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INTEgrated opeRation PLAnning tool towards the Pan-European Network

Work Package 2

Deliverable D2.2

Grid Code and regulation limitations

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Abbreviations

aFRR	Automatic Frequency Restoration Reserve
DCC	Direct Current Connection
DER	Distributed Energy Resource
DFIG	Doubly-Fed Induction Generator
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EV	Electric Vehicle
DG	Distributed Generation
DSR	Demand Side Response
ESS	Energy Storage System
FCR	Frequency Containment Reserve
FSM	Frequency Sensitive Mode
GCESC	Grid Connection European Stakeholder Committee
H2G	Heat to Gas
HTSO	Hellenic TSO
HVDC	High Voltage Direct Current
HV	High Voltage
ICT	Information and Communication Technology
IGD	Implementation Guidance Documents
LFCM	Limited Frequency Sensitive Mode
LFCM-O	LFCM Over-frequency
LFCM-U	LFCM Under-frequency
LV	Low Voltage
mFRR	Manual Frequency Restoration Reserve
MV	Medium Voltage
MW	Mega Watts
NECP	National Energy and Climate Plans
NEMO	Nominated Electricity Market Operators
NC	Network Code
NRA	National Regulatory Authorities
P2G	Power to Gas
PC	Project Coordinator
PGM	Power Generating Module
PPM	Power Park Module

PV	Photovoltaic
RCC	Regional Cooperation Council
RES	Renewable Energy Sources
RfG	Requirements for Generators
RoCoF	Rate of Change of Frequency
SCN	Subversion
SFC	System Frequency Control
SI	Synthetic Inertia
STI	Science Technology and Innovation
TSO	Transmission System Operator

Executive Summary

In this document, the identified practices in the countries of the consortium and related analysis and synthesis already conducted are extrapolated to cover all Member States aiming to identify gaps and barriers for integrating emerging technologies in existing grid codes. For this reason, this extended analysis was performed as follows:

- **Analyse Existing Network Codes related to emerging technologies and spot possible gaps and limitations.**

Under this section, the 'family' codes of ENTSO-e were analysed, i.e., Connection codes, operations and market codes. The omissions and needs for codes regarding emerging technologies are spotted as shown in the next table. It can be seen that the greater omissions exist in emerging technologies such as storage and DR in all family codes.

Table 1. Summary of the ENTSO-e 'family' codes analysis.

Needs as seen in ENTSO-e codes	Connection	Operations	Market
Motivation for the member states to make a clear legal framework for grid connections of RES and emerging technologies.	It doesn't cover chemical energy storages (i.e. battery) and other storage technologies as it should	-	Identify the details of the framework for RES & emerging technologies participation without discriminations.
Facilitation of the participation of RES, demand response and energy storage and make sure they compete with other balancing and ancillary services.	Specific reference to EV should be considered.	The TSO shall use only standard and, where justified, specific balancing energy products in order to maintain the system's balance and overall control.	Identify in details the framework that allow the aggregation of demand facilities, energy storage facilities and power generating facilities in a scheduling area to offer balancing services.
Provide the context for fault-ride-through capability and all stages of frequency control.	An international standard should be proposed while all actors of the modern energy system shall be taken under consideration e.g. Aggregators	More analysis and details should be given for different storage devices technologies to accommodate their unique technical characteristics.	-
Provisions for Electricity operational planning data environment	-	Extra consideration should be given for the emerging technologies and schemes that forecasting is also	-

		needed. e.g demand response, EVs etc. Regarding outage coordination all technologies should be explicitly mentioned and their technical characteristics should be taken care of.	
Detailed rules on cross-zonal capacity allocation in the forward markets,	-	-	The related documents do not cover the market's participants under the technology point of view, but it offers a general context of the procedures that participants need to follow to participate into the forward markets. To secure long-term transmission rights to allow cross-border hedging by 2021 of RES, storage etc. more details per technology should be considered.
Rules on congestion management	-	As energy directive suggests storage can be owned by operators, related regulations on their operation should be included	As storage can play significant role in congestion management, explicit rules on participating in the market for this purpose should be given.

- **Analyse Implementation Guidance Documents on integration of emerging technologies in regulations.**

To determine in detail how the codes are implemented at national level and under certain conditions, ENTSO-e has developed the so-called implementation guidance documents (IGD). All ENTSO-e IGD documents were analysed (see details in Annex 2) whereas the main findings are presented in the main body of the deliverable. From this detailed analysis, it is evident that the implementation of storage technologies and DR are not adequately covered revealing serious shortcomings in the implementation of codes in Europe.

- **Questionnaire based analysis on Grid Codes limitations**

To further diagnose the situation in Europe, the consortium of INTERPLAN has agreed to put together a targeted questionnaire to country stakeholders using a detailed template (Table 2 in Section 3). This was circulated among stakeholders to get their feedback on the degree that the identified emerging technologies were covered in their national codes. Their replies were analysed confirming the findings of deliverable 2.1[1] and the reported gaps and shortcomings from the analysis of ENTSO-e codes and IGDs referred to above.

- **Highlight the status of each Member State regarding their intention to integrate further regulations to achieve EU targets**.

Under this section, clean energy package recommendations regarding technologies were analysed. According to these, the National Energy and Climate Plans (NECP) of each country, the readiness and willingness to fulfil the recommendations were analysed. It has to be mentioned that although most of countries have a high rate of willingness to embrace emerging technologies, they do have low readiness when it comes to solid codes on storage & DR at the same time.

- **Extent the conclusions of the above bullets with further evidence and experience from use cases within INTERPLAN to get more conclusive evidence on the critical issues of grids in operation and possible interconnection limitations needed to be addressed in the future.**
- **Last section reviews the report "A toolbox for TSOs and DSOs to make use of new system and grid services" that focuses on TSO – DSO coordination in congestion management and balancing services.**

This report describes the needs from the operators' point of view to perform analysis and provide services. From the analysis, it is clear that operators need an analytical and flexible tool to do so whereas all emerging technologies should be considered at the same time proving the need for the INTERPLAN tool to complement existing tools and means available to the TSOs and DSOs.

The outcome of this document (D2.2) will provide input for further activities of WP2 and its deliverables on how the identified omissions and barriers could be lifted up and how operators move forward.

1 Introduction

This document is the outcome of the agreed merge of T2.2 Pan European interconnection assessment: detailed study of the main interconnection issues and criticalities, at Pan-European level and T2.3 Regulatory framework study by country at Pan-European level, including existing grid codes. This task will take the D2.1 further to capture the status of all European countries and relate it to current national and European grid codes under the prism of integrating emerging technologies. To do this, different aspects of regulations and grid codes are approached to identify the limitations and this way the outcome of this work will be useful as input to further work on WP2 for providing Grid Code recommendations in the next.

1.1 Purpose of the Document

This document aims to:

- Analyse Existing Network Codes related to emerging technologies and spot possible gaps and limitations.
- Analyse Implementation Guidance Documents on integration of emerging technologies in regulations.
- Highlight the status of each Member State regarding their intention to integrate further regulations to achieve EU targets.
- Extent the conclusions of the above bullets with further evidence and experience from Use cases within INTERPLAN to get more conclusive evidence on the critical issues of grids in operation and possible interconnection limitations needed to be addressed in the future.

1.2 Scope of the Document

This work will assist in:

- qualifying and quantifying the limitations faced by the industry in adapting to the requirements of the emerging technologies and
- relating the findings to the content that developments should address in order to make them responsive to the needs of the system.
- elaborating requirements to the detail required by policy makers.
- providing input to T2.4 Proposal for possible amendments to grid codes and implication on European regulations, for developing the policy and grid codes that will be responsive to the requirements of the emerging technologies and be aligned to the needs of the industry for managing the sustainable solutions that emerging technologies support.

1.3 Structure of the Document

The document is structured as follows: Section 2 analyses the main Grid Codes and highlights, where applicable, the codes limitations and regulation gaps. The Codes are analysed on how they address the emerging technologies and three categories of codes are considered: Connection, Operations and Market. In the same section, an analysis of the Implementation Guidance documents on the codes based on the data provided by ENTSO-e is performed. Some regulation barriers based on findings of sent questionnaires to stakeholders and literature review are also presented in Section 3. In Section 4, clean energy package recommendations are analysed under the prism of the emerging technologies. In the same section and according to the findings of the clean energy package, the NECP plans of all European member countries are reviewed to provide an estimation of the countries willing to integrate regulations and overcome barriers. Section 5 links the Use Cases of INTERPLAN with regulations needed for emerging technologies. Its aim is to investigate the barriers -if any-of the associated regulations under the analysis scope of the Use Cases. Section 6 reviews a key report regarding the need for TSO-DSO integrated approach to active system management. Section 7 presents the conclusions and opens discussion on the main findings.

2 Grid Codes for the Emerging Technologies of European Countries

Within this section, an analysis of the Grid codes in European level is discussed as provided by ENTSO-e. The aim of this section is to highlight the Grid Codes under the prism of emerging technologies and spot any shortcomings or barriers. The methodology that was adopted is described below.

2.1 Categorise the codes and set up code "families"

The categorization of the codes is the one followed by ENTSO-e. Thus, the following categories are formed:

- **Connection codes**
  - Requirements for Generators
  - Demand Connection Code
  - High Voltage Direct Current Connection

- **Operations**
  - System Operations
  - Emergency and Restorations

- **Market**
  - Electricity Balancing
  - Forward Capacity Allocation
  - Capacity Allocation and Congestion Management

2.2 Populate exhaustive list of keywords

The codes text is investigated by using keywords related to the emerging technologies i.e., RES, DG, storage, EVs and DR. The list of keywords are:

> RES, DG, PV, Photovoltaic, Wind, Biomass, Hydro, Wave, Tidal, Storage, Battery, Compressed air, Pump storage, Heat storage, P2G, H2G, Fuel cells, Hydrogen, Flywheels, Electric vehicles, EV, Mobility, Hybrid, Charging, Smart charging, Alternative fuel, Demand Response, DR, Demand Side Management, DSM, Demand flexibility, Flexibility, Aggregator, Inverter, Converter, Power electronic, Sensors, Smart meter

2.3 Forming a table of Shortcomings/Limitations

Table 2 summarizes regulations, description, analysis and spotted limitation per technology/ies and code families. The detailed analysis is presented in ANNEX 1. Here a summary of this analysis is shown in the next table. First column presents the needs/gaps to be addressed as spotted within the codes. Next columns brief the recommendations for further inclusion under each family code by considering issues addressed by INTERPLAN.

Table 2: Summary of the limitations based on codes analysis and INTERPLAN recommendations.

Needs as seen in ENTSO-e codes	Connection	Operations	Market
Motivation for the member states to	It does not cover chemical energy	-	Identify the details of the framework for

make a clear legal framework for grid connections of RES and emerging technologies.	storages (i.e. battery) and other storage technologies as it should		RES & emerging technologies participation without any discriminations.
Facilitation of the participation of RES, demand response and energy storage and make sure they compete with other balancing and ancillary services.	Specific reference to EV should be considered.	The TSO shall use only standard and, where justified, specific balancing energy products in order to maintain the system's balance and overall control.	Identify in details the framework that allows the aggregation of demand facilities, energy storage facilities and power generating facilities in a scheduling area to offer balancing services.
Provide the context for fault-ride-through capability and all stages of frequency control.	An international standard should be proposed while all actors of the modern energy system shall be taken under consideration e.g., Aggregators	More analysis and details should be given for different storage devices technologies to accommodate their unique technical characteristics.	-
Provisions for Electricity operational planning data environment	-	Extra consideration should be given for the emerging technologies and schemes that forecasting is also needed. e.g demand response, EVs etc. Regarding outage coordination, all technologies should be explicitly mentioned and their technical characteristics should be taken care of.	-
Detailed rules on cross-zonal capacity allocation in the forward markets,	-	-	The related documents do not cover the market's participants under the technology point of view, but it offers a general context of the procedures that

			participants need to follow to participate into the forward markets. To secure long-term transmission rights to allow cross-border hedging by 2021 of RES, storage etc. more details per technology should be considered.
Rules on congestion management	-	As energy directive suggests storage can be owned by operators, related regulations on their operation should be included.	As storage can play significant role in congestion management, explicit rules on participating in the market for this purpose should be given.

2.4 Implementation Guidance Documents Analysis.

Further to the codes, ENTSO-E publishes the IGDs on the Grid Related Parameters and the Response to the comments received during the public consultation.
IGDs' scope is to support the national implementation process and provide more information and clarity to both TSOs and relevant stakeholders on a set of non-exhaustive requirements.
More specific, as stated by ENTSO-E they aim to:

- Ensure coordinated approach at synchronous area level of the national implementation on grid related parameters.
- Ensure transparency on the approaches, processes and decisions taken in each country
    - Timing of implementation guidance must be compatible with the timing of each country's national implementation process to be informed by this guidance. The overall timing is driven by the deadlines of NC requirements for Generation (RfG), which was the first connection code to enter into force.
    - Timing for the elaboration of European standards is also to be considered.
    - Coherence between Connection and Operation codes/guidelines need to be ensured.

Research on all code families has been extended through the Implementation Guidance Documents. In ANNEX 2 selected IGDs were analysed to provide a brief overview for each case on the background of the topic and on how this is addressed in the regulation/guideline.

3 Questionnaire based analysis on Grid Codes limitations

The aim of this section is to identify the main limitations and grid codes' barriers related to the emerging technologies such as storage, RES and EV and innovative schemes such as DR through the stakeholders' view.

From the analysis of Deliverable D2.1 [ref.1], it is clear that examined countries, i.e., Italy, Austria, Germany, Poland and Cyprus, adequately address regulation, policies and codes of installation and operation of RES systems. However, storage, EV and DR are issues that are still not covered adequately through regulations, policies and codes and in some countries, they are non-existent. What is more, for all three technologies and DR scheme, modelling and planning tools are not readily available and hence operators have difficulties to plan and operate the active network that is emerging and growing, in an efficient and optimal way.

These issues create shortcomings such as:

- lack of observability for distributed RES in planning and operational practices
- advanced features of power electronics in inverters are not fully utilized
- the aggregated benefits of storage systems with EVs and heat pumps are not used etc.

In order to further elaborate the results presented in Deliverable D2.1, the following template (Table 3) was circulated among external stakeholders to get their feedback and their insight. The replies were analysed to confirm the outcomes found for countries in INTERPLAN consortium and also expand them under a different prism.

Table 3 The template of the circulated questionnaire.

Technology	Shortcomings to be addressed by INTERPLAN	National practices worthy of picking up to extend and replicate
Intermittent RES	A shortcoming for RES integration is the risk of congestion problems in less developed parts of the power system. This issue is the main obstacle in the process of new RES interconnection. Until grid reinforcement is not accomplished the RES can be connected provided that the owner accepts the probability of the RES production being curtailed.	System operators are obliged to publish values of available power that can be connected in each node without causing overloading or voltage problems. One way to calculate this power is to use the concept of coherent nodes, which groups the nodes based on given criterion. This method can also be used to identify parts of the network that can be substituted by simplified equivalent.

Storage including Electric Vehicles, heat pump solutions for heating and cooling	Storage systems must be considered in the same way as intermittent RES with their nominal feed-in power. For the connection assessment of the combination of RES with storage systems, the sum of the nominal power must be considered (only if it is planned that the storage system is also injecting active power to the grid) For storage + RES systems with a nominal power greater than 100kVA, the DSO is allowed to curtail active power in steps of 10% of the nominal power.	The methods for integration in the electrical system of storage systems made by actors different from the System Operators are the same for all types of storage systems. In defining this regulation, there is no distinction between the different technologies for storage in order not to promote the development of some solutions to the detriment of others. From the regulatory point of view, there are no differences between electrochemical storage, pumped-storage plants or other solutions. This approach represents a prime example of technology neutral regulation, as a key principle that will inspire the evolution of the regulation of services for the electricity system in the near future
Flexible Demand Response including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	TSO assumes utilisation of demand response as an available means for balancing purposes, however there is no standard model allowing the incorporation of the methods used by the TSO to acquire the DSR service. The same applies for the aggregator model who manages many loads in the system and can implement reduction order differently amongst its service providers.	(none available so far)

The Centre for Renewable Energy Sources and Saving (CRES) is the Greek organisation for Renewable Energy Sources (RES), Rational Use of Energy (RUE) and Energy Saving (ES). CRES has been appointed as the national co-ordination centre in its area of activity. CRES feedback is shown in Table 4 below.

Table 4. CRES feedback

Technology	Shortcomings to be addressed by INTERPLAN	National practices worthy of picking up to extend and replicate
Intermittent RES	Hosting higher RES capacity by the Greek Power System without significant reinforcement of the grids would require curtailments of EES production during peak hours. The curtailment is a practice used in a small scale on islands such as Crete and only for large Wind Farms. A wider and more efficient use of the method would require implementation on other technologies connected to the mainland system. In order for a solution like this to be viable monetary incentives should be provided to the RES owners.	In terms of planning and hosting RES to the grid the system operator publishes the grid capacities per grid node. Based on this data the selection of areas favourable for RES investments is done.
Storage including Electric Vehicles, heat pump solutions for heating and cooling	Up until recently no storage technologies were permitted to the Greek Power System. These technologies would allow for a more efficient use of RES, with the reduction of congestions, imbalances and other problems on the grid. Ideally, the storage technologies could be owned by RES owners or system operators and operated by the latter in order to resolve the various balancing problems of RES.	The methods for integration in the electrical system of storage systems made by actors different from the System Operators are the same for all types of storage systems. Recently, by Law 4513/2108, it has become possible for communities to participate in the electricity market as energy communities that, among others, can accommodate different storage technologies. Thus, the energy communities which are connected to MV/LV distribution grids and incorporate small RES, flexible loads and storage in principle acquire the main characteristics of microgrids.
Flexible Demand Response including Electric Vehicles, heat pump solutions for heating and	Currently, the HTSO (Hellenic TSO) utilizes demand response only for the curtailment of a small number of big industrial consumers. The model used for that is based on bilateral contracts. A wider and more	(none available so far)

cooling, hot water etc	advanced use of DR would require the engagement of smaller, residential or other consumers. To facilitate this, specific monetary incentives and market models should be developed.	

Generalist für Kälte-, Klima- und Energietechnik und Spezialist für umfassende Problemlösungen,IKET

IKET is the Institute of Refrigeration, Air Conditioning and Energy Engineering. Their main activities are to collect, analyze and compare what is published in materials in the disciplines of refrigeration, climate and energy.

Table 5. IKET feedback

Technology	Shortcomings to be addressed by INTERPLAN	National practices worthy of picking up to extend and replicate
Intermittent RES	A shortcoming for RES integration is the development of concepts on power distribution strategies in times of power shortage. Intermittency of RES and the extension of smart ICT infrastructures may lead to an increase of supply risks due to e.g. dark doldrums. In view of such scenarios' models are missing that target at **resilient** grid planning (suitable cellular decomposition) or resilient distribution management systems/strategies.	In a highly decentralized power system –with new network topologies on the distribution level- ancillary services as they exist should be extended or reviewed - that is broadly neglected. It all begins in the design phase regarding grid extensions. This all the more is emphasized in view of the aforementioned increase of supply risks.
Storage including Electric Vehicles, heat pump solutions for heating and cooling	Same as above. Storage systems should be considered as a crucial aspect when designing resilient power systems: How should micro grids be constructed by taking various feasible storage systems and also other (critical) infrastructure systems into account? For the resilience of dense regions, e.g. urban areas, a continuous functioning of critical infrastructure systems is	See above.

	crucial and should be kept in mind.	
Flexible Demand Response including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	A drastic increase of demand caused by electric vehicles etc. is expected. And it is believed that demand shifts, to reduce demand peaks, are hardly realisable since loading profiles are oriented towards traffic behaviours. The share of electric vehicles is still low and the physical network capacities are still sufficient. A substantial increase of electric vehicles in the next years might lead to overloaded/congested distribution networks. **Thus, integrated models, assessing physical power network stabilities, taking various demand models into account are missing**. Since grid extension takes time and is disruptive such models are important for grid planning issues.	Decision support systems for grid extensions taking (new) demand models into account are not broadly used. But since loads could drastically increase due to e.g. a high share of electric vehicles, grid/asset planning should be more prioritized on a national scale.

The **Scientific and Technological Research Council of Turkey** (**TÜBİTAK**) is a national agency of Turkey whose stated goal is to develop "science, technology and innovation" (STI) policies, support and conduct research and development, and to "play a leading role in the creation of a science and technology culture" in the country. -TurkeyThe following table has been filled considering Turkish case.

Table 6. TÜBİTAK feedback

Technology	Shortcomings to be addressed by INTERPLAN	National practices worthy of picking up to extend and replicate
Intermittent RES	Intermittent RES in Turkey has a “guarantee of purchase” in the market so far, thus they are operating as long as they are actively connected to the system. This situation may create a problem when the amount of generation from RES	As the generation from intermittent RES increases, the regulation of ““guarantee of purchase” will change soon to prevent the uncontrolled generation and less flexible market operations in the system. For the current practices, the

	is at high level. The capacity of intermittent RES has not been at very high level so far. However, during some periods (e.g., spring), high generation from intermittent plants requires a management and coordination of additional bulk reserves and transmission network in the system.	system operator allows only limited connection capacities of RES to some critical HV/MV substation transformers and areas.
Storage including Electric Vehicles, heat pump solutions for heating and cooling	Storage systems, electric vehicles and other solutions are not common in the Turkish electrical network. However, studies regarding development of regulations pertinent with electric storage systems has been contacted by the EMRA of Turkey.	(none available so far)
Flexible Demand Response including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	There is no flexible demand response action in the system. However, there are some regulations in the scope of demand response activity that can be applied in some specific conditions. For instance, there is an “instantaneous demand control”, which enables the low-current relays in case of a frequency disturbance. Moreover, Turkish ISO (TEIAS) allows distribution companies to make necessary demand control in the distribution for the frequency stability.	(none available so far)

In Table 7 below, the main findings from the responses of the three countries i.e. Greece, Turkey, Germany are presented.

Table 7. Synopsis of the questionnaires’ findings.

Spotted needs	**Country**	**Technologies**			**Schemes**
		Storage	**EV**	**RES**	**DR**
	Greece	It is spotted that a need for regulations embracing energy collective organisations such as energy communities can boost emerging technologies penetration and employ DR			

		schemes. This way, more effective exploitation form RES energy will be achieved.		
	Turkey			It is spotted that high RES penetration can affect normal operation of the TSO. Thus, regulations that cope with the above in the DSO-TSO interface should be handed. DR schemes regulation that would alleviate the above could also be addressed. To this extend modelling of node capacity before RES integration should be handled with special care.
	Germany	Integrated models, assessing physical power network stabilities, taking various demand models into account are missing as a planning tool for grid operators. Also, integration of use cases to address grid as a whole and thus its resilience should be addressed.		

The Questionnaire’s findings prove the lack of regulations and grid codes at the present to integrate emerging technologies to the grid without jeopardizing security and reliability. Especially, EV, storage and DR schemes that seem to be missed completely in case of Greece and Turkey. Whereas in case of RES, attention should be given in greater penetration levels. In case of Germany, as already spotted in Deliverable D2.1, some regulations for all technologies are in force. Nevertheless, the need for integrated models and use cases as decision planning tool is underlined. In this context, INTERPLAN grid modelling / design of equivalents and controllers can prove to be a valuable tool for the operators of both transmission and distribution grid.

