration of the available cross-border capacities. The trading is carried out via implicit capacity allocation whereby explicit allocation at individual borders is allowed. The advantage of the SIDC is that cross-border transmission capacities are allocated centrally in Intraday via the SIDC platform. Furthermore, market participants can choose between power exchanges within one delivery zone (in Austria, EPEX and NordPool). Product lengths of 15, 30 and 60 minutes and block products can be traded up to one hour before delivery [9].

At EPEX Intraday spot market, product lengths of 15 min and 1 h are possible. Furthermore, there is the possibility of trading so-called block products. The 15 min products are available every 15 min starting on the hour (<hh>:00 - <hh>:15, <hh>:15 - <hh>:30, <hh>:30 - <hh>:45 and <hh>:45 - <hh+1>:00). In contrast, the 1 h products are only available on the hour. Currently, the minimum bid size is 0.1 MW which can also be purchased in 0.1 MW increments [10]. The maximum volume per classic block order is 600 MW in Germany and Austria and 150 MW in Switzerland. Furthermore, a price range is defined for day-ahead trading, which lies between -500 €/MWh and 4000 €/MWh [11]. The individual products have a lead time of 5 min in Austria, i.e., a product can be traded at the latest 5 min before start, whose length is least 15 min.

Table 1 Overview of timings and product characteristics of EPEX-SPOT bids

		timing			Product								Auction/ procurement rules				Ref.
		GOT	GCT	activation time	product resolution	min bid size	max bid size	bid information	bid symmetry (Y/N)	bid adjustment (Y/N)	bid divisibility (Y/N)	bid increment	pricing rule/remuneration	winner determination	price cap	unit-/portfolio based bidding	
EPEX-SPOT	DA	D-45	D-1 12:00	n/a	15 min, 1 h and blocks, customized blocks	0,1 MW	-	price, volume	N	N	N	0,1 MWh	pay-as-cleared	merit order	4.000 €/MWh	portfolio-based	[10]
	ID	D-1 15:00 (continuous)	D-1 15:00 t-5 min (intra-zonal) t-60 min (cross-zonal)	n/a	15 min (intra-zonal), 1 h (continuous and auction), block/customized products	0,1 MW	-	price, volume	N	N	N	0,1 MWh	pay-as-cleared (auction) / pay-as-bid (continuous)	merit order (auction) / continuous matching	9.999 €/MWh	portfolio-based	[10]

2.2 Balancing markets

Art. 25 of the Electricity Balancing Guideline (EBGL) requires the definition of a set of standard products as part of the implementation framework for European platforms [12], [5]. The list of standard products for balancing energy and balancing capacity may set out at least the following characteristics of a standard product bid:

a) preparation period
b) ramping period
c) full activation time
d) minimum and maximum quantity
e) deactivation period
f) minimum and maximum duration of the delivery period
g) validity period
h) mode of activation.

Moreover, the following variable characteristics of a standard product are to be determined by the balancing service providers during prequalification or when submitting the standard product bid:

a) price of the bid
b) divisibility
c) location
d) minimum duration between the end of the deactivation period and the following activation.

Furthermore, Art. 29 EBGL requires that balancing energy shall be activated based on a TSO-TSO model that used a common merit order list with a single cross-border marginal price [4].

2.2.1 aFRR product requirements

The task of the automatic Frequency Restoration Reserve (aFRR) is to re-establish the initial net frequency. In contrast to FCR, however, aFRR is not activated unselectively in the entire network, but only in those zones, where the cause of the system balance disturbance is located. Such disturbances are detected by the performance frequency control.

2.2.1.1 Balancing procurement

In Austria, the market for aFRR is divided into two separate levels: The capacity auction and the energy auction:

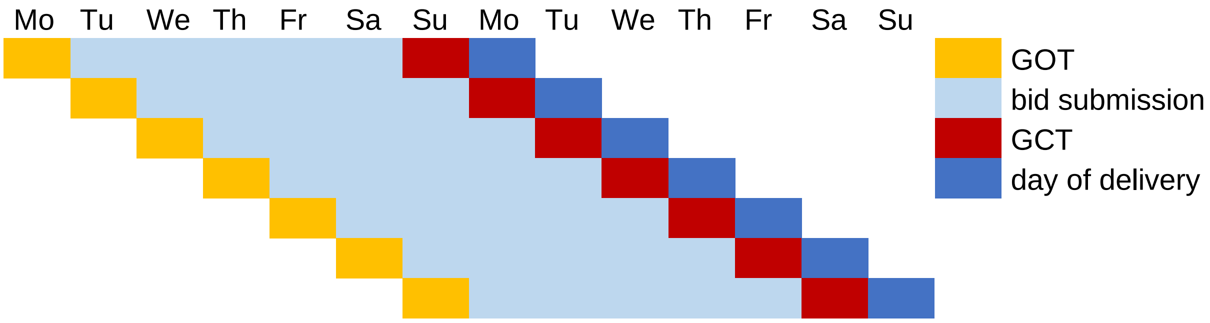
Balancing capacity auction

Within the framework of a balancing capacity auction, market participants offer prequalified capacities for capacity reservation. In addition to the capacity offered, a bid for aFRR is characterized by the capacity price. The bids submitted are ranked in ascending order according to their price (merit order list of capacity price). The bids that are most favourable for the TSO are finally awarded for the provision of capacity in accordance with the published award criteria and requirements [13].

The secondary control reserve is procured daily in six 4-hour products via an auction platform. The minimum bid size per product is 1 MW, the increment is also 1 MW and the maximum bid size is the prequalified capacity.

The required aFRR is auctioned on a calendar day basis (from Monday to Sunday). The GOT is set to D-7 at 10:00 and GCT to D-1 at 09:00 [13]. Figure 3 summarizes the sequence of the discussed dates.

Figure 3 Sequence for a week of delivery in Austria (Source: based on [13])



After the end of the performance auction, bids are ranked and accepted according to the following criteria:

1. Lowest performance price
2. In case of equal performance prices, the bids are accepted according to a reproducible random selection

Market participants whose bids have been awarded receive the submitted performance price of their bid, i.e., settlement follows the 'pay-as-bid' principle. In addition, suppliers must include energy prices in their service bids. The energy prices submitted in the capacity auction will be adopted for the energy auction and can be adjusted until the end of the bidding period of the energy auction [13].

Balancing energy auction

The second stage of the market is an intraday energy auction. Here, suppliers can adjust their energy prices already submitted in the capacity auction or offer other prequalified capacities independently of the capacity auction. The submitted bids are again ranked in a merit order list, now according to their energy price [13].

Secondary balancing energy is procured in a product resolution of 15 minutes. As for the capacity auction, the minimum product size is 1 MW, the increment is 1 MW, and the maximum bid size equals the prequalified capacity.

The required balancing energy is auctioned on an intraday basis (from Monday to Sunday). Starting with the publication of the results of the service tender (D-1 09:30) bids can be submitted and adjusted until 25 minutes before the delivery period of the respective product time slice [13].

After the end of the energy tender bids are ranked, and accepted according to the following criteria:

1. Lowest energy price in case of positive secondary control reserve or highest energy price in case of negative secondary control reserve
2. In case of equal performance prices, the bids are accepted according to a reproducible random selection

Since 2018, in Austria billing is done based on the 2-second frequency of the controller. That is, every 2 seconds the balancing energy quantity that is relevant for billing and the settlement price (maximum of CBMP and bid price) is determined. This principle will also be used in PICASSO.

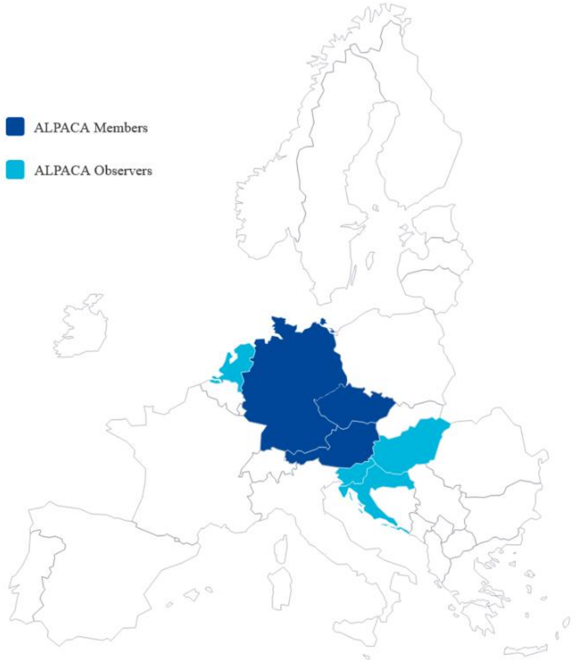
As in Austria, the activation in Germany follows the Merit Order, which means based on the costs of activation. The upper bound for activation time is 5 minutes. The minimum bid size for a supplier's bid per product is 1 MW. Bids may be submitted in whole 1 MW increments, up to a maximum of the prequalified capacity [13], [14].

2.2.1.2 Regional cooperation

Austrian, German and Swiss TSO are part of the International Grid Control Cooperation (IGCC), which altogether consists of 27 European TSOs. The IGCC aims to avoid the simultaneous activation of opposing aFRR by carrying out demand balancing ('imbalance netting') in the participating countries [15].

In addition, cooperation between APG and the German DSOs to optimize aFRR activation was successfully put into operation in 2016 [15],[14]. An optimization through a common merit order list is carried out which is based on a TSO-TSO model[1]. This optimization aims to achieve the joint economic optimum (see Figure 4) [16]. From the go-live of the European platform for the activation of aFRR (PICASSO), this bilateral cooperation will be extended to the European level.

The Austrian and German TSOs established an aFRR cooperation in 2020 exchanging up to 80 MW of aFRR capacity. The aFRR demand of Austria and Germany is procured on a daily basis. The awarding of aFRR bids is carried out by a central procurement algorithm using a common German-Austrian merit order, taking into account cross-border transmission capacities allocated for the aFRR exchange. Information about the acceptance of bids is provided via the respective (national) auction platforms [17], [14]. Joint procurement of aFRR capacity requires that the products and tendering rules are harmonized in Austria and Germany. This happened in 2017 when daily tenders were introduced, and the product time slices were standardized to 4-hour products [17].

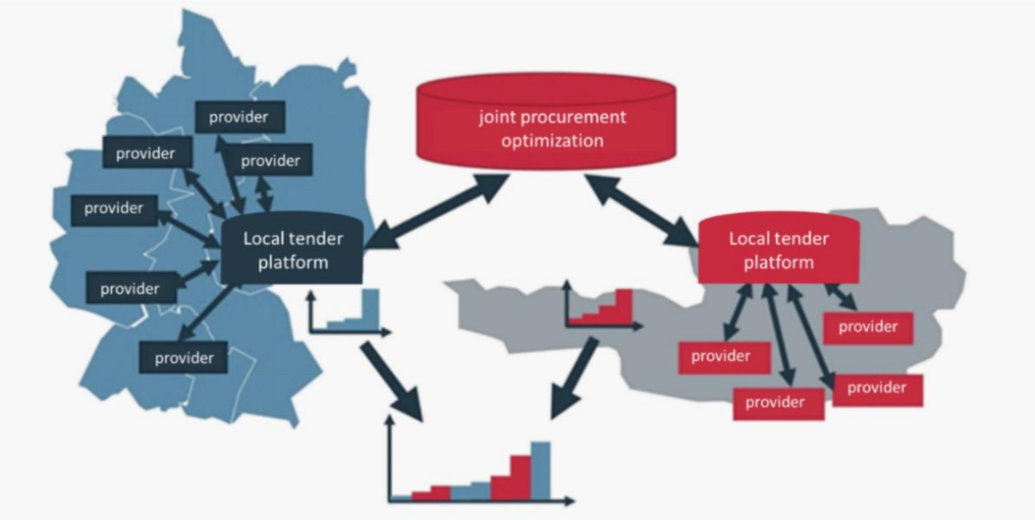


In February 2022, the TSOs of Austria, Czechia and Germany decided to extend the current Austrian-German aFRR balancing capacity cooperation. The future cooperation is called ALPACA, which stands for "Allocation of Cross-

[1] In the TSO-TSO model, the respective TSOs are responsible for the dimensioning, prequalification, procurement, and activation of aFRR and act as first point of contact for aFRR providers in their control area. The operational processes between TSOs and providers for aFRR activation do not change as a result of the cooperation.

zonal Capacity and Procurement of aFRR Cooperation Agreement” [18].

