SMART REGULATORY FRAMEWORK

DELIVERABLE 1.3

CALLIA- Open Inter-DSO Electricity Markets for RES Integration

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DOCUMENT INFORMATION

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SUMMARY

Task 1.3 deals with the regulatory aspects of energy markets, trading and system operation in Europe specifically to try and integrate the CALLIA market concept developed during the project with the existing markets. The design of new products and services during the course of CALLIA, might necessitate making certain adjustments to the framework. Conversely, the analysis of existing regulatory frameworks helps to design the market, products and services in a way that may reduce the necessary adjustments to be made as far as possible.

To identify those fields where adjustments may be necessary, the Turkish and German, as well as the Austrian and Belgian grid structures, daily operation and regulatory frameworks have been analyzed and compared.

Those fields of operation that might pose hindrances, or might need to be adjusted, to/for the integration of the concepts developed during CALLIA with the existing regulatory framework, have been elaborated upon in this document as well as the Deliverable 1.2.

This task works in close co-ordination with tasks 1.1, 1.2 and Work Package 3.

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LIST OF ABBREVIATIONS AND ACRONYMS

Acronym	Meaning
DER	Distributed Energy Resources
TSO	Transmission System Operator
RES	Renewable Energy Source
DSO	Distribution System Operator
BRP	Balance Responsible Party
PV	Photovoltaic
HV	High Voltage
MV	Medium Voltage
LV	Low Voltage
kV	Kilovolt
TWh	Terrawatt-hours
MW	Megawatt
kW	Kilowatt
DA	Day-Ahead Markets
DACF	Day Ahead Congestion Forecast
ID	Intra-Day Markets
OTC	Over The Counter Trading
PCR	Price Coupling of Regions
ATC	Actual Transfer Capacity
FCR	Frequency Containment Reserves
aFRR	automatic Frequency Restoration Reserves
mFRR	manual Frequency Restoration Reserves
RR	Replacement Reserves
WP	Work Package
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
ACER	Agency for the Cooperation of Energy Regulators
NRA	National Regulation Authority
BNetzA	Bundesnetzagentur (Federal Network Agency of Germany (NRA))
EURELECTRIC	European Union of Electricity Industry

LIST OF EUROPEAN REGULATIONS AND GUIDELINES

Relevant regulations and guidelines for the European energy system:

Acronym	Meaning
NC CACM[1]	Network Code on Capacity Allocation and Congestion Management
NC EB	Network Code on Electricity Balancing
NC FCA	Network Code on Forward Capacity Allocation
NC ER	Network Code on Emergency and Restoration
NC OPS	Network Code on System Operations
NC DC	Network Code on Demand Connection
NC HVDCC	Network Code on High Voltage Direct Current Connections
NC RG	Network Code on Requirements for Generators
96/92/EC	Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity.
2003/54/EC	Update of Directive 96/92/EC
Regulation EC No 713/2009	Regulation (EC) No. 713/2009 of the Parliament and of the Council of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators.
Regulation EC No 714/2009	Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003
2009/72/EC	Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC
Regulation EC 2016/679	Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data

[1] All Network Codes are subject to be transformed into EU regulations (instead of ENTSO-E codes). Some of them are already transformed (e.g. Regulation EU 2016/631). https://www.entsoe.eu/network_codes/

LIST OF NATIONAL REGULATIONS

Relevant laws and directives for the Germany energy system:

Acronym	Meaning
EnWG	Energiewirtschaftsgesetz (German Energy Industry Act)
Strommarkt-gesetz	Gesetz zur Weiterentwicklung des Strommarktes (German Law for Energy Market Development, forces changes in EnWG)
EEG	Erneuerbare-Energien-Gesetz (German Law for Renewable Energies)
StromNZV	Stromnetzzugangsverordnung (German grid access regulation)
StromNEV	Stromnetzentgeltverordnung (German grid fees regulation)
TC 2007	German Transmission Code 2007 (VDE), sets rules for general transmission system operation, ancillary services, grid expansion and connection of units
DC 2007	German Distribution Code 2007 (VDN), sets rules for general distribution system operation, ancillary services, grid expansion and connection of units
ARegV	Anreizregulierungsverordnung (German incentive regulation)
NetzResV	Netzreserveverordnung (German regulation on rules or procurement and provision of units in the grid reserve)
AbLaV	Verordnung zu abschaltbaren Lasten (German regulation on agreements for defeatable loads)
MsbG	Messstellenbetriebsgesetz (German Law on the operation of meausering points and the data communication in smart grids)
GzDdE	Gesetz zur Digitalisierung der Energiewende (German Law on the digitalization of the energy transition, forces changes in MsbG)
MessEG	Mess- und Eichgesetz (German Law on placing on the market and provision of meters, their usage and gauging and their prepacking)
BDSG	Bundesdatenschutzgesetz (German Law on data privacy)
StromGVV	Stromgrundversorgungsverordnung (German regulation on common conditions for the basic supply of household customers and the substitute supply with electric energy from the low voltage grid)
NAV	Niederspannungsanschlussverordnung (German regulation on common conditions for grid connection and its usage for the electric energy supply in low voltage)

1 INTRODUCTION

In order to achieve Europe's energy targets, a grid secure integration of RES at all voltage levels is one of the main challenges. Within CALLIA, the challenges, opportunities and requirements for open inter-DSO electricity markets which aim to foster the integration of RES and other flexible production, consumption or storage devices and technologies have been investigated. Thereafter, products and services that were derived have been mapped on multi-actor business case models for intra-DSO and inter-DSO balancing and trading [1].

Besides technical and economic constraints, there are regulatory aspects that must be taken into account for the implementation of the elaborated market concepts; firstly, in the field tests of CALLIA and secondly, in the landscape of European energy markets and system. As the first step, Stadtwerke Heidelberg Netze, University of Stuttgart IFK, TransnetBW and REstore have analyzed the European and national regulatory frameworks. Thereby, possible hindrances that could impede balancing and trading at the distribution grid level have been identified. Secondly, recommendations have been made, as to how these hindrances could be reduced and/or overcome.

For this deliverable, relevant regulatory documents have been considered; laws, regulations, mandatory technical standards and publications of related market parties and regulatory agencies. The analysis of these documents resulted in the definition of four main clusters of regulation, where adjustments could be necessary: Energy markets, grid operation, RES and flexibility and digitalization. The regulatory configuration was studied in detail for Germany. Important aspects from Austria, Belgium and Turkey have been added to outline the bigger picture. A summary on the Turkish regulatory framework is given in the appendix 1. As in western Europe the regulatory framework is quite advanced, there is still a lack in the Turkish system, especially regarding the integration of renewables into the grid.

With the knowledge of all regulatory aspects and the elaboration of the CALLIA market concept that takes grid constraints into account with a market platform, products and services, a set of important regulatory questions have been formulated. Finally from the associated discussions and answers to these questions, recommendations for reducing and eventually eliminating regulatory hindrances have been derived and depicted. In this context, the bdew-traffic light concept has also been enhanced. These questions have been included in the deliverable of task 1.2.

It is to be noted that the CALLIA field test could not consider regulatory changes thereby demonstrating a pilot outside of the national regulation. Within Germany, there was a possibility of using an "experimental-clause", that has been implemented into law. Nevertheless this "experimental-clause" is only to be admitted to the German SINTEG-program [2]. Therefore, the existing and valid regulatory frameworks (especially in Germany and Turkey where the field tests took place) were adhered to, during CALLIA. Hence, it was only possible to make recommendations for the field test, since we were unable to validate our recommendations with real data but have done so only with the results of the simulations in Task 1.1 and Task 3.1.

2 GLOSSARY

Term	Definition
Balancing	Balancing mainly ensures that precisely the same amount of electricity is fed into the power grid as is simultaneously drawn from the grid. In short, it involves the obligations to incorporate all generators and consumers into balancing groups, report balancing schedules based on generation and consumption forecasts and to charge for any unforeseen imbalances using an imbalance settlement system.
Reserve power	In case of frequency deterioration, transmission system operators use balancing power to stabilize the grids. In order to do so, market parties offer three products for frequency restoration. This is (i) primary balancing capacity (frequency containment reserve), that must be fully available within 30 seconds, (ii) secondary balancing capacity (Frequency restoration reserve), within 5 minutes and (iii) the minute reserve (restoration reserve), which must be available within 15 minutes of being requested. [3]
Organized exchange	Organized exchange markets are essentially centralized markets where a regulator is used to complete transactions. It is a standard contract and ensures transaction security. There is less chance of price manipulation in organized exchange markets.
Derivatives market	Derivative markets are financial markets where contracts exist, which derive their values from the prices of an underlying commodity. These markets could be a combination of spot and/or forward markets.
Spot market	Spot markets are physical markets that account for immediate delivery of products or services. They encompass the day-ahead and the intra-day markets.
Day-ahead market	Electricity deliveries for the next day are auctioned on the day-ahead markets, with suppliers and buyers having to submit their bids by noon on the previous day.
Over the counter	On the forward market, companies can agree to deliveries up to six years in advance, with trading for the next three years being particularly liquid. These trades which are agreed outside of the exchange are called over the counter (OTC) trading.
Intraday market	Intraday markets are short term markets that close 45 minutes before delivery.
Flexibility	Ability of a generation unit (including RES), storage system or controllable load to change its generation or consumption based on predefined signals in order to provide ancillary services within the power system [4].
Redispatch	In the occurrence of grid bottlenecks or critical grid situations, observed by TSOs via grid flow calculations, can be avoided with the TSOs instructing power plants, wind farms and solar power plants to adjust their planned production of electricity.
Feed-in management	Shutdown of RES, CHP or mine gas in order to avoid or remedy congestion in the grid. Mostly wind and PV units are controlled. Feed-in management is used if the redispatch potential is not large enough to manage congestion.

3 ELECTRICAL POWER SYSTEMS IN DIFFERENT COUNTIRES IN EUROPE

This section gives a brief overview about the electric power structures in the partner countries for the CALLIA project. 0 focuses on Germany. 0 deals with the power grid in Turkey. 0 and 0 talk about the Austrian and Belgian grid respectively. Since the field tests were performed only in Germany and Turkey, 3.5 gives a direct comparison between the two countries with respect to its grid structure.

3.1 Germany

Germany comprises of four transmission system operators (TSO), TenneT, 50Hertz Transmission, Amprion and TransnetBW, that look after the secure operation of the infrastructure of the transmission grids, maintaining them, building new powerlines, and granting electricity traders/suppliers with non-discriminatory access to these grids. They are supervised by the Bundesnetzagentur (Federal Network Agency), which for example authorizes grid expansion and grid-use fees [5].

Transmission grids facilitate the transport of electricity over large distances throughout Germany and even across borders, with a minimum of loss, and directly to the areas where the power is consumed. The German high voltage grid is linked to the wider European grid by interconnectors. The total length of the German transmission grids is about 36,000 kilometers. In the case of alternating current (AC), electricity is transmitted with a maximum voltage of 220 kilovolts (kV) or 380 kV; the voltage of the planned new high voltage direct current (DC) transmission lines will be up to 525 kV [5].

At the level of the distribution grids the electricity is transmitted at high, medium and low voltage. Lower voltage grids distribute the power to end users. There are a large number of regional and municipal grid operators in this sector [5].

- High voltage: 60 kV to 220 kV (grid length approx. 96,000 km) - The high-voltage grid is the link to the ultra-high voltage grid (transformers). High-voltage grids distribute the electricity to urban areas or directly to major industrial concerns.
- Medium voltage: 6 kV to 60 kV (grid length approx. 520,000 km) - The medium voltage grid distributes the electricity to regional transformer substations, or directly to large facilities such as hospitals or factories.
- Low voltage: 230 V or 400 V (grid length approx. 1,120,000 km) - The low voltage grid is used for fine distribution of the electricity. The low voltage grid serves private households, small industrial companies, commercial enterprises and office premises.

Stadtwerke Heidelberg Netze GmbH is a Distribution System Operator that is responsible for the 110 kV, 20 kV medium and 400 V low voltage levels. There are large differences between the DSOs. Some of them are responsible for a large area over all distribution voltage levels (e.g. Netze BW, Westnetz or Mitnetz). However, most DSOs are responsible for grids comprising the area of a city and its surroundings (like Stadtwerke Heidelberg Netze GmbH) or even smaller areas.

The total electricity generation in Germany is around 654 TWh (2017). The share of RES was 33.3%. The installed capacity is around 203 GW, where RES have a share of ca. 55%.

3.2 Turkey

With a young and growing population, low per capita electricity consumption, rapid urbanization and, until recently, strong economic growth, for nearly two decades, Turkey has been one of the fastest growing power markets in the world. Prior to Turkey's recent economic difficulties, projections by Turkey's Electricity Generating and Transmission Corporation, a public company which owns and operates 15 thermal and 30 hydroelectric plants generating 91% of Turkey's electricity, had indicated that rapid growth in electricity consumption would continue over the next 15 years [6].

With a transmission grid of 66,285 km, the total energy generation and consumption of Turkey is around 227.4 TWh [7]. The Turkish electrical power system is a little different in comparison to the German one with respect to its size, number of system operators as well as the responsible voltage levels. Turkey has one Transmission System Operator, TEİAŞ, that is responsible for the voltage levels of 66, 154, 220 and 380 kV. Its 21 DSOs, one of which is BEDAŞ, are responsible for the 33 kV, 15.8 kV and 10.5 kV at the medium voltage and 400 V at the low voltage levels.

3.3 Austria

The Austrian power system comprises of one TSO, the Austrian Power Grid, responsible for the voltage levels above 110 kV (380 kV, 220 kV and 110 kV) with a length of over 6,700 km and 17 DSOs responsible for the same voltage levels as those of the German DSOs [8].

3.4 Belgium

Elia System Operator is the Belgian Transmission System Operator responsible for voltage levels between 30 and 380 kV. Its 8 DSOs are responsible for the voltage levels of lower than 30 kV. The Belgium transmission grid is shown in Fig. 1. There are 30 and 36 kV underground cable networks, in the Brussels and Antwerp areas. These are not distribution networks because they are meshed and play the role of sub-transmission grids [9].