The questionnaire has proven to give a general insight about the needs of the above countries and European countries in general. To dig further and spot specific missing links a review analysis on NECPs is going to be given in the next subsection.

4 Clean Energy Package and review based analysis on NECP of European countries

The energy sector is important for the European economy: energy prices affect the competitiveness of the whole economy and represent on average 6% of annual household expenditure Clean Energy Package presents an opportunity to speed both the clean energy transition and sustainable growth. [2].

The presented regulatory proposals of Clean Energy package aim at modernising the economy and boosting investments in clean energy related sectors helping to tackle the energy trilemma at the same time.

So, the legislative proposals cover energy efficiency, renewable energy, storage, DR schemes, the design of the electricity market, security of supply and governance rules for the Energy Union.

In the next, the Clean Energy package recommendations on regulations will be given in brief under the emerging technologies perspective i.e storage/EV, RES and DR scheme. After this quote, the implementation level for European countries based on their submitted NECP are going to be linked to these recommendations.

4.1 Storage/EV

According to the outcomes of the package related to storage, regulations should secure the following:

1. Energy storage services should be a market- based activity and developed under competitive terms
2. Efficient use of storage facilities and fair access to storage services for all market participants
3. Avoid distortion of competition and cross-subsidization between storage and distribution/transmission of electricity
4. The new Electricity Directive and Regulation under the Circular Economy Package (CEP), puts in place a new framework for energy storage in the electricity system:
5. Energy storage definition which accommodates the different storage technologies
6. Specific role of network operators
7. Participation of energy storage in the market and provision of flexibility services at a level playing field with other energy resources

4.1.1 DSO and TSO roles foreseen

DSOs and TSOs **should <u>not</u> own** or **operate storage** facilities or **be involved** in development/management of such facilities

Member States could allow operators to get involved in such activity for ensuring reliable and secure operation of the system, under the following cases:

1. If other parties could not invest and deliver storage services
2. For fully integrated network components
3. For battery storage facilities with a FID before the entry into force of the Directive for DSOs, and 2024 for TSOs

4.1.2 Participation of storage in the market

Regulations regarding storage should secure:

1. Participation of energy storage in the electricity market without discrimination
2. Non-discriminatory and effective provision of storage services:

- Balancing
- Non - frequency ancillary services
- Flexibility services for DSOs

3. Market rules for facilitating the participation of energy storage in the market alongside generation and demand response

   - Redispatching rules should account for storage
   - Network tariffs should not discriminate against energy storage
   - Participation in capacity mechanisms
   - Network code on DR and storage

4.2 Renewable Energy Sources-RES

Regulations regarding RES should secure the following:

1. Must not distort markets (as have seen before i.e. feed in tariffs) whereas must incentivise RES producers to respond to market price signals.
2. Should be subject to limited exceptions, support schemes must be market-based (generally through premiums), must involve open, transparent and non-discriminatory tenders and must be technology-neutral.
3. Must be open to cross-border participation by RES in directly interconnected Member States, subject to cooperation agreement.
4. Non-discriminatory and market-based priority dispatch for RES and high-efficiency cogen<400kW (from 2026, only for RES<200kW);

Member States may decide not to apply priority dispatch in accessible and high RES markets

- existing priority dispatch for RES remains until plant modified/new connection agreement/capacity increased
- priority dispatch not grounds for curtailment of cross-border capacities except in emergency

5. curtailment/redispatch of RES to be minimised by

- balancing energy bids for redispatching not to set the balancing energy price
- if non-market-based, then compensation to be paid

4.2.1 DSO and TSO roles foreseen

All DSOs must create an “EU-DSO",with roles in:

- coordination of TSO and DSO networks
- integration of RES and DSR

4.2.2 Participation of RES-E in the market

Day-ahead (DA) and intraday (ID) markets where RES participates should have:

- harmonised gate closure times
- consistent products, volumes (min ≤ 500 kW) to permit participation by all market participants including RES-E), market times (≤ imbalance settlement period), and non-discriminatory access/trading principles
- reliable price signals

Regarding Forward markets:

- Long-term transmission rights
- To allow cross-border hedging by 2021 should be secured.

4.3 Demand Response (DR)

Regulations on DR–active customers and aggregators should be enabling them

1. To act without consent of suppliers, to be balance responsible and to compensate suppliers
2. Non-discriminatory and market- based (ie. based on bids by generators/DSR providers) only subject to specific conditions
3. Curtailment (not running) and redispatching (instructing generators/DSR to change their schedule): non-discriminatory and market-based (ie. based on bids by generators/DSR providers) only subject to specific conditions

4.3.1 DSO and TSO roles foreseen

- NRAs, TSOs, DSOs needs to ensure that DSR can participate fully in flexibility
- Member States to incentivise DSOs to procure flexibility

4.3.2 Participation of DR in the market

When DR participates in the market, the following should hold:

- Equal treatment of generation, demand-side response (DSR) and storage; aggregation of consumers, generators and demand response permitted
- Enhance development of more flexible generation and demand
- All market participants to be balance responsible or to delegate balance responsibility (exceptions for demonstration projects, RES-E below 400 kW– reducing to 200 kW for plant commissioned from 2026–and for existing recipients of feed-in tariff

In the following table, the recommendations of Clean Energy Package and the Energy Directive are summarized:

Table 8. Mapping of Regulation needs according to Clean Energy Package for all technologies

Technologies	Market Regulations	TSO and DSO Roles regulation
Storage	- Services should be a market-based activity and developed under competitive terms. - Provision of flexibility services at a level playing field with other energy resources. So, market rules for facilitating the participation of energy storage in the market alongside generation and demand response - Efficient use of storage facilities and fair access to storage services	- DSOs and TSOs should not own or operate storage facilities or be involved in development / management of such facilities for ensuring reliable and secure operation of the system.

	for all market participants should be foreseen. - Neutral on storage technologies	
RES	- Not distort markets (as have seen before i.e. feed in tariffs) whereas must incentivise RES-E producers to respond to market price signals. - Must be open to cross-border participation by RES-E in directly interconnected Member States, subject to cooperation agreement. - Non-discriminatory and market-based priority dispatch for RES-E - Curtailment/redispatch of RES-E to be minimised	- high integration of RES-E and DSR
DR	- Non-discriminatory and market-based (ie. based on bids by generators/DSR providers) only subject to specific conditions. - Equal treatment of generation, demand-side response (DSR) and storage; aggregation of consumers, generators and demand response permitted. - All market participants to be balancing responsible or to delegate balance responsibility and for existing recipients of feed-in tariff.	-TSOs and DSOs to ensure that DSR can participate fully in flexibility. -Member States to incentivise DSOs to procure flexibility.

4.4 EU countries analysis according to NECPs

According to the Clean Energy Package, EU countries are required to:

- develop integrated NECPs that cover the five dimensions of the energy union for the period 2021 to 2030 (and every subsequent ten-year period) based on a common template
- submit a draft NECP by 31 December 2018 and be ready to submit the final plans by 31 December 2019 to the European Commission
- report on the progress they make in implementing their NECPs, mostly on a biennial basis

The Commission monitors the progress of the EU as a whole, notably as part of the annual state of the energy union report. The countries in the table below have already submitted Draft NECPs submitted to the European Commission (as of 11 March 2019) and expect EC feedback [3,4].
This section aims to evaluate in which level EU countries are willing and ready to implement the directives' recommendation according to their NECPs and under the prism of the technologies mentioned in previous section. It has to be noted that the evaluation of countries is based **ONLY** in the data that they have provided and submitted through their NECPs to EC.

Therefore, for readiness and willingness evaluation, the traffic light colouring is employed where red lettering is used for countries with low readiness level or countries that haven't yet submitted their report. Yellow lettering goes for countries that have a good willingness level, but readiness is still low at the moment and Green Lettering goes for countries with both good readiness and willingness level. The first column provides the analysis/ comments of the INTERPLAN partners (green highlight) whereas the columns per technology (in orange) include representative quotations of the NECPs.

Table 9. Countries status regarding implementing regulations for all technologies.

No	Countries	RES	STORAGE	DR
1	**Austria** According to the NECPs submitted, Austria is on a good truck on achieving higher RES penetration and put significant resources on storage investment. Also, Austria is above average in interconnection with neighbouring countries and ready to build an integral competitive energy market	Ready to: -Expand electricity generation from RES under the Renewable Energy Expansion Act (Erneuerbaren-Ausbau-Gesetz) -Create a '100000 rooftops solar panel and small-scale storage programme' Abolish the tax on self-produced electricity - Set basic conditions for feeding biogas and 'renewable' hydrogen into the existing natural gas infrastructure -Have a Preferential tax treatment for renewable gases -Develop a hydrogen strategy -Support sector-specific investments in the future of the hydrocarbon industry (mining royalties)	Significant investment in storage infrastructure and transmission and distribution networks will be made which is adapted to increase demand. Previous economic investment (e.g. in infrastructure facilities, pipelines, storage facilities, power plants) will contribute towards transforming the energy system.	Competitive pricing mechanisms that take account of tax, duty and incentives will be used to minimise market distortions. Households, commerce and industry will be able to participate actively in the energy market and to react to price signals. Balanced tariff structure is envisaged. Flexible grid tariffs which work in the interests of the system can have a balancing effect on the energy system and thus reduce overall system costs. Grid tariff structures will be simplified and made more transparent for consumers so that they can also take future dynamic pricing into account
2	**Belgium** According to the NECPs submitted, Belgium seems to be left behind regarding the set targets of EU regarding RES	Based on the measures outlined in the entity specific plans, Belgium will generate 18.3% of its gross final energy consumption from	Solutions will be found in response to the increasing need for flexibility using storage, the reciprocal adaptation of supply and demand, the	To encourage market integration, the results of the existing market coupling will be evaluated at regular intervals.

	penetration and interconnection. It is the country's priority to decommission nuclear power whereas it seems willing to work on solutions towards the 5 dimensions of the Energy Directive.	renewable energy sources (RES) by the EU due date.	extension of connections between countries, the improvement of energy networks, the establishment of energy communities and the creation of options for energy storage	
3	**Bulgaria** According to their NECPs, incentives are given to increase RES penetration. Nuclear substation secures energy supplies while interconnection with neighbouring countries are evolving. Gas Storage facilities do exist. Currently, regulations on storage and DR are absent and planning of their implementation looks abstract.	Currently Bulgaria is pursuing a targeted policy for development of renewable energy. Different support schemes have been introduced over the years to ensure that renewable energy production will develop	Further Regulations will be introduced to increase the electricity and natural gas storage capacity by developing the existing storage facilities and by building new storage facilities.	Aims to Enhance the flexibility of the system by developing balancing facilities, energy storage capacity and skills for energy management. Aims to Create appropriate conditions and increased participation of demand response, in individual or aggregated terms, both in the wholesale market and in the balancing market. Bulgaria took steps towards full liberalisation of the electricity market. The full liberalisation of the electricity market will create conditions for enhanced system flexibility by securing conditions for achieving competitive prices and will increase the liquidity on the electricity exchange
4	**Croatia** Within the framework of preparation of the	Renewables are high in the agenda of Croatia and targeted	Energy storage in the power system will contribute to its	Ancillary services and services of flexibility that

	Energy Development Strategy of the Republic of Croatia until 2030 with an outlook to 2050, in November 2018 analytical backgrounds have been developed - the so-called Green Paper. In 2030, the values of the key indicators are: 36.4% and a corresponding reduction in CO_2 emissions and an increase in efficiency in line with the EU objectives. However, the country has no storage facilities and DR is considered as necessary but not planned as yet.	objectives are in line with the EU figures. Moreover, follow a policy of promoting the use of RES at the point of consumption. About electricity interconnection, it is necessary to consider the EU target according to which the desired level of electricity interconnection is at least 15% compared to the installed power of power plants in the observed state by 2030. The transmission system in the territory of the Republic of Croatia already meets and exceeds that target many times over. The same applies if the existing electricity interconnection capacity is compared with the peak load of the system or the installed power of RES in the territory of the Republic of Croatia.	flexibility. In the forthcoming period, the construction of a pumped-storage hydroelectric power plant is expected, which will enable greater integration of variable renewable energy sources, primarily sun and wind. Major technological advances are expected in the application of ICT technologies in all sectors, with particularly great impact in energy and transport sectors. The development of energy storage systems, electric vehicle and battery infrastructure, autonomous systems in various sectors and robotics will play a decisive role.	distribution network users provide to the distribution system operator are not currently used in the Republic of Croatia.
5	**Cyprus** Although the country's national grid system has certain intrinsic and technical limitations affecting RES penetration, Cyprus is having a policy plan that tackles all 5 dimensions of the EU Directive by 2020.	In Cyprus, electricity from renewable sources is no subsidised since 2013 where a net metering scheme and self-consumption has been put in place. In addition, two new schemes were recently announced	There are no Storage Plants to support the further penetration of RES targets at this moment. This leads to various reserves margin requirements as analysed in the JRC Study for the Grid Stability.	The Contingency Reserve will be technology neutral, i.e. will allow the participation of DR, Storage and RES with the necessary technical capability. Preliminary timeframe for this Target is year 2022.

	The country also promotes the EuroAsia Interconnection for uplifting the RES penetration in the system.	for RES: (1) net-billing scheme for PVs and Biomass (CHP) plants and (2) RES plants that will participate in the competitive electricity market. The share of RES is 6.07% of total primary energy consumption in 2016 which is low compared to the national target of 13% by 2020.	According to the country's Policy Decision, pumped storage installation is foreseen for all scenarios. Also, by 2030 72 MW of Li on Batteries are planned to be installed.	
6	**Czechia** She is found behind the targets of EU for RES penetration. Although supports gas storage no further plan for DR and flexibility is yet foreseen	10% of RES penetration is noted in 2016 whereas it is expected 17-22% penetration by the year 2040	Main country's targets: -Efficient functioning of domestic gas-storage facilities -Support projects ensuring the capacity of gas-storage facilities in the Czech Republic at 35–40% of annual gas consumption and availability guaranteed over a two-month period for at least 70% of peak daily consumption in the winter.	Possible measures in this area will depend on the implementation of new national legislation, especially the legislation that will implement the 'Clean Energy for All European' package currently under discussion, specifically the revised texts of the draft regulations and the Internal Electricity Market Directive.
7	**Denmark** The country has full plans for all emerging technologies. Denmark is a frontrunner within the green energy transition with a large share of renewable energy in the system, high security of supply and great focus on energy efficiency and research and innovation. The green	55% of RES by 2030 meeting all EU targets for emission including the 32.5% increase in energy efficiency.	Fully committed to adapt all required legislation, codes and market approach to facilitate the full utilisation of storage facilities. **Towards a climate-neutral Denmark by 2050, the plans are:** -Increased research into carbon dioxide removal and storage.	Full commitments towards market flexibility and DR. National objectives related to other aspects of the internal energy market such as increasing system flexibility in particular related to the promotion of competitively determined electricity prices in line with relevant sectoral law,

	transition encompasses both the energy sector and climate policy. Therefore, there is agreement among all political parties that Denmark will work towards net zero emissions, in accordance with the Paris Agreement, and advocate for the adoption of a target of net zero emissions in the EU and Denmark by 2050 at the latest.		-Use of carbon dioxide removal in climate efforts. -Analysis to improve the monitoring and accounting of carbon dioxide storage in soils and forests. -National objectives with regard to increasing the flexibility of the national energy system, in particular by means of deploying domestic energy sources, demand response and energy storage.	market integration and coupling, aimed at increasing the tradeable capacity of existing interconnectors, smart grids, aggregation, demand response, storage, distributed generation, mechanisms for dispatching, re-dispatching and curtailment, and real-time price signals, including a timeframe for when the objectives shall be met;
8	**Estonia** This country seems to pursue the RES penetration objectives, but no solid measures are foreseen for storage and none DR policies are given.	25% share of RES is foreseen in 2020. This rate can be expanded to 42% by 2030	-500 MW pumped-storage hydro accumulation power plant in operation. Planned measures to be adapted in the future: -Favouring carbon capture and storage in the agriculture and forestry. -According to the Electricity Market Act, the regulator may impose an obligation on the system operator to invite tenders for the creation of new production capacities, energy storage devices or energy efficiency/demand-side management measures if, the capacity reserve of the generating installations of the	n/a

			system falls below the capacity reserve established in the grid code.	
9	**Finland** This country seems to be left behind in comparison with the present policies regarding emerging technologies and the provisions of developing ones in the near future.	In May 2018, Parliament approved the act on the amendment of the act on production aid for electricity from renewable energy sources which laid down provisions on the new premium system for developing RES in the country.	n/a	Finland aims to benefit the "smart and efficient integrated energy system" approach to implement the idea of "energy efficiency first" principle: Combined generation of heat and power, and related district heating and cooling with smart demand response mechanisms improves energy efficiency, helps to increase the share of renewables and link heating with electricity for flexibility.
10	**France** France evaluation will be updated in the next version hoping that the country NECP will be submitted in English.	Documents in French.	Documents in French	Documents in French
11	**Germany** Germany is putting great effort in increasing RES penetration and integrate storage facilities. It seems that current provision of DR schemes is on the low side, expected to follow the flexibility check.	Energy efficiency and the growth of renewables will be the major building blocks of the European energy transition. This supports and fits well with Germany's strategy for transforming its energy supply system.	The Federal Government is continuing to work on smart control concepts aimed at ensuring that decentralised generators, storage facilities and loads can take on more system responsibility.	Germany has decided, together with its electricity neighbours, that a flexibility check should be carried out for Germany and the other EU Member States involved. The aim of this check will be to identify and eliminate obstacles for increasing the flexibility of the electricity market.

12	**Greece** Promoting RES is a top policy priority to move towards the decarbonisation of the economy and the achieved targets are positive. Some regulations regarding storage have already been implemented whereas DR regulations are envisaged in the near future.	-Promoting RES power generation technologies through support schemes such as net metering schemes. -RES penetration in gross final electricity consumption to reach at least 55% by 2030.	-The required regulatory framework has been completed and a number of generation authorisations have been granted for hybrid power plants and solar thermal plants with storage. -Also, by setting a pricing framework, aims to promote the installation of electricity storage systems both in the autonomous systems of the Non-Interconnected Islands (NIIs) and in the interconnected system of Greece. -In particular, Greece is promoting the installation of RES storage systems in 4 autonomous island systems -Separate consideration is given for EV regulation that will be delivered soon.	The country's objective is also to increase demand-side participation in the electricity market and to promote the deployment of storage systems that will enable electricity and gas prices to be restricted and will strengthen the penetration of RES into the system and the power adequacy of the electricity system. -Development of the regulatory framework for demand response is an envisaged policy target. -In line with the electricity market, Greece also aims to integrate the natural gas market and strengthen the participation of both the storage and demand response systems of the gas market. -Both centralised and decentralised storage units will be taken under consideration for the development of a comprehensive regulatory and normative framework for their operation in the energy markets and their integration into electricity grids.
13	**Hungary**	The national objectives are	Hungary aims to maximise the ability of	As can be seen from the Hungarian NECP

	Hungarian commitments relating to energy and climate change, with particular regard to reducing emissions, energy efficiency and the share of renewable energy, the fulfilment of the objectives of the Energy Union, and compliance with the Paris Agreement. These address country targets for RES, CO_2 reduction, increase energy efficiency and country interconnection capacity that are in line with the EU objectives. However, storage, E-mobility and DR / flexibility are just mentioned as a need with no specific plans of how developments are expected to evolve.	encouraging setting ambitious targets: - RES: 20% - CO_2: 30% - Efficiency: 10% The above figures are not satisfactory but they are the ones achievable by the country.	the Hungarian energy and RDI sectors to fulfil the energy and climate policy objectives of Hungary and the European Union. To this end Hungary assigns a priority to the objective of improving innovation, maximising the economic development opportunities underlying energy innovation and climate change. Related key sub-tasks of this process: development of the system integration of electricity generation capacities based on renewable sources, development of household and industrial scale energy storage technologies, support of the development of energy efficient technologies, digitisation and promotion of smart metering.	the national objectives with regard to increasing the flexibility of the national energy system, in particular by means of deploying domestic energy sources, demand response and energy storage. Currently these are just being researched and planned for the future.
14	**Ireland** Under national and EU legislation, renewable generation currently receives both support and priority dispatch in the Irish energy system and wholesale market respectively.	Ireland has a range of policy measures in place aimed at decarbonising the energy system. These include a number of support schemes for renewable electricity such as:	Proposals on lowering carbon footprint include: Strong carbon price in order to incentivise change and a safe and secure regime for Carbon Capture and Storage. Storage appears many times in	As regards Demand Side Units, 500 MW of Demand Side Unit capacity in Ireland cleared the first Capacity Market auction to take place under new rules held in December 2017. This represents double the capacity