Figure 4 Joint procurement optimization concept (Source: [16])



Switzerland is not part of ALPACA. They further procure aFRR by weekly tenders and in the event of insufficient supply, daily tenders are issued to cover the necessary demand. Further differences between Austria and Germany are, that the minimum bid size is 5 MW and bids are exclusively indivisible. However, Swissgrid states that it is expressively desired that bids are submitted in the form of several partial bids to easier determine a cost-minimizing selection [19].

Balancing capacity auction (Switzerland)

In Switzerland, secondary balancing capacity auctions are tendered weekly and only accepts bids with a minimum size of +/- 5 MW up to a maximum of 100 MW. Bids can further only be submitted in 1 MW increments and can be combined but are not divisible. Swissgrid (i.e., Swiss TSO) therefore requests as many quantity-power-price combinations as possible, since a higher granularity facilitates a cost-minimizing selection. In addition, Swissgrid is only allowed to select one offer per supplier (which further increases the incentive for a higher number of offer combinations). The bid selection criterion is based on the minimization of the total costs of service provision. In case of equal offers (taking into account that both lead to the minimum cost), the one that was submitted first gets selected. A small reduction of an offer is only possible if the last offer accepted would exceed the demanded quantity. Awarded bids are remunerated by pay-as-bid (in CHF/MW). If necessary, there can be a second tender, in which case bids from the first tender get fixed and further bids can be submitted identical to the first tender [20].

Balancing energy auction (Switzerland)

Market participants whose balancing capacity offers were accepted are obliged to submit bids according to the amount of awarded quantity. However, offers can also be placed if no balancing capacity offers have been provided or awarded. An offer consists of a price in €/MWh, a quantity of MW for the tender period and has again a minimum size of +/- 5MW and a maximum of 100 MW. The product is, like in Austria and Germany, procured in a resolution of 15 minutes. Offers become binding 25 minutes before call and are exclusively divisible. The remuneration is based on "pay-as-cleared" if they are being activated through PICASSO. In the case Swiss offers are, e.g., due to temporary disconnection from the PICASSO platform, not be taken into account in the price calculation by PICASSO, Swissgrid remunerates bids by pay-as-bid [20].

Table 2 summarizes the aFRR product characteristics of Austria, Germany and Switzerland.

2.2.1.3 PICASSO platform for the exchange of aFRR balancing energy

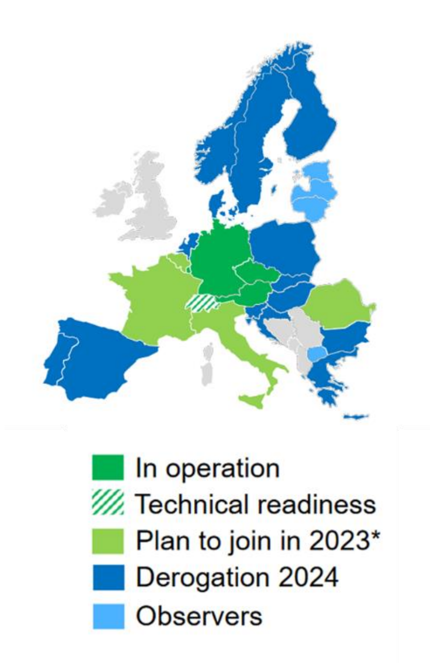


Figure 5 PICASSO: Acceding countries (Source: [23])

PICASSO (Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation) is the implementation project endorsed by all TSOs through the ENTSO-E Market Committee to establish the European platform for the exchange of balancing energy from aFRR, under Article 21 of the Commission Regulation (EU) establishing a guideline on electricity balancing (EB GL). The TSOs of the project countries acceded to the platform in 2022 [21].

The characteristics of standard products as described in Table 2 must be observed by all participating TSOs.

By December 2024, the full activation time will be harmonized to 5 minutes. PICASSO TSOs take a bid validity period of 15 minutes, which means that every 15 minutes a new balancing energy gate closure time would occur, i.e., 96 gates per day. Concerning bid divisibility, it was specified that all aFRR standard bids must be divisible. Furthermore, due to implementation complexity, complex bids and linked bids are not supported by the aFRR platform. The pricing principle is based on marginal pricing (pay-as-cleared) [22].

It is planned to integrate netting into the European balancing power collaboration PICASSO while continuing the IGCC as a separate project [23].

PICASSO's TSO accession roadmap and go-live planning is depicted in Figure .

Table 2 Overview of significant product characteristics for aFRR

	timing				Product							Auction/ procurement rules				Ref.
	GOT	GCT	Activation time	product resolution	min bid size	max bid size	bid information	bid symmetry (Y/N)	bid adjustment (Y/N)	bid divisibility[2] (Y/N)	bid increment	pricing rule/ remuneration	winner determination	price cap	unit-/portfolio based bidding	
AT/DE **(capacity)**	D-7 10:00	D-1 09:00	n/a	6 x 4 blocks of hours	1 MW	200 MW	€/MW	N	Y	Y	1 MW	pay-as-bid	merit order of capacity price	-	both possible	[13], [14]
AT/DE (energy)[3]	D-1	t-25' (BSP)	5 min	96 x 15 min	1 MW	9999 MW	MWh, €/MWh	N	Y	Y	1 MW	pay-as-cleared	merit order	15 000 €/MWh	both possible	[22]
CH	D-7	T-25 min	5 min	96 x 15 min	5 MW	100 MW	CHF/MW (capacity)	N	Y	N	1 MW	pay-as-bid	merit order of energy price	+/- 15000 €/MWh	portfolio	[19]

[2] balancing capacity bids are divisible up to minimum bid size; balancing energy bids can be activated below the bid granularity

[3] These product characteristics apply since Austrian and German TSOs' accession to PICASSO in 2021-2022.

2.2.2 mFRR product requirements

Due to the high technical requirements for the units to provide aFRR the provision of the entire reserve required to cope with even longer-lasting system balance disturbances (due to forecast errors or after power plant outages) aFRR is not reasonable. As an alternative, manual Frequency Restoration Reserve (mFRR) or Tertiary Reserve is provisioned. The requirements for mFRR are correspondingly lower (activation time within 15 minutes, no continuous control signal, but processing as timetable delivery, i.e. in 15-minute intervals) so that technical units with a lower capacity than for aFRR can be considered for provision. mFRR can be applied for up to 1 hour.

2.2.2.1 Balancing procurement

In Austria, mFRR is procured in the same way as aFRR, i.e. via a service tender and an energy tender (see 2.2.1). The only difference is that the GCT of the service tender is 1 hour later at 10:00 CET for mFRR [24].

Since 2006, German TSOs procure mFRR via a joint tender on the internet platform 'regelleistung.net'. In 2020 the German TSOs split their market into a service tender and an energy tender [25]. Bid pooling is possible within a control zone and activation of the mFRR is done electrically via the so-called MOL server [25].

In Switzerland, there are tertiary energy products that can be offered as bids for national use, for MARI, or for a combination of both. Primarily, national mFRR products as well as the combined MARI products are used for national and international redispatch. However, exclusive MARI bids may also be used for redispatch. Bids are procured by weekly tenders and in the event of insufficient supply, daily tenders are issued to cover the necessary demand. Compared to AT and DE, the minimum bid size is 5 MW and bids are exclusively indivisible. There are 24 gate closures, each 30 minutes prior to a 1-hour delivery interval. As in Germany, the FAT is set to 15 min.

2.2.2.2 Regional cooperation

Similar to the aFRR cooperation of Germany and Austria, the Austrian and German TSOs developed a concept for joint mFRR activation, which is also based on a common merit order list and a TSO-TSO model [26]. The nationally awarded mFRR bids are combined in a common merit order list and sorted according to the energy price of the bids. In the case of price equality, the bids are accepted according to a reproducible random selection (see 2.2.1). The procurement of mFRR to reach a joint optimum takes place under consideration of operational restrictions at the Austrian-German border [26]. The products and tendering rules are harmonized to a large extent, the only difference remaining is the FAT, which is set to 12,5 min in Austria and to 15 min in Germany [26].

Through this process, which has been integrated in 2019, Germany and Austria are taking on a pioneering role in Europe, whereby the experience gained can be incorporated into the implementation of a European mFRR platform (MARI).

Table 3 gives an overview of the mFRR products in Austria, Germany and Switzerland.

2.2.2.3 MARI platform for the exchange of mFRR

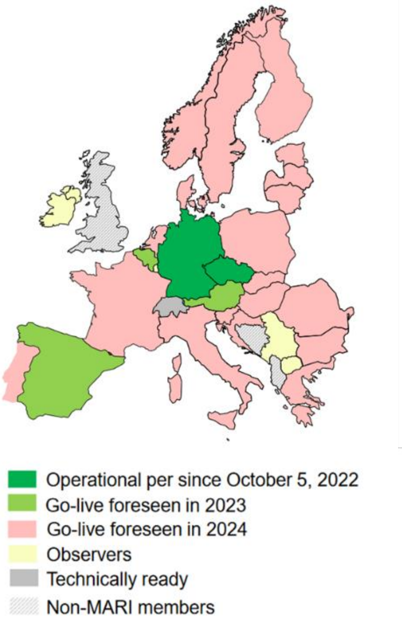


Figure 6 Acceding countries (Source [28])

MARI (Manually Activated Reserves Initiative) aims at implementing a Europe-wide platform for the exchange of control reserve from mFRR [27].

Figure shows the accession roadmap as planned in December 2022.

Two different types of bids are allowed on the mFRR platform: simple bids, which are bids, that are not grouped, and complex bids, which are combinations of simple bids. Concerning simple bids, (full) divisible bids and indivisible bids are possible [28].

Furthermore, every balancing energy bid submitted has one of two activation types [28]:

- Schedule activation only (SA bid): those bids are only available for schedule activation
- Schedule and direct activation (DA bid): DA bids can be cleared either in the schedule or in direct activation

Bids participating in MARI must have the characteristics summarised in Table 3.

The important difference between the two platforms, PICASSO and MARI, is that on the MARI platform activation purposes other than balancing are **not** prohibited (see also Section 2.3.5).