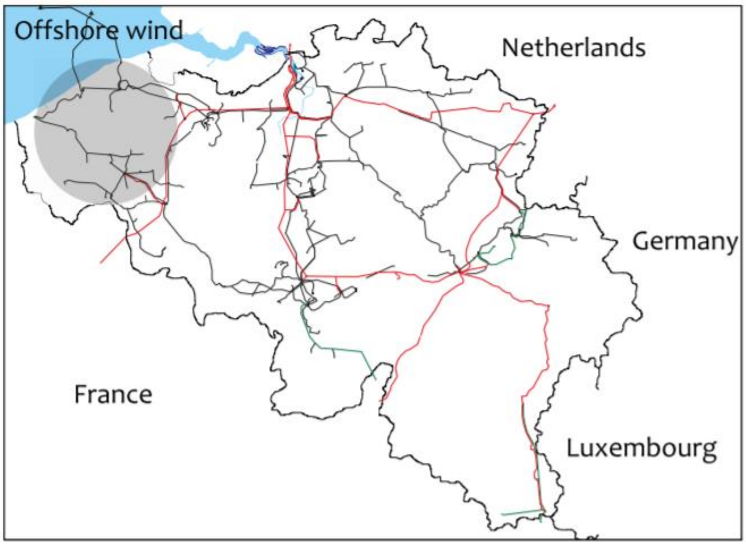

Fig. 1: Overview of the Belgian transmission grid, red 380 kV, black 150 kV, grid congestions mainly occur in the grey area [10]

3.5 Comparison between grid structures in Germany and Turkey

In CALLIA, two DSOs, one from Germany (Stadtwerke Heidelberg Netze GmbH (SWH-N)) and one from Turkey (BEDAŞ) are project partners. The general structures and the main differences between the two of them are shown in Table 1.

Table 1: Comparison between German and Turkish DSOs in CALLIA

Parameters	SWH-N	BEDAŞ
Voltage levels	110/20/0.4 kV	34/15.8/10.5/0.4 kV
Line length	HV cables 46.2 km, HV OH lines 4.7 km	Not Applicable (NA)
	MV- UG lines 409.6 km	MV - UG lines 6500 km, MV OH lines 2000 km
	LV - UG lines 1133.5 km, LV - OH lines 111 km	LV - UG lines 17000 km, LV - OH lines 5200 km
The number of substations	8	33
The annual peak consumption	152 MW	5400 MW
The total size of DER capacities	40 MW	125 MW
The number of transformers	14 for 110/20 kV voltage level	NA
	1147 for 20/0.4 kV voltage level	12000 for 34/15.8/10.5/0.4 kV voltage level
Communication infrastructure	IEC 60870–5–104	IEC 60870-5-104, IEC 61850 and Modbus TCP
Control system	SCADA without any interface with GIS	SCADA with GIS interface
Power System Analysis Tool	Neplan	CYME

4 EXISTING REGULATORY FRAMEWORK

4.1 Grid Operation

According to the Energy Industry Act [11] in Germany, specifically §§ 13 and 14, every transmission and distribution system operator has to ensure efficient, safe, secure and reliable operation in their respective grid areas. In case of hazardous grid situations, like congestion or imbalances, system operators are obliged to take the following measures:

- Grid related measures
- Market related measures
- Cascading operation

The following sub-chapters mainly deal with the different measures carried out by grid operators in Germany and differences, if any, between the partner countries have been penned down wherever possible.

Grid operation is a natural monopoly and is thus subject to regulation. The European regulatory authority, ACER [12], together with the European commission, has defined the framework for this regulation. ENTSO-E [13] has drafted and periodically updates, with relevant stakeholders, the requirements of the network codes and guidelines, e.g. System Operation Guideline (SOGL). National regulatory authorities oversee the drafting and implementation process of guidelines into their national legislation. Thus, the guidelines of the different member states are assumed to be more or less similar. The existing differences, if any, when it comes to Austria, Belgium, Germany and Turkey have been pointed out in this report.

Apart from the regulatory guidelines with regard to the DSO-DSO and TSO-DSO relationship, some supplementary developments have arisen in this sub-chapter due to the progressing energy transition. These developments have also been addressed as they are important for understanding the relationship, communication and emerging collaboration between DSOs and TSOs, which is the central issue in CALLIA, shown by partners from both DSOs (SWH-N and BEDAŞ) and TSO (TransnetBW).

4.1.1 Existing roles of DSOs and TSOs

In this sub-chapter, the general tasks and obligations of grid operators have been described. Therefore, the EU energy packages and the ENTSO-E Network Codes [14] have been considered and how these were implemented within the German national regulation has been described.

As already mentioned at the beginning of this chapter, according to the German Energy Industry Act (EnWG) [11], grid operators are "*committed to providing a safe, reliable and efficient energy supply network to operate without discrimination, to maintain and optimize the actuated demand, enhance and expand the grid as far as it is economically reasonable*". In general, this means that the grid operators must have their grids to:

- be capable of fulfilling the tasks of transmission and distribution
- maintain the system stability by reliable control systems even in critical situations caused by congestion or imbalances
- be safe and secure against intrusion from third party, (also covers IT-security)

Besides these general rules, there is a large basket of specific regulatory guidelines and tasks derived thereof for grid operations that exist. Most of the rules affect both, TSOs and DSOs. Therefore, a clear distinction of responsibilities between the two parties is needed (Fig. 2).

	frequency control	voltage maintenance	power system operation	restoration of supply
TSO	x	x	x	x
DSO		x	x	x*)

system operator

grid operator

Fig. 2: Roles and responsibilities of grid operators

In Belgium, the same roles and responsibilities for DSOs and TSOs exist. In both Germany and Belgium, the DSOs are not involved in the Redispatch process.

In the following sub-chapters, the focus is on power system operation and how TSOs and DSOs solve problems in their respective grids.

4.1.1.1 Measures for prevention and cure of network threatening conditions

Within the scope of system responsibility and grid management, a set of measures are available to prevent or resolve a network threatening condition (see Fig. 3). The measures have to follow the steps defined in the EnWG. The first three steps are clustered in paragraph § 13 par. 1 EnWG and the last two steps in § 13 par. 2 EnWG.

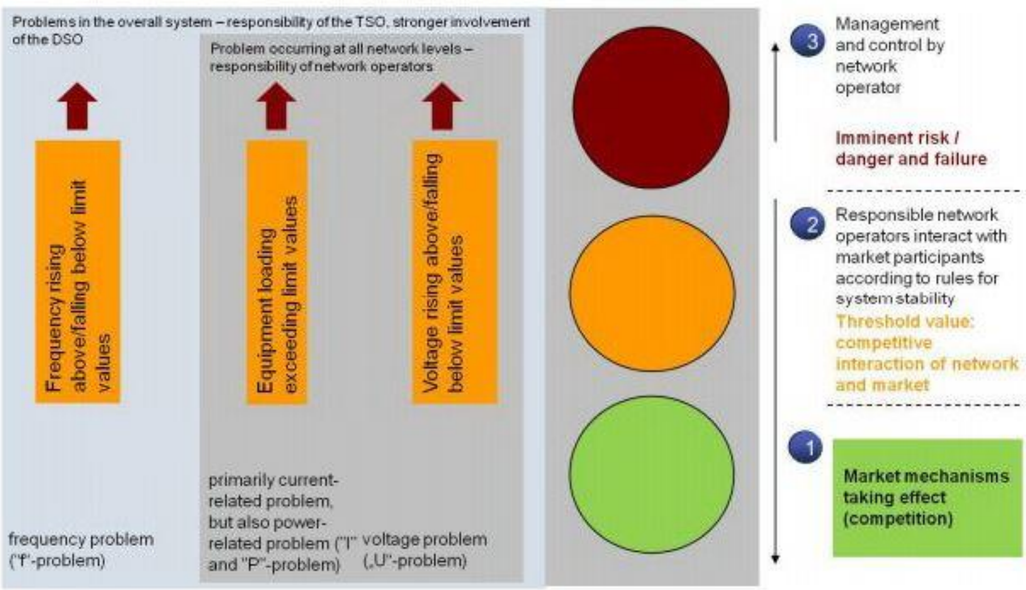

Fig. 3: Traffic Light System

The green phase denotes normal operation of the grid. The yellow phase deals with the possibility of a congestion, system imbalance problems etc. And the red traffic light phase indicates that phase where market activities are prohibited.

Example

To further explain the grid operation, an example is illustrated below. This example contains a very simple grid where different units (producing and/ or consuming, also flexibilities) are connected as shown in the graphic on the right. The following assumptions are made:

- the power flow is from the lower/right area to the upper/left area
- the switch is "open" under normal conditions
- units are feeding in or consuming depending on the market schedule result

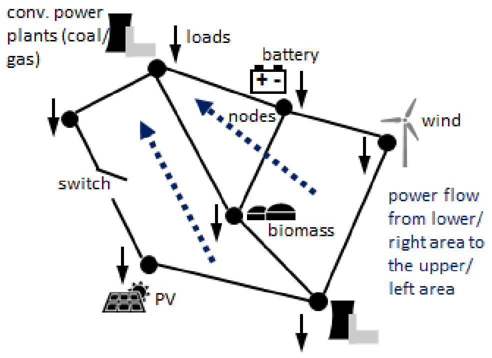

Fig. 4: Exemplary grid without congestion issues

1. If the grid operator realizes a situation where system stability is endangered, (e.g. congestion by load flow calculations) he is obliged to carry out grid related measures at first. This contains for e.g.
   - switching of additional power line connections (like shown in the second graphic),
   - controlling the tap changer of transformers or
   - using other grid elements like capacitors or inductors to redirect the power flow. This should lead to a load relief of the congested power line or transformer
   - Or delaying maintanence.

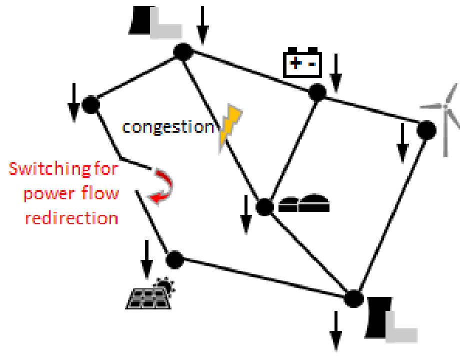

Fig. 5: Solving a congestion issue by switching

2. If grid related measures are not sufficient, the grid operator proceeds to carry out the so-called market related measures (explained in detail in 0). The most extensively used measure in congestion management issues is Redispatch. This means, that if congestion occurs, the power feed-in has to be lowered ahead of and raised behind the congestion to solve it and maintain overall system balance. Thereby, the grid operator is allowed to adjust the schedules of the power plants connected to his grid (if the power plant he wants to use is in another grid area, he has to ask the operator of that grid for assistance), but he is obliged to make a monetary compensation for the costs incurred to the power plant owners. Therefore, either contracts between grid operators and power plant operators exist where the terms and definitions of activation and compensation are described in detail or the legal obligation (not as detailed as a contract) is valid.

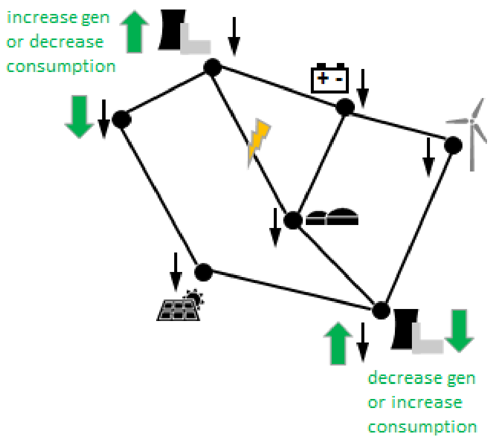

Fig. 6 Solving a congestion issue by redispatch

Other possibilities are e.g. the activation of (dis-)connectable loads and also balancing energy (this is not in the scope of CALLIA, as it is linked to frequency-issues, not to congestion management). It is important for this step to note that just conventional power plants and other conventional generating or consuming units are a part of this regulation, while renewable energies and combined heat and power (CHP) units are not (see step 0).

3. Also for redispatch, but in another legal context, grid and capacity reserves can be used by grid operators (just TSOs; mentioned because of integration in the process of grid operation, but not CALLIA relevant). A TSO is obliged to hold grid reserves for congestion management, voltage control and grid restoration. Grid reserves are generating units which are:
   - not enabled but system relevant (thus they must be enabled)
   - announced for decommissioning but system relevant
   - suitable units abroad (international)

Capacity Reserves are not associated with the grid itself, but with generating units. From winter 2018/2019 TSOs have to hold those reserves (2 GW) to ensure that the deficits in system balance (resulting from market) in case of endangerments or disturbances of security and reliability of the system are balanced. The amount of reserve power is calculated for each year.

4. If the measures from step 1 to 3 for conventional power plants or “units” (generators, loads, flexibilities) are not sufficient to maintain system stability, grid operators can adjust all power inputs, power transits and power exits without remuneration. These cases should be exceptions and every single measure must be justified and indicated by the grid operator to the regulation authority BNetzA.
5. A special case of the power feed-in adjustment mechanism is the so-called “feed-in-management” of renewable energies and combined power and heat units. As already mentioned, the “redispatching” of renewables cannot be requested within this regulation due to the priority infeed (transmission and distribution rules pursuant to the Renewable Energies Act (EEG)). Because of the same reason, they cannot be curtailed without remuneration under the mechanism shown in the “power feed-in adjustment”.