	In general, emerging technologies such as storage including EVs and schemes such as DR have a high prioritisation and measures have already been taken to implement them in the grid.	a) the Alternative Energy Requirement (AER) scheme, b) three Renewable Electricity Support schemes (REFIT 1, 2 and 3), and c) a Prototype Development Fund which supports investment in the development of offshore renewable energy devices up to commercial stage. There are also a number of policy measures currently being developed / piloted. These include: d) a new Renewable Electricity Support Scheme (RESS), e) Microgeneration Scheme	Ireland's report as a means of moving forward and tackling the five dimensions of EU.	that had been previously available. Demand Side Units also have non-discriminatory access to wholesale electricity markets.
15	**Italy** The projection of Italy as regards RES integration is in a good truck and it seems that it is good both in readiness level and willingness level. Also, high rate of innovation regarding storage technology is highlighted and demand response is currently piloted before implementing it.	-By 2016 RES integration has reached 26% of the primary energy consumption in all sectors. -Provision has been made, in fact, to reach more than 11 Mtoe of RES in the heating and cooling sector by 2030.	The sector in which Italy was relatively more active in the electrical sector in 2016, from an innovative stand point, is energy storage (a fifth of the total), but also photovoltaics and wind power, which, together, draw 37% of the innovations produced by the country, coming mainly from Lombardy and Lazio. None of the European countries particularly excels in producing patents on the subject of electrical mobility. With the	The use of demand response and storage facilities to improve the flexibility and security of the system (electrical, and, as a result, also gas) is already in the start-up phase. In particular, in applying the principles of law, ARERA defined the criteria by which demand, unauthorised production units (including those powered by non-programmable renewable sources and distributed generation), storage systems including

			exception of Germany, Italy (23 patents in total) is only performing better than Spain (18) and is still at a similar level to Great Britain (76). Italy's innovative activity is concentrated predominantly on energy accumulation, while little attention is still being paid to hybrid vehicles and recharging stations. As far as the country's regional fragmentation is concerned, Lazio and Veneto produce half of all patents.	electric car batteries, may participate in the dispatching services market. Therefore, pilot projects allowing figures referred to as aggregators to participate in the market by aggregating consumption units, non-relevant production units and relevant production units not yet authorised to participate in the services market, including in mixed configurations (UVAM: authorised mixed virtual units), were launched. Once the trial currently in progress has concluded, these modes of participation in the market will be integrated into the regulatory framework.
16	Latvia Latvia's NECP indicate a high level of willingness. Also, the country is participating in innovation projects that aim to foster the smart grid components in the future. But the readiness level regarding regulatory framework and policy measures at present seem vague in the report.	At least 70% of the financial resources from the Modernisation Fund shall be used to support investments in the generation and use of electricity from **renewable sources**, improvement of energy efficiency, except energy efficiency relating to energy generation using solid fossil fuels, **energy storage** and	In addition to what is included under the column of RES the following are noted: -Continuing close cooperation with regional partners within the framework of the Baltic Energy Market Interconnection Plan (BEMIP) and Connecting Europe Facility (CEF) based on solidarity and mutual financial support principles and	In response to the development trends of the electricity market and changes planned in the EU legislation, transmission system operators of the Baltic States and Finland, Litgrid AB, Elering AS, and AS Augstsprieguma tīkls, organised a working group in 2017 with the aim of developing a conceptual offer for establishing a common framework

		modernisation of energy networks.	balancing national and regional interests for mutually beneficial solutions (e.g. development of natural gas supply and storage infrastructure).	for the market of the Baltic States to introduce demand response services in the balancing market through aggregation (Demand Response through Aggregation – a Harmonized Approach in the Baltic Region).
17	**Lithuania** Lithuania's electricity market is vastly dependent on power imports. In 2009, Lithuania retired its last nuclear reactor, which accounted for 77% of domestic electricity production and abruptly switched from an exporter of electricity to an importer of electricity. Last update of NECPs shows a willingness to support RES and emerging technologies including storage in the future. Time of use tariffs is reported to exist in the country, but market participation and aggregators are foreseen in the future.	Lithuania is focused on reducing the environmental impact of its energy production and use. It is determined to move towards a sustainable and low-carbon economy by modifying its energy mix and methods of generating energy. Lithuania has begun to shift towards more efficient energy production and greater use of renewable energy -Actually some of the RES targets were overachieved before 2020: the share of RES in total final energy consumption was 25.8% in 2017.	Targets and objectives were set in raw lines in the NECP plan for the time horizon 2020 and 2030 with relative tasks.	-Energy savings deriving from Demand Response of distributed consumers by energy aggregators are still absent in Lithuania. -But dynamic pricing for Demand Response measures offered by networks or retail tariffs such as time-of-use tariffs and real time pricing are present in Lithuania. Electricity prices for consumers are state regulated. The DSO offers about 6 to 8 plans for consumers, which take into account: real time of consumption, 1 or 2 time-zones and minimum amount consumed with corresponding discount. Critical peak pricing and peak time rebates are not yet available. A survey was conducted to estimate willingness of market participants to provide

				potential DR services. Meetings and workshops with the most promising customers and groups of consumers, which can be aggregated, were carried out investigating their technical characteristics and technical requirements. This investigation was supposed to provide potential capacities of DR services including cost-benefits analyses for the most promising providers.
18	**Luxembourg** Luxembourg evaluation will be updated in the next version provided that the NECP is submitted in English.	Documents in German.	Documents in German	Documents in German
19	**Malta** Malta has no indigenous energy sources that would provide a secure energy supply for the immediate future and is dependent on imported fuels and electricity to meet its national demand. RES penetration is actually limited due to specific characteristics of the island grid and the limited potential installation of PVs on rooftops. Electrical Storage and DR schemes are not	Malta's energy policy also focuses on maximizing Malta's effective renewable energy potential. The Government increased its efforts to support the deployment of renewable energy, especially photovoltaics and solar water heating systems (which are particularly well suited to Malta's geographical location), and whilst acknowledging the technical,	-The commissioning of the Malta-Italy gas pipeline will offer more storage capabilities. -There is no provision in energy storage planning.	Not applicable

	included in the near future plans.	geographical and spatial barriers limiting renewable energy potential, Malta continues to emphasize the full exploitation of all technically and economically viable indigenous sources of renewable energy. - Government will put forward incentive schemes, consistent with national and EU legislation, to make up for the cost premium over conventional energy and that are optimised to achieve their objectives at the lowest cost. The cost of energy delivered will be a non-exclusive criterion for the adoption of a particular type / category of RES. - An extensive assessment of Malta's technical potential for further deployment of solar PV installations post-2020 shows that this is limited to a number of suitable rooftops within the residential, commercial and industrial sectors, as well as a handful of brownfield sites.		
20	**Netherlands** This county's NECP show great willingness to commit and pursue the EU	-RES are vital for Netherlands to ensure the ambitions of the forthcoming Climate Agreement are put	-Gas storage facilities do exist in the Netherlands and serve the majority of domestic load.	Netherlands aim to build a market where all actors participate equally. This includes parties that provide

	targets. It seems that plans are in place and more effort needs to be put for storage and demand response schemes to be ready to be integrated into the market within the time frame set out by EU legislation.	into practice to achieve the targets. -The objective of the RES policy is to organise careful spatial integration of renewable energy generation and heat transition in the built environment, in a way that is acceptable to society, whilst focusing on the required infrastructure. -Existing plans for energy communities with high RES penetration.	-Regarding electrical storage any obstacles will be removed. The transition to electric cars might be able to contribute to this.	renewable energy, demand response and storage, including through aggregators. No separate national objectives have been formulated to this end up until now.
21	**Poland** This country's NECP provides a consolidated plan and targets on how they move forward and tackle the EU objectives. They have also implemented or are close to implementation RES integration and EV development respectively. Effort shall be put in demand response integration and market development.	The generation of renewable energy constitutes an important element of measures aimed at decarbonisation, as well as at energy diversification and the satisfaction of increasing energy demand.	The flagship project in the field of innovative solutions which are strongly related to the energy sector is the electromobility development project. The effect of the above project in 2020 is to support 50000 electric vehicles through 6 000 charging points and additionally 400 rapid charging points. In the 2025 perspective, an effect of the programme will be approximately a million electric-drive vehicles.	Non-available.
22	**Portugal** Portugal focused in RES integration and has high rate of innovation activities related to emerging	Portugal position itself near the top of the ranking for energy production from renewable sources in EU.	In the case of electrical power, storage is seen as a tool for the flexibility and stability of the NES. No rules	With regards to demand response in the electricity sector, reference is made to the evolution of energy savings

	energy technologies. It seems though that more effort needs to be put for storage and demand response schemes to be ready to be integrated into the market with a consolidated plan for start.		currently exist for establishing strategic energy security reserves and no plans are foreseen as yet. By 2030, an increase in storage capacity is planned towards the end of the decade, based essentially on reversible pumped hydroelectric energy. Initially, hydrogen and battery technology will be employed, more specifically through, fuel cells and power-to gas technology, supported by R&D&I. With regards to objectives for energy storage in the natural gas, oil and oil derivatives sectors, only national rules exist arising from Community legislation to create security reserves with a view to being able to respond to crisis situations. Current underground capacity at Carriço allows all-natural gas security reserves for the coming years to be stored.	resulting from existing and planned efficiency measures and consumption requirements, considering forecasts for increased electrical vehicle use. No foreseen plans yet.
23	**Romania** The country plan regarding RES integration seems solid and accurate. However, no present or foreseen activities related to storage and DR are foreseen.	Romania has invested and supported the development of renewable energy sources such as wind power, solar power, biomass and electrical energy generated in	They aim to develop capacities and mechanisms to integrate the discontinuous RESs in the national energy system and in available electrical storage systems,	No specific plan for DR. Almost zero reference.

		micro-hydropower plants. Their target for 2030 is 27.9% of the total gross energy consumption and they have a plan for that.	including the small storage capacities at the prosumer premises. They mention that Romania will support that, but no consolidated plan is given.	
24	**Slovakia** This country has met RES targets and interconnection targets of EC. It has an innovation plan to integrate emerging technologies to the system and a well justified plan for demand response and flexibility provision for the system.	RES targets fulfil the EC recommendations.	Directive 2009/31/EC on the geological storage of carbon dioxide was transposed into national legislation by Act No 258/2011 on the permanent storage of carbon dioxide in the geological environment and on an amendment and addition to certain laws. Suitable geological locations have been identified in the Slovak Republic. Country's plan includes local electricity storage, electromobility infrastructure development, including the development and testing of new technologies and their impacts on the distribution system as well as the sustainable use of biomass as part of an optimal energy mix. On-going research cover the development of	A plan regarding demand response and smart grid features in general as measure for energy efficiency has been developed.

			energy storage that will ensure the integration of variable RES into the system. Country's plan aims to create an appropriate environment for the flexibility of the storage operators and energy storage. Integrating local energy storage in storage appliances and electric vehicles or in the gas distribution network with its storage capabilities is utilising an important element of the smart grid.	
25	**Slovenia** Slovenia has an Energy strategy plan to fulfil by 2030. To this end, RES target meets the EC target whereas Slovenia's electricity interconnection level was at 83.6 % in 2017, thereby being already well above the 2020 target of 10 % and the 2030 target of 15 %. But no specific objectives of storage are foreseen (probably due to the high level of interconnection) while DR is only in research phase.	Currently, Slovenia's national objective is set at 27 % by 2030 and confirmed by the Slovenian Development Strategy 2030.	Slovenia does not have any specific objectives for energy storage.	In addressing DR issues, energy companies are implementing different development projects (Report on the Energy Sector in Slovenia for 2017, page 8) as innovative projects.
26	**Spain** Spain evaluation will be updated in the next	Document in Spanish	Document in Spanish	Document in Spanish

	version as long as the NECP is submitted in English.			
27	**Sweden** To achieve the targets in a cost-effective manner, regular monitoring of targets and conditions for achieving the targets are required. Sweden has a structure in place where local authorities, business community and other relevant stakeholders are involved in policy planning. Targets are planned and higher than EU set out objectives. Moreover, Sweden has a clear plan in place for all emerging technologies and is practicing DR through smart deployment since a few years back. It is considered one of the most mature markets in EU with best practices in all sectors of energy flexibility efficiency, sustainability and Emobility.	National ambitious targets for 2030 (all above EU targets): 50% more efficient than in 2005 No net emissions of greenhouse gases in 2045 100% RES electricity production in 2040	Energy storage can contribute to increased efficiency in the energy system. In order to increase the individual customers' ability to store their own-produced electricity there is a support for energy storage for own-produced electricity. The subsidy provides financial support to individuals for the installation of storage systems. Electricity prosumers feeding in less electricity into the grid than what they purchase on a yearly basis are exempted from the network charge for the electricity they feed in. Examples of electricity users covered by the exemption are farms with small wind turbines and buildings with solar power systems on the roof.	Description of measures to enable and develop demand response including those addressing tariffs to support dynamic pricing. The Swedish Energy Markets Inspectorate has developed an action plan in which a number of measures to achieve increased demand response are identified. The measures consist of proposals for new or amended regulations, knowledge-enhancing efforts, government assignments and cooperation between authorities and other stakeholders to create long-term conditions and rules. The measures focus primarily on household customers as they have a high potential for demand response that is not taken advantage of today.
28	**United Kingdom** Many consultations on the five dimensions of EU took place whereas new public institutions were set to cope with the national plan of UK regarding Energy and Climate. It	Several support schemes on RES to achieve national targets were set.	In July 2017, BEIS and Ofgem published the “Upgrading our Energy System: Smart Systems and Flexibility Plan” which sets out 29 actions that the UK Government, Ofgem,	The conclusions of Ofgem’s Gas Significant Code Review (SCR) 96 placed an obligation on National Grid to develop a centralised gas demand side response (DSR)

	is one of the few countries that have a demand response scheme already implemented and a consolidated plan for storage integration near to implementation.		and industry will undertake. The aim is to remove barriers to smart technologies, including storage; enable smart homes and businesses; and make electricity markets work towards flexibility. We aim to implement the actions in the Plan by 2022, enabling the electricity system to work more flexibly and efficiently, potentially unlocking £17-40 billion in savings across the electricity system by 2050. In October 2018, BEIS and Ofgem published a progress update to the Plan showing that 15 of the 29 actions have now been implemented. It also sets out the UK Government and Ofgem's forward priorities in this area, which include 9 new actions beyond those set out in the original Plan.	mechanism to encourage greater demand-side participation from industrial and commercial users. National Grid's proposed DSR methodology was approved by Ofgem and went live in October 2016.

5 Linking with INTERPLAN use cases

Within this section the regulatory barriers faced during the implementation of the 7 Use Cases developed INTERPLAN are identified and discussed. As we strongly believe that some regulatory barriers may be confronted as the INTERPLAN project evolves, we consider this document as living document. In specific, this subsection will be reviewed and updated in M30 together with other corrections / updates that will transpire in between April 2019 and M30 following 12 months of development work and associated testing.

Table 10. Use Case 1 evaluation

Use Case 1: Coordinated voltage/reactive power control			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**
Intermittent RES	Yes. In Germany, grid codes for all voltage levels contain regulations related to static voltage control by reactive power provision by intermittent RES. According to the FNN Roadmap “From grid to system”, a system for efficient and transparent procurement of reactive power still needs to be developed.	This is not considered a barrier for UC1 since regulation allows grid operators to define methods for reactive power control even without a procurement system.	N/A
Storage Including Electric Vehicles, heat pump solutions for heating and cooling [JR1]	Yes, see above.	Same as above	N/A
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	Partly. Electric vehicle charging units in the LV grid need to fulfil the same requirements as storages when discharging when it comes to reactive power provision (VDE-	Missing regulation for reactive power provision by flexible loads is not considered a barrier for the UC because there are other reactive power providers available.	N/A

	AR-N 4105). If charging, at least fixed cos phi ranges need to be kept; for stations with powers over 4,6 kW, the grid operator may also define an alternative method for reactive power behaviour during charging. For loads in general, there are no specific regulations when it comes to controllable provision of reactive power.		

Table 11. Use Case 2 evaluation

Use Case 2 Grid congestion management (by means of active power management)			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**
Intermittent RES	Based on the Italian TSO grid code, the production units that are enabled to supply the necessary active power to solve congestion during the operation planning phase are defined in the following: ● The production units which can vary, either increasing or decreasing, their production by at least 10 MW within 15 minutes from start of variation, so that the unit's contribution to the congestion is significant and compatible with the established times for	N/A	N/A

	removal of congestion; ● For hydroelectric units only: the relationship between the energy that may be supplied in one day and the maximum power of the unit is at least 4 hours. Non-dispatchable RES units are thus not allowed to participate in congestion management, since generally these units cannot effectively regulate and forecast their energy production. However, with the Resolution 300/2017/R/EEL, the Authority enabled also emerging technologies, as RES, storage and DR (active demand) to provide ancillary services for congestion management within **pilot projects**. The following units are thus enabled to participate in congestion management within pilot projects: ● **UVAP (Enabled Virtual Production Units)**: virtual power plant (non-		

	dispatchable and dispachable resources including storage) able to vary, either increasing or decreasing, their production by at least 1MW within 15 minutes from the variation starting. The total active power available is 110MW • **UVAC (Enabled Virtual Consumption Units)**: distributed loads, which through aggregators, are able to decrease their power by at least 1MW within 15 minutes from the variation starting. The total active power available is 516 MW.		
Storage Including Electric Vehicles, heat pump solutions for heating and cooling	See above		
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	See above		

Table 12. Use Case 3 evaluation

Use Case 3: Frequency tertiary control based on optimal power flow calculations			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**

Intermittent RES	Yes, COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017, establishing a guideline on electricity transmission system operation: Title 7 - REPLACEMENT RESERVES articles 160 and 161 + ENTSO-E RESERVE RESOURCE PROCESS (ERRP) IMPLEMENTATION GUIDE, 2013-06-06, VERSION 5.0	Considering the use case objectives, the codes and guidelines are not suggesting 1. a solution for decreasing the transmission losses while planning the replacement reserve 2. TSO-DSO collaboration is not considered	This will be clearer after the testing and validation of the use case.
Storage Including Electric Vehicles, heat pump solutions for heating and cooling	See above	See above	
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	See above	See above	

Table 13. Use Case 4 evaluation

Use Case 4: Fast Frequency Restoration Control			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**
Intermittent RES	According to the ENTSO-E definition (Network Code on System Operation), the frequency control is the capability of a power generating module or high-voltage direct current (HVDC) system to	-	

	adjust its active power output in response to a measured deviation of system frequency from a set point, to maintain stable system frequency. The secondary frequency control is a centralised automatic function to regulate the generation in a control area based on activation of secondary control reserves to maintain the power flow interchanges with all other control areas. At the same time, it has to restore the frequency in case of a frequency deviation within the control area to its set-point value in order to free the capacity needed by the primary control and to restore the primary control reserves. The reserve used for this secondary control is the Frequency Restoration Reserve (FRR) which is an operating reserve necessary to restore the frequency to the nominal value after a sudden disturbance and to replace Frequency Containment Reserves (FCR) if the frequency		

	deviation lasts longer than 30 seconds. This category includes operating reserves with an activation time typically between 30 seconds up to 15 minutes. The function of secondary control is also to restore power cross-border exchanges to their programmed set-point values. Operating reserves of this category are typically activated centrally and can be activated automatically (aFRR) or manually (mFRR). Based on the Italian TSO grid code, the secondary frequency control is a service contracted through the ancillary service market (**Mercato del Servizio di Dispacciamento – MSD**). Till 2017, in Italy, only generating units could be qualified to provide ancillary services (no consumption units allowed). The related requirements were: ● Being a generation unit with a rated power greater than 10 MVA; ● Not being a non-dispatchable renewable energy		

	source (RES); ● Not being a generation unit under test period; ● Being able to increase/reduce at least 10 MW of power generation within 15 minutes from the start of the service; ● for hydro power plants, being able to produce at the maximum power for at least 4 hours. Therefore, non-dispatchable RES units, as well as storage and DR were initially not allowed to participate in the ancillary service market for frequency regulation services. However, with the Resolution 300/2017/R/EEL, the Authority enabled also emerging technologies, as RES, storage and DR (active demand) to provide ancillary services for frequency regulation within **pilot projects**. The following units are thus enabled to participate in ancillary service market for frequency control services: ● **UVAP (Enabled Virtual Production Units)**: virtual power plant (non-		

	dispatchable and dispatchable resources including storage). ● **UVAC (Enabled Virtual Consumption Units)**: distributed loads, which ca be aggregated through the aggregators. ● **UVAM (Enabled Virtual mixed units),** characterized by the presence of both non-relevant production units (whether programmable or non-programmable), including storage systems, and consumption units.		
Storage Including Electric Vehicles, heat pump solutions for heating and cooling	See above	-	
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	See above	-	

Table 14. Use Case 5 evaluation

Use Case 5: Power balancing at DSO level			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**
Intermittent RES	**NC SOGL TITLE II** Chapter 3 - Data exchange between TSOs and DSOs within the TSO's control area; Chapter 5 - Data exchange between TSOs, DSOs and distribution-connected power generating modules	The network codes focus on the TSOs	In the SOGL it can be found that each power generating facility owner of a power generating module which is an SGU in accordance with Article 2(1)(a) and (e) connected to the distribution system shall provide the TSO **and the DSO** to which it has the connection point data specified in the regulation. In other words, the DSO should have all data for performing OPF.
	GERMANY: Grid operators are allowed to control intermittent RES which are directly or indirectly connected to their grid in order to avoid grid congestions in the respective grid area, including the upstream grid (“feed-in management”). However, grid operators are obliged to ensure that the largest possible amount of electricity from renewable energies and combined heat and power can be fed into their networks.	-	-

	In the LV grid, the requirements for grid security management are depending on the type of the unit. For photovoltaic generators, three peak active power classes are differed: (i) 0 to30 kWp (ii) 30 to100 kWp (iii) >100 kWp. For class (i), the PV operator may select either to limit the maximal active power infeed to 70% of the installed peak power, or to install a means for remote power deration by the grid operator, e.g. by ripple control. Class (ii) and (iii) generators must be equipped with such means. Class (iii) generators must additionally be equipped with a supervision for the current active power infeed, which can be remotely read by the grid operator.		
Storage Including Electric Vehicles, heat pump solutions for heating and cooling	**GERMANY** German regulation defines three basic operation modes for storages: (i) operation as energy consumers, (ii) operation as energy producers or (iii) operation within a customer island grid disconnected from the public grid.	No information found on storage usage for balancing purposes.	-

	If the stored energy is attributable for collecting feed-in compensation, it must be separately measured per type of primary energy source. It is generally forbidden to use the storage to collect feed-in compensation (e.g. according to EEG or KWKG) for energy which was previously sourced from the public network.		
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	**NC SOGL TITLE II** Chapter 6 - Data exchange between TSOs and demand facilities: Article 53 Data exchange between TSOs and distribution-connected demand facilities or third parties participating in demand response. **GERMANY** “Disconnectable loads” are consumption units that can reliably reduce their consumption power at the request of TSOs by a certain amount. Immediately disconnectable loads are for automated frequency-control. Disconnectable loads in the distribution grid can only be included in consultation with the concerned DSO.	The network codes focus on the TSOs. DR is used as a countermeasure for frequency issues, not for balancing purposes.	See recommendation for RES. It will be considered whether loads should be used as controllable objects in UC5.

Table 15. Use Case 6 evaluation

Use Case 6: Inertia management			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**
Intermittent RES	**NC RfG** Article 21(2) - the relevant TSO shall have the right to specify that power park modules be capable of providing synthetic inertia during very fast frequency deviations (PPM type C and D).	-	-
	-	Lack of regulation on synthetic inertia in national grid codes, therefore it is not yet used for assuring frequency stability in Europe.	Usually in national regulations RES are required to take part in frequency control in case of overfrequency. In some codes (e.g. Irish) wind turbines are required to act on both over- and underfrequency events -> power curtailment is used. This method will be used as well in the use case.
Storage Including Electric Vehicles, heat pump solutions for heating and cooling	No regulation found in EU Network Codes.	No common rules on how storage (even electric vehicles)should be used for frequency control.	Usage of national (e.g. Enhanced Frequency Response in UK) practices/ regulations for ESS
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	**NC DCC** Article 30 - gives the TSO a right to contract a delivery of demand response very fast active power control from demand facilities or closed	-	-

	distribution system operator (**demand not used for inertial support in UC6)**		

Table 16. Use Case 7 evaluation

Use Case 7: Optimal generation scheduling and sizing of DER for energy interruption management			
Technology	**Is there a reference regulation already?**	**Why is this a barrier?**	**Recommendations to overcome barrier**
Intermittent RES	RES is not actively controlled in this use-case. However, the RES is required to disconnect if the network constraints are violated. Many utilities have defined standards that require disconnection of RES from the grid before maximum time of about 10 cycles for serious feeder disturbances (deep voltage sags or interruptions). IEEE has also developed standards; for example, IEEE 929 recommends that small photovoltaic inverters should initiate a disconnect within 6 cycles for such events. The relevant standards are EN 50160, DIN 40041.	No barrier foreseen	
Storage Including Electric Vehicles, heat pump solutions for heating and cooling	Not to be considered.		
DG, Synchronous generator	Standards related to active and reactive	No barrier foreseen	

	power dispatch of DGs connected to LV network are specified in VDE-AR-N 4105. While generators connected to MV network are operated according to VDE-AR-N 4110.		
Fixed load	The cost of interruption of an individual load point depends on the frequency of load point interruption per year, duration of interruption, average power of load interrupted, and cost of load point interruption expressed in dollar/kW.	The cost of energy interruption is very case specific that is why no reference standard has been identified so far.	
Flexible Demand Response Including Electric Vehicles, heat pump solutions for heating and cooling, hot water etc	Flexible loads may define the interruptible part and associate cost to it that can be triggered in emergency situations.	Relevant standard not yet identified.	