Table 3 Overview of significant product characteristics for mFRR

	timing			Product							Auction/ procurement rules				Ref.
	GOT	GCT	Activation time	product resolution	min bid size	max bid size	bid information	bid symmetry (Y/N)	bid adjustment (Y/N)	bid divisibi-lity[4] (Y/N)	bid increment	pricing rule/remuneration	winner determination	price cap	unit-/portfolio based bidding	
AT (capacity)	D-7 10:00	D-1 10:00	-	6 x 4 blocks of hours	1 MW	25 MW	€/MW	N		Y	1 MW	pay-as-bid	merit order capacity price	-	both are possible	[24], [26]
AT/DE (energy)[5]	D-1	t-25'	12,5 min	96 x 15 min	1 MW	9999 MW	MWh, €/MWh	N	N	both (BSP decides)	1 MW	pay-as-cleared/ cross-border marginal pricing	merit order	15 000 €/MWh	both are possible	[28], [22], [29]
DE (capacity)	D-7	D-1	-	6 x 4 blocks of hours/	5 MW	indivisible bids: 25 MW		N		Y	1 MW	pay-as-bid	merit order capacity price	-	both are possible	[30], [25]
CH (capacity)	D-1 and D-7	D-1	?	6 x 4 blocks of hours/	5 MW	100 MW	CHF/MW	N	Until GCT (if too few bids, the bids get fixed on d-2)	N	1 MW	pay-as-bid	merit order	-	both are possible	[31], [32], [33]
CH (energy)	D-1	T-15mi	?	96 x 15 min	5 MW	100 MW	€/MW	N		Y	1 MW	pay-as-bid	merit order	+/- 15000 €/Mwh	both are possible	[31], [32], [33]

[4] balancing capacity bids are divisible up to minimum bid size; balancing energy bids can be activated below the bid granularity

[5] These product characteristics apply in the control areas of the German TSOs and will apply in the Austrian control area as soon as APG accedes to MARI in Q2 2023.

2.2.3 FCR product requirements

Frequency Containment Reserve (FCR) is used for stabilization of the grid frequency as quickly as possible. FCR is designed as a *pro-rata* control system, i.e., it is requested proportional to the deviation of the grid frequency from its set point. As the activation of FCR is controlled solely by the grid frequency, no central control device is necessary. Prequalification in Continental Europe stipulates that full activation of FCR resources must be possible within 30 seconds whereas the maximum duration of the service can be 15 minutes. FCR product is designed to contain system frequency within the range of ±200mHz rather than to bring back the frequency to 50 Hz during large system imbalances.

2.2.3.1 Balancing procurement

In Austria, due to the characteristics already mentioned at the beginning, the market for primary control reserve, in contrast to secondary and tertiary control reserve, is only constructed as a capacity tender [34].

After the GCT, the bids are ranked, and bids are accepted according to the following criteria:

1. Lowest capacity price
2. In case of equal performance prices, the bids are accepted according to the earliest entry.

In Germany, the procurement of FCR is also handled via a capacity tender only. The market allows the symmetrical submitting of at least 1MW bids until 8 am on the delivery day. Capacity is offered in 4h intervals and must be fully activated 30s after the start of the automated retrieval. Bids are ranked as described for Austria [30].

In Switzerland, also only the tendering of primary balancing capacity is remunerated for. A bid consists of an offered quantity and a capacity price in €/MW. Bids can only be submitted in symmetrical (i.e., in the positive and negative direction) with a minimum size of ±1MW up to a maximum of ±25MW, whereby the increments are also 1 MW. Bids can be divisible or indivisible and the maximum number of possible offers is unlimited, however, all submitted bids are binding (hence the combination of these too). The price is determined by pay-as-cleared. In case of a shortage of bids, a second tender gets called. The bids of the first get fixed and the requirements for the second tender are identical to those of the first one. In this respect, the market price is determined together with the bids from both tenders [20].

2.2.3.2 Regional cooperation

FCR is tendered via an internet platform jointly operated by the TSOs responsible for the control areas in question [35]. Participating TSOs are Austria, Germany, Switzerland, the Netherlands, Belgium and France. In 2021 they were joined by Denmark (West) and Slovenia.

All TSOs procure their required FCR in market-based tenders. The GOT of the tenders is daily in D-14 at 11:00 CET. After GCT, daily in D-1 at 08:00 CET, the bids are further proceeded by the common optimisation algorithm [35]. Symmetrical products with a duration of 4 hours are traded. In general, TSOs allow divisible and indivisible bids, with a minimum size of 1 MW and a maximum size of 25 MW for indivisible bids in all participating countries. Another limitation is for sure the maximum transfer capacities between countries. Furthermore, the Cooperation is organized as a TSO-TSO model, where the FCR is procured through a common merit order list where all TSOs pool the offers they received [36], [35].

In general, the assignment of bids is done by the merit order of the capacity price. Regarding payment, two pricing rules have generally been used in Europe. For instance, pay-as-cleared pricing is used in Austria, Germany or Belgium whereas pay-as-bid pricing is applied, for example, in the Netherlands or in France [25], [37].

An overview of the significant product features in the considered countries is given in Table 4.

Table 4 Overview of the significant product characteristics in the FCR Cooperation

	timing				Product							Auction/ procurement rules				Ref.
	GOT	GCT	Activation time	product resolution	min bid size	max bid size	bid information	bid symmetry (Y/N)	bid adjustment (Y/N)	bid divisibility (Y/N)	bid increment	pricing rule/remuneration	winner determination	price cap	unit-/portfolio based bidding	
FCR Coop.	D-7	D-1 08:00	Real-time	6 x 4 blocks of hours	1 MW	25 MW (for indivisible bids)	€/MW	Y		Y	1 MW	pay-as-cleared	Merit Order of capacity price		portfolio	[36],[34], [30],[25], [38], [19]

2.2.4 Technical requirements

Table 5 Technical requirements

		active power (positive for gen, neg for demand), reactive power (pos/neg)	Mode of activation (automatic/manual)	Portfolio/ Unit-based prequalification	Preparation period	Ramping period	Full activation time (FAT)	Deactiva-tion period	Location / Spatial specification	Communication criteria	Ref.
AT	FCR	Active power, symmetric	automatic	Portfolio-based	≥ 30 sec		30 sec		no	data transmission: reserve group -P_{ist}, P_{AP} reserve pool - P_{ist}, P_{AP}, Status and status messages: cyclic every 2 seconds	[34]
	aFRR	Active power, asymmetric	automatic	Portfolio-based	≥ 30 sec		5 min	default: end of product time slice	no	data transmission: reserve group - P_{ist}, P_{AP}, P_{AP*}, $P_{SReg,ist}$ reserve pool - P_{ist}, P_{AP}, P_{AP*}, $P_{SReg,ist}$, $P_{SReg,soll}$, Status Transmission of measured values and status messages: cyclic every 2 seconds	[13]
	mFRR	Active power, asymmetric	manual	Portfolio-based	≥ 30 sec	≤ 10 min	12,5 min	≤ 10 min	no	data transmission: reserve group -P_{ist}, P_{AP}, $P_{Treg,ist}$ reserve pool - P_{ist}, P_{AP}, $P_{TReg,ist}$ transmission of measured values: transmission cycle	[24]
DE	FCR	≥ 1 MW	automatic	Portfolio-based	≥ 30 sec (constant signal	≤ 30 sec	≤ 30 sec	≤ 30 sec	Load-frequenc	Master data (excel file), offline data (proof of	[39]

				(portfolio may consist of several technical units or a single technical unit)	reservation phase before power change period)	(power change period)			y control area	fulfilment) and real-time-data (resolution 1-4 sec): Injection, Operating Point, Actual balancing reserve value, status, current reservation power	
	aFRR	≥ 1 MW	automatic	Portfolio-based (portfolio may consist of several technical units or a single technical unit)	≥ 30 sec (constant signal reservation phase before power change period)	≤ 5 min (power change period)	≤ 5 min	≤ 5 min	Load-frequency control area	Master data (excel file), offline data (proof of fulfilment) and real-time-data (resolution 1-4 sec): Injection, Operating Point, anticipated operation point, Actual balancing reserve value, status, current reservation power, aFRR target	[39]
	mFRR	≥ 1 MW	manual	Portfolio-based (portfolio may consist of several technical units or a single technical unit)	≥ 30 sec (constant signal reservation phase before power change period)	≤ 12,5 min (power change period)	≤ 12,5 min	≤ 12,5 min	Load-frequency control area	Master data (excel file), offline data (proof of fulfilment) and real-time-data (resolution 1 min): Injection, Operating Point, Actual balancing reserve value, status, current reservation power	[39]
CH	FCR	Active power, symmetric	automatic	Portfolio	-[6]	10 sec	30 sec		no		[40]

[6] Information was not found in publicly available sources

	aFRR	Active power, asymmetric	automatic	Portfolio	-[6]	≤ 10 min	5 min		no		[41], [40]
	mFRR	Active power, asymmetric	manual	Portfolio	10 min	≤ 10 min	12.5 min	default: end of product time slice	no		[41], [40]

2.3 Redispatch

In addition to managing energy balancing, congestion management forms part of TSOs' responsibilities aimed at safeguarding system security. Regarding the growing shares of RES in European networks, managing occurring congestion within and between bidding zones is getting more and more challenging. There are different kinds of measures to tackle congestion from non-costly remedial actions, such as the use of phase shift transformers, to redispatch, countertrading (cross-border redispatch) and the use of pre-contracted reserves.

In general, there are two kinds of products for congestion management:

- reserved: a capacity-based product that is procured at a certain availability price which can be activated in case the service is needed
- non-reserved: an energy-based product that is procured at an energy price. Non-reserved products are commonly procured closer to delivery than reserved products.

The main differences between balancing and redispatch are summarized in Table 6. While balancing resources are not geographically bound, the location of a redispatch unit is key to its effectiveness regarding the congestion point. Another point is, that the activated volume cannot be directly translated into the amount of congestion it can relieve. Therefore, besides the cost, the TSO has to take into account the option's effectiveness. The activation direction has to be symmetric, which means that for each activated bid, a symmetric bid has to be activated.

The regulatory framework for capacity allocation and congestion management is addressed in the CACM Regulation [42]. It sets out rules to ensure optimal use of the transmission infrastructure, operational security and optimizing the calculation and allocation of cross-zonal capacity.

Table 6 Overview of the main differences between balancing and redispatch (Source:[43])

	Balancing	Redispatch
Purpose	Frequency control	Congestion management
Procedure	Mainly curative	Preventive and curative
Location	irrelevant within the control area	key criterion
Decision to award	Price-based (merit-order)	Based on cost/price and effectiveness
Action direction	One-way (imbalance dependent)	Symmetric
Timeframe	(mostly) real time	from day-ahead to real-time
Duration	From a few minutes to an hour	From an hour to several hours
Approach to procurement	Market-based/ Mandatory cost-based	Heterogenous
Capacity reservation	Yes	No
Standardized prequalification	Yes	No

2.3.1 Austria

As of today, procurement of redispatch is one of the responsibilities of the Austrian TSO, APG. Therefore, contracts with individual generation units or loads are concluded, according to which the units commit to increase or decrease their output if requested. Requested changes in power production or consumption are remunerated based on incurred costs. In general, it is possible to undertake redispatch measures in different timeframes, day-ahead, intraday or in real time. The procedure is as follows: After receiving load and generation schedules at 14:30 DA, the TSO conducts load flow calculations. If the TSO expects congestions after this process, a start-up request is sent a day-ahead to the contracted plants. The usual duration of activation for redispatch ranges from 4 to 6 hours.

