A Review of the European Grids Services Markets Suitable for Distributed Loads

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Abstract: Insufficient and unreliable data regarding European ancillary service markets lead us to carry out a survey aimed at collecting data and information from European transmission and distribution system operators for the purpose of understanding the markets' capacity for accommodating distributed loads as balancing service providers. A review of literature enhanced the survey knowledge base as far as possible in cases where surveys were not responded to and information was openly available. At the time of writing, the markets found to be closed to the participation of loads or non-rotating masses such as water electrolysers included Croatia, Czech Republic, Estonia, Latvia, Lithuania, Poland, Portugal, Romania and Spain. The European grid service market landscape is highly heterogenous with contrasts seen in market rules, market transparency, technical requirements and least of all price levels. In this report we present the availability and utilisation prices of balancing products that electrolysers are technically suited to providing services to. We provide an overview of the market conditions and also present the countries found to be most favourable with respect to utilisation and availability remuneration. Finally, we address that grid services on the distribution level such as congestion management, capacity management and voltage control are not readily offered on the distribution level by distributed system operators.

Keywords: European electricity grid service markets, Distributed loads, Frequency Containment Reserve (FCR), automated Frequency Restoration Reserve (aFRR), manual Frequency Restoration Reserve (mFRR), Restoration Reserve (RR), availability prices, utilisation prices.

1 Introduction

The European Union (EU) Horizon 2020 framework in collaboration with the Fuel Cell Hydrogen Joint Undertaking (FCH-JU) in a public-private partnership supports research in sustainable hydrogen production. With this sponsorship, a survey was carried out in order to obtain primary data on EU electricity grid service markets in an effort to uncover their business logic under the QualyGridS research project (Project 735485, www.qualygrids.eu). Distributed fast variable loads such as water electrolysers (WEs) have the potential to provide grid services. Their flexibility can be offered to transmission system operators (TSOs) for the provision of balancing services such as frequency containment reserve (FCR), frequency restoration reserve (FRR), or to distribution system operators (DSOs) for congestion management and voltage control among others [1, p.37-38]. European TSOs and DSOs were the target population of the survey. The purpose of this report is to present the findings.

2 Background

Due to the lack of reliable market data in literature, two surveys were conducted, one specifically for TSOs, and another specifically for DSOs. The surveys sent out to TSOs were sent to 36 TSOs from 30 countries (EU-28 plus Switzerland and Norway). The TSO questionnaire offers a brief background on the grid services of particular interest elaborated in Table 6 – FCR, aFRR, mFRR and RR. Followed by a mixture of closed-ended questions pertaining to the grid service characteristics (e.g. *is a load accepted for the provision of the service?*), technical requirements (e.g. *what is the requested minimum output duration of one activation?*) as well as utilisation and availability prices for the year 2016 were requested. With open-ended questions, the final section solicits information regarding general market trends and the existence of aggregators[1] on the market.

Unlike TSOs, a country can have hundreds of DSOs, hence 143 DSOs spanning all 30 countries were randomly selected for the survey. The questionnaire consisted of a section enquiring about the level of demand for the grid services (e.g. *How many hours per year would you typically activate the service?*) and their valuation (e.g. *How much would you pay for the availability?*). The following section enquires about any additional services, specific to the country in question, that can be provided by flexible loads e.g. *voltage control.* While the final section goes on to solicit general information regarding trends affecting the DSO markets, active aggregators and knowledge of any pilot projects testing DSO grid services.

For both questionnaires, the number of questions were kept to a minimum in order to increase the response probability. They were sent out in the winter of 2017/2018 via email and post with addresses sourced from the company web pages, and where possible, to individual DSO members. The TSO response rate was 30% where 12 out of 36 TSOs answered and returned the questionnaires. The DSO response rate was 4% where 6 out of 143 responses were returned from Spain, Bulgaria, Ireland, Latvia, Slovenia and Czech Republic.

Results from the survey were cross-checked with our understanding of the business logic underlying the TSO grid service markets and key sources as summarised in Table 1. Where necessary, results from the survey were crosschecked by means of telephone interviews conducted with TSO and DSO representatives throughout 2018/2019.

Table 1 Grid service market knowledge base

Information category	**Sources**
Balancing market surveys	[2], [3], [4]
TSO balancing products price and volume data repositories	[5], [6], [7], [8], [9], [10], [11], [12],
TSO market design proposals	[13], [14] , [15]

Although widely used by TSOs for reporting balancing prices and volumes, it came to light that Ensto-e’s transparency platform [6] at that time of writing was not coherent and sufficiently

[1] legal entities responsible for the operation of a number of power generating modules and/or demand facilities by means of pooling for the purpose of offering grid services.

easy to interpret. The reason for this is thought to be attributed to the fact that each TSO is given the responsibility of uploading their own data. As a result, varied interpretation of the data was required in addition to verification of the interpretation, without which would render the data unreliable.

3 Results

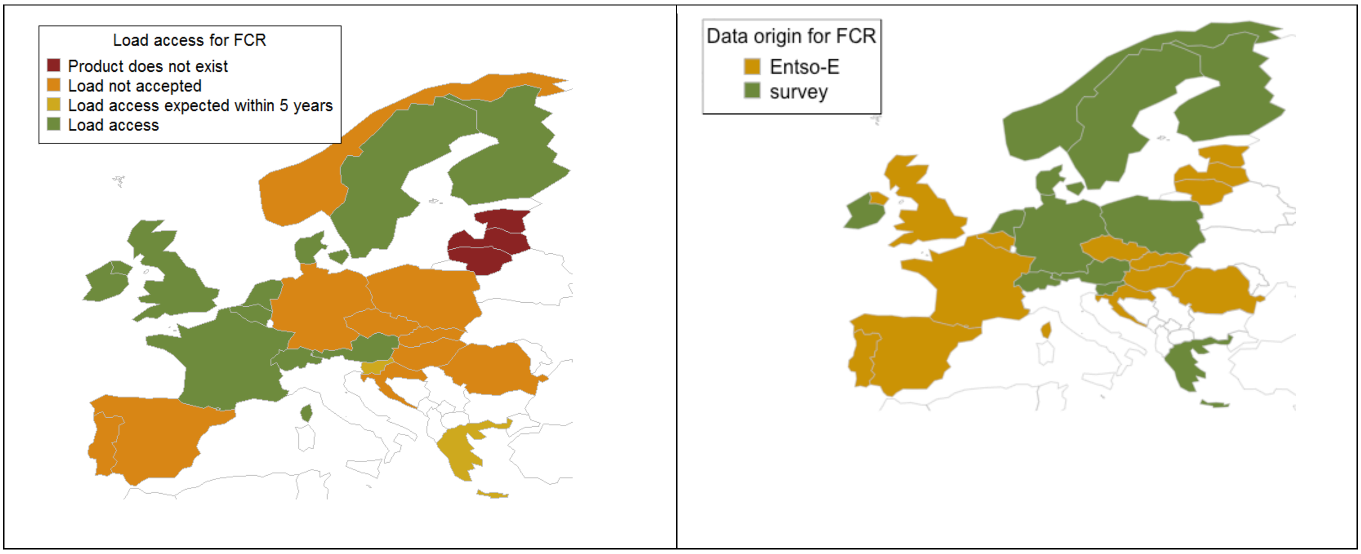
3.1 TSO Survey Results

The heterogenous nature of the national data and data quality available made it difficult to assess some cases, to this end, the evaluation of the TSO grid services bases on a combination of literature, expert interviews and the survey.