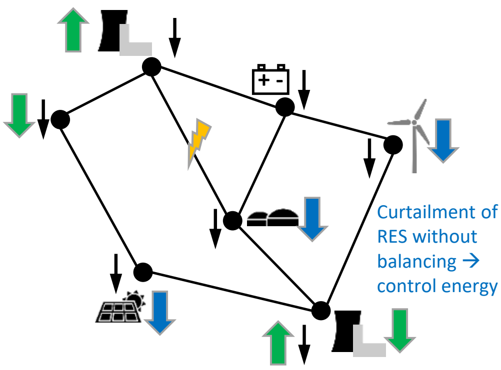

Fig. 7: Solving a congestion issue by redispatch and feed-in-management

6. If a curtailment of renewables is necessary, as shown in the graphic, the reduction realized must nevertheless be compensated for. On top of that, the curtailed energy amount is not balanced with a counter measure by the grid operator (like e.g. in case of redispatch). Thus control energy is needed for maintaining the overall system balance. Besides redispatch, this is one of the biggest cost drivers in the field of grid operation and system services.

A broad overview of available measures for grid operators to maintain security of supply is explained above. In German regulation the products and measures are based on *§§ 13a-j EnWG*. In these paragraphs and in *§§ 11 – 12, 14 EnWG*, the roles of TSOs and DSOs are linked to the different tasks and obligations of grid operation (see also chapter 4.1.1 and 4.1.3 for detailed *§ 14 EnWG* provisions). Also, the BNetzA monitors the grid operation with regard to network and system security-measures [15].

As CALLIA focuses mainly on DSOs, their specific tasks and obligations should be described. As already mentioned, TSOs have a basket full of measures to take because of their system responsibility. For DSOs, some of those measures are not relevant (see Fig. 2).

Therefore, DSOs fulfill the general tasks of grid operation as described briefly in 4.1. According to Fig. 2, DSOs are responsible for power system operation and voltage control. Due to the penetration of RES, DSOs have to adapt the concept of active system management, e.g. forecasting the state of the grid network.

In case of foreseen grid constraints, DSOs have to adjust the feed-in or consumption of units connected to the grid by law *(§13 (2) EnWG*) or contracts *(§13(1) EnWG* in combination with *§14 EnWG*). Hence according to the German regulation, the CALLIA approach should be implementable. More issues have arisen during the more detailed modelling and implementation (field test) phase, e.g. the detailed guidelines for activation of flexibility units by grid operators and the required information flow between market parties. Due to the high penetration of wind energy, DSOs are more than often challenged to perform feed-in management *(§13(2) EnWG*). DSOs are often requested, via the cascading principle, by a TSO to curtail RES due to grid constrains. For example, in Germany, a decline from north to south for feed-in management measures is observable. DSOs in southern Germany or DSOs with an urban grid network do not face these issues yet (e.g. Stadtwerke Heidelberg Netze and BEDAŞ).

Nevertheless, in the future, with more distributed generation and flexibility units, it is conceivable that even those DSOs with no problems will be tasked with taking such measures more frequently. This implies that the cascade *(§13(2) EnWG*) will not only have to work from the top to bottom (TSO→DSO) but in both ways (TSO←→DSO).

4.1.1.2 Electricity Balancing

The subject of electricity balancing is quite difficult to comprehend as it consists of two different areas. There is, on the one hand, the physical need for a balanced system close to real time to maintain a frequency of 50 Hz. If there is an imbalance of generation and consumption occurring, the frequency will drop (generation < consumption) or rise (generation > consumption). The TSO has the final responsibility for maintaining the consumption-generation balance.

On the other hand, the part of market based balancing before real time operation comes into play. Before the actual delivery, the balance responsibility is passed on to a Balance Responsible Party (BRP). A BRP is a legal entity that is responsible to compose a balanced portfolio of consumption and generation. In Germany, every BRP has to have a balanced portfolio at each quarter within their balancing groups. This means that, e.g. a trader is obliged to buy, for every quarter hour, as much energy as he sells. This mechanism is based on forecasts and experience and should minimize the imbalances thereof the resulting frequency deviations in real time operation. If there is evidence that a BRP breaches his duties of balancing, he can be penalized, which will be described more in detail in chapter 4.1.2. As this field of electricity balancing concerns the market phase, it is in the scope of CALLIA. The understanding of roles and the market and product design must be taken into account for CALLIA, if balancing has to be brought to a local and distributed level. Other topics that could violate the regulatory framework include the problem of regulated prices regarding losses and conceivable price caps for preventing market distortions. In case of no price caps, very high prices will occur, e.g. if just one flexibility unit has the ability to solve a congestion or local balancing problem.

If real-time frequency deviations are observed, current problems, it is the legal obligation of the TSOs to ensure that this imbalance is resolved by the use of control energy (Frequency Containment Reserves (FCR), automatic Frequency Restoration Reserves (aFRR), manual Frequency Restoration Reserves (mFRR) and other Replacement Reserves (RR)). In Germany, there exists a platform [16], where these products are procured by the four TSOs via a tendering mechanism, which is also stipulated by the EnWG. Therefore, the physical part as well as the procurement and activation of control energy are not in the scope of CALLIA.

In Belgium, Elia procures its balancing requirements for FCR sequentially via two auctions. The first auction is on the local STAR platform, the second auction on the Regelleistung platform [16]. Short term purchases of secondary and tertiary control volumes are both procured via the STAR platform [3].

In the CALLIA 2030 market [17], all BRPs can introduce their imbalances to the market which tries to clear towards a solution that minimizes the imbalance gap at system level, this does not replace the balancing services such as FCR and aFFR however would result in less redispatch and less balancing requests. Furthermore, the CALLIA 2030 market does not require each local market to balance itself, this can be an indirect result from taking into account losses but is not explicit.

4.1.1.3 Summary of grid operation for CALLIA

Both the TSOs and DSOs have legal rights and obligations which must be perceived. The provisions of § 13 EnWG about congestion management (redispatch, RES curtailment etc.) and of *§ 14 EnWG* about the tasks of the DSOs are to be observed with regard to the research project CALLIA, particularly since they form the basis for the procurement of system services at the distribution grid level. The national legislation of the partner countries may differ at times, and therefore should be coordinated in these areas amongst all the project partners (DE, AT, BE and TR). One potential constraint can be recognized in the presently existing top-down-cascade from TSOs in the direction of subordinated distribution grids, which means that there are no differences in most of the tasks except that the TSO has the responsibility of the whole system and therefore can take measures first. In the future, this cascade must also be applicable from bottom-up, i.e. by the DSO towards superimposed grids within the meaning of the central objective of CALLIA. Thus, a regulatory basis for exchanging information and required data between grid operators, markets and market actors must be created, which has been discussed in detail in deliverable 1.2 [17].

4.1.2 Grid connection, access and fees

4.1.2.1 Grid connection and grid access

Grid operators always have to ensure a discrimination-free connection (*§ 17 EnWG*) and have access (*§ 20 EnWG*) for a fee (0)) to their grid, independent of the voltage level (derogations exist with unreasonableness or impossibility of the connection). So, they have to act as neutral market facilitators. The exact conditions for connection and access to the grid are given in the Electricity Grid Access Regulation [18]. There are also some special regulations for large-scale power plants, biogas plants and offshore wind farms, which are probably not relevant for CALLIA and so, although they have been mentioned here, they will not be described in detail. For other renewable energies or flexibility units, there are no special remarks in the regulation of grid connection and access.

For CALLIA, the role(s) of DSOs in local markets is very interesting. If the DSO is the only buyer in his own local market, he could also obtain the role of the market operator (comparable situation for the procurement of control energy via tenders hosted by the TSOs themselves). If there are other actors buying in the local market, (e.g. aggregators or other DSOs/TSOs) the DSO is not allowed to take the role of market operator. In this case, he would mainly provide simplified grid information in a transparent manner [17] and perform the final check on the outcome from the market. The DSO will not host the market in order to avoid discrimination, which instead could be hosted by an independent party (comparable situation in wholesale markets with neutral market operators (e.g. EEX, EPEX SPOT) where grid operators are buying e.g. their loss energy).

With regard to CALLIA, the arrangements for the balancing group system are especially interesting. In Germany, every actor in the energy economy has to have at least one balancing group (could be grid operators at times or other balancing groups), where every trade (buying or selling) and consumption/generation has to be registered. A balancing group does not have to have boundaries like a coherent geographical area as long as it stays under one control area. In case a retailer wants to sell energy to customers all over Germany, he has to have at least four balancing groups (for each of the four TSO control areas). Balancing groups have to be balanced at all times by compiling schedules to other balancing groups, as shown in a very easy example in Fig. 8. The schedules have to be sent by the Balance Responsible Party (BRP) day-ahead to the Balancing Group Coordinator ("BiKo=Bilanzkreiskoordinator" in Germany), which is the TSO of the respective control area. Schedules can cover energy deliveries within one control area or across control area boundaries. As a speciality, the obligation of balancing of customers (especially households) is transferred to the retailer, which is linked to balancing groups. This means that households just have contracts with their supplier for consuming energy, but do not have to meet their predicted consumption exactly in every quarter-hour like a BRP has to do.

Closely related to the balancing group system, are the market rules for the implementation of balancing group accounting (MaBiS), which regulate the business processes and communication rules for balancing

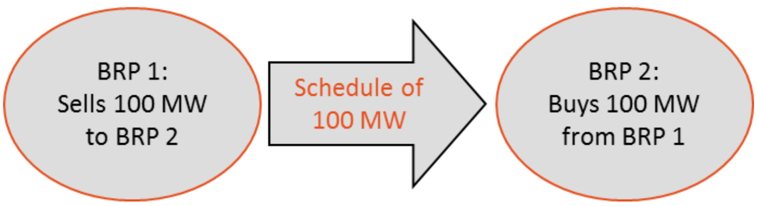

Fig. 8: Example for balancing

group accounting. Although the concept of a BRP is not present in the CALLIA market, it is still accounted for in the balancing services after the market.

The balancing group loyalty, in accordance with *§ 4 StromNZV* is a duty of the BRP. In this context, the BNetzA had, in 2012, identified breaches of forecast duties and therefore adopted a resolution in the [19], which specified the obligations of the BRP to a proper quarter-hourly balancing group management and asked the TSOs for a more targeted analysis of the balancing group accounts. Due to the continued occurrence of breaches of forecast duties, determinations of the resolution were tightened in a position paper [20]. Consequently, the following, now clearly defined, guidelines were released:

- BRPs have to perform a short-term forecast of the infeed of RES to ensure that deviations from the day-ahead planned schedule can be balanced intraday (at night and on holidays some BRPs have no or insufficient activities taken to maintain their balance)
- Management of load profile measured consumers and consumers with standard load profiles can just be done with quarter-hourly procurements (at least in the morning and evening). Procurement with average hourly amounts is not valid.
- Every network operator has to manage his different balancing groups actively on a quarter hourly basis, that also covers the possible deviation forecast (e.g. in extreme weather conditions) of standard load profile customers.
- According to *§ 5 par. 4 StromNZV*, in case of a power plant outage every BRP has to procure replacement within 4 quarter hours (1 hour). If he does not hold an organizational structure which enables him to do so, this is a violation of his obligations.
- For pure trading balancing groups (no physical infeed or exit) it is forbidden to deviate.

The task of monitoring the balancing group loyalty of BRPs was transferred from the BNetzA to the TSOs. If they identify deviations, they have to contact the BRP and clarify bilaterally if and in what way the deviations were evitable. If the TSO has a founded suspicion that a violation of obligations cannot be excluded, he has to send the data and a report to the BNetzA. The BNetzA then decides on the following measures and requirements that have to be carried out by the affected BRP and on possible penalties.

Furthermore, the *StromNZV* regulates the compensation mechanisms for control reserves/ energy, lost energy and the balancing groups of renewable energies. For example, it is clear that the procurement and use of control energy for frequency control and the resulting calculation of the control area balance energy price (reBAP) is the responsibility of the TSO. As balancing group coordinator, the TSO provides a monthly invoice (balancing energy settlement) on the expenses of the BRP caused via the usage of balancing energy due to the difference between the reported schedules and the actual consumption or the actual infeed from power plants. Besides, every grid operator has to procure the energy of grid losses and keep a separate balancing group for those amounts of power. In addition, the leadership of EEG balance group and a differential balancing group is mandatory for grid operators. This is related to both, TSOs and DSOs and therefore is also relevant to CALLIA. It is a possibility, that every grid operator also has to keep a balancing group for congestion management via e.g. flexibility from CALLIA market (nowadays just TSOs have a balancing group for redispatch).

For CALLIA, it is important that the DSOs have access to units of unit operators which are connected to the DSO grid and would like to make offers on the newly created flexibility market. In addition, the new market models and products must be integrated into the existing balancing group system, without violating the legal requirements and obligations of the actors and stakeholders.

4.1.2.2 Grid fees and incentive regulation

The most important way for a grid operator to cover his expenditure is to calculate a fee for the transit of electric energy through his grid which has to be paid by everybody who wants to use the grid of that particular grid operator. The fee is especially dependent on the voltage level and not on the distance between entry and exit. To prevent abuse of the natural monopoly of grid operators, the calculation of grid fees is regulated in quite a detailed manner.

Until 2009, there was a purely cost-based mechanism used, but since then, the Incentive Regulation (*ARegV*) in conjunction with the Electricity Grid Fees Regulation (*StromNEV*) has regulated the fee calculation based on a revenue cap. This means that every grid operator, regardless of whether a DSO or TSO, has to calculate his individual revenue cap. In the next step, the revenue cap is measured against the efficiency of the grid operator compared to the pan-German efficiency level. This should lead to a situation where every grid operator can evaluate his benchmark at the same level independent of grid size or voltage level and should create a situation of simulated competition. Hence, this mechanism focusses on setting incentives for grid operators to raise the productivity and efficiency and to lower the costs.