To assure the availability of sufficient flexible generation and consumption capacities at all times, the so called “grid reserve” (dt.: Netzreserve) was introduced in Austria, aiming at avoiding early decommissioning of power plants. The grid reserve requirement is determined annually by APG as part of a system analysis and procured in a transparent, non-discriminatory and market-based tendering procedure pursuant to Art. 23b ElWOG 2010. Contracted power plants are kept on standby for potential system support and receive long-term capacity remuneration. In case of retrieval, plants are again remunerated on a cost based. Operators of domestic and foreign generation plants, demand response assets and aggregators with a capacity of at least 1 MW are eligible to participate in the auction [44].

Grid reserve plants provide their grid reserve power exclusively at the request of APG. It is important to note that market participation for generators is not permitted. Consumers must ensure that the contractually agreed secured system reserve power is available for CM activations from APG at any time (except for coordinated revisions).

2.3.2 Germany

TSOs in Germany are responsible for a stable grid state and shall activate remedial actions in case of operational security violations (§13 (1) EnWG (Energiewirtschaftsgesetz / German law for electricity and gas supply) and Art. 20 & 21 SO Gl (System Operator Guideline)) [45], [41]. The operational planning process for congestion management starts with the Week-Ahead Planning Processes (WAPP) to decide if plants from the grid reserve (§ 13d EnWG) need to be requested. The main planning processes for redispatch measures (§ 13a EnWG) are the RD-process which starts at 16:30 h day-ahead and the European DACF (Day-Ahead Congestion Forecast) at 18:00 h day-ahead. Therefore, generation schedules are to be sent until 14:30 h to the TSOs (System Operator Guideline (SO Gl) for Significant Grid Users (SGU) and BNetzA BK6-20-059 for smaller generations units). Intraday measures are decided for in the IDCF (Intraday Congestion Forecast) at about 00:00 h. Each redispatch process comprises two or more counter directed measures to ensure system balance. Plants are financially compensated retrospectively on a cost basis.

Since October 2021 smaller generation and storage units <10 MW and >100 kW (and potentially >30 kW) on all voltage levels and including RES, are obliged to participate in redispatch, which is commonly called Redispatch 2.0. Not only TSOs but also DSOs with congestions shall use this process for redispatch and for the corresponding balancing. New processes between resource providers and grid operators have been defined which are currently partly in operation and partly still in the process of being implemented by the different actors [46], [47], [48]. A data provider role was established, and the RAIDA system (connect+) serves as a general data hub between most resource providers and most grid operators. The grid operators shall choose the most cost-efficient redispatch measures for the specific congestion, considering all effective flex resources independently of their voltage level. RES are to be considered with a proxy price of 667,89 €/MWh [49], therefore ensuring the priority of renewable electricity. Resource providers are financially compensated retrospectively on a cost basis.

2.3.3 Switzerland

The Swiss transmission network is closely interconnected with the European power grid. This, together with the geographical size of the country, results in the fact that most congestions cannot be solved by national redispatch measures alone. Therefore, in most cases, transnational interventions are required. International redispatch is carried out either bilaterally, but also with the involvement of several countries. For example, if there is a need for redispatch originating from Italy, Switzerland sometimes has too little capacity to response adequately and therefore gets assistance from Germany. If network congestions are known in advance, they are also treated by reductions in cross-border network capacity in the long term [50].

In General, redispatch resources are available through the Swissgrid’s (the Swiss TSO) integrated market platform for redispatch and mFRR. Swissgrid introduced their so-called Integrated Market in February 2020 with the aim of increasing the availability of redispatch. They have implemented a combined product that can be used for either national mFRR or redispatch. Furthermore, these products can be combined in a way that they can also be submitted for the MARI platform. The coupling of redispatch within the mFRR market is meant to increase the market liquidity for redispatch [51].

Table 7 Country comparison of the trading dimension of redispatch

	timing				Product							Auction/ procurement rules				Ref.
	GOT	GCT	Activation time	product resolution	min bid size	max bid size	bid information	bid symmetry (Y/N)	bid adjustment (Y/N)	bid divisibility (Y/N)	bid increment	pricing rule/remuneration	winner determination	price cap	unit-/portfolio based bidding	
AT	-	-	D-1/intraday	typically 6 to 4 h	-	-	-	-	-	-	-	cost-based	-	-	no	[44]
DE	-	-	D-1/intraday	15 min, several hours are common	Activation resolution of 1 kw possible	-	Defined processes to inform TSOs and DSOs about available potentials and cost, no bids on a market	TSOs shall activate measure and counter-measure, DSOs shall balance measure e.g. via the spot market	Yes, schedules and acitivations may be adjusted when better prognosis are available	Yes, only part of the potential may be activated	Processes and formats allow increments of 1 kW	Regulated, plants are obligated to participate, Cost-based remuneration, no market mechanism	The most cost-efficient potential per effectiveness on congestion shall be chosen, RES considered by calculatory cost	-	-	
CH	D-7 and D-1	T-15min	D-1/Close to real time	96 x 15 min	5 MW	100 MW	Through mFRR procurement	-	Until GCT	No	1 MW	Pay-as-bid	Performance price merit-order	-/+ 15000 €/MWh	portfolio	[31], [32], [33]

2.3.4 Technical requirements for redispatch providers

Austria

So far, in Austria, RD services are procured mainly from large generation units. The most volume of RD is procured day-ahead form a limited number of generators. This is due to several challenges associated with redispatch (e.g. dependence on location, risk of market gaming, volume of required shift. Participation at the RD regime is mandatory for electricity providers and regulated in terms of bilateral contracts between TSO and provider (Art. 66(6) ElWOG)[52]. Specific requirements or the prequalification process have thus not yet been standardized.

Germany

Resource providers of resources that fall under the Redispatch 2.0 regime are obliged to participate in the defined Redispatch 2.0 processes. These processes that have been developed (and are still being refined) under the coordination of the BDEW ('Bundesverband der Energie- und Wasserwirtschaft') and have been published by the BNetzA in stipulations BK6-20-059, BK6-20-060, BK6-20-061 and corresponding notifications [46], [47], [48]. As all generation and storage units >100 kW and < 10 MW (and potentially >30 kW) are obliged to participate in this regime on a cost-basis there are no other technical restrictions that would exclude resources from this obligation. Resource providers ('Einsatzverantwortliche' EIV) are obliged to submit information including technical restrictions about the resource in the master data via the data provider to the connecting grid operator, which completes the resource master data. The complete information is distributed to all affected grid operators via the data provider. If a grid operator requires a specific resource to solve a congestion problem, it must see to the technical restrictions, e.g. the activation time, when sending an activation request.

Depending on the attributes of the resource ('Planwertmodell'/'Prognosemodell mit Plandatenlieferung') the resource provider may be responsible for providing planning data including the redispatch potential to the data provider. In some cases ('Aufforderungsfall') the resource provider is also responsible for receiving the activation document, which has an XML format, in case the resource is requested for a redispatch measure. They must then control the resource accordingly, using an automated or manual process.

Switzerland

Technical requirements for redispatch providers are the same as for mFRR providers (see Section 2.2.4).

2.3.5 The use of balancing energy bids for congestion management

Based on ACER Decision 60-2020, two main activation purposes were identified for balancing energy bids, 1) balancing and 2) system constraints. The latter includes their use for the purpose of congestion management.

Following Art.29 EBGL, the TSOs must forward all submitted BE bids to the platforms, unless they apply for an exception under Art.29(10) if the GCT of the local ID market takes place after the GCT of the cross-border platforms.

The mentioned exception of the obligation of forwarding bids to the international balancing platforms is drawn from the EBGL. Art. 29(14), states that "[e]ach TSO may declare the balancing energy bids submitted to the activation optimization function unavailable for the activation by other TSOs because they are restricted due to internal congestion or due to operational security constraints within the connecting TSO scheduling area."

There are three pre-market mechanisms the TSO can recur to for congestion management:

1) Before submitting the bids to the platform, the TSO may filter those bids that are expected to create congestion
2) The TSO determines the allocation of XB transfer capacity for the exchange of balancing energy that would ensure grid security as well as the desired flow range on an interconnector
3) The global optimization is carried out on the platform level, yet the TSO has the right to block a bid returned by the optimization function.

According to EBGL Art. 29 (10), "[t]he minimum volume of bids submitted by the TSO shall be equal to or higher than the sum of the reserve capacity requirements for its LFC block according to Articles 157 and 160 of Regulation (EU) 2017/1485 and the obligations arising from the exchange of balancing capacity or sharing of reserves" [4]. This means for both aFRR and mFRR that only the volume beyond "the sum of the reserve capacity requirements for its LFC block" could be used for redispatch.

In addition, ACER's Decision on activation purposes of balancing energy does allow the use of mFRR bids for solving system constraints but not of aFRR bids [53].

Concerning bid prices, Art. 29 EBGL obliges the TSOs to forward the cheapest BE bids to the platforms and Art. 13(2) Electricity Regulation stipulates that "balancing energy bids used for redispatching shall not set the balancing energy price" [54]. Furthermore, Art. 30 EBGL specifies the pricing process for balancing energy and cross-zonal capacity used for the exchange of balancing energy or for operating the imbalance netting process. It states, that "[…] balancing energy bids activated for internal congestion management shall not set the marginal price of balancing energy" [4].

On the topic of cross-zonal capacity allocation for the exchange of balancing capacity or sharing of reserves, EB GL Art 38(4) specifies that such capacities shall be used exclusively for frequency restoration reserves with manual activation, for frequency restoration reserves with automatic activation and replacement reserves.

2.4 Other relevant regulatory developments

2.4.1 Framework Guideline on Demand Response and its relevance for the project

2.4.1.1 Overview of the scope of the FG and the timeline

In June 2022, based on Art 59 of the Electricity Regulation, ACER published a draft Framework Guideline on Demand Response (FG DR) for consultation and presented the finalized version to the European Commission in December 2022. That said, the content described below is still subject to change, yet it should provide a good idea of its main building blocks and the principles. Note that the FG DR is non-binding, yet it paves the way to a binding network code (to be expected in 2025).

It contains the new rules with regard to DR, aggregation principles, prequalification processes, baseline definition, demand curtailment, and storage. Notably, DR will include not only load (demand curtailment) but also storage and distributed generation, which are collectively referred to as *"demand response and other relevant resources*" or in general "resources".

In addition, the FG covers the main principles of DSO-DSO as well as TSO-DSO coordination and data exchanges. Its main goal is to advance the standardization of requirements and harmonization of the covered principles and processes on the EU level, strengthen EU market integration as well as to further enable market entry and competition on the demand side.

SO services covered in the FG DR include balancing, congestion management (CM) and voltage control (VC). Among these, CM and VC are referred to as *"local SO services".* While wholesale markets (DA, ID) are taken into account in the FG, retail electricity markets are explicitly excluded.

2.4.1.2 Possible implications for the project

The following aspects are relevant and/or have potential implications for the analysis of this Deliverable:

1. The principles in the FG DR will apply to those flexibility resources that are planned to be connected to the flexibility platform(s) studied or envisaged in the project.
2. It is **not** intended to introduce EU-wide standardization of requirements but at least standardization on the EU-Member-State level based on the same guiding principles.
3. It is intended to provide product and pricing rules for CM and VC (similar to the EBGL for balancing). As to market design for CM, the rules will include such variables as *"structure, number and clearing of market sessions, gate closure times (where relevant), products procured"* for the SOs to observe when designing national markets for CM [7].
4. ***"The procurement and activation shall be market based,*** *through a process that ensures transparency and the selection of the most cost-efficient resource. Market based processes may be different for long/short term procurement and activation, depending on the products and the timeframe." (91)*[7]

They will also include the alternatives for procurement if market-based is deemed as a result of a market test or a CBA not to be economically efficient or *"would lead to severe market distortion or higher congestion".*

5. The new rules would oblige SOs to publish the information related to the requirements for becoming a CM product provider and, if applicable, prequalification requirements, as well as market results *"including information on volumes, prices, bids – if necessary in an aggregated and anonymous format - and bid selection criteria applied".* Timing should be "early enough" for market actors to account for them [7].