Malta is the only country without a TSO. The following countries did not reply to the survey: Italy, France, UK, Belgium, Bulgaria, Spain, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Luxemburg, Portugal, Romania, and Slovakia. While it could be confirmed from the Entso-e [2] and /or SEDC [3] surveys that Croatia, Estonia, Latvia, Lithuania, Poland, Portugal, Romania and Spain do not accept non-rotating masses and/or loads for the provision of TSO grid services. In the case of France, additional channels were explored to get into contact with the TSO, but with no response. Hence only official documentation was consulted. Although no response came from the UK, it was possible to establish a working channel of communication with the TSO for the provision and

verification of data. The result was 85 TSO grid services were identified as candidate cases for the application of distributed variable loads in the TSO grid service markets from the 30 countries. The following tables display a mix of the empirical data obtained from the survey in addition to secondary data from Entso-E [2] and SEDC [3]. FCR, aFRR and mFRR refer to groups of sub-products, which can be found in detail in Table 6.

Table 2 Load participation ('access') for different products in different EU countries



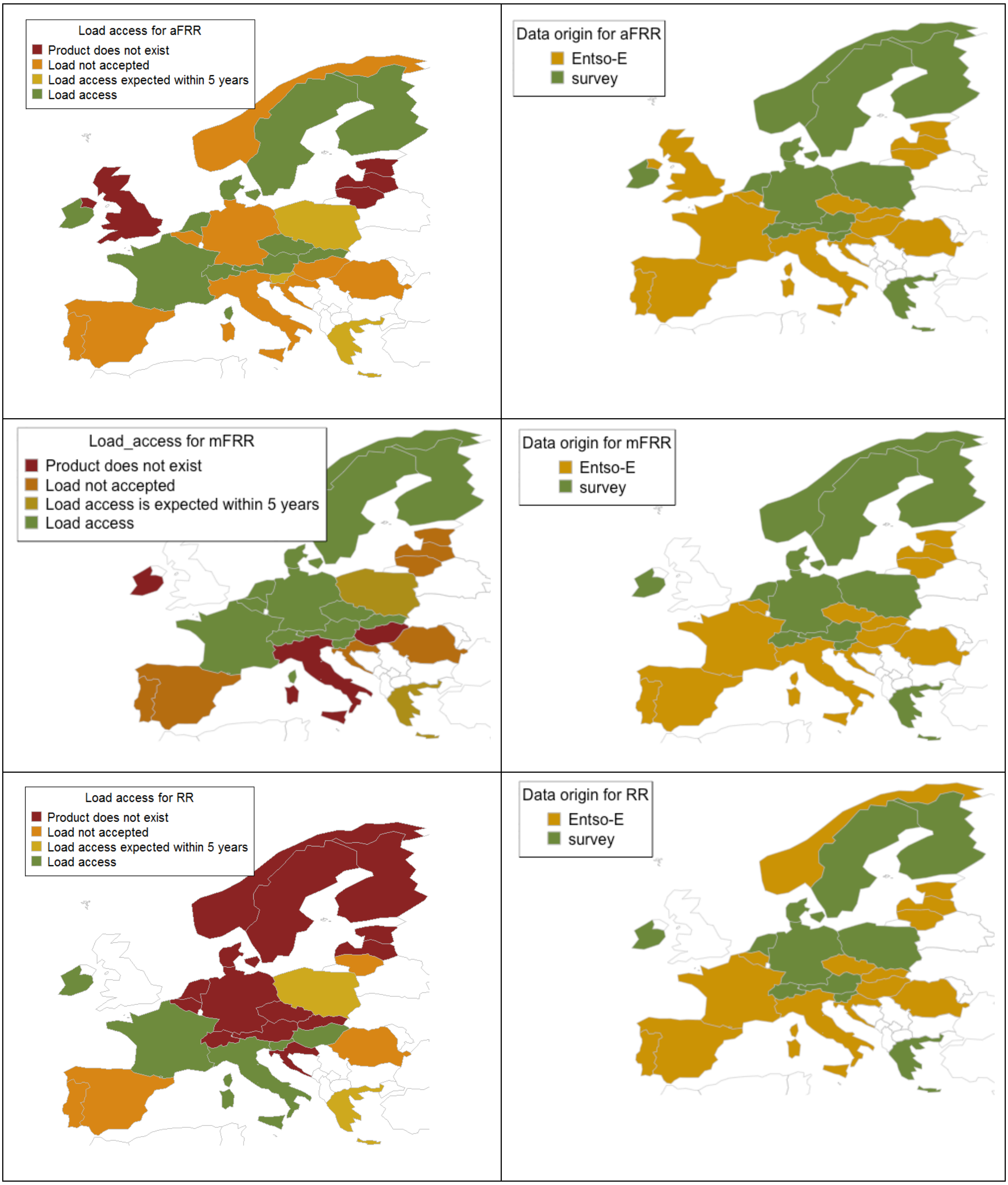

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Table 3 Non-rotating mass accessibility for different products in EU countries