The costs are distinguished in permanently non-influential and inherently influential costs. It is described in the *ARegV* where costs refer to the type. First, the non-influential costs are described in detail (e.g. statutory levies, concession levy, investment measures, research & development and many more). Then, it is stated that every cost which cannot be matched with those, which fall under the CAPEX-deduction of the current regulation period and which are temporarily non-influential are influential costs. The goal is to identify efficient and inefficient costs of the particular grid operator, which affect the revenue cap directly. In addition, investments in grids, the quality of supply and adequate equity yield rate (as conceded profit) are taken into account for the calculation of grid fees. The determination of the revenue cap therefore follows several steps; from cost review via allocation of costs to cost-centres and cost units up to the derivation of grid fees from the specific annual costs.

If a grid operator acts more efficiently than his specification, it can generate an additional profit as an incentive (loss if not efficient enough). This gain will be passed on in the next regulatory period to the grid customers in the form of a lower revenue cap and hence lower grid fees. The revenue cap is calculated in the so-called “cost-basis-year” and then will develop through the next regulative period (five years nowadays) according to the approved efficient and inefficient costs. Possible developments are shown in the figure below (cost-basis-year 2016, grid operator exceeded his cost defaults by 2.5 %).

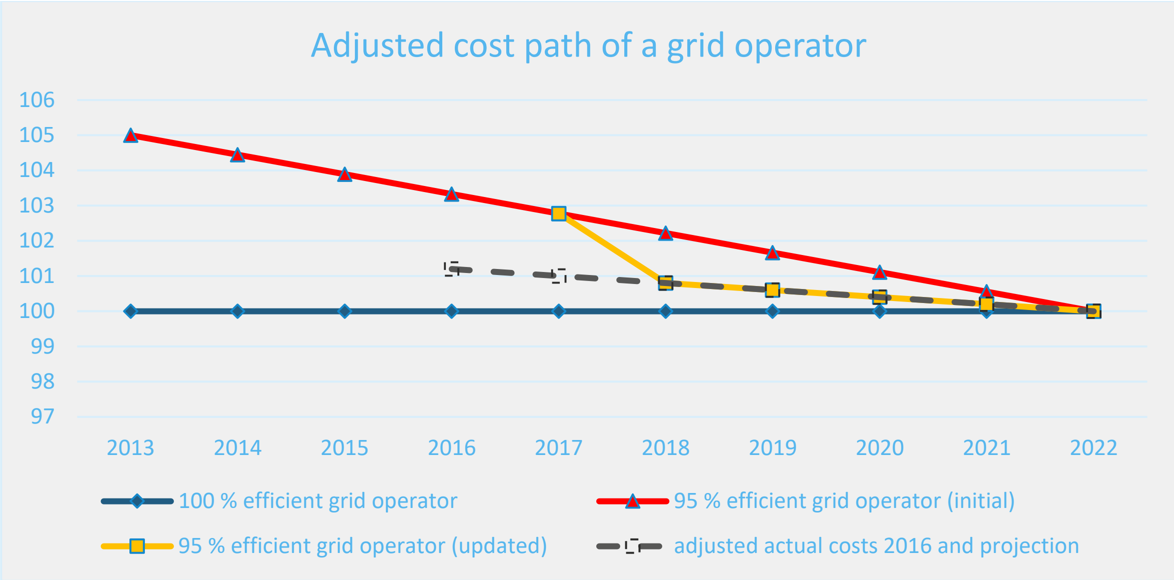

Fig. 9: Cost path and adjusted cost path of exemplary grid operator due to statutory provisions of the incentive regulation

The complete process is outlined in the aforementioned legal regulation and various accompanying documents and shall not be considered more in detail in this paper as it is not in the scope of CALLIA. Here, it is however possible to refer to the position paper "grid fee system of electric power" of the bdew [21]. Within the frame of CALLIA, it will have to be considered whether and how any costs that may possibly occur for the grid operators can be accepted in the process of grid fee calculation, elaborated upon in 1.2. Also, the future treatment and recognition in the context of grid expansion of storages as grid resources shall be discussed in this coherently. Another point to have in mind is the assumption of different grid fee calculation schemes in different countries which have to be considered in the case of cross border inter-DSO-trading (e.g. from Turkey to Germany).

4.1.3 Relationship and collaboration of TSO-DSO and DSO-DSO

4.1.3.1 Goals for reinforcing TSO-DSO coordination

From a historical point of view, the energy system is structured and designed in a top-down hierarchy. This is valid for energy flows as well for information flows. Nowadays within the process of energy transition there are many new challenges and opportunities which require the reinforcement of the "vertical" collaboration and coordination of TSOs and DSOs. This was also recognized by the grid operators and their organizations. ENTSO-E, in close association with other organizations, published the "TSO-DSO data management report" and the "General guidelines for reinforcing the collaboration between TSOs and DSOs" [22] [23]. In these documents, new challenges for energy transition, market design and renewables are described and it is shown how the roles of TSOs and DSOs could be shaped, organized and concatenated in this new environment.

4.1.3.2 Cascading principle/Cascade

In section 0 of 0, measures to be taken successively when standard grid operation is not possible have been described. Besides the order on horizontal transmission level there is also an order in the vertical direction if feed-in-management measures have to be taken (red traffic light phase). It works from transmission system operators via distribution system operators on HV-level right up to small distribution grid operators at the LV-level, and is called the "cascading principle" or simply "cascade". The basis for this is the *§ 14 par 1c EnWG* where it is stated that requirements from superimposed grids must be carried out with the smallest possible impact. It is also possible for grid operators to pass requirements for themselves downwards (e.g. initial problem on HV-level passed to MV-level and further to LV-level, if necessary).

The transmission system operators have an overview of the whole system and are responsible for the system security. They are responsible for handling situations outside the defined operative parameters by regular contact and access to generators on their system level or by requesting support from grid operators at the HV-level (and further to MV-level by HV-level and to LV-level by MV-level). DSOs (independent of voltage level) have an insight into their own grid and regular contact and access to generators and loads on the corresponding voltage levels while generators and (controllable or interruptible) loads provide support by raising or lowering the generation/consumption. Thus, the cascade (measures taken) must always follow the principles of proportionality and be free from discrimination.

The cascade could be triggered either by congestion problems (current or voltage-problem) or by system imbalances (frequency-problem). The first problem requires a local correction whereas the second problem could be solved globally. Independent of the problem, it is the superimposed grid operator who sends a requirement to the lower level grid operator who has to confirm the receipt and the execution of the requirement. In case the superimposed grid operator revokes the requirement, this has to be confirmed by the lower level grid operator again. It is important to point out, that the communication works straight top-down and never skips a voltage/grid level. VHV delegates to HV, while HV delegates to MV and MV to LV. The confirmation messages follow the same bottom-up system without skipping voltage/grid levels. Communication techniques and protocols are not clarified by law, so they can either take place by telephone, E-mail or fax.

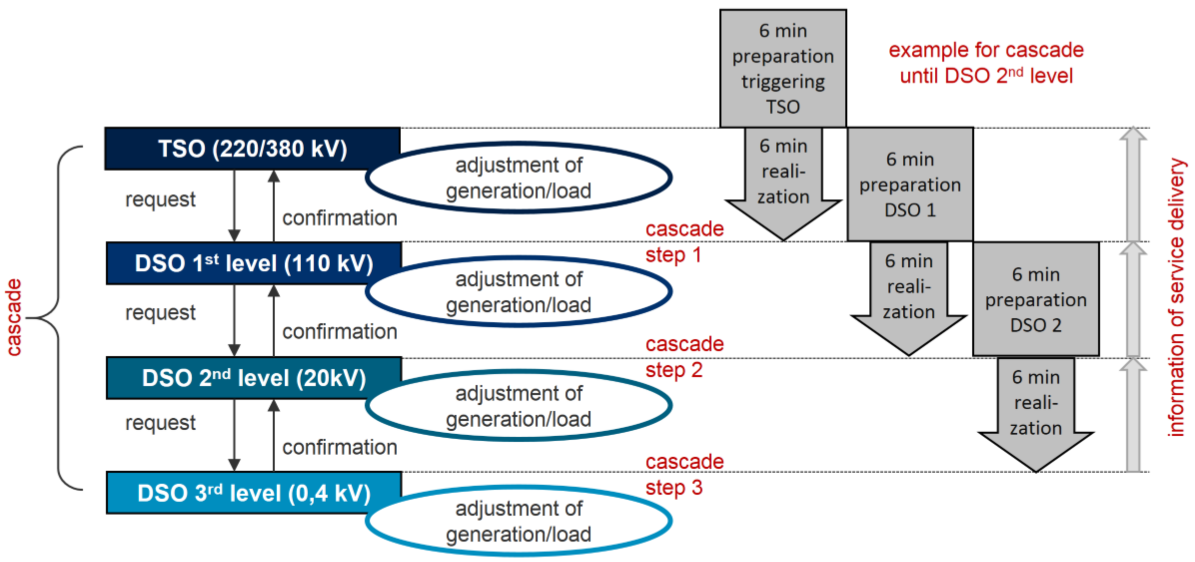

Fig. 10: cascading principle as implemented in Germany

With the laws for the digitalization of the energy transition, a first step was taken to distribute information to those entities that need it for their own operation instead of keeping the flow of information strictly within the cascade (the law addresses all situations, not just situations where the system security is endangered). More information concerning this law and the corresponding effects can be found in chapter 4.4.

4.1.4 Unbundling

The Third Internal Energy Market Package further tightened the regulations concerning the unbundling of vertically integrated energy supply companies. This has been implemented in the German legislature since 2005 and can now be found in Part 2 of the *§ 6-10 EnWG*. With the novel of EnWG in 2011, TSOs have been subject to stricter rules than DSOs. The objectives of unbundling, i.e. the separation of value-added steps in vertically integrated utilities, ensure transparency and non-discriminatory network operation, as shown in Fig. 11.

The first essential step consists of the accounting and informational unbundling according to §§ 6a et seq. EnWG which all TSOs, DSOs and storage operators are obliged to follow. However, the legal and operational unbundling pursuant to *§§ 7, 7a-b EnWG* is mandatory just for TSOs. Storage operators and DSOs with less than 100,000 connected grid customers are exempted from these obligations. The assumption is that they do not have a big influence on the market and lack necessary resources. For TSOs, the obligation is beyond ownership unbundling *(§ 8 EnWG*) to obtain the certification as an independent system operator (*ISO, § 9 EnWG*) or as an independent transmission grid operator (*ITO, § 10 EnWG*). If the transmission grid was in the property of a vertically integrated utility until 3rd September 2009, there was the choice to nominate an ISO or an ITO to operate the transmission grid. The special regulations for TSOs are not, in particular, important for CALLIA but should also be mentioned to reach a good overview.

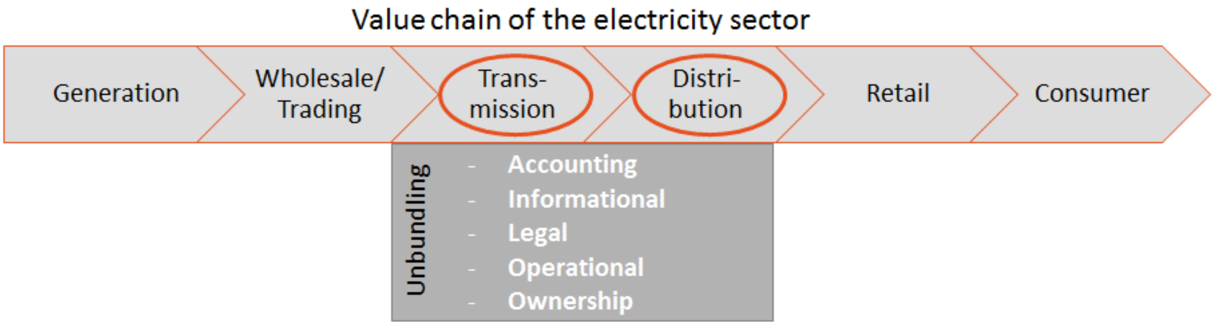

Fig. 11:Value chain of the electricity sector

Therefore, constraints within the scope of CALLIA exist especially in the role of DSOs if they also act as market actors in addition to the regular network operators (nowadays small DSOs with <100,000 grid customers can do so). The EU, in contrast, aims to have, on the DSO side, a stronger unbundling to prevent taking advantage of the in-depth market knowledge, as well as to ensure non-discriminatory and transparent markets. Thereby, the understanding of roles in the energy market has grown historically and has been recorded in different publications [24] [25]. In particular, the usual role of TSOs and DSOs as neutral market facilitators should be emphasized upon here, as they are likely to participate in the CALLIA market(s) as buyers and/or sellers.

4.2 Energy Markets

4.2.1 Definitions of different types of markets

In general, energy markets can be separated in two sections in all countries participating in CALLIA. On the one hand, there are markets and products only available for system operators in order to guarantee security of supply. On the other, there is the energy market for all market parties available to trade energy as a commodity (distinction in physical (short-term) and financial (long-term) markets). This section briefly describes the status quo, which markets, market concepts, market actors and timeframes of market processes currently exist as well as which products are defined in different countries. Furthermore, the paper aims to reach an understanding, where similarities and differences are present and what has to be changed or adjusted in order to implement CALLIA solutions. Aligned with these questions, the embedding of the CALLIA market (products and markets) into the overall system has to be identified, which has been emphasized upon in deliverable 1.2 [17].

The basic decision by the EU commission to enable the development of free energy markets and presently established market framework was taken in 1998. Up until 1998, electricity providers had set supply areas wherein power supply and grids were usually owned by the same company. Liberalization has ended this monopoly and competition has made electricity production and supply more efficient. Ever since unbundling (4.1.4), the interaction between market roles rules the energy system. System operators (SO) are especially decoupled from energy generation and trade. Due to unbundling, there exist markets for system operators to perform system services (4.2.2.1) and energy markets available for all market parties (4.2.1). Due to the European network codes and their unification, energy should be freely traded across borders. This special market is explained in chapter 0.