6. It intends to simplify and harmonize the prequalification process for balancing, CM and VC and distinguishes between *ex-ante* prequalification, primarily for standard balancing products, and *ex-post* validation, for non-standard products as well as for CM and VC. However, SOs still can introduce a prequalification process for CM and VC, subject to the NRA's approval.

7. Prequalification requirements are planned to be simplified in several ways:

   "The new rules shall provide that an existing prequalification in one product is accepted by the SOs as a prequalification for another product if the ToE [table of equivalences] indicates that the existing prequalification has more challenging technical requirements in all attributes, both products have similar IT and communication requirements and the SP requests for providing the latter product.

   The new rules shall provide that already prequalified technical requirements in one product are accepted by the SOs as tested for another product if the ToE indicates that the prequalified technical requirements are more challenging than the corresponding technical requirements of the prequalification process of the latter product." [7].

8. Local flexibility markets would be covered in regulation for the first time: DSOs are **not** precluded from operating „local SO markets" (CM and VC). Such markets may also be operated by third parties; **forwarding of local bids by a third-party operator to the wholesale markets may be allowed nationally and would be subject to the FSP's consent.**

9. It defines common rules for data exchanges between TSOs-DSOs-FSPs-third parties, including the event of the activation of resources in the grid of another SO (i.e. connecting SO ≠ requesting/affected SO).

10. The FG further highlights the need for interoperability to enable FSPs to participate in different markets (e.g. a single flexibility register/ SO system provision tool (relevant for the preparation phase); all SO's ToE…). The FG proposes the new rules to define a table of equivalences (ToE) of products requiring prequalification, so here TSOs and DSOs should agree on a common list of comparable attributes for all products. However, the purpose is **not** to set the same rules for different national products. Rather an effort to streamline different processes and critically review of there are some requirements that are no longer needed.

11. Key provision on market interaction (54):

    "The new rules shall provide that the overall market design on national level may include, among others:

    • whether and under which conditions bids offered in intraday or balancing markets can be used for local congestion management for distribution and/or

transmission grids. *In this case, the new rules shall provide the possibility for organising additional local markets, allowing for SOs to procure products others than the ones traded on intraday or balancing markets;*

• *whether and under which conditions third party market operators of local markets for SO services may inject bids from SPs, aggregated or not, into wholesale markets;*

• *roles, responsibilities and interactions of different entities, such as SOs, wholesale markets and third party operators of local SO markets."*

12. Besides the definition of local service markets, it should further define whether and under which conditions local products may be purchased in the wholesale markets, whether third parties may operate local markets but also if and how bids may circulate between local and wholesale markets.

2.4.2 Redispatch 3.0

Recently, Germany further developed its RD mechanism with the introduction of the so-called 'Redispatch 2.0'. The main motivation for measure was the integration of feed-in management (Ger. *Einspeisemanagement*) in the planning of RD processes. The introduction of so-called minimum factors guarantees that RES and combined heat and power (CHP) plants are last to be curtailed. Thus, it was ensured that the RES dispatch priority remained in place. Furthermore, the RD 2.0 regime takes into account decentralized generation and storages (>100 kW) as well as units that can be remotely controlled by a system operator. Although the RD potentials increased, a problem that remained is the lack of sufficient positive RD potential in the south of Germany.

A way out would be the inclusion of small demand-side units such as EVs and heat pumps, of which, due to the population distribution a large number is expected especially in the West and in Southern Germany. The main deterrent for their participation is that the current cost-based RD regime does not allow the use of decentralized flexibility for redispatch.

Therefore, a German study conducted by E-Bridge in collaboration with TransnetBW and TenneT, comes to the conclusion that the existing, cost-based redispatch is not future-proof if small-scale decentralized flexibilities and storage facilities are to be included into the redispatch regime. Instead, they propose a hybrid form of cost-based redispatch for conventional powerplants that are already used in RD 2.0 and a marked-based approach for all other flexibility resources. Both, long-term capacity services and short-term energy bids shall be included in the RD 3.0 mechanism. Participation in this complementary market-based mechanism should be on a voluntary basis. A non-discriminatory selection of all available potentials form both, the RD 2.0 and the RD 3.0 is ensured by a common merit order list of all RD offers, whereby the supplementary market-based RD is remunerated according to their offer prices (pay-as-bid). In order to minimize gaming risks, the new approach proposes baseline monitoring. The first demo is planned for 2023 and the implementation is expected in 2026 [55].

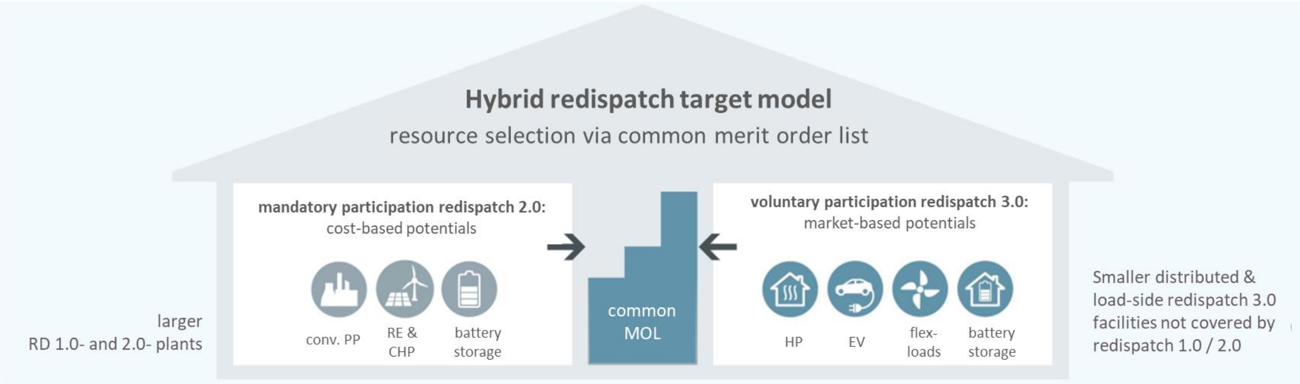


Figure 7 ‚Hybrid Redispatch mechanism' (Based on [55])

3 Proposal for standardization

Goal of this chapter is to analyze potential for standardizing heterogenous flexibility products and possible approaches to doing so. The standardization of requirements for flexibility is aimed at enabling a more efficient use of flexibility for multiple use cases, balancing, congestion management, but also the intraday market, promising an increase in market liquidity and – in the best case – lower system costs.

The goal of increasing liquidity in the flexibility market(s) must be balanced against the difficulties of meeting more specific system needs and product customization. Furthermore, a standardized flexibility product is not efficient in revealing the value of individual flexibility attributes that are e.g., technology specific. However, as we show below, standardization in fact represents a scale, on which the tradeoffs between liquidity, system efficiency, ease of participation and implementation effort characterize the solutions on the scale to varying degrees.

Besides technical and product-related attributes, a relevant question for standardization is whether only short-term (energy) or also long-term (capacity) flexibility is procured and then if both can and should be standardized.

The term "standardization" is subject to interpretation. In this Chapter, we analyze the potential for standardization on two levels:

1) Product-wise standardization on the international level
2) Cross-product integration

The main aspects of the two levels are summarized in Figure 8.

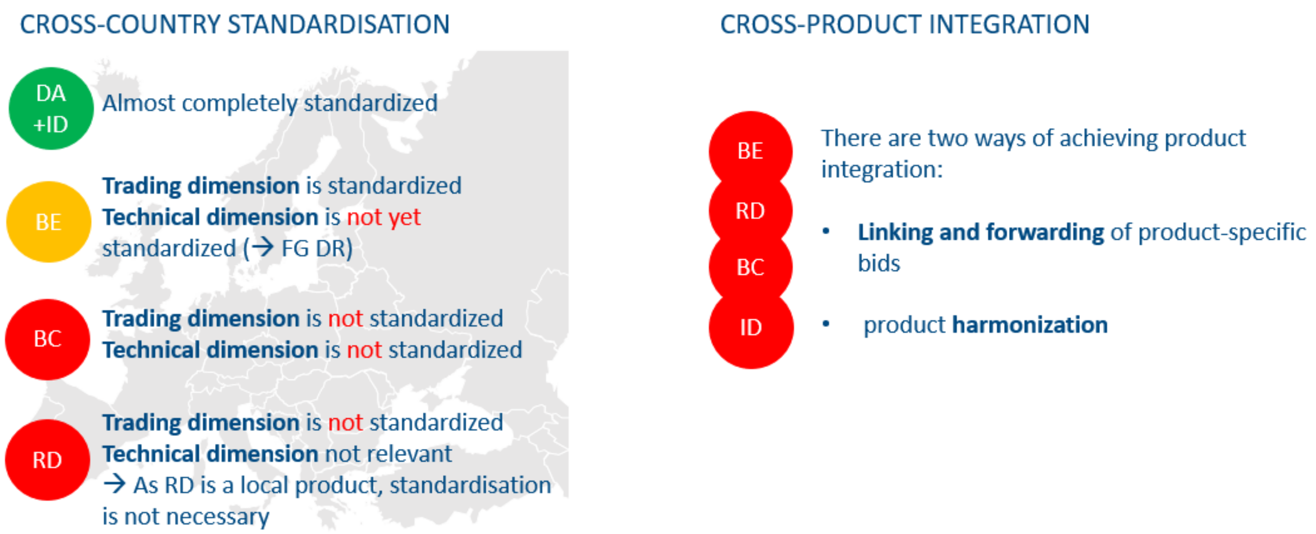


Figure 8 Comparison of the two possible levels of product standardization, cross-country standardization vs. cross-product integration.

Product-wise standardization on the international level aims at an integrated European energy market and cross-border exchanges, competition and joint procurement of flexibility services by multiple parties. The largest advantage of a product-wise standardization approach is that it creates a level playing field for actors from different countries taking part in integrated markets. System operators, in turn, can profit from a larger flexibility pool.

In contrast to the first option, cross-product integration does not increase liquidity in a market through transnational cooperations. Instead it can be achieved through advanced bid linking options or a full-scale product harmonization of product attributes nationally. A product attribute is harmonized when no divergence is allowed between different purposes. Therefore, a ‘common value’ will be agreed upon for this attribute, requiring a definition of minimum requirements of different services (see also Section 3.1.1).

We analyze the two approaches, based on the identified classification of flexibility attributes (Chapter 1) from the technical and trading perspectives. Among others, we try to answer questions such as ‘What effects do different approaches to market/product integration have on the bidding strategies of participants?’ and ‘Which degree of standardization would increase the efficiency of flexibility procurement and where does the tradeoff between standardization and efficiency losses for system operators lie?’

3.1 Product-wise standardization on the international level

In the following, we aim to analyze the current level of product-wise standardization on the international level, focusing on the technical and trading dimensions.