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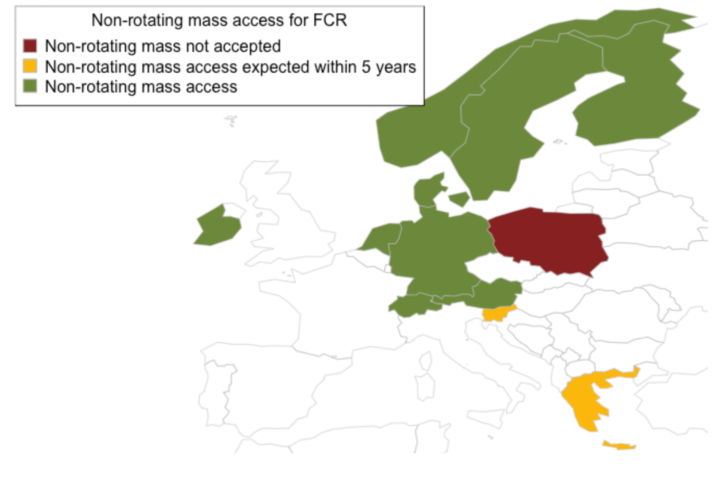
<tr><td>
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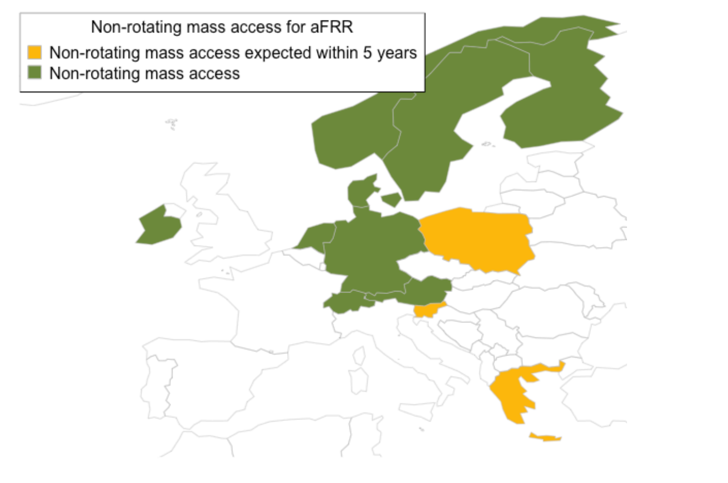
<tr><td>
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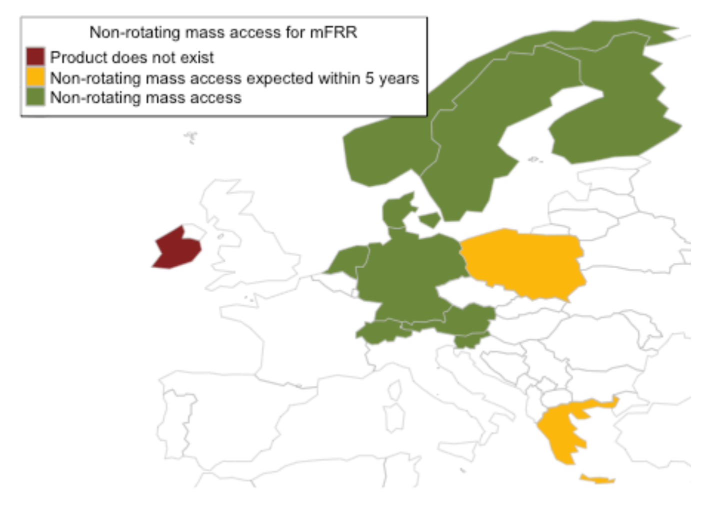
<tr><td>
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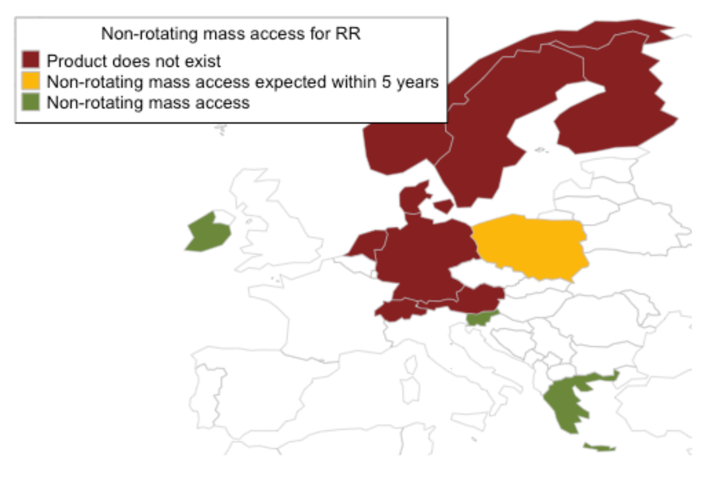
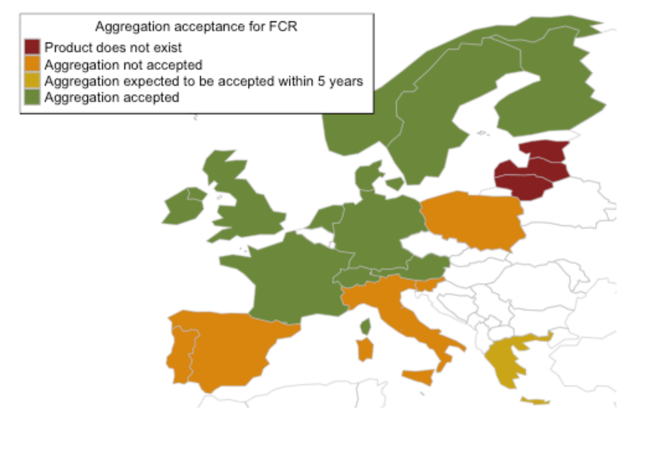
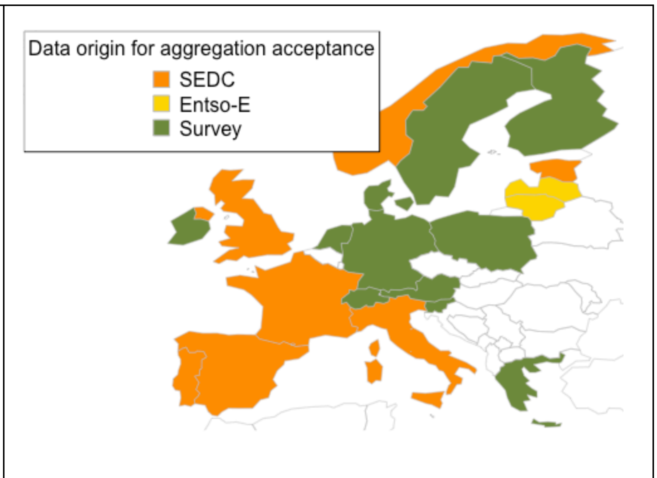
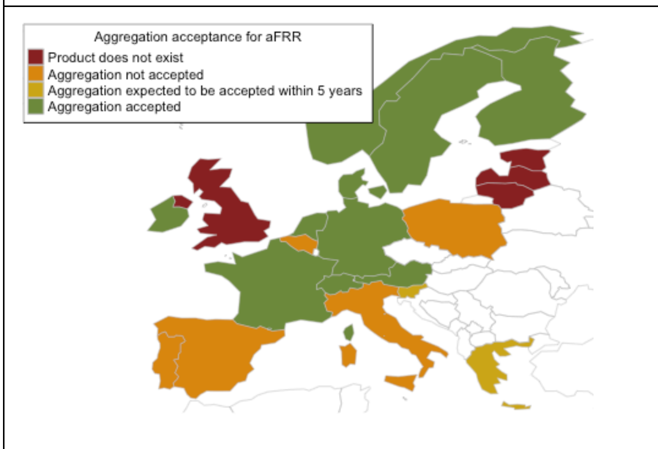
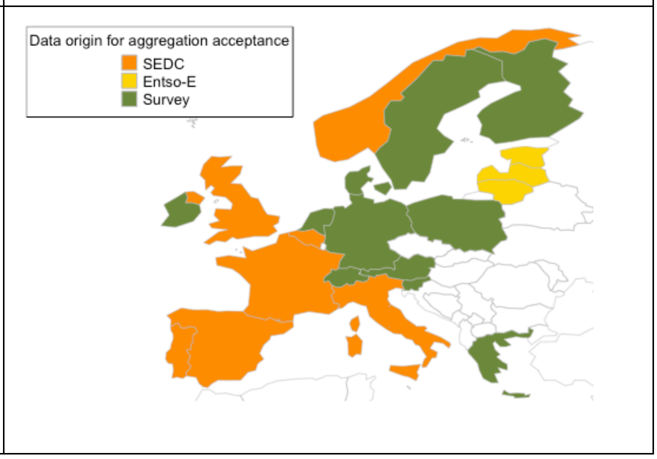