4.2.2 Functioning of markets

4.2.2.1 System services

The transmission system operators use balancing capacity to balance out any unanticipated differences. The system of balancing groups and imbalance settlement controls synchronization. As a result of the interaction between these mechanisms, the balancing electricity market provides remuneration for energy and capacity. Transmission system operators rectify bottlenecks in the grid by expanding and upgrading the power grid, or/and, on an interim basis, by using other measures like redispatch or feed-in-management (explained in the forthcoming subtopics). The system services are shown in Fig. 12. In CALLIA, the focus is set on voltage control and power system operation.

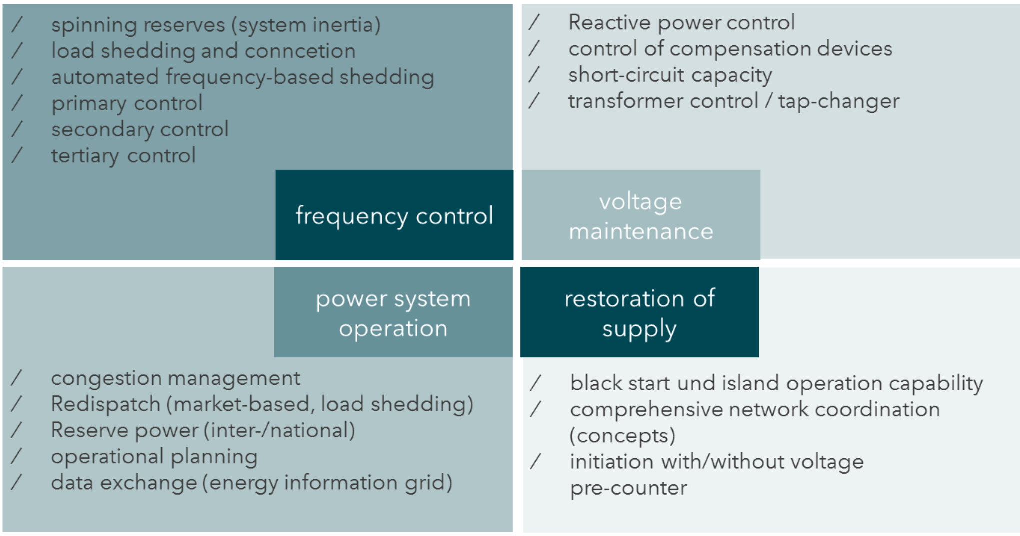

Fig. 12: System services from a TSO perspective

The most important measures for system operators within the system service of power system operation are also shown in Fig. 13. Costs, control mechanism, time horizon and the legal basis are described, showing their regulatory status in Germany for the year 2018. Therefore, Fig. 13 gives a good overview of the already mentioned mechanisms (e.g. redispatch or RES curtailment) within this document.

	costs		control via		time horizon		
	market-based	regulated	… call	… casacde	implemented	disscussed	German law
measures by topology and operational units					x		§ 13 Abs. 1 Nr. 1 EnWG
balancing energy with units at …							§ 13 Abs. 1 Nr. 2 EnWG
… transmission system	x		x		x		
… distribution system	x		x		x		
contracted controllable loads (AbLa and ZuLa) with > 5 MW shifting potential at…							§ 13 Abs. 1 Nr. 2 EnWG § 13 Abs. 1 Nr. 6 EnWG
… transmission system	x		x		x		
… distribution system	x		x		x		
Redispatch with conv. units at …							§ 13 Abs. 1 Nr. 2 EnWG
… transmission system		x	x		x		
… distribution system with power of …							
… at least 10 MW		x	x	x	x		
… less than 10 MW	in discussion and part of Callia					x	
Redispatch with EE-units at …							not regulated yet
… transmission system		x	x				
… distribution system		x	in discussion			x	
grid reserve is not within the focus of Callia							
grid reserve with unita at…							§ 13 Abs. 1 Nr. 3 EnWG
… transmission system		x	x				
… distribution system		x	x			x	
measures according to § 13.2 (independent of voltage level)				x	x		§ 13 Abs. 2 EnWG

Fig. 13: Measures available for system operators according to EnWG

4.2.2.2 Energy wholesale

The electricity market mainly consists of a number of 'submarkets' that generate the pricing signal which electricity production and consumption align to. The EU goal is to trade electricity as a commodity within the "energy only" principle. Electricity is traded on the exchange in spot markets and over the counter (OTC).

Standardized products are bought and sold in a transparent process on the exchange, e.g. the European Energy Exchange EEX in Leipzig or the European Energy Exchange EPEX SPOT in Paris. However, companies primarily still enter into direct supply contracts with electricity producers. Trade with these supply contracts which are agreed outside the exchange (but mostly monitored by an exchange in the role of market operator) is known as OTC. The general market structure frameworks which are relevant in the context of CALLIA are shown in Fig. 14 for Germany, Austria and Belgium and in Figure Fig. 15 for Turkey. The aspiration of Turkey to align its regulatory framework with the European regulatory framework is reflected in the very similar set-ups of Turkey and the region of EPEX SPOT.

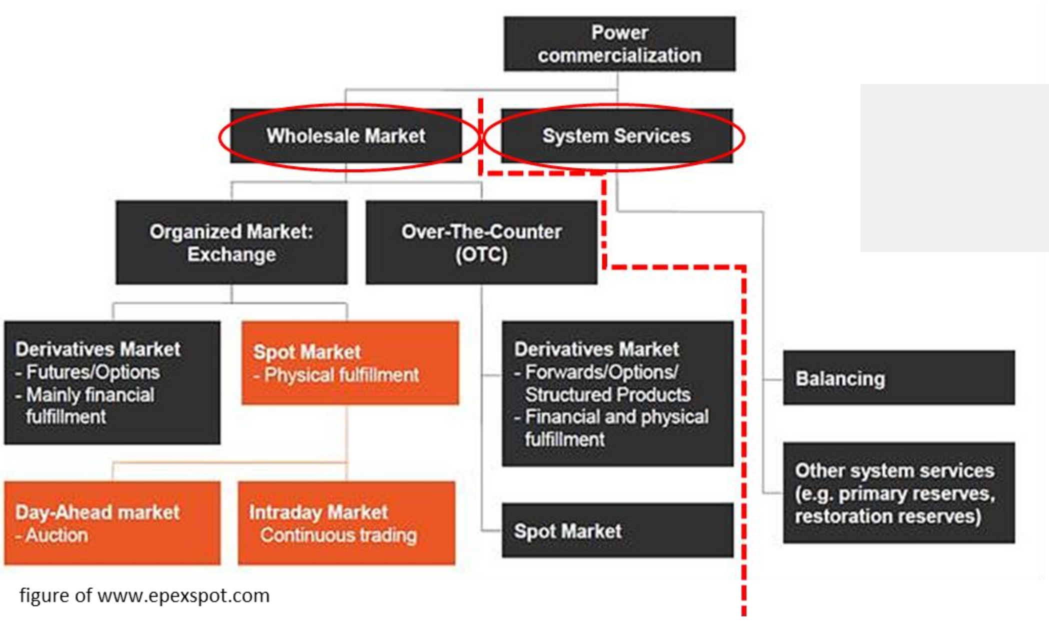

Fig. 14: Market structure framework for EPEX Spot, so for Germany, Austria and Belgium

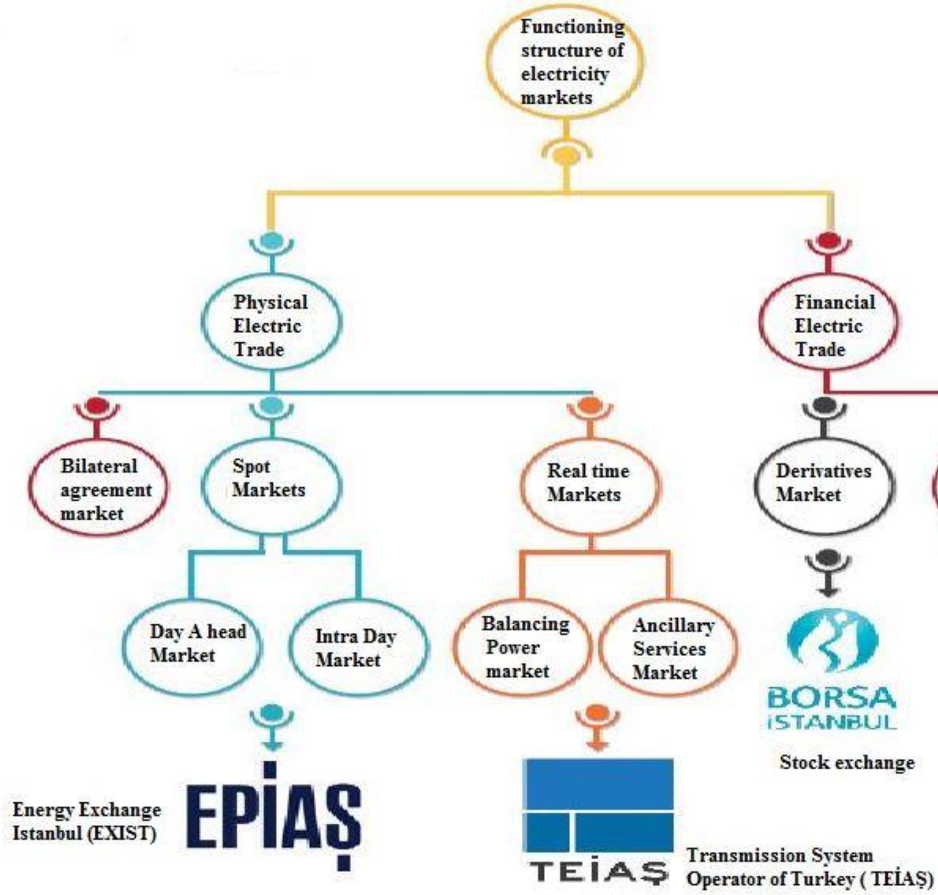

Fig. 15: Market structure framework for Turkey

The wholesale market, where large amounts of energy are traded, has most of the characteristics of other commodity markets. Generators, traders and suppliers can buy and sell on the spot and forward, bilaterally or through organized markets, trade both physical and financial products, etc. At wholesale markets, like the day-ahead or intraday markets, only energy is traded as different products, like ¼-h products, 1h products or different blocks (e.g. base and peak or high time and low time). There is also the possibility to trade smart block orders, e.g. as linked or exclusive block orders [26] [27]. In Germany, double marketing of the same energy amount is prohibited, while in other European countries this is allowed to some extent. E.g. in Germany, it is prohibited to offer the energy amount of a battery which is fully allocated to the control reserve market at the regular spot markets. In Belgium instead, it is technically possible, but the market penalizes this severely. There are still some differences between the European countries (esp. for GCT times or granularity), but in the recent years these deviations have been minimized by standardization processes. In Fig. 16 the timeframes are shown by EPEX SPOT for the related markets. The present valid timeframes (e.g. GCT times) of different markets, so also e.g. control reserve market in Germany are shown more detailed in Fig. 17. As was to be expected, a large congruency is evident as the national market frameworks are mainly harmonized with the market frameworks of the corresponding exchanges.

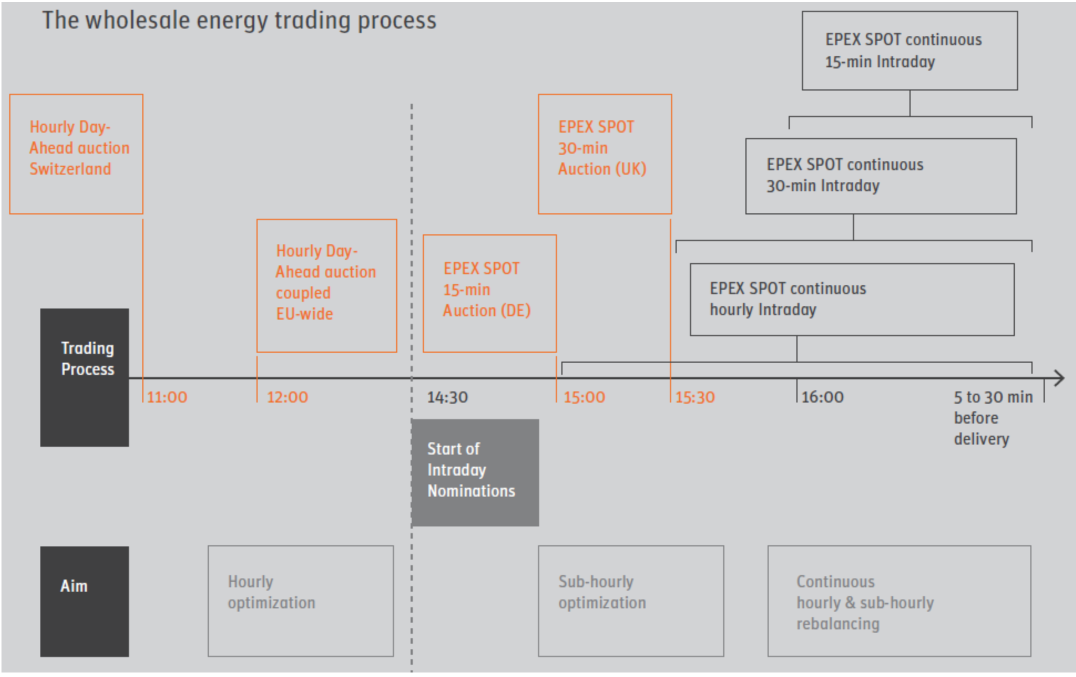

Fig. 16: Present valid timeframes for standardized markets and products operated by EPEX SPOT

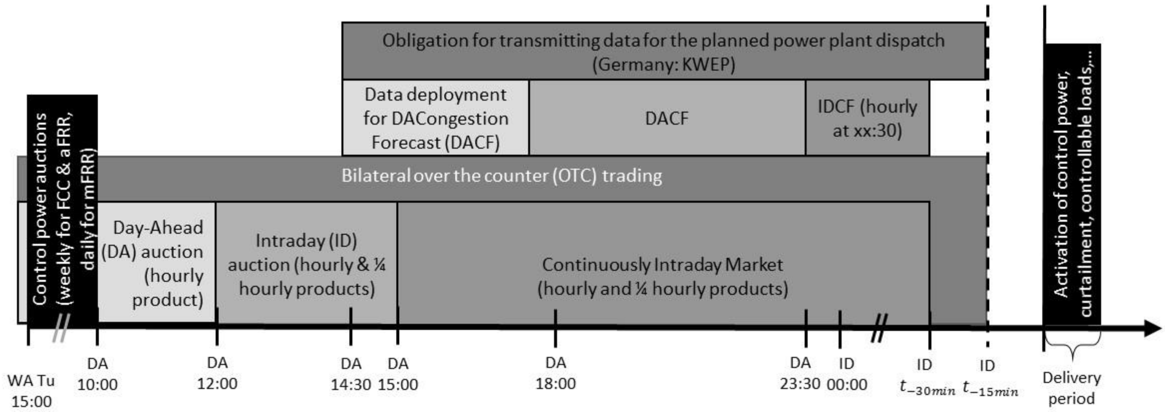

Fig. 17: Present valid timeframes for standardized markets and products for the German-Austrian bidding zone

Within CALLIA one of the biggest challenges is the integration of a new flexibility market to the above explained framework, e.g. regarding gate opening, gate closing, product definitions and operation of the trading algorithm. A viable solution for integrating the CALLIA framework into the existing framework is shown in Fig. 18. The information how the market processes and the trading algorithm works can be found in the CALLIA Deliverable 1.2 [17].