3.1.1 Technical Dimension

As described in Chapter 2, the technical requirements for the European DA, ID and balancing energy markets are already standardized to a large degree. For now, prequalification processes only exist for balancing products. The current regulatory framework demands that FSPs need to be prequalified for all markets they intend to participate, meaning that no matter the product requirements, the FSP has to undergo several prequalification processes.

However, the prequalification process is not standardized among different TSO but also not standardized for different products. As pointed out in Section 2.4.1, the Framework Guideline on Demand Response proposes, among others, to introduce unique and common European principles for prequalification to ease the process and lift any unnecessary entry barriers by simplifying the overall process and avoiding duplications in the prequalification. The avoidance of duplications in prequalification processes is expected to be achieved with the help of a table of equivalences between the minimum technical requirements of each product [7]. Beyond the common principles, however, the Guideline does not require a full international standardization of the prequalification process, which remains the prerogative of individual TSOs.

As to congestion management and redispatch as a service, much less strict requirements are applied to its providers whereas there is no prequalification process in most countries – except for those where redispatch is procured together with a balancing product. Following the draft FG DR, it would remain the prerogative of individual TSOs whether a prequalification process for redispatch should be introduced (see Section 2.4.1 for more details). Due to the locational nature of redispatch, it is in any case questionable whether a high degree of product standardization on the EU level would be necessary and does not so far seem to be the intention.

3.1.2 Trading Dimension

In general, flexibility product specifications are used by TSOs to define requirements on performance of FSPs providing bids for system services. Similar to balancing market rules and operational philosophies, there are national differences between products requirements across Europe (e.g, due to a more proactive or a more reactive system management). In particular in the past, such differences used to provide substantial barriers to possibility for cross-border exchanges, competition, and therefore joint service procurement. Some differences are quite fundamental, such as different requirements on the speed of activation, minimum bid size, locational specification, or pricing rules. This leads to a distorted representation of the European FSP mix, as FSPs with equal technical capabilities would typically deliver different products if located in different countries.

To overcome some of these issues (at least for balancing products), and to foster the integration and completion of an integrated European balancing market, standardization of balancing products was deemed considered a key issue. The Electricity Balancing Guideline [4] is key foundation for such standardization. As described in detail in Section 2.2, thanks to the introduction of the European platforms, TERRE, MARI and PICASSO, product-wise standardization for balancing energy is already at an advanced level and has already produce significant welfare gains for the participating TSOs since the go-live in 2022, according to ENTSO-E's estimations [56]. It is noteworthy though, that this applies to balancing energy and not to balancing capacity markets, which are still national (with the exception of few countries and products).

Product standardization is particularly high in the coupled DA and ID markets.

In contrast, redispatch is the least standardized service and varies greatly in terms of procurement methods, lead times, pricing rules and general requirements.

Timing

In Europe, the electricity market is organized as a series of markets in different - sometimes overlapping - timeframes.

Most markets are currently organized sequentially, meaning that the GCT of the markets are subsequent and the respective merit orders are independent of each other. A possible way to increase liquidity in a market with such a structure would be the introduction of a **bid forwarding concept** (for more details see Section 3.2.1) [57].

aFRR and mFRR are currently organized as **parallel** markets, meaning that the GCT of the energy markets is the same. So far, these are operated completely independently of each other, implying that FSPs have to decide in which of the parallel markets they want to place their flexibility bids. This leads to a reduction in liquidity, especially since some assets are prequalified for more than one service. One way to overcome this issue and use available flexibility resources more efficiently would be to introduce the concept of **bid substitution**. This concept would enable the FSPs to provide their bids for more than one service, e.g., through exclusive bid linking(for more details see Section 3.2) [57].

Product rules

Besides the already mentioned benefit of joint procurement and enabling cross-border exchange, product-wise standardization approach has the advantage of allowing for the optimization of product characteristics that are customized for the respective application. In case some technical requirements should need amendments, implementation is far easier and could be done without considering potential impacts on the other products.

Auction/Procurement rules

The current sequential/parallel design of the European energy markets has the advantage that the separate markets for balancing and congestion management allow for a clear differentiation between costs allocated to each service, enabling a more precise indication of future investments in transmission grids [58].

If one seeks increasing liquidity in one of the markets through a common procurement with other products, the difficulty of different pricing rules that may lead to distorted incentives arises. Remuneration levels and rules of the products highly matter, as FSPs likely will not be willing to provide a flexible service when the price of another flexibility service is expected to be significantly higher. This could lead to FSPs not prequalifying for less financially attractive products, preventing the positive effects of the introduced organizational model.

This issue implies that an increase in liquidity would require cross-product integration at least to a certain extent (see Section 3.2).

3.2 Cross-product integration

In general, approaches for cross-product integration can vary in degree. The bid forwarding concept briefly mentioned in the introduction is located on the more flexible end of the scale whereas a fully harmonized flexibility product (hereafter referred to as a “universal flex product”) is located on the opposite side of the standardization scale [59]. Products would be only partially harmonized if some of their individual features remain intact. These options are presented on a scale in Figure 9 and are discussed in the subsequent sections.

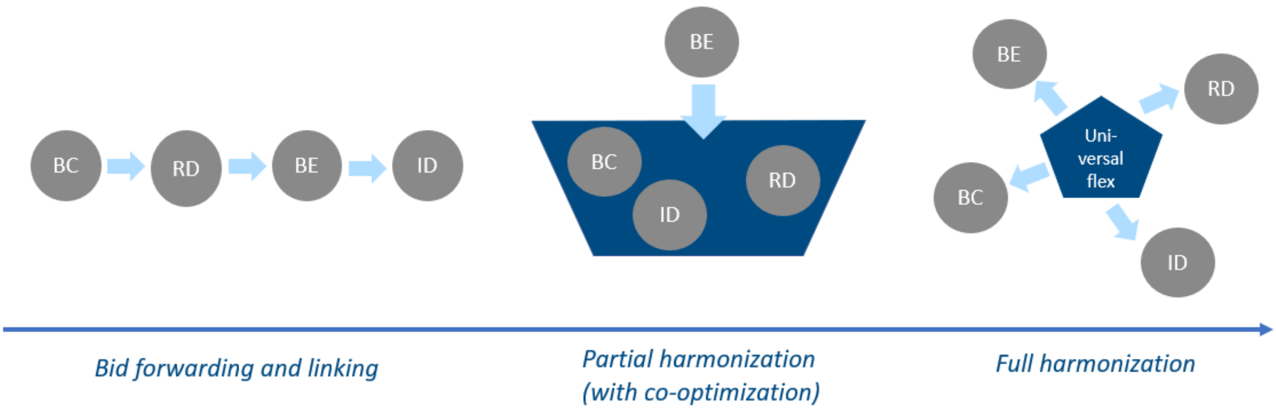


Figure 9 Product standardization scale

3.2.1 Bid forwarding

Bid forwarding refers to a concept that would allow a market operator / a TSO to forward bids that have not been awarded in a one market to other markets with subsequent GCTs.

The main benefit for an FSP is the chance to participate in more than one market with the same flexible resource and therefore simplify the decision-making process on the FSP side. On the flipside, depending on the exact forwarding rules, this option might be less transparent and potentially more difficult for an FSP to plan for.

A necessary assumption for bid forwarding is that the FSP is fulfill the requirements of and prequalified for each market the bid is forwarded to or prequalification is not foreseen for a product.

The exact sequence of markets is essential since bid forwarding potentially leads to an increase in liquidity in subsequent markets given that the exchange of bids between the markets would only be possible in one direction. Furthermore, an increase in liquidity is only possible if assets that cannot prequalify for the whole chain of markets are not excluded from the process. That is, an FSP that is technically capable of delivering a single product in the chain should still be able to participate in it and is not unduly disadvantaged. This also implies that an FSP should be able to join and submit their bid at any point in the market chain and declare their preferences. It is, however, a design choice whether the bids could still be adjusted by the FSP before being forwarded to the next market.

In the case of a sequential market structure, a co-optimization by the TSO is not possible. This bears the risk of forwarding too few/too many bids to the subsequent market [57].

With the help of exclusive bid linking the same bid could be considered for several markets. The prequalification information, FSP's preferences, bid information (including its locational information, if required) could be stored on a dedicated flexibility platform, which would perform the following functions:

- Entry point for smaller flexibilities
- Communication platform between FSPs and the respective markets (bid and market results, activation signals)
- Handling of flexibility/pool bid parameters and their forwarding to respective markets.

In order to implement a bid forwarding concept in accordance with EU regulation, a capacity management mechanism would be required. Based on the requirements set out for the EBGL[7], the introduction of a capacity management mechanism would be necessary to allow for balancing bids used for RD. That is, a pre-filtering process is needed in order for the TSO to retain balancing energy bids and use them for congestion management[8] [57]. As pointed out in Section 2.4.1, following the draft FG on DR, the TSO may recur to intraday or balancing bids for CM, subject to the NRA's approval.

In principle, the bid forwarding concept would be implemented independently of the integrated markets and products standardized across European countries since the platform

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[7] E.g., EB GL Art 29(14): *"Each TSO may declare the balancing energy bids submitted to the activation optimisation function unavailable for the activation by other TSOs because they are restricted due to internal congestion or due to operational security constraints within the connecting TSO scheduling area."*

[8] A capacity management or a filtering process is further required in order for the TSO to avoid issues on the lower distribution grid level where some of the flexible resources are likely to be connected. This highly complex process and the TSO-DSO coordination are, however, out of the scope of this deliverable.

is used in the pre- and post-market phases. However, the internationally established processes and market GCTs can be regarded as constraints affecting the platform capabilities and process definition.

3.2.2 Partially harmonized flexibility products

In this option, products are standardized/harmonized to a large extent, yet retain their individual qualities. That is, an FSP still has a possibility to submit their bids to different products. As a result, their technical requirements may still differ (as opposed to the fully harmonized option below). All flexibility products are submitted to the same flexibility platform with the same GCT. In this way, valuable flexibility potential is not excluded while the TSO may deploy flexibility in a more efficient manner using co-optimization. An FSP prequalified for several products could use exclusively linked bids pointing to the same flexible resource. Consequently, a TSO could substitute bids between several markets if this action would increase overall efficiency / reduce total system costs.

A bid substitution mechanism is an alternative of the bid forwarding concept applied to parallel markets, i.e. markets with the same GCT. It could be designed in two ways [57]:

1. A bid from one market could be used in another one if it solves the respective issue more efficiently (assumption: prequalification for the market it is substituted to). For this approach, flexibility does not necessarily have to be the same.
2. The FSP places the same bid in more than one market. This would require the introduction of exclusively linked bids, allowing the FSPs to submit the same flexibility to more than one market.

Bid substitution again simplifies the decision process for FSPs as their flexibility bids are not restricted to one market. The associated cost is the loss of transparency since FSPs would not know in advance for which purpose their bid will be activated for.

One of the advantages of a parallel market structure is the possibility to exchange bids in more than one direction, as compared to the bid forwarding concept above.

To exploit the whole potential of bid substitution, co-optimization by the TSO of all involved markets is required. It is a design choice whether such co-optimization is conducted by a single TSO or in a coordinated TSO-DSO or, internationally, a TSO-TSO process.

Despite several obvious benefits of this approach, it is not immediately practicable under current market rules: the definition of a common GCT for all products in self-dispatch systems would be extremely cumbersome and likely to close to real time raising system security concerns. That said, it is conceivable that such an option plays a role for a limited number of products (e.g. mFRR and aFRR energy that are already parallel today).