Table 4 Possibility of aggregation









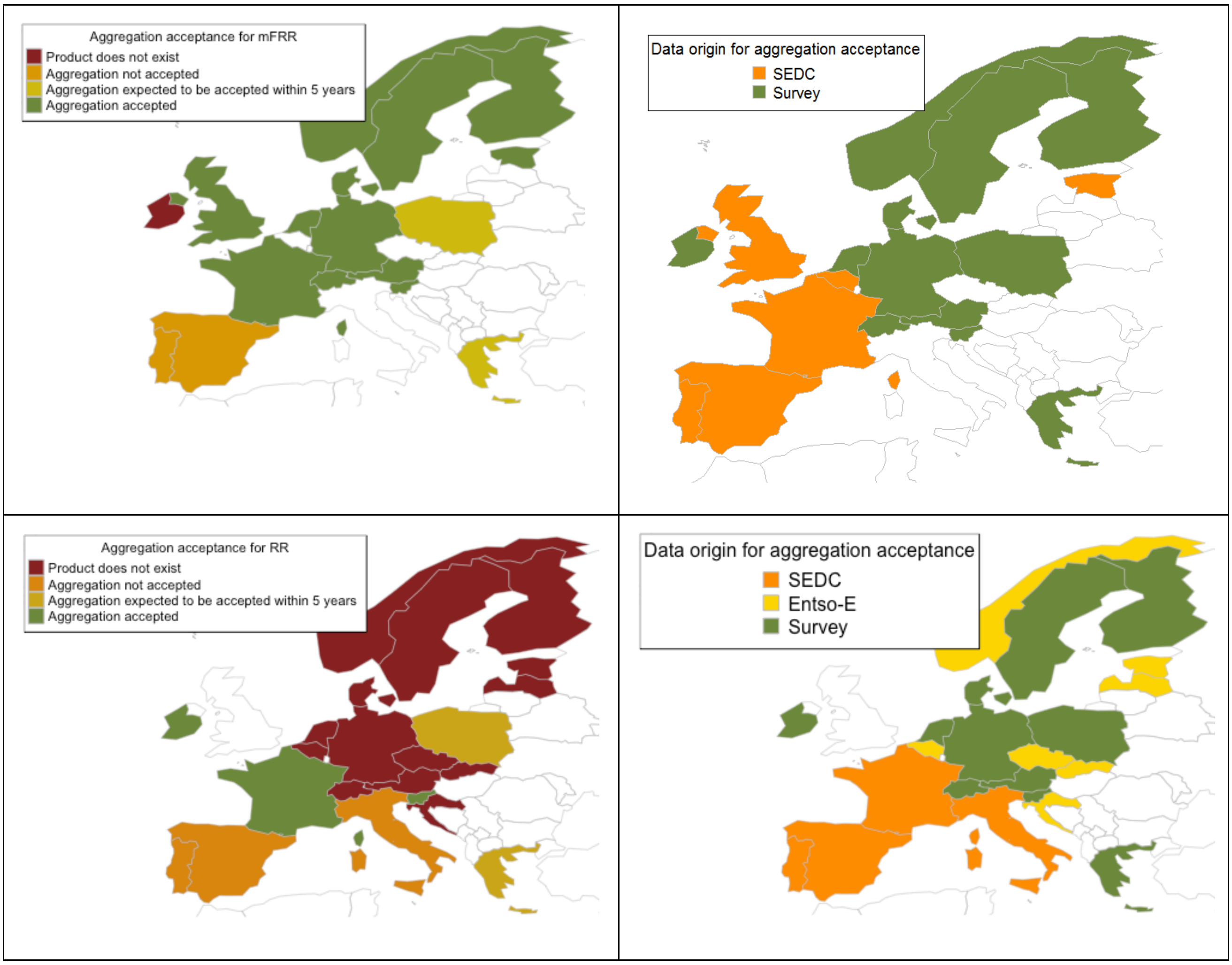