6 TSO – DSO coordination to active system management

This section analyses the main findings of the report “**A toolbox for TSOs and DSOs to make use of new system and grid services”** [5] that focuses on TSO – DSO coordination in congestion management and balancing prepared by CEDEC, E.DSO, ENSTO-E, EURELECTRIC and GEODE. It is clear from the following introductory statement of the Operators in the above report that the need for addressing the planning and operational complexities of the emerging technologies DG RES, storage, EVs and DR is a need and still a not solved problem technically, operationally and commercially (policy, market and regulation) are lagging: *“The constant increase in distributed renewable generation and in storage, and the expected rise of active customers engaging in demand response and electric mobility, trigger a key question to be addressed to support the energy transition: how to integrate the flexibility services provided by these new assets and actors into the energy market and use their services for congestion management and further in balancing, while ensuring efficient and reliable system operation and enabling the market uptake for flexibility resources?*
Only the latter part of this key question, focusing on the roles – assigned to DSOs and TSOs through the national regulatory framework – will be treated in this report. Network codes and Guidelines, currently under implementation, provide the first basis for congestion management and balancing (especially SO GL and EB GL).” Fig.1 shows how congestion management and balancing services intertwine with market to provide flexibility.
In short, the report covers the following important insides on congestion management and balancing (for details please see Annex 3) with clear messages for INTERPLAN project:

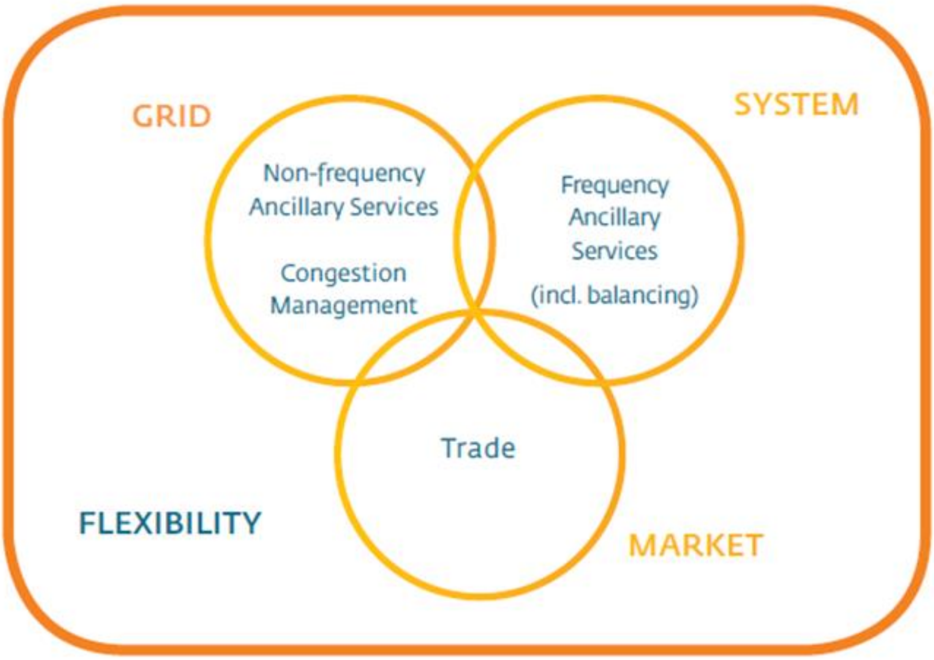

Figure 1. Cross cutting services to provide flexibility [5]

- The report addresses the important shift towards an integrated active system management of the emerging grid and puts forward an important and highly revealing definition for this need.
- It is evident from the approach that is given to the problem but moreover of the proposed solutions that the Operators, consider the emerging technologies highly complex requiring a

multi-dimensional portfolio of solutions that are dynamic starting from a year and more ahead to intraday needs. Hence, what we are putting forward as solutions through INTERPLAN using grid equivalents and controllers are aligned with the approach that the Operators are initially instigating.

- TSOs and DSOs are clear in their opinion as market facilitators that the emerging technologies transform the grid and the way forward is an integrated approach. This is in line with the thoughts of the INTEPLAN consortium for developing solutions that aim a system approach incorporating all emerging technologies through appropriate models, equivalents and controllers down to the LV network.
- It is clear from the approach on congestion and how can efficiently be managed, that the use of generated flexibilities on the side of the users from the emerging technologies is a source that should be given equal footing and a platform through which they can be usefully integrated. Means should be made available that will allow such analysis that can be dynamic and responsive to various time zones.
- From the description given by the Operators in treating congestion management process and information exchange, it is clear that solutions provided should be capable of being flexible and adaptive. This is a strong message for INTERPLAN project covering all required time frames for emerging technologies contributing effectively and efficiently to the needs of the integrated grid in managing DGs.
- From the approach of the Operators and how they will judge solutions and systems and to what degree they fit in the needs of the integrated system, it is clear that the enhanced analytical tool that the INTEPLAN is promising fits in well with their targeted objectives. The pre-qualification of available solutions and how they are aggregated is a need that the promised solutions through INTERPLAN will allow the Operators to evaluate within the planned timeframe.
- The market is critical in the emerging grid dynamics and how the Operators envisage the evolution in this direction is very enlightening. It is clearly understood that congestion can be highly local and hence the system planning, and operation should have this analytical capability to drill deep in the system to identify problems and solutions. At the same time the effect in the integrated system should be acknowledged and this is what the INTERPLAN solutions will facilitate. Moreover, the time frame is vital and the analytical tool responsive. This is clearly a need from the recommendations of the Operators.
- An appropriate platform will provide the required options for facilitating the smooth operation of the integrated system. It is clear from the approach of the operators that there is a need since the plethora of energies that will prevail should be captured in the models in a universal way giving a technology agnostic environment, accessible by all singly or aggregated for managing planning and operational needs. Interoperability should be guaranteed in models and solutions giving access both in data and energy at the required timeframes.
- The Congestion Management process entails activities as detailed below which give a clear message as to what is expected from the analytical tools that will support the process as shown in Fig.2.

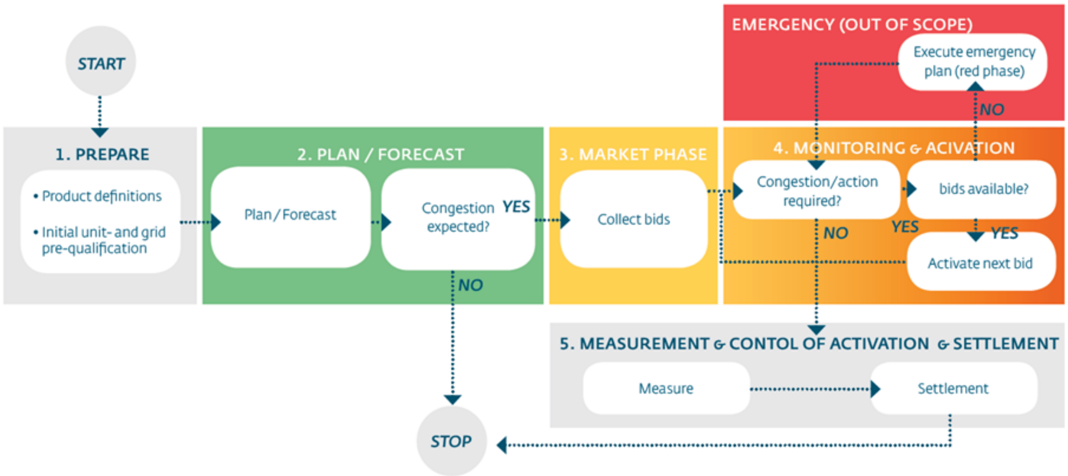

Figure 2. Congestion Management Process [5]

7 Discussion and Conclusions

The main objective of this deliverable D2.2 is to review existing network codes related to emerging technologies and spot possible gaps and limitations. To do so, all code families from ENTSO-e were studied and analysed under the prism of the emerging technologies. In general, the codes are quite analytical and include specifications for TSOs to analyse, simulate and operate their system. However, recommendations of the Clean Energy package as spotted in Section 4 and Energy directives [6-9] need to be integrated into the codes especially the ones that refer to emerging technologies and DR schemes. To that context, grid codes should expand to include explicitly the emerging technologies and provide in details the connection standards, operation and their market integration. Most of codes at present consider mature technologies such as RES, whereas storage, EV or DR schemes are missing vastly. The same conclusion was drawn after feedback of European stakeholders through questionnaires that were circulated by INTERPLAN partners.
Along with the codes, ENTSO-e provides Implementation Guidance Documents (IGD) to determine in detail how the codes are implemented at national level and under certain conditions. All IGD documents were described and the covering need was analysed to evaluate these documents as useful tools for the operators. Still, the detailed implementation of storage technologies and DR should be considered in the future.

Moreover, the document also tries to capture the status of each EU Member State regarding their intention to integrate further regulations to achieve EU targets and thus integrate national codes for the emerging technologies integration. To do so, clean energy package objectives regarding technologies were analysed. According to these recommendations, the NECP of each country, regarding the readiness and willingness to fulfil the recommendations were analysed. It has to be mentioned again that the evaluation is based only in the content of NECP documents as they were submitted. In general, most of countries have a high rate of willingness to embrace emerging technologies and meet the highlighted recommendations. But it is worth mentioning that again the vast majority of European countries have low readiness when it comes to solid codes on storage and DR.

To extent the above conclusions with further evidence, INTERPLAN use cases are analysed for the critical issues of grids in operation to spot possible interconnection limitations needed to be addressed in the future. Some use cases may have spotted some omissions, but the barrier section is to be fulfilled in the next version of the document where a better picture will be acquired.
Finally, the last section reviews the report “A toolbox for TSOs and DSOs to make use of new system and grid services” that focuses on TSO – DSO coordination in congestion management and balancing services. This report describes the needs from the operators view to perform analysis and provide services. From the analysis, it is clear that operators need an analytical and flexible tool to do so whereas all emerging technologies should be considered at the same time.

8 References

[1]Limitations in the analytical tools of the interconnected grid (https://interplan-project.eu/wp-content/uploads/2018/07/INTERPLAN-D2.1_Limitations-in-the-analytical-tools-of-the-interconnected-grid.pdf)
[2]Analysis of the Clean Energy Package proposals, BRIDGE report
[3]https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans
[4]Energy union factsheets for EU countries
[5]TSO – DSO Report, An integrated approach to active system management (https://docstore.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf)
[6]Regulation on the governance of the energy union and climate action ((EU)2018/1999)
[7]Revised Energy efficiency directive (2018/2002)
[8]Revised Renewable energy directive (2018/2001)
[9]Revised Energy performance of buildings directive (2018/844)

9 ANNEX 1

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9.3 Connection codes

The tables below summarize regulations, description, analysis and spotted limitation per technology/ies and code families[1]. It is important to note that text shaded in orange is extracts from codes and text shaded in green is comments, interpretations and / or conclusions of the INTERPLAN team.

Table 17. Connection codes-Requirements for Generators

ENTSO-E Network Code	Connection codes-Requirements for Generators
Technology (Intermittent RES / storage / flexible DR)	**RES / DR**
Source documents	**RES** *Article 3: Scope of application* *Article 4: Application to existing power-generating modules* *Article 6: Application to power-generating modules, pump-storage power-generating modules, combined heat and power facilities, and industrial sites* *Article 15: General requirements for type C power-generating modules* ***Alternative fuel*** *Article 42: Common provisions for compliance testing* ***Demand response*** *Article 4: Application to existing power-generating modules* ***Aggregator*** *Article 30: Operational notification of type A power-generating modules* ***Converter/ Power Electronic*** *Article 2: Definitions* *Article 15: General requirements for type C power-generating modules*
Description	*This Regulation should provide for ranges of parameters for national choices for fault-ride-through capability to maintain a proportionate approach reflecting varying system needs such as the level of renewable energy sources ('RES') and existing network protection schemes, both transmission and distribution. In view of the configuration of some networks, the upper limit for fault-ride-through requirements should be 250 milliseconds. However, given that the most common fault clearing time in Europe is currently 150 milliseconds it leaves scope for the entity, as designated by the Member State to approve the requirements of this Regulation, to verify that a longer requirement is necessary before approving it.* ***RES*** ***Article 3: Scope of application*** *This Regulation shall not apply to:* *(a) power-generating modules connected to the transmission system and distribution systems, or to parts of the transmission system or distribution systems, of islands of Member States of which the systems are not operated synchronously with either the Continental Europe, Great Britain, Nordic, Ireland and Northern Ireland or Baltic synchronous area;*

[1] https://www.entsoe.eu/network_codes/

	(b) power-generating modules that were installed to provide back-up power and operate in parallel with the system for less than five minutes per calendar month while the system is in normal system state. Parallel operation during maintenance or commissioning tests of that power-generating module shall not count towards the five-minute limit; *(c) power-generating modules that do not have a permanent connection point and are used by the system operators to temporarily provide power when normal system capacity is partly or completely unavailable;* *(d) storage devices except for pump-storage power-generating modules in accordance with Article 6(2).* ***Article 4: Application to existing power-generating modules*** *Following a public consultation in accordance with Article 10 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing power-generating modules.* *For that purpose, a sound and transparent quantitative cost-benefit analysis shall be carried out, in accordance with Articles 38 and 39. The analysis shall indicate:* *(a) the costs, in regard to existing power-generating modules, of requiring compliance with this Regulation;* *(b) the socioeconomic benefit resulting from applying the requirements set out in this Regulation; and* *(c) the potential of alternative measures to achieve the required performance.* ***Article 6: Application to power-generating modules, pump-storage power-generating modules, combined heat and power facilities, and industrial sites*** ***Storage*** *'pump-storage' means a hydro unit in which water can be raised by means of pumps and stored to be used for the generation of electrical energy* *1.Offshore power-generating modules connected to the interconnected system shall meet the requirements for onshore power-generating modules, unless the requirements are modified for this purpose by the relevant system operator or unless the connection of power park modules is via a high voltage direct current connection or via a network whose frequency is not synchronously coupled to that of the main interconnected system (such as via a back-to-back convertor scheme).* *2.Pump-storage power-generating modules shall fulfil all the relevant requirements in both generating and pumping operation mode. Synchronous compensation operation of pump-storage power-generating modules shall not be limited in time by the technical design of power-generating modules. Pump-storage variable speed power-generating modules shall fulfil the requirements applicable to synchronous power-generating modules as well as those set out in point (b) of Article 20(2), if they qualify as type B, C or D.* *3.With respect to power-generating modules embedded in the networks of industrial sites, power-generating facility owners, system operators of industrial sites and relevant system operators whose network is connected to the network of an industrial site shall have the right to agree on conditions for disconnection of such power-generating modules together with critical loads, which secure production processes, from the relevant system operator's network. The exercise of this right shall be coordinated with the relevant TSO.* *4.Except for requirements under paragraphs 2 and 4 of Article 13 or where otherwise stated in the national framework, requirements of this Regulation relating to the*

capability to maintain constant active power output or to modulate active power output shall not apply to power-generating modules of facilities for combined heat and power production embedded in the networks of industrial sites, where all of the following criteria are met:
(a) the primary purpose of those facilities is to produce heat for production processes of the industrial site concerned;
(b) heat and power-generating is inextricably interlinked, that is to say any change of heat generation results inadvertently in a change of active power-generating and vice versa;
(c) the power-generating modules are of type A, B, C or, in the case of the Nordic synchronous area, type D in accordance with points (a) to (c) of Article 5(2).
5.Combined heat and power-generating facilities shall be assessed on the basis of their electrical maximum capacity.
Article 15: General requirements for type C power-generating modules
Type C power-generating modules shall fulfil the following requirements relating to frequency stability:
▪ *with regard to disconnection due to under frequency, power-generating facilities capable of acting as a load, including hydro pump-storage power-generating facilities, shall be capable of disconnecting their load in case of underfrequency. The requirement referred to in this point does not extend to auxiliary supply;*
Alternative fuel
Article 42: Common provisions for compliance testing
1. Testing of the performance of individual power-generating modules within a power-generating facility shall aim at demonstrating that the requirements of this Regulation have been complied with.
2. Notwithstanding the minimum requirements for compliance testing set out in this Regulation, the relevant system operator is entitled to:
(a) allow the power-generating facility owner to carry out an alternative set of tests, provided that those tests are efficient and suffice to demonstrate that a power-generating module complies with the requirements of this Regulation;
(b) require the power-generating facility owner to carry out additional or alternative sets of tests in those cases where the information supplied to the relevant system operator in relation to compliance testing under the provisions of Chapter 2, 3 or 4 of Title IV, is not sufficient to demonstrate compliance with the requirements of this Regulation; and
(c) require the power-generating facility owner to carry out appropriate tests in order to demonstrate a power-generating module's performance when operating on alternative fuels or fuel mixes. The relevant system operator and the power-generating facility owner shall agree on which types of fuel are to be tested.
Demand response
Introduction
(60) 'installation document' means a simple structured document containing information about a type A power-generating module or a demand unit, with demand response connected below 1 000 V, and confirming its compliance with the relevant requirements;
Article 4: Application to existing power-generating modules
Following a public consultation in accordance with Article 10 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the

	regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing power-generating modules. *For that purpose, a sound and transparent quantitative cost-benefit analysis shall be carried out, in accordance with Articles 38 and 39. The analysis shall indicate:* *(a) the costs, in regard to existing power-generating modules, of requiring compliance with this Regulation;* *(b) the socioeconomic benefit resulting from applying the requirements set out in this Regulation; and* *(c) the potential of alternative measures to achieve the required performance.* *Before carrying out the quantitative cost-benefit analysis referred to in paragraph 3, the relevant TSO shall:* *(a) carry out a preliminary qualitative comparison of costs and benefits;* *(b) obtain approval from the relevant regulatory authority or, where applicable, the Member State.* ***Aggregator*** *Article 30: Operational notification of type A power-generating modules* *The power-generating facility owner shall ensure that the relevant system operator or the competent authority of the Member State is notified about the permanent decommissioning of a power-generating module in accordance with national legislation.* *The relevant system operator shall ensure that such notification can be made by third parties, including aggregators.* ***Converter*** *Article 2: Definitions* *(49) 'U-Q/Pmax-profile' means a profile representing the reactive power capability of a power-generating module or HVDC converter station in the context of varying voltage at the connection point;* *Article 15: General requirements for type C power-generating modules* *Type C power-generating modules shall fulfil the following general system management requirements:* *(c) with regard to the simulation models:* *(ii) the models provided by the power-generating facility owner shall contain the following sub-models, depending on the existence of the individual components:* *— alternator and prime mover,* *— speed and power control,* *— voltage control, including, if applicable, power system stabiliser ('PSS') function and excitation control system,* *— power-generating module protection models, as agreed between the relevant system operator and the power-generating facility owner, and* *— converter models for power park modules;* ***Power electronic*** *Article 2: Definitions* *(17) 'power park module' or 'PPM' means a unit or ensemble of units generating electricity, which is either non-synchronously connected to the network or connected through power electronics, and that also has a single connection point to a transmission system, distribution system including closed distribution system or HVDC system;*
Article Analysis and	The above articles' aim is to provide the context for fault-ride-through capability to maintain a proportionate approach reflecting varying system

spotted limitations	needs such as the level of renewable energy sources ('RES') and existing network protection schemes at both transmission and distribution. Regulation goes through the power-generating modules that the regulation shall not apply and refer to storage devices except for pump-storage power-generating modules in accordance with Article 6(2). More analysis should be given for the storage devices that are taken under consideration. As storage types lie in a broad range and EV can be seen under this category, further details are expected. Also regarding regulation application to existing power-generating modules, the analysis shall indicate a,b,c under the context of smart grid and modern energy concepts e.g. energy communities, microgrids etc. Regarding Article 42 and the Common provisions for compliance testing, an international standard should be proposed. Regarding the Article 4: Application to existing power-generating modules, again, for the sound and transparent quantitative cost-benefit analysis that shall be carried out, in accordance with Articles 38 and 39, the context of the smart grids concept should be taken under consideration and then approved by the national RAs. Regarding the operational notification of type A power-generating modules, the power-generating facility owner shall ensure that the relevant system operator or the competent authority of the Member State is notified about his fault-ride-through capacities and timing. The relevant system operator shall ensure that such notification can be made by third parties, including aggregators.