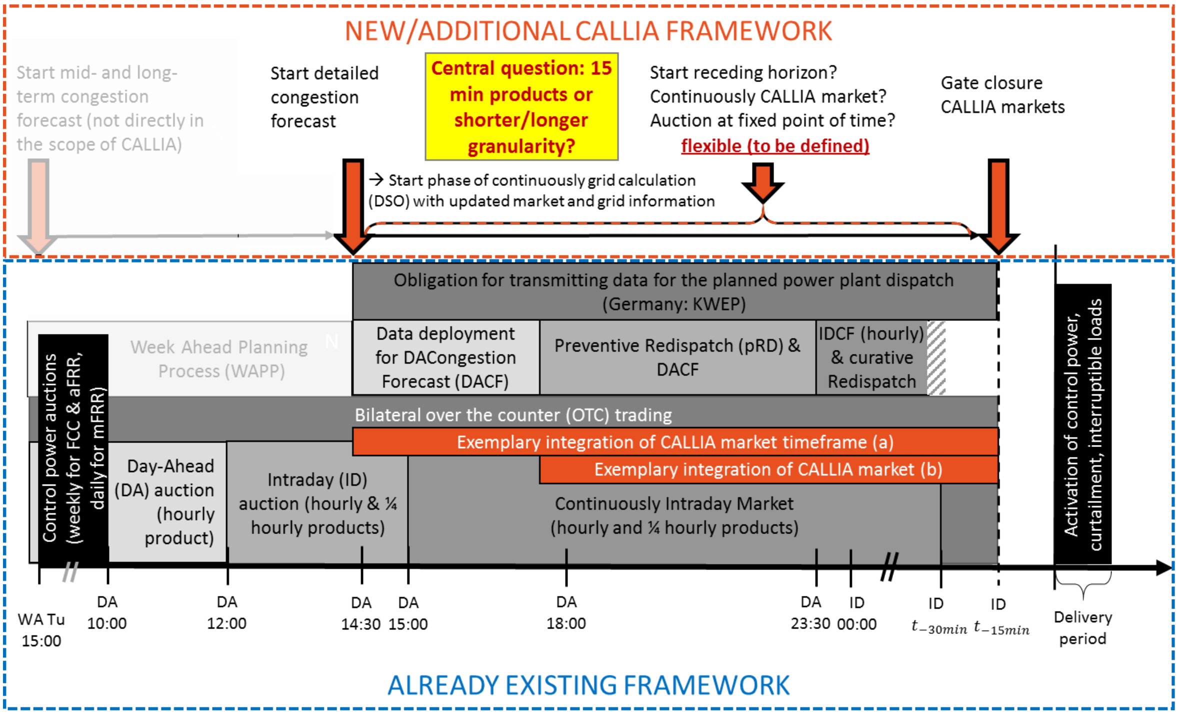

Fig. 18: Possible integration of CALLIA into the existing market framework

Ancillary/System services are mainly procured in separate markets, by contract or by legal obligation. Control Reserves in Germany e.g. are procured in different timeframes and product categories. FCR is procured weekly, while aFRR is procured on a daily basis since 2018, just as mFRR. For other services like system operation (redispatch, feed-in-management), there is no market at all and reactive power is procured on contractual basis. CALLIA tries to combine the wholesale market with system services what leads to new regulatory questions that will be answered in this document and [17].

4.2.3 Cross-border capacity allocation: auctioning

The European markets are largely coupled and continue to grow together. Market players face the same general conditions across Europe due to the network codes that have been defined for the same. In particular, the network codes set the framework for general, day-to-day cross-border electricity trading. They deal with both the organization of cross-border short-term trade and issues surrounding long-term trade and cross-border access to balancing energy. There are several types of cross-border-trading established. The two main types are depicted in Fig. 19.

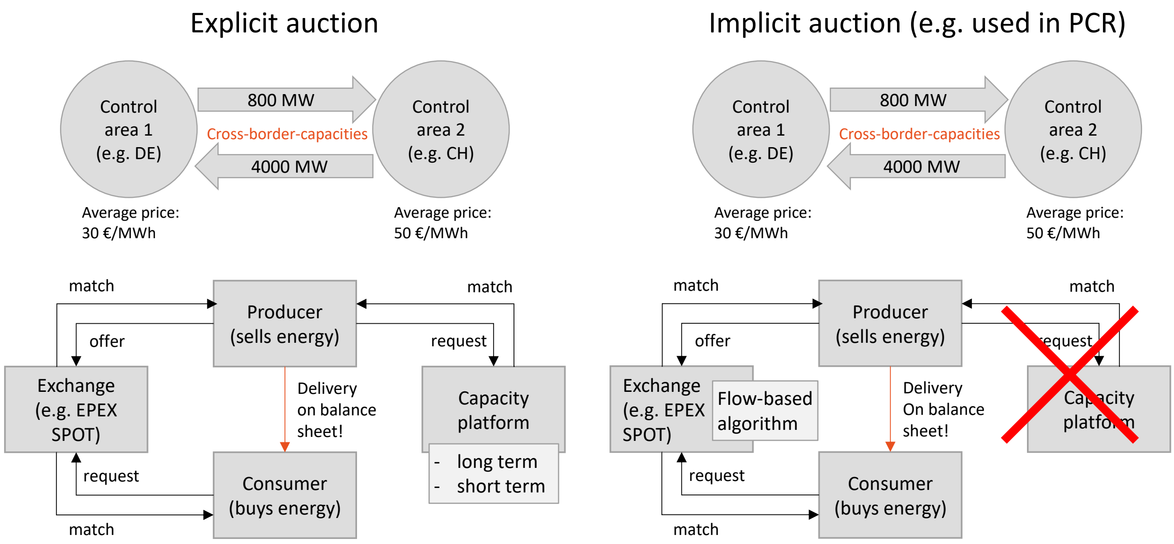

Fig. 19: Two main types of cross-border-trading

The classic type is the explicit auction on the left, where capacities have to be booked separately of the traded energy. Market participants can obtain capacities via a JAO auction [28]. JAO is a joint service company of twenty-two Transmission System Operators from nineteen countries. It mainly performs the yearly, monthly and daily auctions of transmission rights on 29 borders in Europe and acts as a fallback for the European Market Coupling [29]. In implicit auctions, as shown on the right implemented nowadays, the capacities are established in the Price Coupling of Regions (PCR) and are booked implicitly with the trading volume. If the capacity demand exceeds the actual transfer capacity value (ATC), the prices will differ in those regions (e.g. Germany and France). For PCR, a flow-based algorithm – EUPHEMIA – is implemented. Fig. 20 shows that the day-ahead energy prices for 2018 are often overlapping in coupled regions. The prices for UK differ significantly from those of continental European regions.

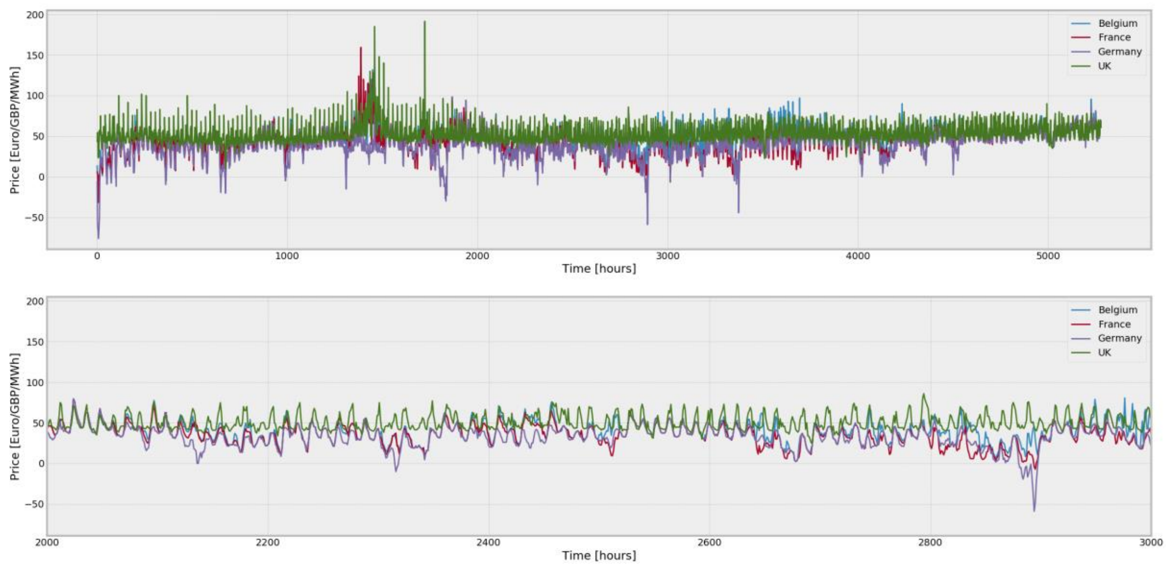

Fig. 20: Day-ahead energy prices for 2018, indicating that except for the UK prices are often overlapping.

4.2.4 Opportunities for integration of flexibility

In the context of CALLIA, flexibility is a very important factor. Flexibility can be used for both, market purposes and grid purposes as Fig. 21 indicates.

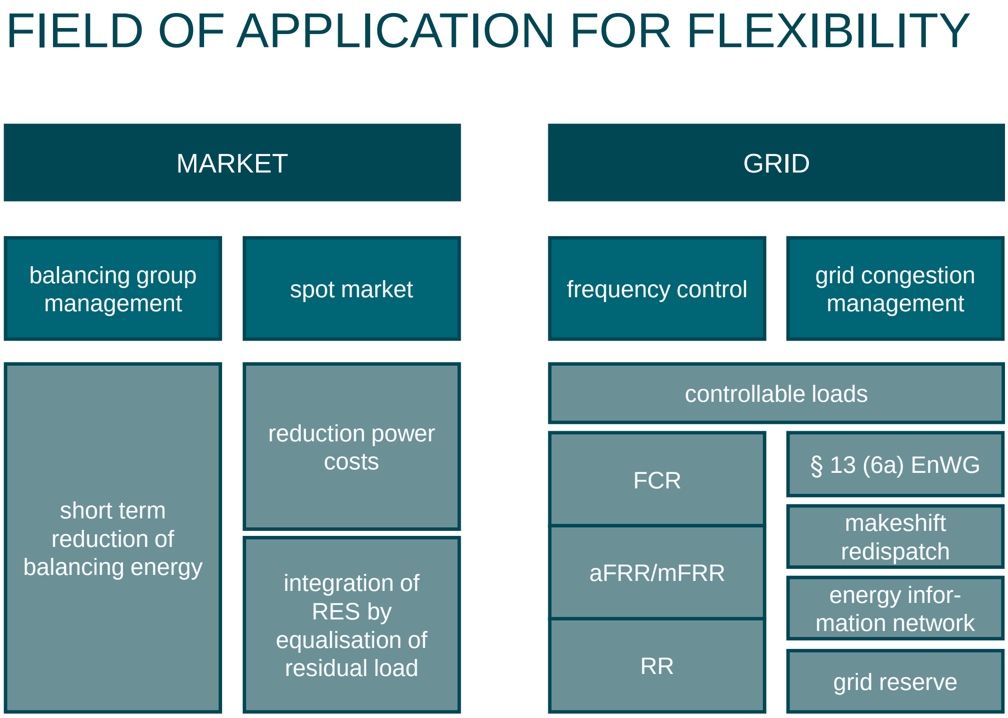

Fig. 21: Possible field of flexibility allocation on existing markets or other processes (esp. grid side) respectively

Besides the market framework, the market participants are also subject to development. In recent years, a new market role has emerged: the aggregator. In Belgium, France, Germany and the UK methods for aggregation have already been implemented, while in Germany aggregation is only a business model especially for control reserve.

The basic principle of aggregation is to assemble a portfolio by contracting multiple assets like storages or controllable loads (for demand side management). The flexible use of the different assets within the portfolio is the main advantage of this concept as it allows the aggregator to offer e.g. control reserve in an optimized way with a high reliability of delivering the correct energy amount. In CALLIA, the aggregator has a central role, as he connects the flexible (small) assets, the market platform and the grid operator by novel and innovative communication techniques, as comparatively shown in the CALLIA deliverable 2.1. It is to be emphasized upon, that a major task of this project is to incorporate this role smoothly into the regulatory framework.