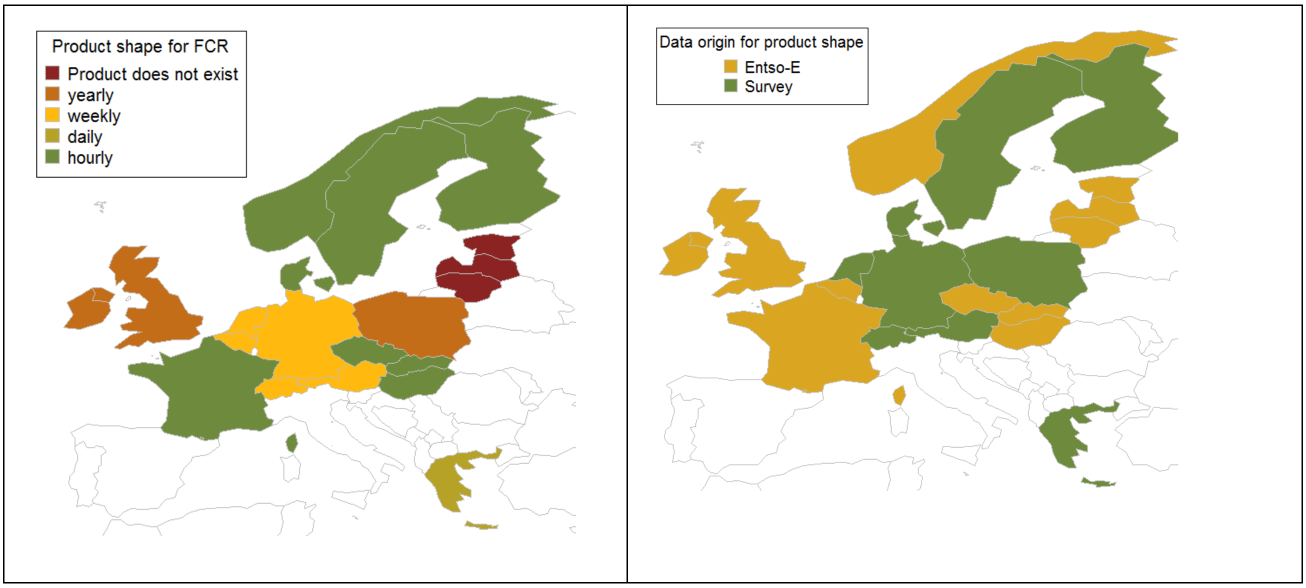
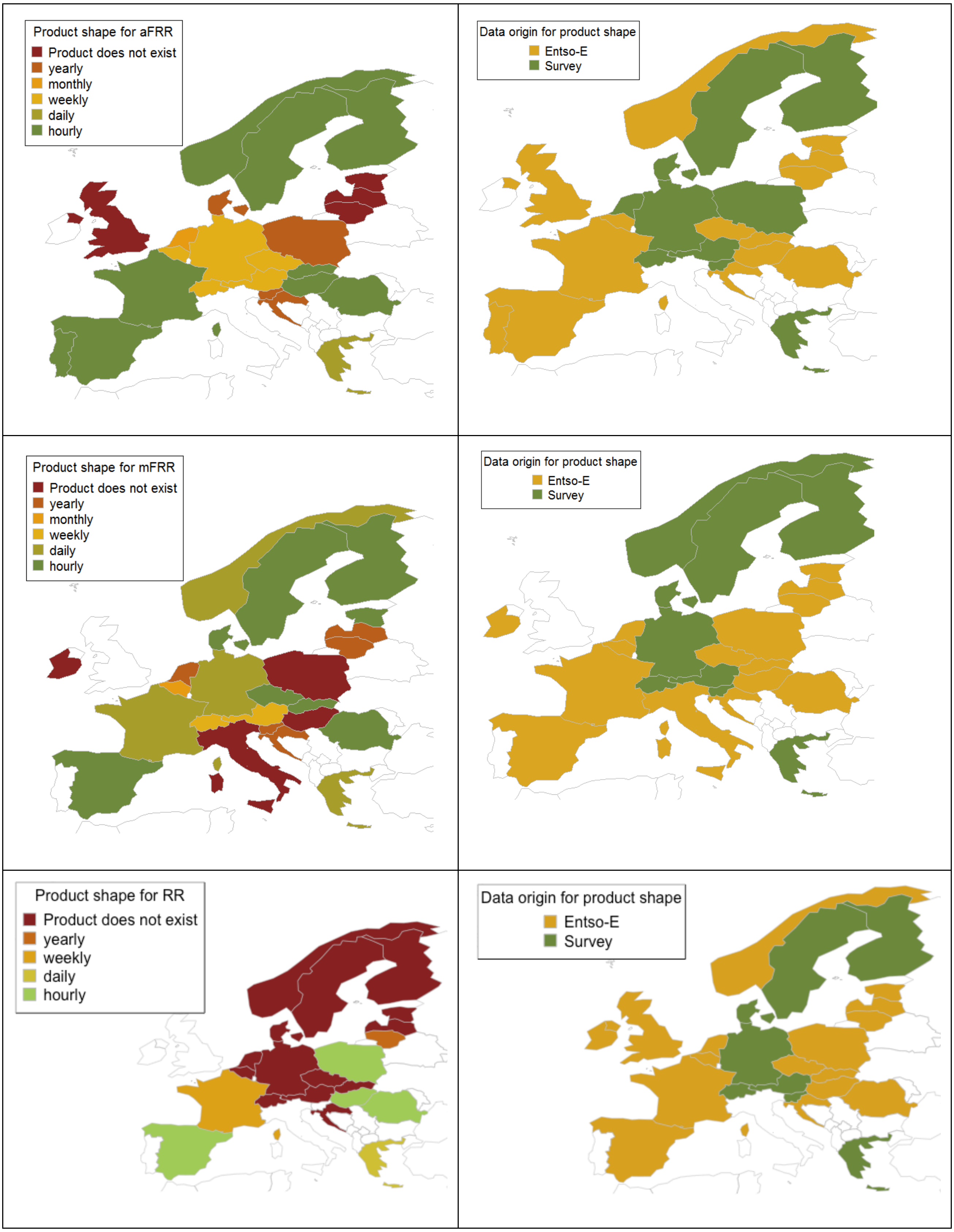