Table 18. Connection codes-Demand Connection Code

ENTSO-E Network Code	**Connection codes-Demand Connection Code**
Technology (Intermittent RES / storage / flexible DR)	**RES / Storage / Flexible DR / EVs**
Source documents	***RES*** *Article 1/Article 4: Application to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units used to provide demand response services* *Article 3: Scope of application* *Article 5: Application to pump-storage power generating modules and industrial sites* *Article 49* ***Storage & Pump Storage*** *Article 3&5* ***Distributed Generation*** *Article 4: Application to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units used to provide demand response services*

	Converters *Article 21: Simulation models*
Description	***Renewable Energy Sources*** *Article 4: Application to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units used to provide demand response services* *Following a public consultation in accordance with Article 9 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems, or existing demand units used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator or relevant TSO.* ***Storage*** *Article 3: Scope of application* *This Regulation shall not apply to:* *(a) demand facilities and distribution systems connected to the transmission system and distribution systems, or to parts of the transmission system or distribution systems, of islands of Member States of which the systems are not operated synchronously with either the Continental Europe, Great Britain, Nordic, Ireland and Northern Ireland or Baltic synchronous area;* *(b) storage devices except for pump-storage power generating modules in accordance with Article 5(2).* *Article 5: Application to pump-storage power generating modules and industrial sites* *1. This Regulation shall not apply to pump-storage power generating modules that have both generating and pumping operation mode.* *2. Any pumping module within a pump-storage station that only provides pumping mode shall be subject to the requirements of this Regulation and shall be treated as a demand facility.* *3. In the case of industrial sites with an embedded power generating module, the system operator of an industrial site, the demand facility owner, the power generating facility owner and the relevant system operator to whose system the industrial site is connected, may agree, in coordination with the relevant TSO, on conditions for disconnection of critical loads from the relevant system. The objective of the agreement shall be to secure production processes of the industrial site in case of disturbed conditions in the relevant system.* ***Demand Response*** *Majority of articles (see next)* ***Distributed generation*** *Article 4: Application to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units used to provide demand response services* *Following a public consultation in accordance with Article 9 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing transmission-connected demand*

	facilities, existing transmission-connected distribution facilities, existing distribution systems, or existing demand units used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator or relevant TSO. ***Converters*** *Article 21: Simulation models* *Each TSO shall specify the content and format of those simulation models or equivalent information.* *The content and format shall include:* *(a) steady and dynamic states, including 50 Hz component;* *(b) electromagnetic transient simulations at the connection point;* *(c) structure and block diagrams.* *For the purpose of dynamic simulations, the simulation model or equivalent information referred to in paragraph 3(a) shall contain the following sub-models or equivalent information:* *(a) power control;* *(b) voltage control;* *(c) transmission-connected demand facility and transmission-connected distribution system protection models;* *(d) the different types of demand, that is to say electro technical characteristics of the demand; and* *(e) converter models.*
Article Analysis and spotted limitations	**RES & DG** Harmonised rules for grid connection for demand facilities and distribution systems should be set out in order to provide a clear legal framework for grid connections, facilitate Union-wide trade in electricity, ensure system security, facilitate the integration of renewable electricity sources, increase competition, and allow more efficient use of the network and resources, for the benefit of consumers. Article 1: 2. This Regulation, therefore, helps to ensure fair conditions of competition in the internal electricity market, to ensure system security and the integration of renewable electricity sources, and to facilitate Union-wide trade in electricity. Article 4: 3. Following a public consultation in accordance with Article 9 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems, or existing demand units used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator or relevant TSO. Article 49: 2. A cost-benefit analysis shall be in line with the following principles: (c) the relevant TSO, demand facility owner or prospective owner, DSO/CDSO or prospective operator, shall quantify the benefits to the internal market in electricity, cross-border trade and integration of renewable

	energies, including at least: (i) the active power frequency response; (ii) the balancing reserves; (iii) the reactive power provision; (iv) congestion management; (v) defence measures; **Storage & Pump Storage** Article 3: 2. This Regulation shall not apply to: (b) storage devices except for pump-storage power generating modules in accordance with Article 5(2). Article 5: Application to pump-storage power generating modules and industrial sites. 1. This Regulation shall not apply to pump-storage power generating modules that have both generating and pumping operation mode. 2. Any pumping module within a pump-storage station that only provides pumping mode shall be subject to the requirements of this Regulation and shall be treated as a demand facility. **Demand Response & Flexibility** (7) In view of the need to provide regulatory certainty, the requirements of this Regulation should apply to new transmission-connected demand facilities, new transmission-connected distribution facilities, new distribution systems and new demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant transmission system operators ('TSOs'). The requirements of this Regulation should not apply to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units that are or can be used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs. The requirements of this Regulation also should not apply to new or existing demand facilities connected at the distribution level unless they provide demand response services to relevant system operators and relevant TSOs. However, the requirements of this Regulation should apply in case the relevant regulatory authority or Member State decides otherwise based on evolution of system requirements and a full cost-benefit analysis, or in case a substantial modernisation or replacement of equipment impacting the technical capabilities of an existing transmission-connected demand facility, an existing transmission-connected distribution facility, an existing distribution system, or an existing demand unit within a demand facility or a closed distribution system connected at a voltage level above 1000 V has been performed. (8) Demand response is an important instrument for increasing the flexibility of the internal energy market and for enabling optimal use of networks. It should be based on customers' actions or on their agreement for a third party to take action on their behalf. A demand facility owner or a closed distribution system operator ('CDSO') may offer demand response services to the market as well as to system operators for grid security. In the latter case, the demand facility owner or the closed distribution system operator should ensure that new demand units used to provide such services fulfil the requirements set out in this Regulation, either individually or commonly as part of demand aggregation through a third party. In this regard, third parties have a key role in bringing together demand response capacities and can

	have the responsibility and obligation to ensure the reliability of those services, where those responsibilities are delegated by the demand facility owner and the closed distribution system operator. (10) The requirements applicable to a demand facility connected to a transmission system should set out the capabilities at their interfaces and the necessary automated responses and data exchange. These requirements aim at ensuring the operability of the transmission system, and the capacity to utilise the generation and demand response embedded in these networks over system operational ranges and critical events. (11) The requirements applicable to a distribution system connected to a transmission system or another distribution system should set out the operational range of these systems and the necessary automated responses and data exchange. These requirements should ensure the effective development and operability of the transmission system, and the capacity to utilise the generation and demand response embedded in these networks over system operational ranges and critical events. (12) The requirements applicable to a demand unit used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs should ensure the capacity to use the demand response over system operational ranges thereby minimising critical events. (13) The administrative burdens and costs associated with providing demand response should be kept within reasonable limits, in particular as regards domestic consumers, who will play an increasingly important role in the transition to low carbon society and their uptake should not be unnecessarily burdened with administrative tasks. (19) A process for derogating from the rules should be set out in this Regulation to take into account local circumstances where exceptionally, for example, compliance with those rules could jeopardise the stability of the local network or where the safe operation of a transmission-connected demand facility, a transmission-connected distribution facility, a distribution system, or a demand unit used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs, might require operating conditions that are not in line with this Regulation. (20) Subject to approval by the relevant regulatory authority, or other authority where applicable in a Member State, demand facility owners and relevant system operators should be allowed to propose derogations for certain classes of transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems and demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs. Article 1: 1. This Regulation establishes a network code which lays down the requirements for grid connection of: (d) demand units, used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs.

	Article 2: (16) ‘demand response active power control’ means demand within a demand facility or closed distribution system that is available for modulation by the relevant system operator or relevant TSO, which results in an active power modification; Article 2: (17) ‘demand response reactive power control’ means reactive power or reactive power compensation devices in a demand facility or closed distribution system that are available for modulation by the relevant system operator or relevant TSO; Article 2: (18) ‘demand response transmission constraint management’ means demand within a demand facility or closed distribution system that is available for modulation by the relevant system operator or relevant TSO to manage transmission constraints within the system; Article 2: (19) ‘demand aggregation’ means a set of demand facilities or closed distribution systems which can operate as a single facility or closed distribution system for the purposes of offering one or more demand response services; Article 2: (20) ‘demand response system frequency control’ means demand within a demand facility or closed distribution system that is available for reduction or increase in response to frequency fluctuations, made by an autonomous response from the demand facility or closed distribution system to diminish these fluctuations; Article 2: (21) ‘demand response very fast active power control’ means demand within a demand facility or closed distribution system that can be modulated very fast in response to a frequency deviation, which results in a very fast active power modification; Article 2: (22) ‘demand response unit document’ (DRUD) means a document, issued either by the demand facility owner or the CDSO to the relevant system operator for demand units with demand response and connected at a voltage level above 1000 V, which confirms the compliance of the demand unit with the technical requirements set out in this Regulation and provides the necessary data and statements, including a statement of compliance. Article 3: 1. The connection requirements set out in this Regulation shall apply to: (d) new demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs. Article 3: 1. Based on compliance monitoring in accordance with Title III, the relevant TSO shall refuse demand response services subject to Articles 27 to 30 from new demand units not fulfilling the requirements set out in this Regulation. Article 4: 1. Existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units that are or can be used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator or relevant TSO, are not subject to the requirements of this Regulation Article 4: 2. For the purposes of this Regulation, a transmission-connected demand facility, a transmission-connected distribution facility, a distribution

	system, or a demand unit that is, or can be, used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator or relevant TSO Article 4: 3. Following a public consultation in accordance with Article 9 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems, or existing demand units used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator or relevant TSO. Article 10: The Agency for the Cooperation of Energy Regulators (the Agency), in close cooperation with the European Network of Transmission System Operators for Electricity (ENTSO for Electricity), shall organise stakeholder involvement, regarding the requirements for the grid connection of transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems and demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs, and other aspects of the implementation of this Regulation. This shall include regular meetings with stakeholders to identify problems and propose improvements notably related to the requirements for grid connection of transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems and demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs Article 27: 1. Demand response services provided to system operators shall be distinguished based on the following categories: (a) remotely controlled: (i) demand response active power control, (ii) demand response reactive power control, (iii) demand response transmission constraint management. (b) autonomously controlled: (i) demand response system frequency control, (ii) demand response very fast active power control. Article 27: 2. Demand facilities and closed distribution systems may provide demand response services to relevant system operators and relevant TSOs. Demand response services can include, jointly or separately, upward or downward modification of demand. Article 27: 3. The categories referred to in paragraph 1 are not exclusive and this Regulation does not prevent other categories from being developed. This Regulation does not apply to demand response services provided to other entities than relevant system operators or relevant TSOs. Article 28: 1. Demand facilities and closed distribution systems may offer demand response active power control, demand response reactive power control, or demand response transmission constraint management to relevant system operators and relevant TSOs.

	Article 28: 2. Demand units with <u>demand response</u> active power control, <u>demand response</u> reactive power control, or <u>demand response</u> transmission constraint management shall comply with the following requirements, either individually or, where it is not part of a transmission-connected demand facility, collectively as part of demand aggregation through a third party: (i) notify the relevant system operator or relevant TSO of the modification of <u>demand response</u> capacity. The relevant system operator or relevant TSO shall specify the modalities of the notification; Article 29: 1. Demand facilities and closed distribution systems may offer <u>demand response</u> system frequency control to relevant system operators and relevant TSOs. Article 29: 2. Demand units with <u>demand response</u> system frequency control shall comply with the following requirements, either individually or, where it is not part of a transmission-connected demand facility, collectively as part of demand aggregation through a third party: (g) be able to detect a change in system frequency of 0,01 Hz, in order to give overall linear proportional system response, with regard to the demand response system frequency control's sensitivity and accuracy of the frequency measurement and the consequent modification of the demand. The demand unit shall be capable of a rapid detection and response to changes in system frequency, to be specified by the relevant TSO in coordination with the TSOs in the synchronous area. An offset in the steady-state measurement of frequency shall be acceptable up to 0,05 Hz. Article 31: 1. The operational notification procedure for demand units used by a demand facility or a closed distribution system to provide demand response to system operators Article 31: 2. Each demand facility owner or CDSO, providing <u>demand response</u> to a relevant system operator or a relevant TSO, shall confirm to the relevant system operator, or relevant TSO, directly or indirectly through a third party, its ability to satisfy the technical design and operational requirements as referred to in Chapter 1 of Title III of this Regulation. Article 31: 3. The demand facility owner or the CDSO shall notify, directly or indirectly, through a third party, the relevant system operator or relevant TSO, in advance of any decision to cease offering <u>demand response</u> services and/or about the permanent removal of the demand unit with <u>demand response</u>. This information may be aggregated as specified by the relevant system operator or relevant TSO. Article 32: 3. Based on an installation document, the demand facility owner or the CDSO shall submit information, directly or indirectly through a third party, to the relevant system operator or relevant TSO. The date of this submission shall be prior to the offer in the market of the capacity of the <u>demand response</u> by the demand unit. The requirements set in the installation document shall differentiate between different types of connections and between the different categories of <u>demand response</u> services. Article 32: 4. For subsequent demand units with <u>demand response</u>, separate installation documents shall be provided.

	Article 32: 6. The installation document shall contain the following items: (a) the location at which the demand unit with demand response is connected to the network; (b) the maximum capacity of the demand response installation in kW; (c) the type of demand response services; (d) the demand unit certificate and the equipment certificate as relevant for the demand response service, or if not available, equivalent information; Article 33: 1. The operational notification procedure for a demand unit within a demand facility or a closed distribution system connected at a voltage level above 1000 V shall comprise a DRUD. The relevant system operator, in coordination with the relevant TSO, shall specify the content required for the DRUD. The content of the DRUD shall require a statement of compliance which contains the information in Articles 36 to 47 for demand facilities and closed distribution systems, but the compliance requirements in Articles 36 to 47 for demand facilities and closed distribution systems can be simplified to a single operational notification stage as well as be reduced. The demand facility owner or CDSO shall provide the information required and submit it to the relevant system operator. Subsequent demand units with demand response shall provide separate DRUDs. Article 34: 1. Transmission-connected demand facility owners and DSOs shall ensure that their transmission-connected demand facilities, transmission-connected distribution facilities, or distribution systems comply with the requirements provided for in this Regulation. A demand facility owner or a CDSO providing demand response services to relevant system operators and relevant TSOs shall ensure that the demand unit complies with the requirements provided for in this Regulation. Article 34: 2. Where the requirements of this Regulation are applicable to demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs, the demand facility owner or the CDSO may totally or partially delegate to third parties tasks such as communicating with the relevant system operator or relevant TSO and gathering the documentation from the demand facility owner, the DSO or the CDSO evidencing compliance. Third parties shall be treated as single users with the right to compile relevant documentation and demonstrate compliance of their aggregated demand facilities or aggregated closed distribution systems with the provisions of this Regulation. Demand facilities and closed distribution systems providing demand response services to relevant system operators and relevant TSOs may act collectively through third parties. Article 35: 1. The compliance of a demand unit used by a demand facility or a closed distribution system to provide demand response services to relevant TSOs, shall be jointly assessed by the relevant TSO and the relevant system operator, and if applicable in coordination with the third party involved in demand aggregation. Article 36: 1. Testing of the performance of a transmission-connected demand facility, a transmission-connected distribution facility, or a demand unit with demand response active power control, demand response reactive power control or demand response transmission constraint management,

	shall aim at demonstrating that the requirements of this Regulation have been complied with. Article 41: 1. With regard to the demand modification test: (a) the technical capability of the demand unit used by a demand facility or a closed distribution system to provide demand response active power control, demand response reactive power control or demand response transmission constraint management to modify its power consumption, after receiving an instruction from the relevant system operator or relevant TSO, within the range, duration and time frame previously agreed and established in accordance with Article 28, shall be demonstrated, either individually or collectively as part of demand aggregation through a third party; Article 41: 2. With regard to the disconnection or reconnection of static compensation facilities test: (a) the technical capability of the demand unit used by a demand facility owner or closed distribution system operator to provide demand response active power control, demand response reactive power control or demand response transmission constraint management to disconnect or reconnect, or both, its static compensation facility when receiving an instruction from the relevant system operator or relevant TSO, in the time frame expected in accordance with Article 28, shall be demonstrated, either individually or collectively as part of demand aggregation through a third party; Article 42: 1. Simulation of the performance of a transmission-connected demand facility, a transmission-connected distribution facility, or a demand unit with demand response very fast active power control within a demand facility or a closed distribution system shall result in demonstrating whether the requirements of this Regulation have been fulfilled or not. Article 42: 2. Simulations shall be run in the following circumstances: (b) a new demand unit used by a demand facility or a closed distribution system to provide demand response very fast active power control to a relevant TSO has been contracted in accordance with Article 30; Article 45: 1. The model of the demand unit used by a demand facility owner or a closed distribution system operator to provide demand response very fast active power control shall demonstrate the technical capability of the demand unit to provide very fast active power control to a low frequency event in the conditions set out in Article 30. Article 48: 5. The proposal made by the relevant TSO to the regulatory authority or, where applicable, the Member State pursuant to paragraph 4 shall include the following: (a) an operational notification procedure for demonstrating the implementation of the requirements by the existing transmission-connected demand facilities, existing transmission-connected distribution facilities, existing distribution systems and existing demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs; (b) a transitional period for implementing the requirements which shall take into account the classes of transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems and demand units used by a demand facility or a closed distribution system to

	provide demand response services to relevant system operators and relevant TSOs and any underlying obstacles to the efficient implementation of the equipment modification/refitting. Article 52: 1. Demand facility owners or prospective owners, and DSOs/CDSOs or prospective operators, may request a derogation to one or several requirements of this Regulation for transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems, or demand units used by a demand facility or a closed distribution system to provide demand response services to a relevant system operator and a relevant TSO. Article 58: 3. Regulatory authorities shall ensure that agreements between system operators and owners of new or existing demand facilities or operators of new or existing distribution systems subject to this Regulation and relating to grid connection requirements for transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems and demand units used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs, in particular in national network codes, reflect the requirements set out in this Regulation. **Converter** Article 21: 4. For the purpose of dynamic simulations, the simulation model or equivalent information referred to in paragraph 3 (a) shall contain the following sub-models or equivalent information: (e) converter models. **RES & DG** The ENTSO-E demand connection code asks to motivate the member states to make a clear legal framework for grid connections of renewable electricity sources. **Storage & Pump Storage** The ENTSO-E demand connection code focuses only on the pump-storage. Although this demand connection code is issued in 2016, it doesn't cover chemical energy storages (i.e. battery) and other storage technologies. **Demand Response & Flexibility** The ENTSO-E demand connection code defines the role of all stakeholders dealing with demand response. **Storage & Pump Storage** The updated version for ENTSO-E demand connection code should take into consideration the new storage technologies like batteries.

Table 19. Connection codes-Requirements for Generators-High Voltage Direct Current Connection

ENTSO-E Network Code	**Connection codes-Requirements for Generators-High Voltage Direct Current Connection**
Technology (Intermittent RES /	**RES / DG/ Flexible DR /**

storage / flexible DR)	
Source documents	***Renewable Energy Sources/Distributed generation/ Demand Response*** *Article 4: Application to existing HVDC systems and DC-connected power park modules.*
Description	***Renewable Energy Sources/Distributed generation/ Demand Response*** ***Article 4: Application to existing HVDC systems and DC-connected power park modules****.* *Following a public consultation in accordance to Article 8 and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing HVDC systems and/or DC-connected power park modules.* *For that purpose, a sound and transparent quantitative cost-benefit analysis shall be carried out, in accordance with Articles 65 and 66. The analysis shall indicate:* *(a) the costs, in regard to existing HVDC systems and DC-connected power park modules, of requiring compliance with this Regulation;* *(b) the socioeconomic benefit resulting from applying the requirements set out in this Regulation; and* *(c) the potential of alternative measures to achieve the required performance.*
Article Analysis and spotted limitation	The Network Code on Requirements for Generators is harmonising standards that generators must respect to connect to the grid. These harmonised standards across Europe will boost the market of generation technology and increase competitiveness. The recommendations refer to prerequisites, simulation models and testing in great details. Maybe in the future, extended simulation models for the emerging technologies should be included.

9.4 Operations

Table 20. System Operations

ENTSO-E Grid Code	**System Operations**
Technology(Intermittent RES / storage / flexible DR)	**RES, storage, demand response (converter, power electronics)**
Source documents	***RES*** *Article 65 (Year ahead scenarios)* *Article 105 (Control area adequacy analysis)* *Article 106 (Control area adequacy up to and including week-ahead)* *Article 107 (Control area adequacy in day-ahead and intraday)* ***Storage***

	Article 114 (General provisions for ENTSO for Electricity operational planning data environment) *Article 116 (Outage coordination):* *Article 117 (System adequacy)* ***Demand response*** *Article 2 (Scope)* *Article 53 (Data exchange between TSOs and distribution-connected demand facilities or third parties participating in demand response):* *Article 54 (Responsibility of the SGUs):* *Article 81 (Regional adequacy assessment):* *Article 105 (Control area adequacy analysis):* *Article 107 (Control area adequacy in day-ahead and intraday):* *Article 127 (Frequency quality defining and target parameters):* ***converter/power electronics*** *Article 22 (Categories of remedial actions):*
Description	***Renewable energy sources (RES)*** *(3) Harmonised rules on system operation for transmission system operators (‘TSOs’), distribution system operators (‘DSOs’) and significant grid users (‘SGUs’) should be set out in order to provide a clear legal framework for system operation, facilitate Union-wide trade in electricity, ensure system security, ensure the availability and exchange of necessary data and information between TSOs and between TSOs and all other stakeholders, facilitate the integration of renewable energy sources, allow more efficient use of the network and increase competition for the benefit of consumers.* *(5) All TSOs should comply with the common minimum requirements on procedures necessary to prepare real-time operation, to develop individual and deliver common grid models, to facilitate the efficient and coordinated use of remedial actions which are necessary for real-time operation in order to maintain the operational security, quality and stability of the interconnected transmission system, and to support the efficient functioning of the European internal electricity market and facilitate the integration of renewable energy sources (‘RES’).* ***Article 65 (Year ahead scenarios)****:* *1. All TSOs shall jointly develop a common list of year-ahead scenarios against which they assess the operation of the interconnected transmission system for the following year. Those scenarios shall allow the identification and the assessment of the influence of the interconnected transmission system on operational security. The scenarios shall include the following variables: (b) the conditions related to the contribution of renewable energy sources;* *2. When developing the common list of scenarios, TSOs shall take into account the following elements: (a) the typical cross-border exchange patterns for different levels of consumption and of renewable energy sources and conventional generation;* ***Article 105 (Control area adequacy analysis):*** *1. Each TSO shall perform control area adequacy analysis by assessing the possibility for the sum of generation within its control area and cross-border import capabilities to meet the tottal load within its control area under various operational scenarios, taking into account the required level of active power reserves set out in Articles 118 and 119.* *2. When performing a control area adequacy analysis pursuant to paragraph 1, each TSO shall: (b) take into account the contributions of generation from renewable energy sources and load;* ***Article 106 (Control area adequacy up to and including week-ahead):***

	3. Each TSO shall update its control area adequacy analysis if it detects any probable changes to the availability status of power generating modules, load estimations, renewable energy sources estimations or cross zonal capacities that could significantly affect the expected adequacy. ***Article 107 (Control area adequacy in day-ahead and intraday):*** *1. Each TSO shall perform a control area adequacy analysis in a day-ahead and intraday time-frame on the basis of: (c) forecasted generation from renewable energy sources;* ***Storage*** ***Article 114 (General provisions for ENTSO for Electricity operational planning data environment):*** *1. By 24 months after entry into force of this Regulation, ENTSO for Electricity shall, pursuant to Articles 115, 116 and 117, implement and operate an ENTSO for Electricity operational planning data environment for the storage, exchange and management of all relevant information.* ***Article 116 (Outage coordination):*** *1. The ENTSO for Electricity operational planning data environment shall contain a module for the storage and exchange of all relevant information for outage coordination.* ***Article 117 (System adequacy):*** *1. The ENTSO for Electricity operational planning data environment shall contain a module for the storage and exchange of all relevant information for performing a coordinated adequacy analysis.* ***Demand Response*** ***Article 2 (Scope):*** *1. The rules and requirements set out in this Regulation shall apply to the following SGUs: (d) existing and new demand facilities, closed distribution systems and third parties if they provide demand response directly to the TSO in accordance with the criteria in Article 27 of Commission Regulation (EU) 2016/1388 (3);* *Article 52 (Data exchange between TSOs and transmission-connected demand facilities):* *2. Unless otherwise provided by the TSO, each transmission-connected demand facility owner shall provide the following data to the TSO: (c) in case of participation in demand response, a schedule of its structural minimum and maximum power range to be curtailed;* ***Article 53 (Data exchange between TSOs and distribution-connected demand facilities or third parties participating in demand response):*** *1. Unless otherwise provided by the TSO, each SGU which is a distribution-connected demand facility and which participates in demand response other than through a third party shall provide the following scheduled and real-time data to the TSO and to the DSO: (a) structural minimum and maximum active power available for demand response and the maximum and minimum duration of any potential usage of this power for demand response; (b) a forecast of unrestricted active power available for demand response and any planned demand response; (c) real-time active and reactive power at the connection point; and (d) a confirmation that the estimations of the actual values of demand response are applied.* *2. Unless otherwise provided by the TSO, each SGU which is a third party participating in demand response as defined in Article 27 of Regulation (EU) 2016/1388, shall provide the TSO and the DSO at the day-ahead and close to real-time and on behalf of all of its distribution-connected demand facilities, with the following data: (a) structural minimum and maximum active power available for*

	demand response and the maximum and minimum duration of any potential activation of demand response in a specific geographical area defined by the TSO and DSO; (b) a forecast of unrestricted active power available for the demand response and any planned level of demand response in a specific geographical area defined by the TSO and DSO; (c) real-time active and reactive power; and (d) a confirmation that the estimations of the actual values of demand response are applied. 25.8.2017 L 220/41 Official Journal of the European Union EN ***Article 54 (Responsibility of the SGUs):*** *4. Upon request from the TSO or DSO, pursuant to Article 41(2) of Regulation (EU) 2016/631 and Article 35(2) of Regulation (EU) 2016/1388, the SGU shall carry out compliance tests and simulations in accordance with those Regulations at any time throughout the lifetime of its facility and in particular after any fault, modification or replacement of any equipment, which could have an impact on the facility's compliance with the requirements of this Regulation regarding the capability of the facility to achieve the values declared, the time requirements applicable to those values and the availability or contracted provision of ancillary services. Third parties providing demand response directly to the TSO, providers of redispatching of power generating modules or demand facilities by means of aggregation, and other providers of active power reserves shall ensure that the facilities in their portfolio comply with the requirements of this Regulation.* ***Article 81 (Regional adequacy assessment):*** *2. Each TSO shall provide the regional security coordinator with the information necessary to perform the regional adequacy assessments referred to in paragraph 1, including: (a) the expected total load and available resources of demand response;* ***Article 105 (Control area adequacy analysis):*** *1. Each TSO shall perform control area adequacy analysis by assessing the possibility for the sum of generation within its control area and cross-border import capabilities to meet the total load within its control area under various operational scenarios, taking into account the required level of active power reserves set out in Articles 118 and 119.* *2. When performing a control area adequacy analysis pursuant to paragraph 1, each TSO shall: (a) use the latest availability plans and the latest available data for: (iii) possible demand response provided pursuant to Articles 52 and 53;* ***Article 107 (Control area adequacy in day-ahead and intraday):*** *1. Each TSO shall perform a control area adequacy analysis in a day-ahead and intraday time-frame on the basis of: (g) capabilities of demand facilities with demand response in accordance with the data provided pursuant to Articles 52 and 53 and their availability statuses.* ***Article 127 (Frequency quality defining and target parameters):*** *8. The proposal for modification of the values pursuant to paragraph 6 and 7 shall be based on an assessment of the recorded values of the system frequency for a period of at least 1 year and the synchronous area development and it shall meet the following conditions: (a) the proposed modification of the frequency quality defining parameters in Table 1 of Annex III or the frequency quality target parameter in Table 2 of Annex III takes into account: (vi) the number and response of demand units operating with activated demand response system frequency control or demand response very fast active power control as defined in Articles 29 and 30 of Regulation (EU) 2016/1388; and* ***Article 154 (FCR technical minimum requirements):***