4.3 Renewable Energy Sources (RES) and Flexibility

4.3.1 RES

At the EU level, as well as in every European country, besides the goals of raising energy efficiency and reducing greenhouse gas emissions, there are goals for the development and integration of renewable energy sources (RES). The European goals for a successful energy transition are formulated as shown in Fig. 22. These goals are embedded in overall energy strategies for 2020, 2030 and 2050, as well as in further programs like the "Clean Energy for All Europeans" package.

energy goals of EU	2020	2030	2050
reduction of green-house gas emission	20%	40%	80-95%
share of RES of consumption	20%	27%	high RES scenario: 75% overall and 97% electricity
energy savings	20%	27%	high energy efficiency scenario: 41%
renewable energy in transport sector	10%	n/a	included in share of RES overall

Fig. 22: Goals of the Europeans Union for a successful energy transition [30] [31]

Fig. 22 also reveals that RES are one of the main drivers for reducing CO_2 emissions within the energy transition. To reach the defined goals, subsidies for RES were established at the national level. Such funding schemes are implemented in various versions in different countries in the EU (and also worldwide). Therefore, on the one hand, the expansion of RES reduces CO_2 emissions, but on the other hand, a high share of RES raises new issues. The energy production is very volatile due to its high dependency on the availability of sun and wind. RES and thus generation units are connected to the low and middle voltage grid level. Thus active system management becomes a key activity for DSOs, and challenges all DSO sectors. At present, regulation is not designed for bottom-up load flows (e.g. grid tariffs). Not only for regulation but also for grid management, the high PV/wind penetration may lead, in special situations, to voltage problems. The location of power generation and consumption is also drifting apart. Especially in Germany, TSOs face more and more grid congestion because the grid line capacity is not sufficient to transport the energy from north to south.

As already mentioned, the used funding schemes for RES differ across Europe. The most popular funding schemes are as follows:

- Feed-in-tariffs (e.g. Germany before 2016)
- Direct marketing with bonus (also used in Germany)
- Rate model (e.g. Great Britain or Turkey)

Tendering of as the main purpose of CALLIA is to find ways to integrate RES better into the system on a technical and marked-based level, the detailed design of these funding models is not in the focus of CALLIA. Therefore, there will be no further elaboration within this document.

To create tools that grid operators can use to deal with the problems RES are (partially) causing, the regulatory framework is continually extended. Usually RES have the highest priority for feeding the produced energy into the grid. In former days, the low penetration of RES caused no problems. Nowadays in situations with high feed-in of PV and/or wind energy, system security and stability can be threatened, e.g. due to congestion. In those cases, grid operators are allowed to curtail the production, if there are no other market-based measures (e.g. redispatch) left. While conventional power plants do not receive financial compensation, RES do so. Another example from Germany is the tool "peak capping" or "peak shaving", where the grid operators are allowed to cap 3% of the yearly produced energy from PV or wind plants within their grid planning process. This means that this is not only done operationally but also leads to higher grid connection capacity because rare situations with a very high production can be assumed as capped in grid planning. As an example, around 70% of the installed capacity of a wind power plant must be taken into account for grid planning, not the whole capacity.

4.3.2 Flexibility

CALLIA aims at enabling flexible assets for means of congestion management and for balancing (not in terms of control reserve) the volatility of energy production of RES or the counterpart in case of redispatching RES. Therefore, the regulatory status of such assets, especially batteries, demand response/ demand side management and e-mobility as special forms of storage is in focus. Unfortunately, the regulatory framework does not take flexibility sufficiently into account. There are also conflicts with unbundling if a grid operator builds storage systems with the intention of not just using it for grid related measures, but also to offer its flexibility to the market. Furthermore, any curtailment of EE is outside of market activity within *§13(2)* and not as desired in *§13(1) EnWG*.

As an example, since last year the regulation in Germany defined storages simply as "grid users" which means that they also have to pay grid fees for charging and the "EEG-reallocation charge" for charging and discharging. There are some exceptions for not having to pay grid fees, like if the charged energy is discharged only into the grid. E.g. pumped storages benefit from this regulation, while e.g. smaller storages do not (exceptions from this are just small home storages in combination with PV < 10kW). Since 2017 the "EEG-reallocation charge" is not to be paid for charging and storage losses, as long as it is paid for the discharged energy. This regulation is applicable for 500 kWh/a per kW-capacity and abolishes one main hurdle for storage operators to use the flexibility potential of their storage in new business models. Nevertheless, in the EU the regulation of storages and the incentives to use them as flexibility (e.g. in aggregation models) should be further improved.

Therefore, it will be a main issue of the CALLIA project to elaborate, define and determine suggestions on how the regulatory framework could be developed in a smart way to enhance the usage of the full flexibility potential – technically and economically.

4.4 Digitalization

Smart Meters - Recording, transmitting and analyzing meter data is of interest both to network operators and suppliers and consumers. Meter data is therefore a fundamental element of the regulated network as well as the liberalized market. Hence, a "Smart Meter Rollout" concept has been defined for Germany, according to the "Meter Operation Law" (Messstellenbetriebsgesetz) [32].

The Rollout procedure has been planned starting from 2017 to 2032 and can be as seen below:

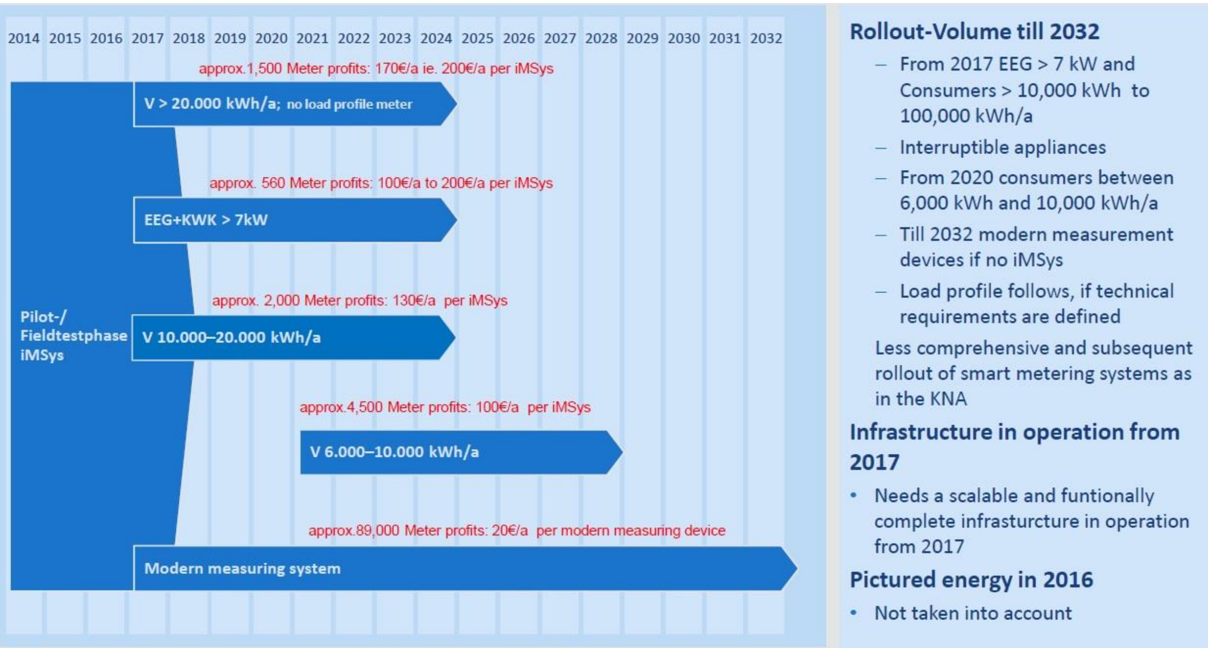

Fig. 23: Goals of the Europeans Union for a successful energy transition

In Belgium, there is currently no national plan for a rollout of smart meters since meters are maintained by the DSO's which are regional entities. In Flanders, there are currently 41,000 smart meters installed for test trials. Starting in 2019, the DSOs in Flanders can start the rollout of smart meters to other customers. In Wallonia and Brussels, the rollout is currently unplanned.

Turkey has seen the world's second largest increase in demand for energy over the last ten years, growth which is expected to continue at around 7% until 2023. To ensure the country's energy supply in the face of this growth, CLK Enerji (Turkey's largest electricity distribution and retail group) planned Turkey's largest ever smart meter pilot rollout, covering four distribution networks in 11 provinces. The rollout aims to test the relative benefits of different smart meter and communication infrastructures for the Turkish power system [33].

5 SUMMARY

This chapter gives an overview of those questions that have arisen over the course of the project, that need to be answered in order for the CALLIA market to be integrated into the existing regulatory framework in Europe.

1. **Which incentives do stakeholders (TSOs, DSOs, flex owners/aggregators, RES operators, traders etc.) have, in order to participate in the CALLIA Market? How could non-participating parties be included?**

Besides the envisaged general gain in social welfare by adding a possibility for energy trading and eliminating grid congestion in the same optimization problem, each stakeholder has different incentives or disincentives for participating in the CALLIA Market.

Table 2: Incentives and disincentives for different roles/actors for participating in the CALLIA Market

Role	Pro	Con
TSO	+ higher liquidity of flexibility in order to solve congestion + alternative for grid expansion, esp. in situations where grid expansion would not be efficient + chance for establishing better cooperation and communication processes (more efficient congestion management)	- grid information is shared with the party running the market algorithm - better cooperation and communication processes needed (higher workload)
DSO	+ same points valid as for TSO + congestion management now possible on distribution level	- same points valid as for TSO
Flex owner/ aggregator	+ new market and products as useful for new and/or extended business models + incentive to build new flex units in areas with high demand	- locational advantages and disadvantages at market start are hard to overcome
RES operator	+ new market and products as useful for new and/or extended business models	- locational advantages and disadvantages at market start are hard to overcome - RES especially wind and PV are insufficiently controllable; for biomass and hydro this is not a con
Trader	+ new market and products as useful for new and/or extended business models	- questionable if pure traders (without flex units)

		should have access to this kind of market
Market Operator/ Exchange	+ new business area and tasks	- Higher market amount and complexity to handle
NRAs/Governments	+ supports the aims of energy transition + opportunity to shape the yellow traffic light phase	- CALLIA Market is a kind of redispatch market, which contradicts the principle of merely cost-covering redispatch
...		

These incentives and disincentives are valid from a general point of view. As the focus is set on grid constraints and improved congestion management with flexibilities in the CALLIA Market, the main conclusion is that for social welfare there is an optimum between grid expansion and the use of flexibility to solve congestion. Not 100% grid expansion nor 100% use of flexibility will be the optimal solution for solving congestion issues. Nevertheless, grid reinforcements should be the first option to solve congestion issues, as this measure eliminates congestion not just for the moment, but for a very long time. We state that in the end there is a long-term equilibrium somewhere in between, but CALLIA project does not want to state where this equilibrium is located (could be different for every single grid operator, so no universal statement should be made). Otherwise grid operators as well as other market parties would have no incentive to participate in such a market construct.

A connection to other questions regarding, e.g. pricing mechanism or cost sharing can be done.

2. **Who pays for the flexibility traded on the CALLIA Market?**

Due to the consideration of grid constraints in the optimization problem the shadow prices of the CALLIA Market will differ from the optimal prices by assuming a copper plate without any grid constraints. This offset from the uniform price the market should show must be paid by someone. There are several options, e.g. the market parties or grid operators depending on who should be incentivized to manage and solve congestion situations. Most likely the grid operator that has the congestion problem, thus leading to off-set prices should pay for the difference. These prices/costs should be allocated to the grid fees, as the usage of flexibility avoiding grid congestion is an intermediate and alternative method to grid reinforcements, which should be incentivized first. Furthermore, also owners of flexibility and aggregators are incentivized by the possibility of gaining additional profits by offering existing or new flexibilities to the CALLIA Market. This area needs to be analysed further in detail.

3. **Are there energy or power products and how should they be defined?**

There is a broad variety of conceivable options for defining new products from the drawing table. Besides energy products and power products a hybrid of both is possible.

At the CALLIA Market an energy product [€/MWh] is traded. This is in line with the conceptions of the European Commission and NRAs to create and establish energy only market(s) for electric energy. The problem of taking grid constraints into account can be done explicit or implicit. In former times the transfer capacity between regions was often tendered explicitly. Thus, a power price must be paid for reserving free transfer capacity at specific borders and just afterwards energy could be traded. To avoid this hybrid product construction energy products come along with implicit consideration. An example would be the Price Coupling of Regions (PCR) mechanism with its algorithm "EUPHEMIA". It allows for international energy trading, just with energy products. The CALLIA Market works with a mechanism comparable to PCR but on a more local level also in distribution grids. The products themselves could look like trace bids or block orders (linked, smart, standalone).

Another relevant question, which CALLIA not intended to answer is, if such a market needs regulated prices or even price caps, e.g. to avoid very high revenues in extreme situations what may could lead to an overall loss in social welfare.

The embedding of the CALLIA framework with its products could be done as shown in the figure below, where the market environment for Germany is depicted (other countries may have e.g. other GCTs).