3.2.3 Fully harmonized flexibility products

A product attribute is harmonized when no divergence is allowed between different purposes. Therefore, a ‘common value’ or a common denominator is agreed upon for this attribute. That is, there is no distinction between the different products on the FSP side and it is the prerogative of the TSO (or DSO or both) to decide where this flexibility could be used best. All product requirements, in the technical and trading dimensions, are then harmonized by definition. At least in theory, such an approach would simplify decision-making for FSPs since only one trading decision has to be made.

The “universal flex” product could then be defined more or less restrictively.

If a more restrictive product definition is implied, the product would become more versatile for the TSO (and potentially also for the DSO) but also more restrictive for potential FSPs as required product characteristics would converge to the highest common denominator. This would ensure a high quality of the harmonized services, yet it would also exclude a large share of potential providers. As a result, instead of increasing market liquidity it could even reduce it if the common denominator is set too high.

On the other side, a less restrictive product definition would potentially endanger the product quality, while it would allow for the inclusion of a wider range of possible heterogenous providers with different capabilities.

Product harmonization to a full extent presents even more implementation challenges than the option described above. It is therefore understood by the project partners that, at this point in time, this option represents a long-term option of a more theoretical nature.

Considering different characteristics of the existing products and markets, in the following, we take a closer look at the implications of the options above for the balancing and intraday markets as well as for their integration with redispatch procurement. We analyze the potential market and product combinations considering common product attributes and harmonization needs. Both flexible capacity and energy are considered. Due to its incompatibility with the current market rules, we do not consider the option of partially harmonized products described in Section 3.2.2 further. We do include some remarks concerning the universal-flex option in the next Section for the sake of completeness.

3.2.4 Intraday market

When it comes to the intraday market (IDM), one can distinguish between two market types: auction-based, discrete ID markets and continuous ID markets. In a discrete ID market, unique market clearing prices and a set GCT are applied. Continuous ID markets are based on a ‘limit order book’ mechanism, meaning that submitted bids are continuously matched at the platform up to the GCT. Since continuous IDM is mostly used by the market actors in the project countries, in the following, this market form is analyzed.

Flexibility bids for the IDM or from the IDM could be potentially used in different ways:

1. use non-awarded flexibility bids in the IDM
2. cover the remaining need for ID RD through the IDM [57]
3. use ID bids for balancing purposes

These options are further analyzed in terms of technical and trading dimension in the next subsections.

3.2.4.1 Technical Dimension

There are no technical restrictions associated with Option 1 since there are no specific technical requirements on the IDM. Thus, no adaptations on the technical level are required and all non-awarded flexibility bids can be used in the IDM.

Option 2 is more complex as using IDM bids for RD would require FSPs to include location in their bid information. This concept is, for instance, used by GOPACS project in the Netherlands where the associated ID platform ETPA also includes location of the submitted bids. However, even if locational in IDM is not available, its loss could in theory be overcome with the help of a flexibility platform [60]. That is, the locational information associated with the bid would remain preserved on the platform and a unique bid ID until the end of the entire market chain. In this way, the bid retrieved from the IDM could be matched back to the "parent" bid and its locational information.

From the technical point of view, for Option 3, only those ID bids could potentially be used for balancing that fulfill the corresponding technical requirements.

If full or partial product harmonization is aspired to, for the first two options, the prequalification process would not need amendments, whereas Option 3 would require the introduction of a prequalification process for ID bids.

3.2.4.2 Trading Dimension

Timing

A combination of IDM and other flexibility markets is conceivable with different organizational market models. For the option of forwarding non-awarded flexibility bids in the IDM, a sequential model, as it is organized now, is most likely. The only requirement is the introduction of a linking concept, as proposed in Section 3.2.1.

In the case of intending to implement a combination of RD and IDM market, it is assumed that in the short term, it is unrealistic that the TSOs would cover most of their RD demand in the ID timeframe due to a high risk for security that close to real time. Therefore, we assume the main RD process to continue to take place in the D-1 timeframe whereas only the remaining RD need could be covered through the IDM. Nevertheless, in the long run, RD procurement may shift closer to real time as more and more participants with low lead times and high potential of short-term flexibilities enter the market. Basically, there are two organizational options for this approach. First, the introduction of a parallel market together with a bid substitution concept (see Section 3.2.2). This would enable communication between the two markets at least to some extent and enable sharing of available potential. Second option would be the introduction of a harmonized product in a combined market, requiring a high degree of product harmonization and locational information for ID bids.

Independent of the organizational model, a remaining issue concerning timing is that in the special case of RD, the flexibility is typically activated for several hours. This implies that several ID bids (or forwarded balancing bids in a sequential context) would have to be combined [57].

Similarly, the option of using ID bids for balancing could be organized with the help of bid substitution in parallel markets or through a combined-market approach. The latter does not seem to be practicable in the current setting, considering the established GCTs of the balancing energy and intraday markets. Concerning the former, a period of time could be defined during which ID bids from the continuous market could be forwarded to the balancing energy market as voluntary bids – provided these are prequalified.

Product rules

The higher the extent of cross-product integration, the higher the loss of product characteristics that are customized for the respective application. So, in case some amendments in product design are needed, implementation is quite difficult and one has to consider potential impacts on the other products.

Using non-awarded flexibility in the IDM is a case of using a more restrictive product for a less valuable service, hence there is no need for harmonization of product rules.

The already addressed problem that comes with the combination of ID and ID RD are the different product resolutions. Using IDM bids for balancing would either require aggregation of smaller bids on the flexibility platform or an adjustment of the minimum bid size (currently, 0.1MW vs 1MW).

Auction/Procurement rules

Independent of the chosen mechanism and organizational structure, the main challenge is the differing pricing rules of the products concerned. If the same bid is used in the different markets, it might be hard to argue why it would be priced differently. On the other hand, since the markets in question are associated with different activation probabilities, one could argue that different bid prices could be justified. However, if one service is still remunerated at cost whereas another one at a market price, this would likely lead to distorted incentives at the FSP level. The logic is similar for marginal versus pay-as-bid pricing: the FSP would likely optimize their strategy to participate in the market that is more lucrative undermining the purpose of product integration.

3.2.5 Balancing energy markets

In terms of balancing energy markets, there are different harmonization options. First, there is the option of harmonization of **different balancing energy products**. The main benefit would be the option to allow FSPs to submit the same flexibility bid for different products, simplifying the market entry and increasing liquidity.

Another option would be the harmonization of a **balancing and redispatch** products. This approach would open the RD market for participants that operate with a shorter planning or forecast horizon. Ideally, this would lead to a higher liquidity in markets closer to real time. Besides, the combination of balancing energy and redispatch would have the advantage of lowering the gaming potential for redispatch providers as FSPs would not know the service for which they will be activated for in advance [57].

Emerging design questions again address the issue of how to harmonize these products without loss of reliability on the one hand and to increase liquidity in the respective markets on the other hand.

3.2.5.1 Technical Dimension

From today's perspective, a combination of balancing energy products seems not very likely, as the technical requirements for the products differ significantly. This is because the products have been designed for different kinds of applications and therefore activation requirements differ considerably. However, following the FG DR, it is advisable to simplify the prequalification procedure for FSPs in case they have already been prequalified for one of the products or in case minor changes to the flexibility pool were made (see also Section 2.4.1). This would also be essential if a bid forwarding/substitution concept is introduced, in which, e.g. the same flexible pool is offered to the aFRR and mFRR market via exclusively linked bids.

Another not very likely option of a harmonized product is the combination of FCR and RD products as it would come with a large number of challenges: technical requirements, such as ramping period or full activation time differ substantially. Therefore, a high degree of standardization of FCR and RD would require an extremely strict prequalification process or it would otherwise hamper the quality of the FCR product [57]. Furthermore, locational information would have to be included in the technical attributes of FCR. From the FCR perspective, this does not make much sense, as FCR bids are activated in the whole synchronous area.

Harmonization of aFRR and RD also proves somewhat challenging, as the most valuable product attributes differ (e.g., speed of activation) [57]. The same problems as for FCR occur, as the technical requirements for aFRR may be hard to fulfil for some redispatch providers, resulting in their exclusion from the market. Another point would be the missing locational information, that would be required when using aFRR bids for RD.

RD and mFRR are commonly combined due to the similarity of activation profiles and technical product requirements. In fact, most European countries have been using balancing energy for redispatching [61]. Therefore, in the short term, this is assumed to be the most likely combination option [57]. The only additional requirement is the locational information for mFRR bids unless the bids are submitted to the flexibility platform where this information is stored before forwarding the bids to the balancing market (see also Section 3.2.4).

3.2.5.2 Trading Dimension

Timing

Keeping harmonization at the technical dimension in mind, possible options of timing and market sequences are relatively restricted. A harmonized aFRR/mFRR and RD market could again be organized sequentially. The linking concept introduced in Section 3.2.1 would avoid the need for a full product harmonization and appears to be the most viable option for integration with other markets.

Parallel procurement with exclusive linking and/or bid substitution would allow for more flexible use of resources not only before mFRR/aFRR and RD but also between aFRR and mFRR that are already organized as two parallel markets (see also Sections 2.2.1 and 2.2.2).

The harmonized market approach introduced in Sections 3.2.2 and 3.2.3 seem securing sufficient bids for the remedial actions cannot be guaranteed as most FSPs may bid close to real time. This means that an additional mechanism for ensuring enough flexibility volume for congestion management in the day-ahead time frame would remain necessary [57]. In addition, this approach would require the harmonization of prequalification requirements, potentially setting the bar for redispatch providers too high.

Product rules

The extension of required product rules harmonization is dependent on the respective organizational model. Sequential, parallel would not require harmonization of product rules whereas the implementation of a universal flexibility product would require full harmonization of product rules.

Concerning the need for locational information for redispatch, this could be solved through a flexibility platform, as described in more detail in Section 3.2.4.

Auction/Procurement rules

See the respective subsection in Section 3.2.4.

In addition, in the case of a combined market approach and therefore co-optimization by the TSO, avoiding bid activations could lower the overall system costs.

3.2.6 Balancing capacity markets

From the TSO perspective, a combination of the balancing capacity market and the RD market has the advantage that short-term liquidity can be ensured and a fixed amount of flexibility which can be accessed can be secured in advance. Furthermore, as we learned from the project I4RD[9], one of the major issues especially for smaller DR assets is that, if cost-based remuneration for redispatch is not sufficient for FSPs to cover their fixed costs, creating a lack of investment incentives. A way to solve this issue would be to include capacity remuneration for redispatch. The biggest disadvantage, however, that this would not only imply additional costs for the TSO through reservation payments for redispatch but also would reduce liquidity in the short-term electricity markets.

If the combined balancing capacity market and RD market is the only possibility to provide flexibility for RD, the provision of short-term flexibility would not be possible. To overcome this issue, voluntary bids have to be allowed in the RD market as well, which would increase the complexity of the overall system.

A possible approach for keeping the costs of an RD capacity market low would be to contract providers for a specific “service window” when demand for the concerned flexibility service is typically high (e.g., winter evenings) to reduce reservation costs.