	8. Each reserve connecting TSO shall monitor its contribution to the FCP and its FCR activation with respect to its FCR obligation, including FCR providing units and FCR providing groups. Each FCR provider shall make available to the reserve connecting TSO, for each of its FCR providing units and FCR providing groups, at least the following information: (c) droop of the governor for type C and type D power generating modules as defined in Article 5 of Regulation (EU) 2016/631 acting as FCR providing units, or its equivalent parameter for FCR providing groups consisting of type A and/or type B power generating modules as defined in Article 5 of Regulation (EU) 2016/631, and/or demand units with demand response active power control as defined in Article 28 of Regulation (EU) 2016/1388. ***Converter*** ***Article 22 (Categories of remedial actions):*** *1. Each TSO shall use the following categories of remedial actions: (c) control voltage and manage reactive power by means of: (vi) requesting the change of reactive power output of the converters of transmission-connected non-synchronous power generating modules;* ***Power electronics*** ***Article 22 (Categories of remedial actions):*** *1. Each TSO shall use the following categories of remedial actions: (c) control voltage and manage reactive power by means of: (iii) switching of the power-electronics-based devices used for voltage and reactive power management;*
Article Analysis and spotted limitation	The System Operation specifies what transmission system operators should do in managing their grid. The fact that the generation mix in Europe is integrating more and more renewables, that there is more and more interconnections and cross-border competition has been considered in the System Operation Guideline. It lays the ground for the next power system and for example makes regional coordination a legal obligation for grid operators. **Article 107 (Control area adequacy in day-ahead and intraday):** 1. Each TSO shall perform a control area adequacy analysis in a day-ahead and intraday time-frame on the basis of: (c) forecasted generation from renewable energy sources. Extra consideration should be given for the emerging technologies and schemes that forecasting is also needed. e.g demand response, load forecasting, EVs etc **Article 114 (General provisions for ENTSO for Electricity operational planning data environment):** 1. The ENTSO for Electricity operational planning data environment shall contain a module for the storage and exchange of all relevant information for outage coordination. EVs explicitly should also be considered **Power electronics** **Article 22 (Categories of remedial actions):** 1. Each TSO shall use the following categories of remedial actions: (c) control voltage and manage reactive power by means of: (iii) switching of the power-electronics-based devices used for voltage and reactive power management; Is direct control of the customers' side from TSO insinuated? or this is a request to third parties. It needs clarification.

Table 21. Operation: Emergency and Restoration

ENTSO-E Grid Code	Operation: Emergency and Restoration (ENTSO-E Family Codes)
Technology (Intermittent RES / storage / flexible DR)	RES/ Storage / Flexible DR/ Converter/ Power electronics
Source documents	***Network Code Requirement for Electricity transmission system operation:*** ***RES*** *Article 65: Year ahead scenarios* *Article 105: Control area adequacy analysis* *Article 106: Control area adequacy up to and including week-ahead* *Article 107: Control area adequacy in day-ahead and intraday* ***Storage*** *Article 114: General provisions for ENTSO for Electricity operational planning data environment* *Article 116: Outage coordination* *Article 117: System adequacy* ***DER*** *Article 2: Scope* *Article 52: Data exchange between TSOs and transmission-connected demand facilities* *Article 53: Data exchange between TSOs and distribution-connected demand facilities or third parties participating in demand response* *Article 54: Responsibility of the SGUs* *Article 81: Regional adequacy assessment* *Article 105: Control area adequacy analysis* *Article 107: Control area adequacy in day-ahead and intraday* *Article 127 (Frequency quality defining and target parameters)* *Article 154 (FCR technical minimum requirements):* ***Converter*** *Article 22 (Categories of remedial actions):* ***Power electronics*** *Article 22 (Categories of remedial actions):* *1. Each TSO shall use the following categories of remedial actions: (c) control voltage and manage reactive power by means of: (iii) switching of the power-electronics-based devices used for voltage and reactive power management;*
Description	***RES*** ***Article 65: Year ahead scenarios*** *1. All TSOs shall jointly develop a common list of year-ahead scenarios against which they assess the operation of the interconnected transmission system for the following year. Those scenarios shall allow the identification and the assessment of the influence of the interconnected transmission system on operational security. The scenarios shall include the following variables: (b) the conditions related to the contribution of renewable energy sources;* *2. When developing the common list of scenarios, TSOs shall take into account the following elements: (a) the typical cross-border exchange patterns for different*

	levels of consumption and of renewable energy sources and conventional generation; ***Article 105: Control area adequacy analysis*** *1. Each TSO shall perform control area adequacy analysis by assessing the possibility for the sum of generation within its control area and cross-border import capabilities to meet the total load within its control area under various operational scenarios, taking into account the required level of active power reserves set out in Articles 118 and 119.* *2. When performing a control area adequacy analysis pursuant to paragraph 1, each TSO shall: (b) take into account the contributions of generation from renewable energy sources and load;* ***Article 106: Control area adequacy up to and including week-ahead*** *3. Each TSO shall update its control area adequacy analyses if it detects any probable changes to the availability status of power generating modules, load estimations, renewable energy sources estimations or cross zonal capacities that could significantly affect the expected adequacy.* ***Article 107: Control area adequacy in day-ahead and intraday*** *1. Each TSO shall perform a control area adequacy analysis in a day-ahead and intraday time-frame on the basis of: (c) forecasted generation from renewable energy sources;* ***Storage*** ***Article 114: General provisions for ENTSO for Electricity operational planning data environment*** *1. By 24 months after entry into force of this Regulation, ENTSO for Electricity shall, pursuant to Articles 115, 116 and 117, implement and operate an ENTSO for Electricity operational planning data environment for the storage, exchange and management of all relevant information.* ***Article 116: Outage coordination*** *1. The ENTSO for Electricity operational planning data environment shall contain a module for the storage and exchange of all relevant information for outage coordination.* ***Article 117: System adequacy*** *1. The ENTSO for Electricity operational planning data environment shall contain a module for the storage and exchange of all relevant information for performing a coordinated adequacy analysis.* ***DER*** ***Article 2: Scope*** *1. The rules and requirements set out in this Regulation shall apply to the following SGUs: (d) existing and new demand facilities, closed distribution systems and third parties if they provide demand response directly to the TSO in accordance with the criteria in Article 27 of Commission Regulation (EU) 2016/1388 (3);* ***Article 52: Data exchange between TSOs and transmission-connected demand facilities*** *2. Unless otherwise provided by the TSO, each transmission-connected demand facility owner shall provide the following data to the TSO: (c) in case of participation in demand response, a schedule of its structural minimum and maximum power range to be curtailed;* ***Article 53: Data exchange between TSOs and distribution-connected demand facilities or third parties participating in demand response***

	1. Unless otherwise provided by the TSO, each SGU which is a distribution-connected demand facility and which participates in demand response other than through a third party shall provide the following scheduled and real-time data to the TSO and to the DSO: (a) structural minimum and maximum active power available for demand response and the maximum and minimum duration of any potential usage of this power for demand response; (b) a forecast of unrestricted active power available for demand response and any planned demand response; (c) real-time active and reactive power at the connection point; and (d) a confirmation that the estimations of the actual values of demand response are applied. *2. Unless otherwise provided by the TSO, each SGU which is a third party participating in demand response as defined in Article 27 of Regulation (EU) 2016/1388, shall provide the TSO and the DSO at the day-ahead and close to real-time and on behalf of all of its distribution-connected demand facilities, with the following data: (a) structural minimum and maximum active power available for demand response and the maximum and minimum duration of any potential activation of demand response in a specific geographical area defined by the TSO and DSO; (b) a forecast of unrestricted active power available for the demand response and any planned level of demand response in a specific geographical area defined by the TSO and DSO; (c) real-time active and reactive power; and (d) a confirmation that the estimations of the actual values of demand response are applied. 25.8.2017 L 220/41 Official Journal of the European Union EN* ***Article 54: Responsibility of the SGUs*** *4. Upon request from the TSO or DSO, pursuant to Article 41(2) of Regulation (EU) 2016/631 and Article 35(2) of Regulation (EU) 2016/1388, the SGU shall carry out compliance tests and simulations in accordance with those Regulations at any time throughout the lifetime of its facility and in particular after any fault, modification or replacement of any equipment, which could have an impact on the facility's compliance with the requirements of this Regulation regarding the capability of the facility to achieve the values declared, the time requirements applicable to those values and the availability or contracted provision of ancillary services. Third parties providing demand response directly to the TSO, providers of redispatching of power generating modules or demand facilities by means of aggregation, and other providers of active power reserves shall ensure that the facilities in their portfolio comply with the requirements of this Regulation.* ***Article 81: Regional adequacy assessment*** *2. Each TSO shall provide the regional security coordinator with the information necessary to perform the regional adequacy assessments referred to in paragraph 1, including: (a) the expected total load and available resources of demand response;* ***Article 105: Control area adequacy analysis*** *1. Each TSO shall perform control area adequacy analysis by assessing the possibility for the sum of generation within its control area and cross-border import capabilities to meet the total load within its control area under various operational scenarios, taking into account the required level of active power reserves set out in Articles 118 and 119.* *2. When performing a control area adequacy analysis pursuant to paragraph 1, each TSO shall: (a) use the latest availability plans and the latest available data for: (iii) possible demand response provided pursuant to Articles 52 and 53;* ***Article 107: Control area adequacy in day-ahead and intraday***

	1. Each TSO shall perform a control area adequacy analysis in a day-ahead and intraday time-frame on the basis of: (g) capabilities of demand facilities with demand response in accordance with the data provided pursuant to Articles 52 and 53 and their availability statuses. ***Article 127 (Frequency quality defining and target parameters):*** *8. The proposal for modification of the values pursuant to paragraph 6 and 7 shall be based on an assessment of the recorded values of the system frequency for a period of at least 1 year and the synchronous area development and it shall meet the following conditions: (a) the proposed modification of the frequency quality defining parameters in Table 1 of Annex III or the frequency quality target parameter in Table 2 of Annex III takes into account: a) (vi) the number and response of demand units operating with activated demand response system frequency control or demand response very fast active power control as defined in Articles 29 and 30 of Regulation (EU) 2016/1388; and* ***Article 154 (FCR technical minimum requirements):*** *8. Each reserve connecting TSO shall monitor its contribution to the FCP and its FCR activation with respect to its FCR obligation, including FCR providing units and FCR providing groups. Each FCR provider shall make available to the reserve connecting TSO, for each of its FCR providing units and FCR providing groups, at least the following information: (c) droop of the governor for type C and type D power generating modules as defined in Article 5 of Regulation (EU) 2016/631 acting as FCR providing units, or its equivalent parameter for FCR providing groups consisting of type A and/or type B power generating modules as defined in Article 5 of Regulation (EU) 2016/631, and/or demand units with demand response active power control as defined in Article 28 of Regulation (EU) 2016/1388.* ***Converter*** ***Article 22 (Categories of remedial actions):*** *1. Each TSO shall use the following categories of remedial actions: (c) control voltage and manage reactive power by means of: (vi) requesting the change of reactive power output of the converters of transmission-connected non-synchronous power generating modules;* ***Power electronics*** ***Article 22 (Categories of remedial actions):*** *1. Each TSO shall use the following categories of remedial actions: (c) control voltage and manage reactive power by means of: (iii) switching of the power-electronics-based devices used for voltage and reactive power management;*
Article Analysis	"The Emergency and Restoration Code fixes the processes that the transmission system operators must follow when they face an incident on their grid. The highest standards and practice in dealing with emergency situations will thus apply in all Europe. According to the above-mentioned articles, TSOs should identify the influence of RES on operational security during development of year ahead scenarios and performing control area adequacy analysis. Storage module should be included in ENTSO for Electricity operational planning data environment. In case of participating in demand response Grid Code defines what data shall be exchanged between facility providing this service and TSO. Grid Code also indicates that providers of demand response directly to the TSO

	should carry out compliance tests and simulations in accordance with Article 41(2) of Regulation (EU) 2016/631 and Article 35(2) of Regulation (EU) 2016/1388. In addition, each FCR provider should make available to the TSO information on demand units with demand response active power control as defined in Article 28 of Regulation (EU) 2016/1388. Demand response capabilities should be included during performing regional adequacy assessment and control area adequacy analysis. Converters and power electronics are mentioned in reference to voltage and reactive power remedial actions. **Recommendations on short comings** This regulation includes storage systems in defence plan and provides guidelines on how it should behave in case of frequency disturbance. The details are left to be specified by TSOs. As for the demand response, this code requires that before load-shedding takes place a demand response should be activated. It also indicates what kind of compliance tests should be applied for facilities providing demand response

9.5 Market

Table 22. Market-Electricity Balancing

ENTSO-E Network Code	**Market - Electricity Balancing**
Technology (Intermittent RES / storage / flexible DR)	**RES / Storage / Flexible DR / EVs**
Source documents	***Network Code Requirement for Electricity Balancing****:* ***Renewable Energy Sources (RES)*** ***Article 3:*** *Objectives and regulatory aspects.* *This regulation aims at facilitating the participation of renewable energy sources and support the achievement of the European Union target for the penetration of renewable generation.* ***Article 18:*** *Terms and conditions related to balancing –* ▪ *4 The terms and conditions for balancing service providers shall: allow demand facility owners, third parties and owners of power generating facilities from conventional and renewable energy sources as well as owners of energy storage units to become balancing service providers.* ▪ ***Article 25:*** *Requirements for standard products* ▪ *5 The list of standard products for balancing energy and balancing capacity shall set out at least the following variable characteristics of a standard product to be determined by the balancing service providers during the prequalification or when submitting the standard product bid:* *Facilitate the participation of demand facility owners, third parties and owners of power generating facilities from renewable energy sources as well as owners of energy storage units as balancing service providers.* ***Article 60:*** *TSO report on balancing* ▪ *2. The report on balancing shall:*

	Analyse the costs and benefits, and the possible inefficiencies and distortions of having specific products in terms of competition and market fragmentation, participation of demand response and renewable energy sources, integration of balancing markets and side-effects on other electricity markets; ***Article 62:** Derogations* *▪ 8. When assessing the request for derogation or before granting a derogation at its own initiative, the relevant regulatory authority shall consider the following aspects: The impacts of non-implementation of the concerned provision or provisions, in terms of non-discrimination and competition with other European market participants, in particular as regards demand response and renewable energy sources;* ***Storage*** ***Article 3:** Objectives and regulatory aspects* *▪ 1. This regulation aims at: (f) facilitating the participation of demand response including aggregation facilities and energy <u>storage</u> while ensuring they compete with other balancing services at a level playing field and, where necessary, act independently when serving a single demand facility.* ***Article 18**: Terms and conditions related to balancing* *▪ 4 - The terms and conditions for balancing service providers shall:* *● (b) allow the aggregation of demand facilities, energy <u>storage</u> facilities and power generating facilities in a scheduling area to offer balancing services subject to conditions referred to in paragraph 5 (c);* *● (c) allow demand facility owners, third parties and owners of power generating facilities from conventional and renewable energy sources as well as owners of energy storage units to become balancing service providers;* *▪ 5. The terms and conditions for balancing service providers shall contain:* *● (c) the rules and conditions for the aggregation of demand facilities, energy storage facilities and power generating facilities in a scheduling area to become a balancing service provider;* ***Article 25:** Requirements for standard products* *▪ 6. Standard products for balancing energy and balancing capacity shall: Facilitate the participation of demand facility owners, third parties and owners of power generating facilities from renewable energy sources as well as owners of energy storage units as balancing service providers.* ***Demand Response*** ***Article 3:** Objectives and regulatory aspects* *▪ This regulation aims at:* *● (f) facilitating the participation of demand response including aggregation facilities and energy storage while ensuring they compete with other balancing services at a level playing field and, where necessary, act independently when serving a single demand facility;* ***Article 60**: TSO report and balancing* *▪ 2. The report on balancing shall:* *● (d) analyze the costs and benefits, and the possible inefficiencies and distortions of having specific products in terms of competition and market fragmentation, participation of demand response and renewable energy sources, integration of balancing markets and side-effects on other electricity markets* ***Article 62:** Derogations* *▪ 8. When assessing the request for derogation or before granting a derogation at its own initiative, the relevant regulatory authority shall consider the following aspects:*

	● *(d) the impacts of non-implementation of the concerned provision or provisions, in terms of non-discrimination and competition with other European market participants, in particular as regards demand response and renewable energy sources;*
Description	*"The Electricity Balancing Guideline is about creating a market where countries can share the resources used by their transmission system operators to make generation equal demand always. It is also about allowing new players such as demand response and renewables to take part in this market. All in all, the Balancing Guideline should help increase security of supply, limit emissions and diminish costs to consumers."*
Article Analysis	Articles mentioned are: ● Article 3: Objectives and regulatory aspects ● Article 18: Terms and conditions related to balancing ● Article 25: Requirements for standard products ● Article 60: TSO report and balancing ● Article 62: Derogations Based on these articles: ● It is aimed to facilitate the participation of renewable energy sources, demand response and energy storage and make sure they compete with other balancing services. ● Demand facility owners, third parties and owners of power generating facilities from conventional and RES, and owners of energy storage units can become balancing service providers ● The terms and conditions for balancing service providers shall allow the aggregation of demand facilities, energy storage facilities and power generating facilities in a scheduling area to offer balancing services. ● After the approval of each implementation framework and no later than the time when a TSO uses the respective European platform, the TSO shall use only standard and, where justified, specific balancing energy products in order to maintain the system's balance. ● At least once every two years, each TSO shall publish a report on balancing covering the previous two calendar years, respecting the confidentiality of information. This report shall analyse the costs and benefits, and the possible inefficiencies and distortions of having specific products in terms of competition and market fragmentation, participation of demand response and renewable energy sources, integration of balancing markets and side-effects on other electricity markets. ● When assessing the request for derogation or before granting a derogation at its own initiative, the relevant regulatory authority shall consider the impacts of non-implementation of the concerned provision or provisions, in terms of non-discrimination and competition with other European market participants, in particular as regards demand response and renewable energy sources and the impacts on overall economic efficiency and smart grid infrastructure.

Table 23. Forward Capacity Allocation

ENTSO-E Network Code	**Forward Capacity Allocation**
Technology (Intermittent RES / storage / flexible DR)	**RES/STORAGE** Article 63 Monitoring Article 37 Terms and conditions for participation in the forward capacity allocation Article 39 Operation of the forward capacity allocation
Source documents	**None of the keywords in the list were spotted. General codes that is although applicable of RES and storage are quoted below.**
Description	*(1) The urgent completion of a fully functioning and interconnected internal energy market is crucial to the objectives of maintaining security of energy supply, increasing competitiveness and ensuring that all consumers can purchase energy at affordable prices. A well-functioning internal market in electricity should provide producers with appropriate incentives for investing in new power generation, including in electricity from* ***renewable energy sources****, paying special attention to the most isolated Member States and regions in the Union's energy market.* *A well-functioning market should also provide consumers with adequate measures to promote more efficient use of energy, which presupposes a secure supply of energy.* ***Article 63 Monitoring*** *ENTSO for Electricity shall monitor the implementation of forward capacity allocation and the establishment of single allocation platform in accordance with Article 8(8) of Regulation (EC) No 714/2009. Monitoring shall cover in particular the following matters:* *(a) the progress and potential problems with the implementation of forward capacity allocation, including fair and transparent access for market participants to long-term transmission rights;* *(b) the effectiveness of the methodologies for splitting long-term cross-zonal capacity in accordance with Article 16;27.9.2016L 259/67 Official Journal of the European Union* *(c) the report on capacity calculation and allocation in accordance with Article 26;* *(d) the effectiveness of the operation of the forward capacity allocation and the single allocation platform.* ***Article 37 Terms and conditions for participation in the forward capacity allocation.*** *1.Market participants shall be registered with the single allocation platform and meet all eligibility requirements under the harmonised allocation rules before being entitled to participate in the auctions or transfer their long-term transmission rights. The eligibility requirements shall comply with the principles of non-discrimination and transparency.* *2.Following a market participant's request for registration, the single allocation* *3.platform shall notify the market participant whether it fulfils all eligibility requirements and is entitled to participate in the auctions or transfer its long-term transmission rights from a specified date.* *4. Market participants shall fully comply with the harmonised*

	5.allocation rules. They shall keep all information relating to their participation up to date and notify the single allocation platform of any changes to this information without delay. *6.The single allocation platform shall be entitled to suspend or withdraw a market participant's right to participate in the auctions or transfer its long-term transmission rights following a breach of its contractual obligations under the harmonised allocation rules.* *7.The suspension or withdrawal of the right of the market participant to participate in the auctions or transfer its long-term transmission right pursuant to the harmonised allocation rules shall not exonerate a market participant or the single allocation platform from their obligations deriving from long-term transmission rights allocated and paid before the suspension or withdrawal.* ***Article 39 Operation of the forward capacity allocation*** *Each market participant shall submit its bids to the single allocation platform prior to the gate closure time and in accordance with the conditions set out in the auction specification.*
Article Analysis	This Regulation lays down detailed rules on cross-zonal capacity allocation in the forward markets, on the establishment of a common methodology to determine long-term cross-zonal capacity, on the establishment of a single allocation platform at European level offering long-term transmission rights, and on the possibility to return long-term transmission rights for subsequent forward capacity allocation or transfer long-term transmission rights between market participants. 2. This Regulation shall apply to all transmission systems and interconnections in the Union, except the transmission systems on islands which are not connected with other transmission systems via interconnectors. 3. In Member States where more than one TSO exists, this Regulation shall apply to all TSOs within that Member State. Where a TSO does not have a function relevant to one or more obligations under this Regulation, Member States may provide that the responsibility for complying with those obligations is assigned to one or more different, specific TSOs. 4. The single allocation platform may be opened to market operators and TSOs operating in Switzerland on the condition that its national law implements the main provisions of Union electricity market legislation and that there is an intergovernmental agreement on electricity cooperation between the Union and Switzerland. So, the document does not cover the market's participants under the technology point of view, but it offers a general context of the procedures that participants need to follow in order to participate into the forward markets. Both this document and the linked document of Allocation Rules for Forward Capacity Allocation needs to secure long-term transmission rights to allow cross-border hedging by 2021 of RES. Same applies for storage owners as indicated by Electricity Directive.