Table 5 Product shape (e.g. products with weekly, daily or hourly blocks)





From Table 2, the following can be seen:

- The aggregation is widespread

- mFRR is the most accessible market for distributed loads with regards to load access and the possibility of aggregation (with Ireland's mFRR being the only one closed to aggregation)
- Product shapes are predominantly hourly
- The Baltic states are mainly characterised as having mFRR yearly markets (apart from Lithuania's yearly RR and Estonia's hourly mFRR market), and as such can be characterised as being relatively closed and undeveloped markets.
- Greece and Poland in particular are expecting their balancing markets to be more accessible by 2021 with regards to the possibility of aggregation and load access.
- Markets found to be closed to aggregation are Poland, Portugal and Spain. With Poland expecting this to change for mFRR and RR by 2021.
- Markets found to be closed to non-rotating masses are Croatia, Czech Republic, Estonia, Latvia, Lithuania, Poland, Portugal, Romania and Spain.

Additionally, the following general market conditions were ascertained:

- The Nordic countries predominantly have a pay-as-cleared settlement rule for the procurement of capacity and energy of ancillary services, whereas the majority of countries utilise pay-as-bid (Austria, Switzerland, Germany, UK) and others such as France utilise pay-as-bid, pay-as cleared and regulated pricing depending on the markets and procurement type.
- Procurement schemes are largely market-based[2], some countries also make use of a combination of markets and mandatory participation of generators[3] (Denmark, France, Greece, Ireland, Norway and Poland).
- In many countries RR does not exist and for Nordic countries the same is true as mFRR fulfils the role of RR.
- The majority of FCR products are symmetrical, in line with Entso-E regulation, however a few asymmetric FCR products exist on the French and Nordic markets, such as the hourly and yearly FCR-D+ in Finland, the yearly FCR-D+ in Denmark East and FCR+ and FCR- in Denmark West as indicated in Table 6.
- Denmark was found to have a unique market setup. Although belonging to two separate synchronous areas: Denmark East (DK2) and West (DK1), it is considered to be one synchronous area with regard to mFRR on the Nordic Regulation Power Market (NORD POOL). Norway supplies Denmark East's aFRR capacity over the Skagerrak interconnection via Denmark West through a 5-year bilateral agreement (2015-2020).
- Expected changes in the next five years include:
  - a shift toward shorter resolution products e.g. hourly to quarter-hourly,
  - an acceptance of rotating masses or loads for the provision of grid services in those countries where it is not already practiced,
  - an acceptance of aggregation in those countries where it is not already practiced,
  - a smaller accepted minimum bid size.

3.1.1 Availability Prices

TSO grid services are generally valorised by two means: remuneration for availability ('power reserve') of the service provider, and remuneration for the utilisation ('energy'). Figure 1 shows the set of the average availability prices per country and product for the year 2016. The values for symmetrical products are divided by two for comparability with asymmetrical products. There are significant price differences among the countries. For example, average remuneration of availability for FCR in Norway (FCR-N) is 3.4 €/MW/h whereas in Finland (FCR-N hourly) it is 34.7 €/MW/h. Furthermore, availability of aFRR- is remunerated in Finland approximately 23 times higher than in Germany. Overall, the most favourable availability prices are exhibited by Finland, Switzerland and Denmark. In 2016 the Swedish TSO, Svenska

[2] Auctions, tenders and market platforms

[3] hybrid

Kraftnät, required only mFRR (which is remunerated for utilisation only) despite FCR and aFRR being tradable products on the balancing market [20]. Hence, FCR and aFRR do not appear in Figure 1. Despite no demand for FCR and aFRR, their market prices shown in Table 6 are understood as being the result of the system price[4], which is crucial for the price formation within other time windows such as the intra-day and balancing markets [21].

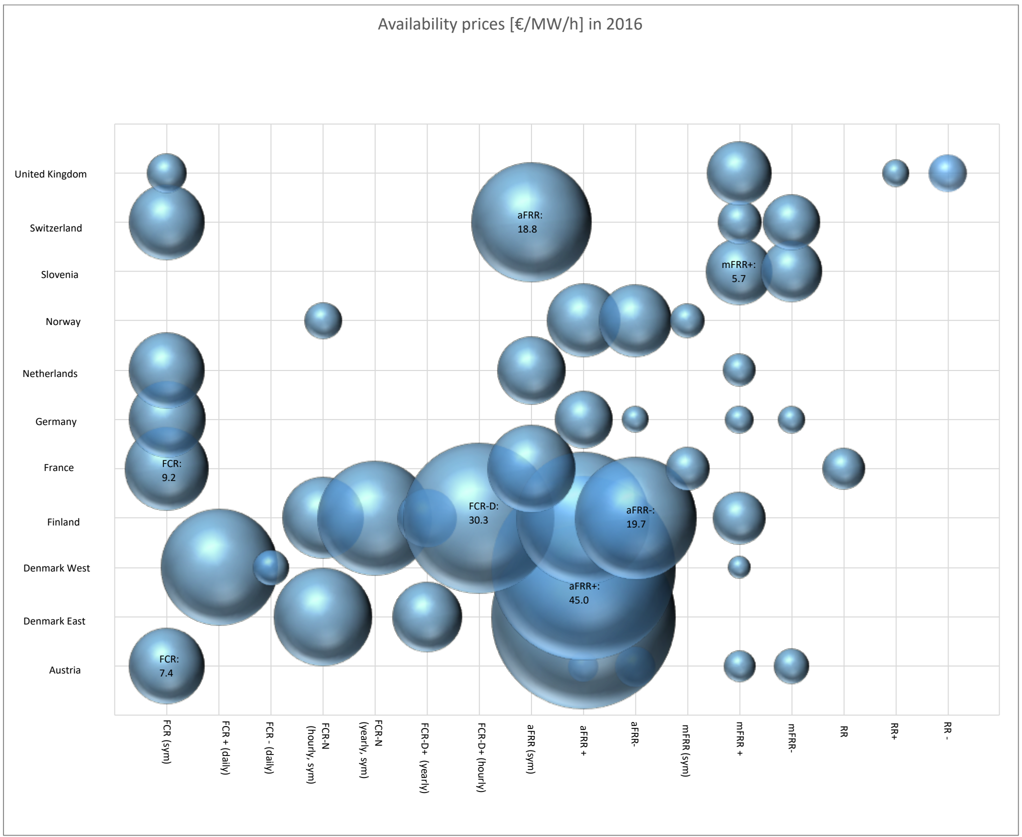


Figure 1 Average 2016 availability prices for FCR, FRR and RR and country specific products [€/MW/h in 2016]. The bubble size corresponds to price. Values for symmetrical products are divided by two for comparability with asymmetrical products. For Ireland, availability prices for FFR, POR, SOR, TOR, TOR2, RR are available but very low (≤3 €/MW/h) with products that are not standardized and therefore not shown in the plot. The numeric price data can be found in Table 6.

3.1.2 Utilisation Prices

Figure 2 shows the economic value added (EVA) from utilisation per country and product for the year 2016. The bubble areas are proportional to the EVA, where the additional income from activation is compared with a case where no income is received and the provider pays the average day-ahead price for electricity consumption which is assumed to be constant and equal to the national SPOT base price. Austria (mFRR), Germany (mFRR) and UK (RR) exhibit the most lucrative profits from their balancing products with respect to utilisation. The white bubbles exhibit cases with negative EVAs for example UK mFRR+. This is due to the day-ahead price of electricity (47.44€/MWh) for providing upward regulation costing more than the

[4] The common Nordic price for all hours of the next 24-hour period on the day-ahead spot market.

remuneration awarded for the service of upward activation of energy (2.77€/MWh). Effectively, the balancing service provider is running at a loss of 44.7€/MWh.