In general, however, a combination of the two does not appear sensible also because the amount that needs to be reserved for one product is largely independent of the other, that is, the co-optimization potential is likely negligible. The two possible synergies between the balancing capacity market and the provision of redispatch would be:

[9] https://www.nefi.at/en/project/industry4redispatch/

1) The bids not awarded in the balancing capacity market are forwarded to the redispatch mechanism/market, provided these were submitted with locational information, as proposed in Section 3.2.1.
2) "Constrained awarding of balancing capacity": The choice of balancing capacity bids is conducted considering the expected congestion and its location thus preferring the reservation of the bids in the areas of expected congestion, as proposed in project UC2 (see Deliverable 3.3 for more details).

3.2.6.1 Technical Dimension

Neither bid forwarding for redispatch nor "constrained awarding of balancing capacity" would require an adjustment of technical requirements. Both options would require location information to be provided with the bids.

3.2.6.2 Trading Dimension

Neither bid forwarding for redispatch nor "constrained awarding of balancing capacity" would not require an adjustment of trading requirements.

As already mentioned, reservation payments for redispatch would circumvent that smaller FSPs have to bear the risk of investment costs and in this way provide some kind of investment security. Furthermore, it could reduce gaming, as FSPs are not that reliant on revenues from an activation anymore.

3.2.7 Aggregation

The critical point for redispatch procurement is that it addresses the power flow on specific elements in the electricity grid. Therefore, the exact location of the RD providing unit and thus, the corresponding sensitivity with regard to the network elements is highly relevant.

When it comes to aggregation, the mentioned locational dependence poses difficulties as it increases the complexity of the RD problem significantly, if flexible resources in a common pool that are situated in different geographic locations must be taken into account. On the other hand, a strict requirement to submit unit-based pools for redispatch risks to significantly restrict the market or the procurement mechanism, in particular for smaller flexible assets.

To tackle this problem, it is necessary to define regions within which aggregation is possible. Thereby it is necessary to bridge the gap between efficient pooling of flexibility potentials and provision of enough granularity to ensure efficient redispatch. For instance, it was found in project Industry4Redispatch[10] that the best compromise between these two components would be aggregation at the 110 kV grid level, meaning that assets within one distribution grid may be aggregated.

[10] https://www.nefi.at/en/project/industry4redispatch/

4 Conclusion

As we have shown in this Deliverable, different degrees of product standardization are conceivable, both on the international and purely national levels. The benefits of a full standardization should, however, be evaluated against the background of potential tradeoffs such as the risk of excluding some of the valuable flexibility potential or the implementation costs. Thus, in the short run, the harmonization of several products is not considered very likely due to the barriers on organizational, technical and regulatory levels. Furthermore, it is not considered very likely that the vast majority of redispatch volume will be procured very close to real time for system security reasons. It is therefore recommended to fully exploit the potential of international product-wise standardization, on the one hand, and cross-product integration using innovative bid linking concepts, on the other hand, in order to maximize the use of available and new flexibility resources. For this, the main design steps, as shown in Figure 10, include:

1. The (voluntary or mandatory) inclusion of locational information in balancing and/or intraday bids.
2. Definition of aggregation rules that are compatible with portfolio bidding yet, have a sufficient geographical granularity for their efficient use for congestion management.
3. Harmonization of pricing rules is likely necessary in order to ensure that flexibility providers are profit-neutral and reduce gaming opportunities.

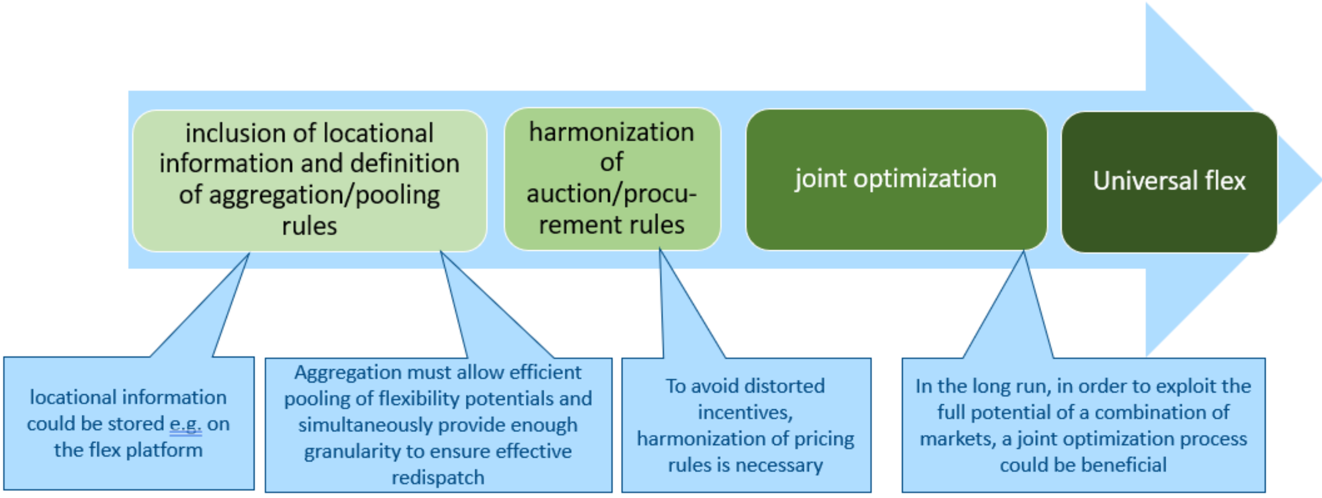

Figure 10 Standardization roadmap

The handling of the first two points could be carried out on a purely national level, for example, with the help of a flexibility platform handling the data collection and forwarding, bid updates and activation signals in pre-market and post-market phases. Harmonization of the pricing and/or other market rules (point 3 above) would likely require international standardization in order to avoid new entry barriers, distorted incentives for international market actors and market fragmentation.

Interpreted in terms of a standardization timeline, the standardization roadmap can be split into two parts, a short to mid-term strategy and a standardization target for the long run (see Figure 11).

Short-term to mid-term strategy:

As already mentioned, most likely reachable standardization goal in the near future would be the full exploitation of international product-wise standardization. As standardization of ID products and in case of balancing energy products on the trading level is already at an advanced stage, next steps could be the standardization of the technical dimension of balancing products.

The next crucial point for the combination of redispatch procurement with other markets that needs to be addressed is that for each analyzed organizational model, only those bids that contain locational information could be forwarded/substituted for (intraday) RD. Therefore, (voluntary or mandatory) inclusion of locational information is required.

As soon as providing flexibility for more than one purpose is allowed, it is necessary to consider the influence of pricing signals on the bidding strategies of market participants. From today's point of view it seems necessary to harmonize pricing signals to such a degree that distorted incentives can be avoided.

The mentioned activities should go hand in hand with a simplification of the prequalification processes, in order to further extend the pool of eligible market participants.

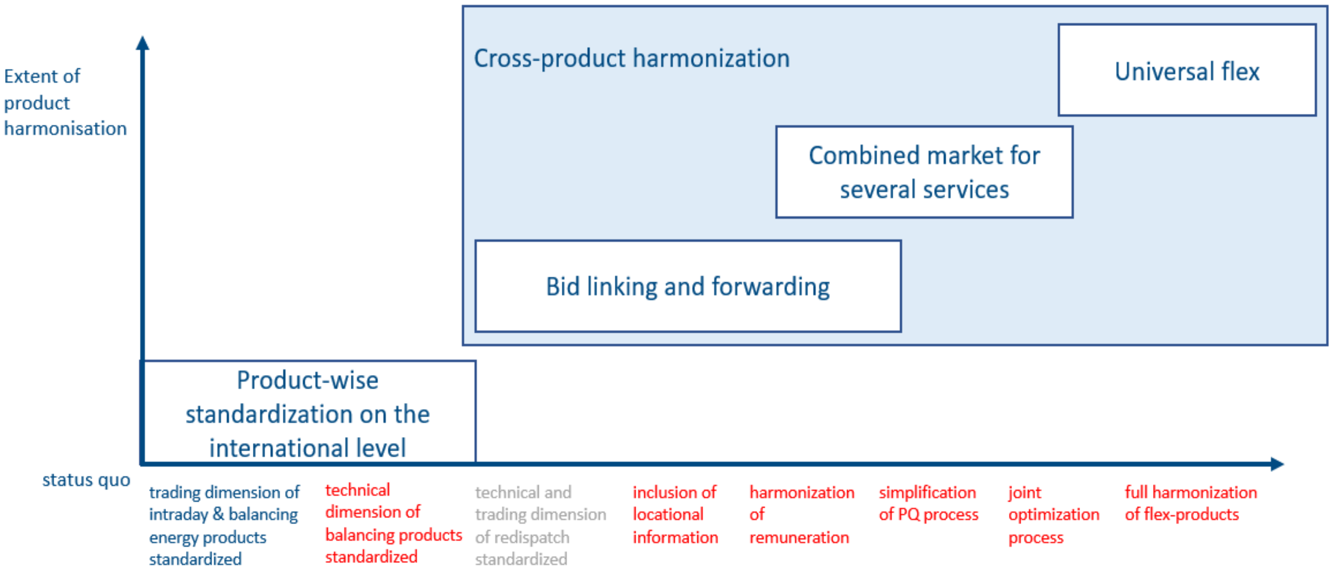

Figure 11 Overview of options on the standardization scale.

Concluding, in the short- to mid-term, even if full harmonization is not aspired to or is not deemed sensible, a certain level of harmonization of product specifics would be necessary to ensure the compatibility of a flexible bid for several products. These considerations are addressed per product characteristic (see also Figure 1 for the overview diagram) in Table 8 below:

Table 8 Required level of harmonization of product characteristics

Timing	GOT / GCT	in the short- to medium term, harmonization is not required and is not expected. Nevertheless, especially for the bid linking concept, definition of the GOTs/GCTs is highly relevant in particular with regard to the option of bid adjustment.
	Activation time	under the assumption of using more valuable products (e.g. BE) for services with lower requirements (e.g., RD, ID), no harmonization required

	Product resolution	harmonization can be prevented by combining subsequent products – ‘stitching together’
Product rules	Minimum bid size	unless the flexibility platform handling flexibility bids before forwarding to respective markets also performs aggregation, harmonization of minimum bid sizes to the lowest common denominator would be needed to enable the bid’s use for different products
	Bid increment	same as for minimum bid size, harmonization to the lowest common denominator of bid increment is required to enable the bid’s use for different products
	Maximum bid size	as long as the flexibility bids are divisible, maximum bid size is not a restricting attribute
	Bid information	locational information would be required for all bids if products are (partially) harmonized and are, among others, used for redispatch. It is an open design choice whether this information should be provided on a voluntary or mandatory basis
	Bid symmetry	should be harmonized even if linking (especially if an asymmetric product is possible in the first/preceding market)
	Bid adjustment	would be necessary especially if a minimum bid size or different pricing applies to the subsequent market(s)
Auction/procurement rules	Pricing rule/remuneration	is crucial to harmonize to avoid possible distorted incentives of FSPs
	Winner determination	whether the bids are awarded based on a merit order, pro rata or other principles
	Price cap	if price caps are applied for (partially) standardized products and the same flexibility can be submitted for both, the price caps will need to be standardized as well to avoid distortions.
	Unit-/portfolio-based bidding	As mentioned in Section 3.2.7, the use of flexibility for balancing or intraday markets and for redispatch opens the question of the aggregation level that is both feasible to preserve portfolio bidding and its use for redispatch.

Long-term target:

Long term target of the harmonization process is the introduction of a universal flex market, aiming at a full harmonization of flexibility attributes. From today’s perspective however, there are still major open issues that need to be addresses before this stage can be achieved.

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