Table 24. Capacity Allocation and Congestion Management

ENTSO-E Network Code	**Capacity Allocation and Congestion Management**
Technology (Intermittent RES / storage / flexible DR)	**RES** **None of the keywords in the list were spotted. General codes that is although applicable of RES and storage are quoted below.**
Source documents	***RES*** *(16) The development of more liquid intraday markets which give parties the ability to balance their positions closer to real time should help to integrate renewable energy sources into the Union electricity market and thus, in turn, facilitate renewable energy policy objectives.*
Description	*The Guideline on Capacity Allocation and Congestion Management (CACM) sets out the methods for calculating how much space can market participants use on cross border lines without endangering system security. It also harmonises how cross border markets operate in Europe to increase competitiveness with renewables' integration. CACM is the cornerstone of a European single market for electricity.*
Article Analysis and spotted limitation.	This Regulation aims at: (a) promoting effective competition in the generation, trading and supply of electricity; (b) ensuring optimal use of the transmission infrastructure; (c) ensuring operational security; (d) optimising the calculation and allocation of cross-zonal capacity; (e) ensuring fair and non-discriminatory treatment of TSOs, NEMOs, the Agency, regulatory authorities and market participants; (f) ensuring and enhancing the transparency and reliability of information; (g) contributing to the efficient long-term operation and development of the electricity transmission system and electricity sector in the Union; (h) respecting the need for a fair and orderly market and fair and orderly price formation; (i) creating a level playing field for NEMOs; (j) providing non-discriminatory access to cross-zonal capacity. Explicit reference to storage should be given as an asset of operators for congestion.

10 ANNEX 2

10.1 Implementation Guidance Documents Analysis.

Research on all code families through the Implementation Guidance Documents were completed and extended. In this section, selected IGDs are summarised to provide a brief overview for each case on the background of the topic and on how this is addressed in the regulation/guideline.

10.2 Automatic Reconnection [2]

Table 25. Automatic connection/reconnection

Topic	**Automatic connection/reconnection**
Technology	PGMs type A, B, C (not allowed for type D)
Reference	IGD on "*Automatic connection/reconnection and admissible rate of change of active power*"
Source documents	● NC RfG – Article 13(7) and 14(4) ● NC DCC – Article 19.4
Background	*"Uncoordinated/uncontrolled reconnection of a large amount of distributed generation after system disturbance could result in system stability problems and cause system split or islanding."*
How this is addressed in the regulation / guideline?	*"The document provides guidance on implementing the capability of power generating modules related to voltage and frequency ranges, observation time and gradient of active power increase for connection or reconnection.* *If no settings are specified by the relevant TSO or relevant DSO (in coordination with the relevant TSO), the default settings for an automatic reconnection for power generating units after an incidental disconnection could be recommended as follows:* ● *Voltage range: 0.9 pu ≤ U ≤ 1.1 pu; and* ● *Frequency range:* ○ *Continental Europe: 49.9 Hz ≤ f ≤ 50.1 Hz* ○ *Other synchronous areas 49.0 Hz ≤ f ≤ 51.0 Hz; and* ● *Minimum observation time: 60 s;* ● *Maximum gradient of active power increase ≤ 20 % of $P_{max/min}$* *Automatic reconnection after incidental disconnection is allowed when the system frequency and the voltage at the grid connection point are within the specified range for the defined observation time, and any protection tripping has been cleared."*

[2] ENTSO-E, "Automatic connection/reconnection and admissible rate of change of active power", 31.01.2018, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 31.04.2019)

10.3 Data Exchange [3]

Table 26. Data exchange

Topic	**Data exchange**
Technology	PGMs type B, C and D, transmission-connected demand facilities and distribution systems, HVDC systems, DC connected PPMs
Reference	IGD on *"Real time data and communication"*
Source documents	• NC RfG – Article 14.5(d) • NC DCC – Article 18 • NC HVDC – Article 31 and 51
Background	NC RfG Preamble (21): *"Adequate information exchange between system operators and power generating facility owners is a prerequisite for enabling system operators to maintain system stability and security. System operators need to have a continuous overview of the state of the system, which includes information on the operating conditions of power generating modules, as well as the possibility to communicate with them in order to direct operational instructions."*
How this is addressed in the regulation / guideline?	*"The three Connection Network Codes establish different requirements to the Grid Users in terms of information to be exchanged with the relevant TSO and/or to the relevant system operator of the facilities connected to the network." "It's recommended to require the communication capability in a non-exhaustive manner, because the detail on the information to be exchanged depends on the operational strategies specified by the relevant system operator and the Relevant TSO."* *"DC connected PPMs shall comply with the articles of NC RfG, where Art 14.5 (d) applies."* *"In SO GL, the information exchange requirements and methodology is covered in Title 2. Specifically, the various categories of information to be exchanged structural, scheduled and real time data is defined in the SO GL Articles 41 – 53. In NC ER the information exchange requirements is specified in Chapter V."*

10.4 Demand Response [4]

Table 27. Demand Response

Topic	Demand Response
Technology	Demand Response
Reference	IGD on *"Demand Response – System Frequency Control"*
Source documents	• NC DCC – Article 29(2)
Background	*"An alternative to adjusting generation output to address the load and generation balance is to adjust demand using DR SFC. In principle DR SFC could contribute to simulate either or both FSM, LFSM or a combination of both."*

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[3] ENTSO-E, "Real time data and communication",16.11.2016,https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

[4] ENTSO-E. "Demand Response – System Frequency Control", 31.01.2018, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

	"Every power demand unit that has a latent thermal store, for example refrigeration, space heating/cooling, water heating/cooling and any other heating/cooling device could be used to provide DR SFC." *"The trigger for this service is a change in system frequency - deviation from nominal value (absolute delta f) which may be measured at the supply point of any device connected within a demand facility. This may be achieved by measuring the frequency from its electrical supply. Therefore, the entire control and operation of DR SFC can be built into the device, minimising cost and complexity. In effect a device can be bought with a DR SFC controller built in and simply 'plugged in' to become operable."*
How this is addressed in the regulation / guideline?	*"The objective of this guidance document is to help to determine the main criteria/motivation for the recommended settings and applications of the DR SFC capabilities of demand units at a synchronous system and national level."* *"In order to best coordinate active power response by DR SFC with the provision of FCR, it is recommended to activate it at full deployment of FCR, i.e. to set the frequency threshold such, that there is no overlap or gap between FCR and the initiation of DR SFC."* *"The full capability of DR SFC as selective shedding of non-essential loads should be activated by frequency before low frequency demand disconnection is operated as non-selective load shedding also affecting essential loads. This will ensure that non-essential loads offered for DR SFC are disconnected before the need to shed essential loads. In this context essential load means an electricity consuming device which the final user directly utilizes and will notice any reduced operation, whereas the non-essential load has an internal buffer which decouples the energy consumption from the practical use."*

10.5 Inertia Decrease [5]

Table 28. Inertia decrease

Topic	**Inertia decrease**
Technology (Intermittent RES / storage / flexible DR)	PPMs type C and D, HVDC systems, demand facilities or closed distribution system
Reference	IGD on *"Need for synthetic inertia (SI) for frequency regulation"*
Source documents	• NC RfG - Article 21.2(a) • NC DCC – Article 30.1 • NC HVDC - Article 14.1
Background	*"The need for SI applies particularly for smaller synchronous areas with high penetration of non-synchronous generation which tend to have lower total system inertia and greater frequency volatility (such as Ireland and Great Britain). It may also apply to large synchronous areas to prevent total system collapse in case of a system split and subsequent island operation. From a system operation perspective, it can therefore be of crucial importance that all generators, HVDC systems are able to provide SI and supported further by fast action from suitable demand units. SI could then facilitate further expansion of RES, which do not naturally contribute to inertia."*

[5] ENTSO-E, "Need for synthetic inertia (SI) for frequency regulation", 31.01.2018, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

How this issue is addressed in the regulation / guideline?	*"Based on Article 21 (2) (b) of RfG, the operating principle of control systems installed to provide synthetic inertia and the associated performance parameters shall be specified by the relevant TSO. Hence, RfG focuses on the performance requirement of the SI from a functional perspective rather than details on technical implementation to achieve the objectives."* *"Each TSO choosing to apply SI shall define at least the following requirements for the relevant elements:* *● Frequency or df/dt measurement criteria:* *o time window (speed)* *o accuracy, and* *o total delay time* *● Function characteristics (e.g. df/dt vs. Δf, deadband and droop)* *● TSO input signal for activation and access to alter settings such as droop."* Requirements on SI are **non-mandatory**.

10.6 Large rate of change of frequency [6]

Table 29. Large rate of change of frequency

Topic	Large rate of change of frequency
Technology (Intermittent RES / storage / flexible DR)	PGMs type A (and above), HVDC systems, DC-connected PPMs, demand units
Reference	IGD on *"Rate of Change of Frequency (RoCoF) withstand capability"*
Source documents	● NC RfG: Articles 13 (1) (b) and 15 (5) (b) (iii) ● NC DCC: Articles 28 (2) (k) and 29 (2) (g) ● NC HVDC: Articles 12 and 39 (3)
Background	*"[...] RoCoF [...] was traditionally of minor relevance for systems with generation mainly based on synchronous generators, because of the inertia of these generators, which inherently counteract to load imbalances and thus limit RoCoF in these cases. It however becomes relevant now during significant load-generation imbalances, when larger RoCoF values may be observed because of low system inertia caused by (amongst others) disposal of synchronous generation in case of high instantaneous penetration of non-synchronously connected generation facilities."* *"Large df/dt values may endanger secure system operation because of mechanical limitations of individual synchronous machines (inherent capability), protection devices triggered by a particular RoCoF threshold value or timing issues related to load shedding schemes."*
How this issue is addressed in the regulation / guideline?	*"The requirement aims at ensuring that power generating modules (NC RfG), demand units offering Demand Response (DR) services (DCC), HVDC systems and DC-connected power park modules shall not disconnect from the network up to a maximum rate of change of frequency (df/dt)."* *"NC RfG and DCC require that the Relevant TSO shall specify the df/dt (RoCoF), which a power generating module (RfG) or a Demand Unit (DCC) shall at least be capable of withstanding."*

[6] ENTSO-E, "Rate of Change of Frequency (RoCoF) withstand capability", 31.01.2018, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

10.7 Shortage of capability to provide frequency response [7]

Table 30. Shortage of capability to provide frequency response

Topic	**Shortage of capability to provide frequency response**
Technology (Intermittent RES / storage / flexible DR)	PGMs type A
Reference	IGD on ***"****Special issues associated with type 'A' generators"*
Source documents	Network Code (NC) Requirement for Generators (RfG): ● Article 13, Special Requirements for Type A generators ● Article 30, Operational notification of type A power generating modules ● Article 40 Responsibility of the power generating facility owner ● Article 62 Paragraph 12, Request for a derogation by a power generating facility owner TITLE VI Transitional arrangements for emerging technologies
Background	*"The categorization of type A generators is set at the European level as generators above 800W up to a maximum level of from which a Power Generating Module (PGM) is of type B (where a type A generator becomes a type B generator) varies from one synchronous network to another. The limit for maximum capacity threshold where this occurs in the requirement for generators network code is reflective of the collective impact that type A generation may have on a synchronous network. Accordingly, the 100kW limit for maximum capacity threshold for Ireland as the smallest synchronous network rises to 1MW for Continental Europe. These limits for maximum capacity thresholds largely relate to the percentage of the generation portfolio that might be type A. Higher percentage Type A with the maximum limit in a country, tends to justify choosing a lower boundary between A and B to ensure the further capabilities associated with Type B are available in sufficient volume under all operating conditions."*
How this issue is addressed in the regulation?	*"The equipment certification is expected to be used [...]." "The European industry has responded to the impending introduction of the network code requirements for generators by updating some of its standards to reflect the codes."* *"[...] These standards set the frequency range that a generator unit shall be capable of withstanding and maintaining operation at the worst-case values that may be selected from Table 2 in the requirements for generators for any synchronous system and the Rate of Change of Frequency to 2.5Hz/sec withstand capability. ENTSO-E supports the selected range and consequently and expect that any generating plant and associated equipment complying with these standards by default would provide evidence of compliance for the requirement[s] and therefore be adequate for any European synchronous network in this regard."* *"[...] Wider frequency ranges and a higher ROCOF setting could be required of type A generators in a local region of a wider synchronous system due to the risk of system separation. However, this is not expected, given that type A*

[7] ENTSO-E, "Special issues associated with type 'A' generators",16.11.2016,,https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

	generators that have adhered to European standards will have already applied the widest permissible range.”

10.8 Frequency Stability [8]

Table 31. Frequency stability

Topic	**Frequency stability**
Technology	PGMs type C and D
Reference	IGD on *“Frequency Sensitive Mode”*
Source documents	● NC RfG – Article 15(2)(d)(e)
Background	*“Frequency Sensitive Mode (or ‘FSM’) means the operating mode of a power-generating module or HVDC system in which the active power output changes in response to a change in system frequency, in such a way that it assists with the recovery to target frequency.” “The objective of frequency containment reserve is to maintain the balance between generation and demand within a synchronous area. By the joint action of all interconnected parties/TSOs, it aims to stabilize the system frequency at a stationary value after such disturbance or incident in the time-frame of seconds. It depends on generation or load resources made available to the TSOs, which are called frequency containment reserves (FCR) and are in fact deployed by generators or demand units running in frequency sensitive mode (FSM).”*
How this is addressed in the regulation / guideline?	*“The objective of this guidance document is to help to determine the main criteria/motivation for the specifications of the FSM capabilities of power generating modules at national level.” “NC RfG allows for two options for defining P_{ref} for power park modules, either P_{max} or the actual active power output at the moment the FSM threshold is reached.”* *“In the event of a frequency step response, the PGM controller should carefully manage overshoot and damping of the response aiming at avoiding unnecessary active power oscillations.” “[...] The initial activation of active power frequency response required shall not be unduly delayed.” “For power-generating modules without inertia, the relevant TSO may specify a shorter time than two seconds.”* *“Regarding maximum full activation time default value can be proposed referring to normal operating conditions across a synchronous area. In case of forming local islands accidentally, a faster maximum full activation time could be requested by the TSO with the purpose of facilitating an appropriate system restoration.”* *“[...] The following settings are to be defined:* ● *Frequency response deadband: selectable value between 0 and LFSM threshold. Setting the deadband width equal to the LFSM-O/-U thresholds is equivalent to disable the FSM mode,* ● *Active power range: between 1,5 – 10%,* ● *Droop: between 2 – 12%,* ● *Frequency response insensitivity: between 10 – 30 mHz,*

[8] ENTSO-E, “Frequency Sensitive Mode”, 31.01.2018, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

	● Min initial delay of FSM activation: SPGM (2 s) & PPM (to be specified by the relevant TSO), *● Max delay of FSM full activation: 30 s."*

10.9 System stability at over- and underfrequency[9]

Table 32. System stability at over and under frequency

Topic	System stability at over and underfrequency
Technology	PGMs type A (and above), except for Article 13(2)(b)
Reference	IGD on *"Limited frequency sensitive mode"*
Source documents	● NC RfG – Article 13(2) ● NC RfG – Article 15(2)(c)
Background	*"Limited frequency sensitive mode at overfrequency (LFSM-O) is to be activated, when the system is in an emergency state of overfrequency and needs fast reduction of active power production. Consequently, all frequency containment reserves (FCR) in negative direction have already been deployed.* *Limited frequency sensitive mode at underfrequency (LFSM-U) is to be activated, when the system is in an emergency state experiencing underfrequency and needs fast increase in active power production. Consequently, all frequency containment reserves (FCR) in positive direction have already been deployed."*
How this is addressed in the regulation / guideline?	*"LFSM-U capability shall not be understood as requiring power generating modules to run at a reduced active power output just to be prepared for an increase in case of an unlikely low frequency event."* *"[...] priority of the local constraint management over the LFSM-U performance can be granted by allowing the Relevant Network Operator to block the LFSM-U function given that:* *• LFSM-U blocking is activated only in case of network constraints observed in real time and not based on forecasts of possible constraints.* *• LFSM-U blocking is strictly limited to the constrained part of the network.* *• The Relevant Network Operator shall provide the TSO control room with a signal identifying the scale of LFSM-U blocking activated within its network in real-time."* *"Concerning the LFSM-O/-U capabilities NC RfG requires to define at national level:* *• Frequency threshold of LFSM-O/-U activation* *• Droop settings to determine the sensitivity of a change in active power to change in frequency.* *Due to the system-wide effect of frequency-related issues, a harmonized setting of these parameters within a synchronous area is essential."* *"In order to best coordinate active power response by LFSM-O/-U with the provision of FCR, it is recommended to activate it at full deployment of FCR, i.e. to set the frequency threshold such, that there is no overlap or gap between FCR and LFSM-O/-U." "Concerning the droop settings, it is recommended to*

[9] ENTSO-E, "Limited frequency sensitive mode", 31.01.2018, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

	keep an adjustable range of 2% - 12% for both LFSM-O/-U." "[...] No definite recommendation for LFSM-U droop is given." *"[...] This IGD recommends the relevant settings even though they are not addressed by NC RfG." "The recommended response times for active power increase in case of decreasing frequency:* *• [...]* *• Power park modules (except for wind generators): 10 s for an active power change of 50% maximum power,* *• Power park modules (wind generators): 5 s for an active power change of 20% maximum power, if the current active power is above 50% of maximum power. At operating points below 50% of maximum power a slower reaction may apply, because the wind generator response is limited by the kinetic energy of rotating masses. Nonetheless, the response time shall be as fast as technically feasible and justified to the relevant network operator if > 5s.* *The recommended response times for active power decrease in case of increasing frequency:* *• [...]* *• Power park modules: 2 s for an active power change of 50% maximum power. Recommended values for settling time are:* *• active power decrease in case of increasing frequency during LFSM-O/-U activation: power park modules: ≤ 20 s,* *• active power increase in case of decreasing frequency during LFSM-O/-U activation: power park modules: ≤ 30 s."* *"[...] Extensive dynamic studies have been performed on frequency stability criteria [...]. These reports clearly conclude that in future LFSM-O response times of 1s are required to withstand severe disturbance like a system split [...]". "The recommendations on response times clearly take into consideration what generation technology can deliver today and in the near future and are evidently less stringent than what would be needed from a system engineering perspective."*

10.10 Active power reduction at low frequencies [10]

Table 33. Active power reduction at low frequencies

Topic	Active power reduction at low frequencies
Technology	PGMs type A (and above)
Reference	IGD on "*Maximum Admissible active power reduction at low frequencies"*
Source documents	NC RfG – Article 13(4) and (5)
Background	*"A system frequency drop is always linked to a power imbalance in the system. To support system frequency stability and not to impair system response to an initial event, it is important that at low frequencies the active power output of PGMs is reduced as little as technically possible. However, large frequency deviations (i.e. frequency below 200mHz) are expected to be very rare. Nevertheless, the consequence of not having sufficient support for running generating units can be very large."*

[10] ENTSO-E, "Maximum Admissible active power reduction at low frequencies", 31.01.2018,https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

How this is addressed in the regulation / guideline?	*“The objective of this guidance document is to help determining the main criteria for the specifications/motivation, at national level, of the capability not to reduce active power output more than an admissible value due to frequency decrease.” “The implementation of article 13(4) of the NC RfG shall establish at least a $P_{max}(f)$ - characteristic which falls within the acceptable range defined by the NC RfG.” “It is important to note that any decrease of active power at low frequencies is detrimental to system security and therefore each generator shall reduce active power output as little as technically feasible in such a situation. Therefore, the requirement shall define the maximum admissible active power reduction at low frequencies but no intentional decrease of active power to align the NC requirement will be accepted.” “Taking into account the range defined by the NC, no active power reduction is considered admissible above 49Hz. Below 49Hz, the most stringent value in line with the NC would consider a maximum active power reduction of 2%/Hz to be admissible although it is not expected, as PPMs have no specific technology limitation within this range. This maximum admissible active power reduction at low frequencies would be required from a time (t1) after the beginning of the frequency transient and until time (t3) which is aligned with the minimum duration for frequency withstand capability of the power plant as defined by national implementation of the NC RfG article 13(1). The time t1 is linked to the maximum speed at which the system can reach 49Hz. This is therefore related to the maximum RoCoF which can be expected in case of large instantaneous penetration of PPM and linked to the defined withstand capability of PGMs. In line with the IGD on RoCoF where, for the normative incident a value of 2 Hz/s could be expected, the recommended value for t1 is then 0.5s. No voluntary active power reduction is accepted if the PGM does not have inherent technology constraints, duly demonstrated by the PGM owner.” “No active power reduction is considered admissible during the observed power system transients for the normative incident above the load shedding frequency threshold. The main aim is to maintain active power output constant until the stage of load shedding is potentially activated.” “According to the wind industry, wind farms based on full converter technology have very limited reduction of active power at low frequencies. Impact on active power is mainly due to auxiliary equipment and change of losses in step-up transformers. Additionally, wind farms based on DFIG technology do need to reduce slightly more the active power at low frequencies to compensate the increase of current related to the decrease frequency. These limitations for wind technology do not prevent wind generation to comply with the most onerous specifications allowed by the RfG. Furthermore, the initial reactive power output and the acceptability of a P over Q priority control scheme at low frequencies could further increase the wind farm capabilities keep constant active power with falling frequencies.”*