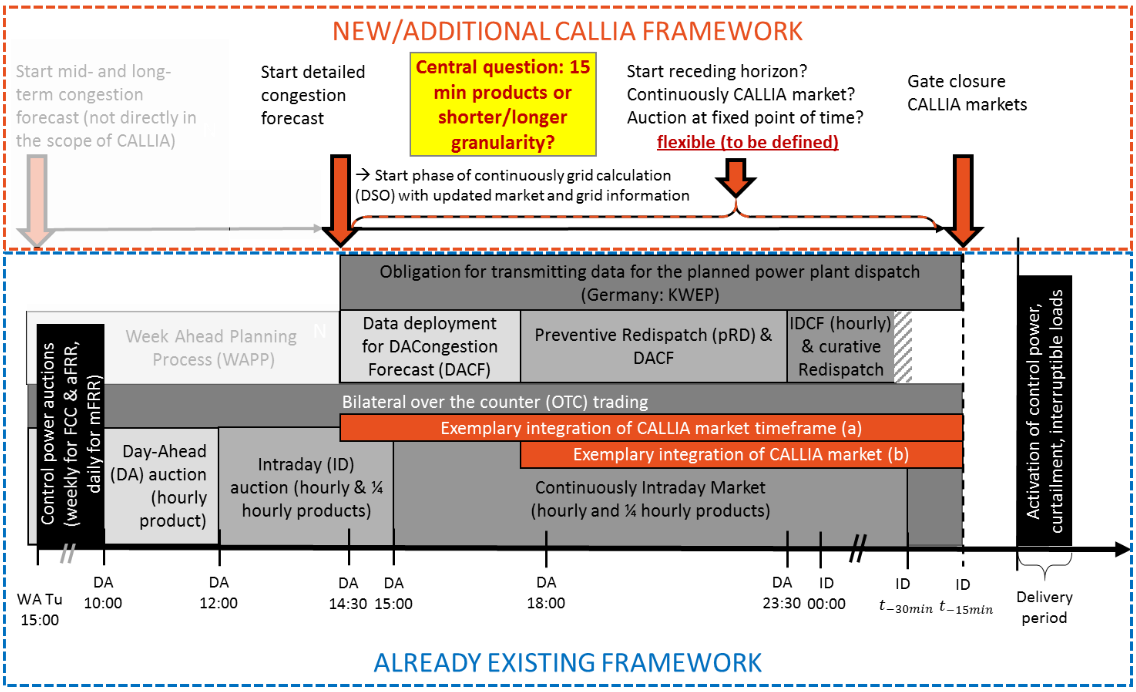

Fig. 24: Existing market framework extended by the CALLIA market

The CALLIA Market concept with energy products fits also to the balancing group system as shown in the figure.

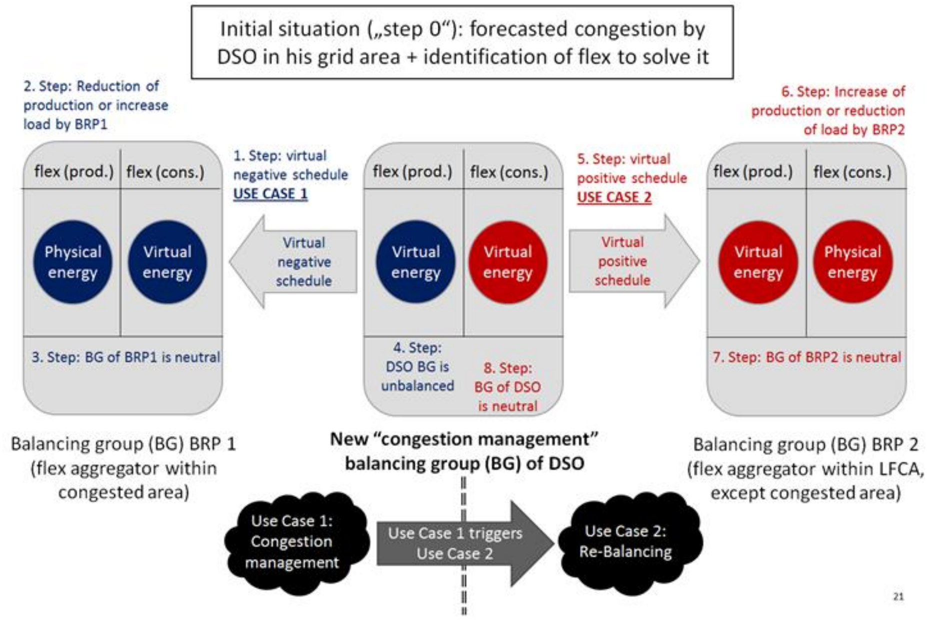

Fig. 25: CALLIA integration in balancing group system

4. How can the conflict between grid data confidentiality and transparency (reasonability) be resolved?

The answer to this question is highly correlating with the question who is running the market algorithm (see question 5). Both questions have to be seen in context. According to the ISO 27001 norm, all grid operators need to be certified in terms of grid data safety and security. Since grid data is sensitive information, a secure and safe interface to needs to be developed. One important and possible solution is the use of SMGW which with the Law of Digitalization determines who can access data and where can it be accessed from. The CALLIA project offers the concept of a "market – grid operator – interface" for a possible solution for the secure information and data exchange between the grid operator and the market.

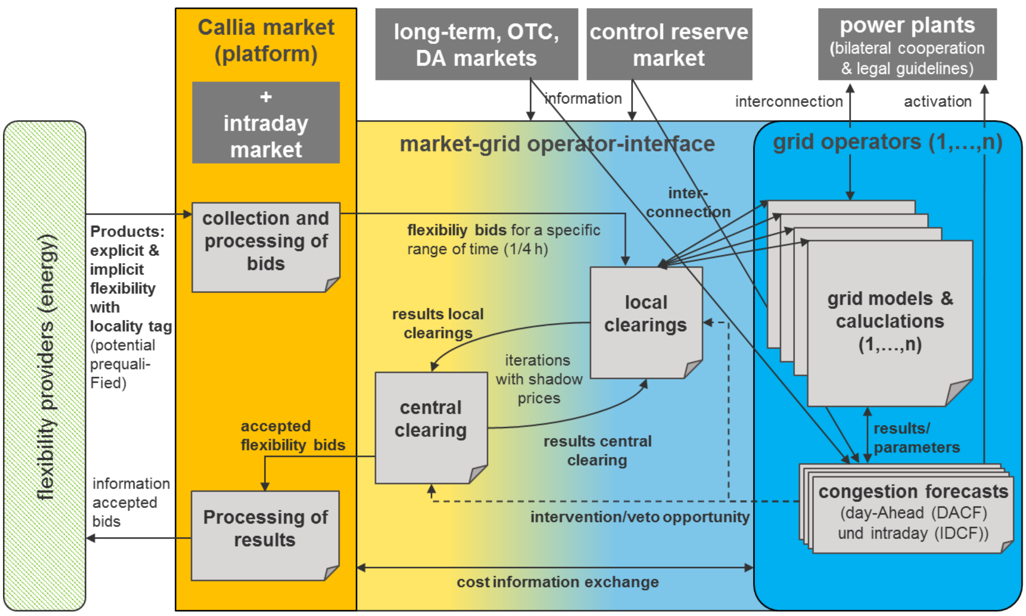

Fig. 26: CALLIA „market – grid operator – interface"

Furthermore, research was done by University of Stuttgart regarding opportunities for taking grid constraints into account of the market optimization problem. Here a methodology was developed which allows to linearize grid constraints expressed in sensitivity matrices that can be exchanged within the shown "market – grid operator – interface". Thus the optimization problem is solving congestion issues whilst not forcing grid operators to reveal all their internal and confidential grid data.

5. **Who runs the market algorithm? How can market abuse be avoided (e.g. regarding unbundling of market and grid, market power of single flexibility)?**

The answer to this question is highly depending on the answer to question 4 and especially on the answer how much knowledge of the grid the party running the market algorithm should have. All in the following described variations and options have assumed advantages and disadvantages. These are especially linked to the central question who is hosting the algorithm – nominated electricity market operator (NEMO) or grid operator? An overview is given in the following table.

	Advantages	Disadvantages
Grid operator (TSOs/ DSOs)	+ in depth knowledge of the grid constraints. Hence, no additional (probably sensitive) data needs to be sent to any other market actor + first point reduces the number of iterations that need to be run, in turn also assures easier implementation of the clearing algorithm + algorithm hosted by grid operators will lead to more vertical (TSO-DSO) and horizontal (DSO-DSO) communication + grid operator is a regulated party + the chain of congestion management remains in the sphere of grid operators in case of required short-termed measures where they have in every case the final say	- grid operators would have as market operator very detailed information regarding the whole grid structure and possible constraints what could give them a trading advantage towards e.g. aggregators. As a regulated party they should not use this market power, but this has to be checked - there is a possibility of discrimination since the market algorithm is no longer transparent for all market participants - grid operators would have to adapt knowledge of operating an clearing a market
NEMO	+ clearing algorithm hosted by a third party that is not participating in the market will lead to more independent and neutral solutions + since third parties like EPEX or EEX already have know-how in market operation the system in general will be more transparent, more efficient and indiscriminate	- grid operators in this case will be obliged to provide relevant and update the data periodically - if grid operators procure reduced grid information, e.g. linearized sensitivity matrices the result will be deteriorated (in comparison to the anyway

	+ better coordination between the CALLIA Market and the already existing energy markets	non-optimal result due to decomposition) - Due to the grid operators being obliged to giving out necessary grid data, data security (ISO 27001) could be a major issue - ICT is not available 24-7, as backup systems are costly, breaking the possible business case

So it gets clear that there can't be a solution where one of the two parties hosts the whole CALLIA Market and the belonging processes, whilst the other party isn't involved at all. To overcome most of the disadvantages five options that use the CALLIA "market – grid operator – interface" (question 4) were developed, shown in the following table.

	Option 1	Option 2	Option 3	Option 4	Option 5
Market	A + B	info	A + info	A + B*	A
Grid	info	A + B	B + info	B	A* + B

In the table shown above "A" represents the optimization algorithm and "B" represents the grid model. "Info" means that this party has to provide full information to the other party. The asterisk indicates a proxy connection, so the information stays in the boundary of this entity, but the other one has defined access privileges. In general there are three different fundamental variations, which could be shaped in different ways representing all five options in the table.

1) The market algorithm runs at nominated electricity market operator (NEMO)
   a. The NEMO receives full grid information. In this case grid operators should become shareholder of the NEMO as they procure all relevant internal and probably sensitive grid information (grid models). → Option 1
   b. The NEMO receives a reduced grid model to solve congestion within the optimization routine. This could be done e.g. through sensitivity matrices like described in the question before. Other linearization or grid reducing methodologies are also conceivable. → Option 1 (but with lower informational content)
   c. The compilation of the model is done at grid operators' side. The NEMO receives just an executable file without knowledge of the detailed grid information that is stored in this file. → Option 4
2) A third party will be installed next to NEMO and grid operator. This third party will run the market algorithm by receiving the necessary information from both, NEMO and grid operator. This concept would guarantee, that internal sensitive information would just be given to a secured environment and not passed to another stakeholder of the

CALLIA Market. The NEMO and the grid operator should become shareholder of this third party entity. → Option 3

3) The market algorithm runs at the grid operators (TSO/DSO)
    a. The compilation of the model is done at the NEMO, such that the grid operator receives only an executable file. This leads to the question, which grid operator represents the other grid operators, such as in Germany there are 4 TSOs and approximately 900 DSOs. In other countries there is not such a high diversity of grid operators (e.g. Turkey, Belgium or Austria with 1 TSO and just several DSOs). Nevertheless, also in these countries there must be one grid operator who is running the algorithm, as the algorithm is designed centrally. → Option 5
    b. The grid operator runs the full market model, adapting the knowledge of market clearing processes and receiving a license for operating a market place. The question of 3a). is the same, so the grid operators could probably install a new entity where each grid operator will be shareholder. → Option 2

Some other projects give also hints how this problem could be solved, e.g. IDCONS in the Netherlands or platforms developed within the German SINTEG program.

6. **What are the incentives for system operators for optimal employment between the usage of flexibility via the CALLIA market and grid reinforcements? How can this trade-off be measured (anticipated)?**

This question was already touched in the answer of question 1. Nevertheless, it is a very relevant question for the setting of the regulatory framework and depends also on how the products (question 3) will be defined and how arising cost will be shared (question 2).

Today there is no monetary incentive using flexibility by grid operators, but grid reinforcements. Using flexibility is motivated by law using market-based tools to avoid grid instability. Relevant measures are redispatch, curtailment of RES and other grid reserves. Nevertheless, knowing the optimal monetary turning point from which on grid reinforcement is more beneficial than using flexibility cannot be quantitatively in the CALLIA project.

A hint where the equilibrium could be and how it could be measured or calculated is given in the article, "Koordinierung netz- und systemdienlicher Flexibilitäten im Verteilungsnetz" [34] and "intelligenz und Kupfer – Bewertung netzoptimierender Maßnahmen im Verteilungsnetz" [35] in the ew-magazine of July 2017 (unfortunately just available in German).

7. **What happens if the market fails to produce a result? What are the costs in this case and who bares them?**

In CALLIA we adapt the traffic light concept. According to the German EnWG TSO and DSO are able to use flexibility, resp. redispatch measures, in order to resolve grid congestions (See §13(1) EnWG). This is denoted as the yellow traffic light phase. If the yellow phase and such the market participation (optimal solution within the CALLIA market) fails, the grid situation is in a critical state. This allows the grid operator to directly manage (control) production and load units within their grid. This is denoted as the red traffic light phase, following §13(2) EnWG in Germany. According to the law, there is no reimbursement of costs. Nevertheless, there is an exemption for RES according to §14EEG in Germany. Therefore, if the CALLIA market fails, grid state switches from yellow to red, providing grid operators the relevant tools to stabilize the overall energy system.

8. **Can system operators include the costs for the usage of flex from the CALLIA market in their grid tariffs? How can this be regulated? How can system operators justify these costs to the regulating agencies?**

In the present scenario, there is no provision for system operators to include costs for the usage of flex from the CALLIA market in their tariffs. This point should be investigated further.

9. **What could the pricing structure look like (nodal, flat/uniform, hybrid pricing)?**

The decision on market pricing structure is a political decision. The CALLIA project never intended to deliver any answers to this relevant question. Therefore, CALLIA proposes further projects and studies to support politicians within their decision making.

10. **How could low liquidity in regional/local clearing areas be dealt with (incentives for DSOs?)?**

The question as it is formulated is relevant for a separate flex market to the energy market. Therefore, the question needs to be posed differently, at which point a market party/ flex trader realizes its unique position within the grid to resolve a repetitive congestion. This knowledge would possibly lead to market abuse, increasing the energy price for this certain flexibility. Within the CALLIA project the question of market abuse was not at scope within the proposal, such that further studies should be performed to answer this relevant question.

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