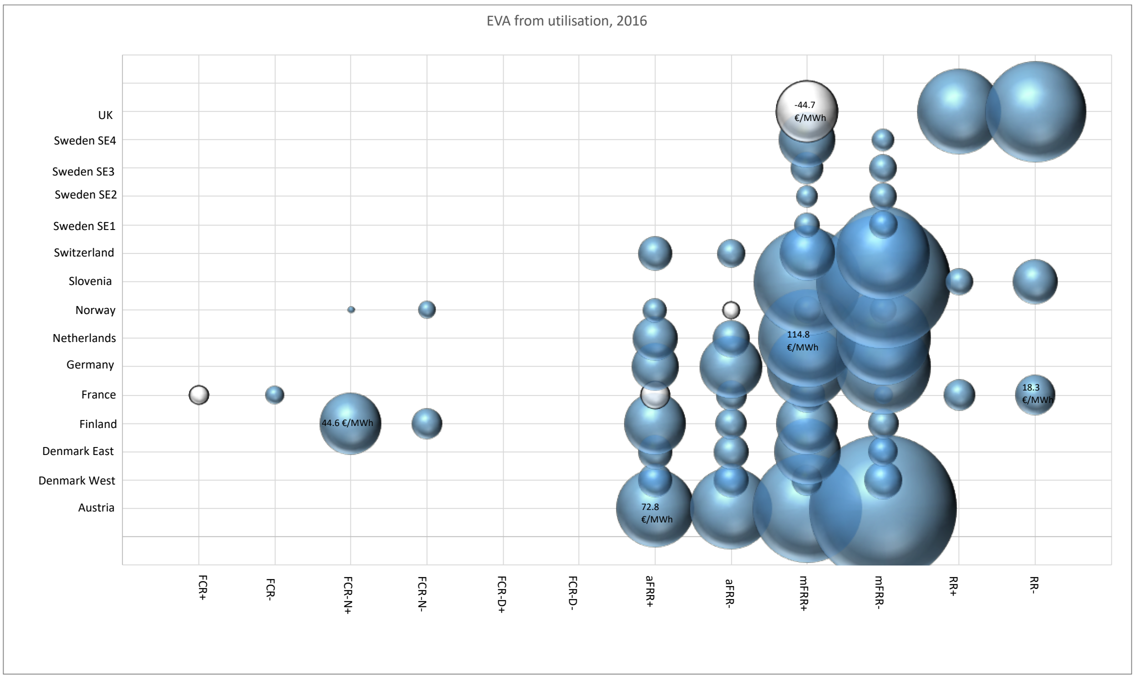


Figure 2 EVA 2016 from utilisation for TSO grid services. The area size corresponds to the EVA, where blue bubbles represent a positive profit, and white bubbles represent a loss.

Table 6 References for average price data. Availability prices for symmetric products are expressed as x/y, where y=½ x is the price comparable with asymmetric products.

Country	Product	Availability price [€/MW/h]	Utilisation price [€/MWh]	Reference
Austria[5]	FCR (symmetrical)	14.76 / 7.38	NA	[22], [23]
	aFRR+ (weekly average)	1.12	101.73	
	aFRR- (weekly average)	2.1	-49.61	
	mFRR+ (weekly average)	1.25	171.9	
	mFRR- (weekly average)	1.52	-232.57	
Denmark	FCR+ (DK1, daily)	17.98	NA	[16], [24], [25]
	FCR- (DK1, daily)	1.56	NA	
	FCR-N (DK2, yearly, symmetrical)	25.34 / 12.67	NA	
	FCR-D+ (DK2, yearly)	6.18	NA	
	aFRR+ (DK1, DK2)	90 / 45[6]	13.4	
	aFRR- (DK1, DK2)	90 / 45[7]	-13.4	
	mFRR+ (DK1)	0.62	37.43	
	mFRR- (DK1)	not traded	10.02	
	mFRR+ (DK2)	not traded	80.16	
	mFRR- (DK2)	not traded	19.63	

[5] Weekly averages are time weighted values based on weekly peak and off-peak products.

[6] Course estimate based on January and August Contracts 2016

[7] Course estimate based on January and August Contracts 2016

Country	Product	Availability price [€/MW/h]	Utilisation price [€/MWh]	Reference
Germany	FCR (symmetrical)	15.27 / 7.64	-	[26], [23]
	aFRR+	4.25	54.85	
	aFRR-	0.85	17.14	
	mFRR+	0.98	106.2	
	mFRR-	0.86	78.83	
Finland	FCR-N (yearly, symmetrical)	17.42 / 8.71	77 (up) 22 (down)	[27], [28]
	FCR-N (hourly, symmetrical)	34.7 / 17.36	77 (up) 22 (down)	
	FCR-D+ (yearly)	4.5	NA	
	FCR-D+ (hourly)	30.3	NA	
	aFRR+	23.4	77	
	aFRR-	19.7	22	
	mFRR+	3.6	77	
	mFRR-	not traded	22	
France	FCR+	9.18	32.47	[23], [29], [30]
	FCR-	9.18	32.98	
	aFRR+	10.04	27.14	
	aFRR-	10.04	26.38	
	mFRR+	2.37	50.84	
	mFRR-	not traded	32.78	
	RR+	2.23	47.97	
	RR-	not traded	18.50	
Ireland	FRR+	2.06	NA	[31], survey, cross checked with [32] and [33].
	POR+	3.09	NA	
	SOR+	1.87	NA	
	TOR 1+	1.48	NA	
	TOR 2+	1.18	NA	
	RR+ (synchronized)	0.24	NA	
	RR+ (desynchronized)	0.53	NA	
Netherlands	FCR (symmetrical)	14.91 / 7.46	NA	[34], [23]
	aFRR (symmetrical)	12 / 6	55 (up) 16.93 (down)	
	mFRRda+	1.28	147	
	mFRRda-	not traded	-74	
Norway	FCR-N (symmetrical)	3.44 / 1.72	26.41 (up) 22.75 (down)	[35]
	aFRR+	7.05	32.31	
	aFRR-	6.78	29.30	
	mFRR+	1.44	34.39	
	mFRR-	not traded	17.72	
Slovenia	aFRR (symmetrical)	20.89 / 10.44	55.8 (up) 18.6 (down)	[36], [37]
	mFRR+	5.71	173.8	
	mFRR-	4.84	-180	
	RR+	NA	43.9	

Country	Product	Availability price [€/MW/h]	Utilisation price [€/MWh]	Reference
	RR-	NA	13	