10.11 Post-fault voltage stability [11]

Table 34. Post-fault voltage stability

Topic	**Post-fault voltage stability**
Technology	PGMs type B (and above), HVDC systems
Reference	IGD on *"Fault current contribution from PPMS & HVDC"*
Source documents	• NC RfG - Articles: 20.2 (b) and (c) • NC HVDC - Article 19
Background	*"As a result of conventional power units displacement, the total contribution to system faults will decrease further with voltage sensitivity, increasing if no other measures are taken in the system. Reactive current injection during faults helps to both recovering the voltage during faults and to injecting enough current quickly enough for system protections to function reliably. Both of these aspects which are part of the performance aspects of fault-ride-through family of requirements are essential to wider system stability."*
How this is addressed in the regulation / guideline?	*"Fast fault current contribution needs to be defined for non-synchronous equipment such as Wind turbines with partial or full-size converter, Photovoltaics or HVDC converters. Non-synchronous implying in this context that at least a portion of the active power is fed to the grid via Power Electronics (PE). These devices can be utilized very flexibly since their behaviour is predominantly determined via software (performance by design). In contrast, synchronous generators react inherently to any voltage deviation. Hence, they do not have to be considered regarding this requirement."* *"The requirement is specific for power park modules or HVDC systems connected to distribution or transmission networks to deliver an adequate reactive current injection during short circuits and after fault clearing when the voltage has not recovered. The objective of this requirement is to limit the consequences of a short circuit with regards to unwanted operation of protection devices and to stabilize the voltage after secured faults on transmission level."* *"According to Article 20 of NC RfG type B (and above by default) power generating modules shall be capable of providing a fast fault current. The relevant TSO shall have the right to specify the:* *• characteristics, timing and accuracy of the fast fault current,* *• interdependency between fast fault reactive current injection requirements and active power recovery."*

[11] ENTSO-E, "Fault current contribution from PPMS & HVDC", 16.11.2016, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

10.12 Post-fault frequency stability[12]

Table 35. Post-fault frequency stability

Topic	**Post-fault frequency stability**
Technology	PGMs type B (and above), PPMs type B, HVDC systems
Reference	IGD on *"Post-fault active power recovery"*
Source documents	• NC RfG - Article 17(3) • NC RfG - Article 20(3) • NC HVDC - Article 28
Background	*"Active power recovery after a fault is important in order to restore the pre-fault operation after fault clearance. The relative priority of restoring the reactive power and voltage versus real power and frequency depends upon the system size, predominantly of the synchronous area. For smaller synchronous areas [...] the active power restoration is particular time critical in order to avoid reaching a system frequency following a large sudden power imbalance. For larger synchronous areas with relatively low penetration of PPMs, the importance of post fault active power recovery performance to ensure the frequency stability is smaller and the emphasis may be laid on the post fault voltage stability and reactive power support, depending on the local voltage conditions."* *"Loss of the active power during and directly after the fault affects negatively on frequency stability [...] but also can lead to the local voltage problems:* *• voltage drop phenomena which propagates across large geographical areas around the point of the fault,* *• temporary overvoltage phenomena which can occur in long AC connections of offshore PPMs [...],* *therefore, even if there is no risk of loss of frequency stability, post-fault active power recovery should be considered as a countermeasure to ensure voltage stability independently for each new PPM connection projects to minimalize the risk of disconnection due to local voltage problem which have to be studied individually."*
How this is addressed in the regulation / guideline?	*"The requirement is specify for synchronous power generating modules (PGMs) and power park modules (PPMs) connected to distribution or transmission networks to deliver active power after the fault clearance on the transmission level within a certain time. The objective of this requirement is to limit the consequences of a short term loss of active power infeed and to stabilize the frequency and local voltage after secured faults on transmission level. Finally in order to prevent tripping caused by large frequency deviations within a synchronous area."* *"As in case of a fault on the transmission system level a voltage drop will propagate across large geographical areas around the point of the fault during the period of the fault, the increased levels of distributed generation (including Type B generators) must add value to such post fault conditions." "[...] PPMs connected to the grid through the power electronics, have possibilities to control the response after the faults therefore detailed requirements at national level have to be defined during the implementation process."*

[12] ENTSO-E, "Post-fault active power recovery", 16.11.2016,https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

10.13 Reactive power control [13]

Table 36. Reactive power control

Topic	Reactive power control
Technology	PPMs type B and C, HVDC systems
Reference	IGD on *"Reactive power control modes for PPM & HVDC"*
Source documents	• NC RfG – Article 21(3)(d) • NC HVDC – Article 22
Background	*"As a result of conventional power units displacement (by non-synchronous power generating units), the provision of reactive power control options for Power Park Modules (PPMs) and HVDC converters in the medium voltage (MV) to extra high voltage (EHV) level grid becomes critical." "Reactive power control and, thus, voltage control for types C and D Power Park Modules and HVDC might be a cross-border issue in some cases. The absence of such facilities can lead to voltage instability which can spread to neighbouring systems and affect cross-border trading."*
How this is addressed in the regulation / guideline?	*"NC RfG requires three reactive power control modes: (a) voltage control mode (b) reactive power control mode (c) power factor control mode" "The reactive power control modes are intended for steady-state and quasi-steadystate operation. These requirements allow the power system to operate in an acceptable and secure state prior to any perturbation. In case of perturbation such as change in grid loading or generation patterns or in case of outages and maneuver, the reactive power control modes are to be designed to support the voltages while remedial actions are put into place by the system operators." "The choice which of the reactive power control mode is to be applied is done by the relevant system operator in coordination with the relevant TSO and the PPM owner."*

10.14 Reactive power management [14]

Table 37. Reactive power management

Topic	Reactive power management
Technology	Grid equipment, PGMs, demand units
Reference	IGD on *"Reactive power management at T – D interface"*
Source documents	NC DCC – Article 15

[13] ENTSO-E, "Reactive power control modes for PPM & HVDC", 16.11.2016, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

[14] ENTSO-E, "REACTIVE POWER MANAGEMENTAT T – D INTERFACE", 16.11.2016,, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

Background	*"[...] reactive power is traditionally provided by generating units thanks to the limited marginal investment compared to the delivery of active power only. As in the future, a larger share of the total generation installed capacity will be connected to distribution grids, the provision of reactive power at transmission level and distribution level shall be coordinated."*
How this is addressed in the regulation / guideline?	*"This IGD is clarifying the impacting aspects to be considered for the definition of the reactive power and voltage requirement at the T-D interface, including influence from the reactive power and voltage control capabilities of grid equipment, demand users and generating units."* *"The NC DCC prescribes the boundaries within which the relevant TSO can set design limitations on reactive power exchanges of transmission-connected demand facilities and transmission-connected distribution systems. As this is a connection code, no link is directly made for the utilization of the capability. However, utilization of the capabilities will be implemented in operational network codes / guidelines and national regulations."* *"[...] For the benefit of the system and pursuing local reactive compensation, it is essential that transmission-connected demand facilities and transmission-connected distribution systems are capable to maintain their operation at their Connection Point within a pre-established and limited reactive range. It is then also expected that by the future transition of generation to the distribution grids and related requirement at the Transmission System Operator – Distribution System Operator (T-D) interface, reactive or voltage related requirements for distributed connected users will need to be reviewed nationally."* *"A core principle that should underpin all TSO & DSOs interactions with regard to reactive power is that each system operator is responsible for ensuring voltage requirements on its network."* In Annex III of this IGD "*Possible process for the definition of the reactive power and voltage requirement at the T-D interface, including influence from the reactive power and voltage control capabilities of grid equipment, demand users and generating units*" can be found.

10.15 Reactive power provision at low/zero power[15]

Table 38. Reactive power provision at low/zero power

Topic	**Reactive power provision at low / zero power**
Technology	PPMs type C, HVDC systems
Reference	IGD on "*Reactive power requirement for PPMS & HVDC at low / zero power*"
Source documents	• NC RfG – Article 21.3 and 25.5 • NC HVDC – Article 20-22, 38, 40.2 and 46 • NC HVDC ANNEXES 4, 7 and 8
Background	*"[...] The total reactive power capability and utilization from devices in both the transmission and distribution system must be considered in aggregate to meet local, region and national needs." "In order to operate the electrical system [...]*

[15] ENTSO-E, "Reactive power requirement for PPMS & HVDC at low / zero power", 16.11.2016, https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

	during all the network conditions [...] the system operator must have at their disposal reactive power resources that are able to regulate the network node voltage. These resources are primarily provided by users i.e. generating units, third party HVDC circuits and demand side response." "Both Power Park Modules (PPMs) and HVDC systems can provide reactive power and, in many cases, can comply with the network code requirements without the need for additional equipment. However, at low/zero active power additional equipment may be required in order for them to be able to continue to maintain proper reactive capability."
How this is addressed in the regulation / guideline?	*"Both HVDC links and onshore PPMs have general requirements in Article 21 of both the NC HVDC and NC RfG that permit the system operators to specify reactive power characteristics that should be met below maximum active power output." "[...]The NC HVDC also sets requirements for DC connected PPMs (a power park module that is connected via one or more HVDC interface points to one or more HVDC systems) and the remote end convertors to which they are connected." "In the case of DC connected PPMs, provision is made to allow the delayed installation of the installation of a reactive power capability. This is restricted to an AC network linking the DC connected PPMs and the remote end convertor which will only impact on one user."* *"In addition to the immediate capability needs to provide or absorb reactive power or the capability to control it, the TSO must consider the operation philosophy they intend to apply and the operational actions in future years for the life of the equipment."* *"The provision of reactive power at low active power levels for PPMs and HVDC systems equal to their maximum can be achieved but due to technology characteristics can be dependent on additional equipment being installed."*

10.16 Voltage stability [16]

Table 39. Voltage stability

Topic	Voltage stability
Technology	PGM type C and/or D, HVDC links, grid users connected above 110 kV
Reference	IGD on *"Parameters related to voltage issues"*
Source documents	• NC RfG – Article 16(2)(a), 15(3), 16(2)(b)(c), 20(2)(b), 21(3)(e) • NC HVDC – Article 18, 19, 23 • NC DCC – Article 12(1), 12(5)
Background	*"Voltage requirements are critical to secure planning and operation of a power system within a synchronous area. Voltage issues have a cross border impact as disturbances can propagate widely and, in the worst case, can cause significant disconnection of Power Generating Modules (PGMs), either directly or because of the consequence of a large disturbance on the system frequency."*
How this is addressed in the	*"The objective of this guidance document is to provide general but more detailed guidance on a cluster of parameters related to voltage issues and to give a framework to define the related non-exhaustive technical requirements. This*

[16] ENTSO-E, "Parameters related to voltage issues", 16.11.2016,https://www.entsoe.eu/network_codes/cnc/cnc-igds/ (accessed 02.05.2019)

regulation / guideline?	*guidance also seeks to ensure consistency between the requirements for generators, HVDC links and demand facilities to ensure voltage stability or recovery."* ***"Time period for operation within the defined voltage ranges:" "****Voltage ranges are defined for grid users connected above 110 kV." "The time period chosen shall be sufficient for the voltage to return to the unlimited range. It has to be long enough for the TSO to take the necessary mitigating actions and short enough to limit the constraints on the grid users' equipment." "For Continental Europe and Nordic synchronous areas NCs RfG [...] and DCC [...] specify a time period of 20 to 60 minutes to be selected by each TSO for operation from 1.05-1.1pu for 400kV. NC HVDC for HVDC links above 300kV for operation from 1.05-1.0875pu defines the time period for Continental Europe as "To be specified by each TSO, but not less than 60 minutes"[...]. The longer period for HVDC reflects the importance placed on keeping the major components of the system operational."* ***"Wider voltage ranges:" "****Wider voltage ranges or longer minimum time periods within those voltage ranges can be defined for power generating modules of type D and HVDC links, if needed to preserve or restore system security." "This requirement shall be defined in specific cases."* ***"Automatic disconnection:" "****Automatic disconnection is required from HVDC links, power generating modules type C and D (but not mandatory for type D) and transmission connected demand facilities, transmission connected distribution facility, transmission connected distribution systems at specified voltage levels. During national implementation, the voltage level for disconnection and the technical parameters shall be defined. For transmission connected demand facilities, transmission connected distribution facility, transmission connected distribution systems, HVDC circuits and power generating modules type D, this requirement is not mandatory. However, in the event that there is a risk to voltage stability (notably collapse) system operators may require additional protection to disconnect demand or generation necessary to permit the timely connection of new facilities or generators and maintain security of supply. For power generating modules, the voltage criteria will depend on whether the PGM contributes actively to voltage regulation. In this case, the PGM shall stay connected within the whole voltage range defined at national level (or in the code for type D) in order to contribute to voltage restoration for as long as possible. On the contrary, if the reactive power contribution of the PGM isn't linked to the voltage at the connection point, the PGM shall disconnect when its contribution increases the voltage disturbance. For HVDC circuits, transmission-connected demand facilities, or transmission-connected distribution facilities/systems the same principle shall apply as with PGMs. The other parameter to define is the delay between the time the voltage reaches the voltage criteria and the actual disconnection." "[...] The time shall be long enough to avoid automatic disconnections. in case of a transient voltage deviation. On the other hand, it must be short enough to avoid any equipment damage. The time for resynchronization after disconnection shall also be taken into account."*

11 ANNEX 3

TSO – DSO Report. An integrated approach to active system management: Focus on TSO – DSO coordination in congestion management and balancing

CEDEC, E.DSO, entsoe, EURELECTRIC, GEODE

It is clear from the following introductory statement of the Operators in the above report that the need for addressing the planning and operational complexities of the emerging technologies DG RES, storage, EVs and DR is a need and still a not solved problem technically, operationally and commercially (policy, market and regulation are lagging: *"The constant increase in distributed renewable generation and in storage, and the expected rise of active customers engaging in demand response and electric mobility, trigger a key question to be addressed to support the energy transition: how to integrate the flexibility services provided by these new assets and actors into the energy market and use their services for congestion management and further in balancing, while ensuring efficient and reliable system operation and enabling the market uptake for flexibility resources?*

Only the latter part of this key question, focusing on the roles – assigned to DSOs and TSOs through the national regulatory framework – will be treated in this report. Network codes and Guidelines, currently under implementation, provide the first basis for congestion management and balancing (especially SO GL and EB GL)."

The report addresses the important shift towards an integrated active system management of the emerging grid and puts forward the following important and highly revealing definition for this need: "*Active System Management (ASM) is a key set of strategies and tools performed and used by DSOs and TSOs for the cost-efficient and secure management of the electricity systems. It involves the use and enhancement of smart and digital grids, operational planning and forecasting processes and the capacity to modulate, in different time frames and distinct areas, generation and demand encompassing flexibility instruments (toolbox) to tackle challenges impacting system operation, thus ensuring proper integration of Renewable Energy Sources (RES) and a high share of Distributed Energy Resources (DER), as well as the integration with energy markets."*

It is evident from the approach that is given to the problem but moreover of the proposed solutions that the Operators consider the emerging technologies highly complex requiring a multi-dimensional portfolio of solutions that are dynamic starting from a year and more ahead to intraday needs. Hence, what we are putting forward as solutions through INTERPLAN using equivalents and controllers are aligned with the approach that the Operators are initially instigating:

"*A TOOLBOX FOR ASM - To realise efficient and co-ordinated electricity grids, DSOs and TSOs need a toolbox comprising different types of Solutions for undertaking congestion management and balancing. To this effect rule-based solutions curtailments as a consequence of the implementation of technical requirements from connection codes that are available in last-resort or emergency situations. Typically, non-frequent congestion could be more efficiently treated with the activation of flexibility whereas prolonged or high levels of congestion could call for a system reinforcement."*

TSOs and DSOs are clear in their opinion as market facilitators that the emerging technologies transform the grid and the way forward is an integrated approach. This is in line with the thoughts of the INTEPLAN consortium for developing solutions that aim a system approach incorporating all emerging technologies through appropriate models, equivalents and controllers down to the LV network:

- *"TSOs and DSOs should pursue an integrated system approach when developing new solutions and should avoid any isolated solution.*
- *TSOs and DSOs shall use those flexibility tools that are effective, cost-efficient and that suit their needs."*

It is clear from the approach below on congestion and how can efficiently be managed, that the use of generated flexibilities on the side of the users from the emerging technologies is a source that should be given equal footing and a platform through which they can be usefully integrated. Means should be made available that will allow such analysis that can be dynamic and responsive to various time zones:

"So as to foster competition and new services in the European electricity market, the long-term view of system operators is that congestion should be solved through a market-based allocation of flexibility services (voluntary or mandatory bidding, possibly in combination with cost-based regulation when considered appropriate by the Regulator) where technically feasible and cost-efficient, rather than compulsory limitation procedures. The design should be developed with the stakeholders in a stepwise and pragmatic manner."

From the description given by the Operators in treating congestion management process and information exchange it is clear that solutions provided should be capable of being flexible and adaptive. This is a strong message that comes through to the consortium of INTERPLAN covering all required time frames for emerging technologies contributing effectively and efficiently to the needs of the integrated grid in managing DGs:

"Some general EU principles can be developed but the intrazonal congestion management processes details should be established and implemented on a national level.

- *TSOs and DSOs should optimise their processes and actions in collaboration.*
- *There should be an incentive for market parties to provide good schedules with relevant locational information to the system operators, which is crucial to get a proper forecast for congestion management.*
- *System operators should properly communicate their needs in the different timeframes.*
- *Information on flexibility resources that are pre-qualified or are seeking participation in congestion management and balancing should be shared and available (typically nationally) for both TSOs and DSOs, through a flexibility resources register. TSOs and DSOs jointly recommend that the concept of flexibility resources register should be acknowledged at the European level and the implementation should be decided on a national level."*

From the approach of the Operators and how they will judge solutions and systems and to what degree they fit in the needs of the integrated system, it is clear that the enhanced analytical tool that the INTEPLAN is promising fits in well with their targeted objectives. The pre-qualification of available solutions and how they are aggregated is a need that the promised solutions through INTERPLAN will allow the Operators to evaluate within the planned timeframe:

- *"In addition to regular pre-qualification commitments from the connecting system operator, there are two ways of enabling more flexibility service providers being qualified: a. conditional grid pre-qualification, where the pre-qualification is dependent on certain conditions being met, or b. dynamic grid pre-qualification, where the pre-qualification can change over time. The aim of both concepts is to increase the pre-qualified volume on the market.*
- *The pre-qualification process should be user friendly, striving to minimise the different steps and standardise them when possible.*
- *Pre-qualification could take place on an aggregated/ portfolio level if technically acceptable."*

The market is critical in the emerging grid dynamics and how the Operators envisage the evolution in this direction is very enlightening. It is clearly understood that congestion can be highly local and hence the system planning and operation should have this analytical capability to drill deep in the system to identify problems and solutions. At the same time the effect in the integrated system should be acknowledged and this is what the INTERPLAN solutions will facilitate. Moreover, the time frame is vital and the analytical tool responsive. This is clearly a need from the recommendations of the Operators that are reflected below:

- *“Products for congestion management should comply with the needs of system operators within the different timeframes (from long-term to real time) and take into account the possibilities of the market parties, including retail. Existing tools and services should be considered.*
- *Product definition should allow for aggregation as much as technically feasible.*
- *Timings of most market processes (day-ahead, intraday, balancing) are evolving towards an alignment on a European target model. However, the timing for congestion management can differ at a national level, depending on local specificities. It is recommended that these markets are compatible with the markets at the EU level, but that the corresponding timeframes are defined on a national level. This would ease the effort of TSO – DSO coordination.*
- *Irrespective of the options chosen, system operators should always exchange all the relevant information from their grid and the relevant connected assets, from structural data (potential flexibility services and their characteristics) to more dynamic data (forecast and activation of bids): this is needed to allow efficient flexibility procurement without creating issues on the grid.*
- *The activation of bids for congestion management creates an imbalance that shall be counteracted to maintain system balance. This can be done by: a) the service provider, who delivers the bid and takes responsibility for the imbalance created, b) the system operator performing the congestion management action, meaning a redispatch, or c) the TSO, who combines this with its balancing task.”*

An appropriate platform will provide the required options for facilitating the smooth operation of the integrated system. It is clear from the approach of the operators that there is a need since the plethora of energies that will prevail should be captured in the models in a universal way giving a technology agnostic environment, accessible by all singly or aggregated for managing planning and operational needs. Interoperability should be guaranteed in models and solutions giving access both in data and energy at the required timeframes:

- *“Access should be easy for the customer: For both end consumers as well as market parties offering flexibility to system operators, easy access should be facilitated irrespective of the platform arrangement (e. g. whether separate or joint platforms are created).*
- *Interoperability with other platforms must be ensured: Platforms developed by TSOs, DSOs or jointly should always respect and ensure a level playing field for the market. This will require coordination and (an) agreed interface(s) between the regulated and commercial domains.*
- *Platforms must avoid harmful interference and conflicts beyond their associated grids: Platforms should contain a functionality to ensure that any TSO or DSO interaction does not create any harmful impact on their respective grids or on the system as a whole. This requires correct and timely data exchange between platforms and a set of well-designed algorithms.*
- *Platforms solutions should be technology agnostic: In defining platforms and solutions, TSOs and DSOs should be technology and hardware agnostic.”*

The Congestion Management process entails activities as detailed below which give a clear message as to what is expected from the analytical tools that will support the process:

Moreover, the emergence of flexibilities and the need to efficiently and effectively manage the congestion problems of the grid are well understood by the Operators and these are clearly depicted in the schematic below with the required actions at specific timeframes.

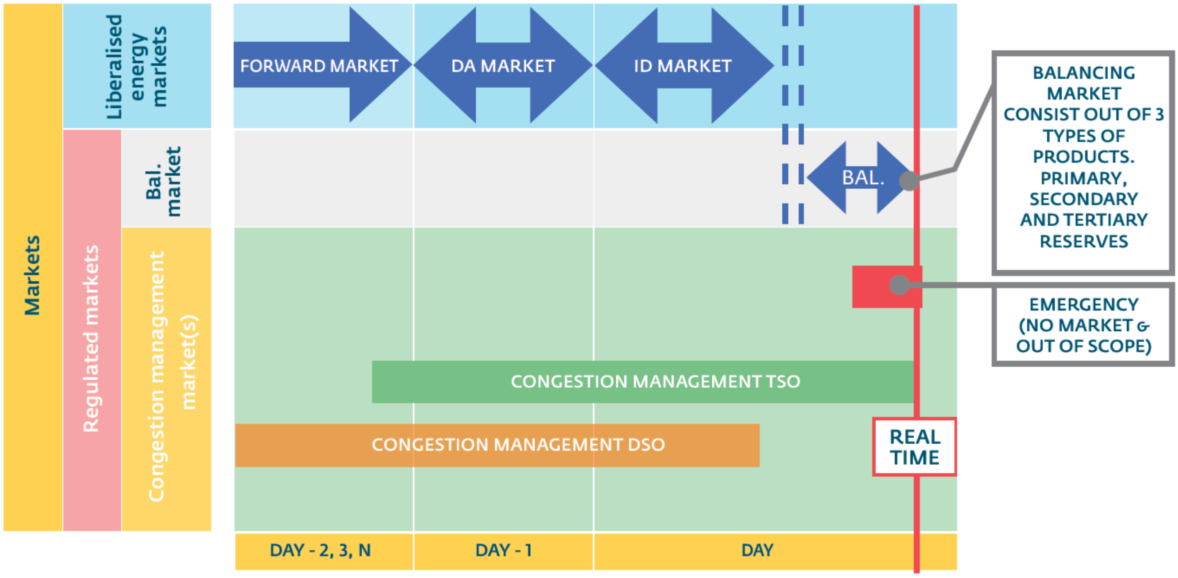

Figure 3. Required actions for congestion management on behalf of the operators. [5]

For these to be managed to the detail described, the corresponding analytical tools are required with the appropriate models, equivalents and control points. As clearly stated by the Operators the codes have just touched on these needs to a very basic form ("*Guidelines, currently under implementation, provide the first basis for congestion management and balancing (especially SO GL and EB GL)").*