Sweden[8]	FCR-N (symmetrical)	25.65 / 12.83	SE1 35.89 (up) 20.01 (down)	[38],[39], [40], [28]
			SE2 34.06 (up) 20.81 (down)	
			SE3 41.07 (up) 20.78 (down)	
			SE4 66.05 (up) 24.22 (down)	
	FCR-D (symmetrical)	6.21	SE1 35.89 (up) 20.01 (down)	
			SE2 34.06 (up) 20.81 (down)	
			SE3 41.07 (up) 20.78 (down)	
			SE4 66.05 (up) 24.22 (down)	
	aFRR+ SE1	18	35.89	
	aFRR- SE1	9.5	20.01	
	aFRR+ SE2	18	34.06	
	aFRR- SE2	9.5	20.81	
	aFRR+ SE3	18	41.07	
	aFRR- SE3	9.5	20.78	
	aFRR+ SE4	18	66.05	
	aFRR- SE4	9.5	24.22	
	mFRR+ SE1	NA	35.89	
	mFRR- SE1	NA	20.01	
	mFRR+ SE2	NA	34.06	
	mFRR- SE2	NA	20.81	
	mFRR+ SE3	NA	41.07	
	mFRR- SE3	NA	20.78	
	mFRR+ SE4	NA	66.05	
	mFRR- SE4	NA	24.22	
Switzerland	FCR (symmetrical)	14.63 / 7.32	NA	[23], [14], [41]
	aFRR (symmetrical)	37.65 / 18.82	50.82 (up) 28.91 (down)	

8 Only mFRR is currently demanded by Swedish TSO, hence Swedish aFRR and FCR are not included in the price comparison shown in Table 6.

	mFRR+ (weekly)	2.38	73.07	
	mFRR- (weekly)	4.03	-65.05	
United Kingdom	FFR (symmetrical) (FCR)	4.03 / 2.02	NA	[8], [42], [43]
	Fast Reserve+ (mFRR+)	5.3	2.77	
	DTU- (RR-)	1.8	73.08	
	STOR flex+ (RR+)	1.07	132.09	

3.2 DSO Survey Results

For DSO grid services, no relevant established market with transparent price information, product definitions and market rules were found in Europe. The survey responses were unanimous in that none of the DSOs could valuate[9] congestion management, capacity management or voltage control (where included). Moreover, none could offer any response to the hours of availability these services would typically be provided in a year. From this it can be understood that no DSO grid service markets exist as of yet. Some responses were explicit in stating this outright in Table 7. The following responses broadly summarise the main positions of the DSOs:

- in Latvia the TSO provides these services rather than the DSO,
- the Czech DSO has no legal right to procure non-frequency ancillary services (AS) [10]
- in some cases, services do not exist on the distribution level,
- in other cases, congestion problems are not being experienced in the distribution network and therefore warrant no need for DSO grid services as of yet,
- some DSOs do not perceive load flexibility as being valuable, while others do not expect any kind of revenue generation from it in the future as it will be expected to become a mandatory requirement for loads in any case; similar to other generators,
- as mentioned prior in Spain and Portugal, loads have no legal right to provide AS,
- voltage control on the medium voltage (MV) level is provided via different means in Bulgaria, Czech Republic and Latvia.

Further details can be found in Table 7.

Table 7 Summary of key statements from the DSO survey

Country / DSO	Summary
Bulgaria / CEZ Distribution Bulgaria	Survey not filled in[11] The majority of the DSO grid consists of single medium voltage (MV) feeders According to legislation DSOs cannot operate RES in real time Voltage regulation in the distribution network, as part of **voltage and reactive power management in the power system, is tertiary regulation**
Czech Republic / CEZ Distribuce	**Retailers act as aggregators** and will continue to have this role in Czech Republic Demand response is in place to deal with decreasing loads

[9] in €/MW and year of availability

[10] voltage control, inertia and black-start capability among others.

[11] Correspondence via email clarifying position in response to survey

	Possible future grid services are defined by the European Commission's Clean Energy Package, under which **DSOs will only be allowed to procure non-frequency Ancillary services (AS)** **Voltage control:** • Is currently procured through reactive power from large generating assets in the HV/MV grid with a wide reactive power range • **Is not remunerated by DSOs and is compulsory** for all new generation offering active power control in a narrow range • **the most promising and cost-effective way for DER integration** on the DSO level is via reactive power It was pointed out that WP6 of a pilot project (InterFlex[12]) focuses on flexibility on the DER and EV side and it states that **flexibility** is foreseen as **a future requirement of DER or EV without remuneration.**
Ireland / ESB Networks	**Does not perceive flexible high-power load as valuable.** Aggregators are on the market but ESB has no contractual relationships with them
Latvia / Sadales tikls AS	• **Latvian DSOs are not working to create flexibility services yet** given that Latvia has few distributed generating units • **Congestion & capacity management are provided by TSO**. • Voltage regulation in MV is provided via local regulation of transformer voltage output if necessary • No aggregators are active in DSO grid services provision
Slovenia / Regional distribution company: Elektro-Gorenjska	• Elektro-Gorenjska is **not experiencing any congestion or capacity problems** • Elektro-Gorenjska has no involvement in DSO grid services • No aggregators are active in DSO grid services provision
Spain / Endesa	• **Participation of loads in the provision of AS is not allowed in the Iberian Peninsula** • **No specific services have been developed for the distribution network** that could be covered in the future by demand aggregators. • Based on the market design principle of the necessity for suppliers to participate in equal conditions, if demand was allowed to participate in AS then no payment for capacity (€/MW/yr) would be awarded or would be justifiable for congestion management until the scheme were implemented for generators alike

4 Conclusion and Outlook

The surveys were sent out to 36 TSOs and 143 DSOs in the EU, in an effort to obtain primary data on electricity grid service markets, identified were 85 TSO grid services within 12 countries as being commercially and technically feasible candidates for distributed variable loads, such as water electrolysers – a key technology of sustainable hydrogen production, that can offer high operational flexibility for the grid services identified.

[12] EU Horizon 2020 project that explores pathways to adapt and modernize the electric distribution system in line with the objectives of the 2020 and 2030 climate-energy packages of the European Commission.

TSO grid services are generally valorised by two means: remuneration for the availability (‘power reserve’) of the Reserve Providing Unit, and remuneration for utilisation (‘energy’). While distribution system operator grid services were found to have no relevant established market with transparent price information and product definitions in Europe.

The TSO grid service markets differ among countries with regard to market rules, market transparency and price levels. For example, average remuneration of availability for FCR in Norway (FCR-N) is 3.4 €/MW/h whereas in Finland (FCR-N hourly) it is 34.7 €/MW/h. Furthermore, availability of aFRR- is remunerated in Finland approximately 23 times higher than in Germany, with similar spreads found with the other products. Overall, the most favourable availability prices were found in Finland, Switzerland and Denmark and the most favourable utilisation prices were found in Austria, Germany and the UK.

Congestion management, capacity management and voltage control are grid services not offered on the DSO level for different reasons depending on the country.

Most changes in the next five years are particularly expected in those countries whose barriers to market entry for distributed variable loads are relatively high whereas those countries whose markets are more advanced anticipate having shorter time resolution products.

A general sentiment is that the emergence of the harmonisation of the EU electricity balancing markets is expected to have the effect of converging market mechanisms, product prices, types and requirements for efficient cross-border trading and crucially improving data transparency.

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