Study on energy storage – Contribution to the security of the electricity supply in Europe

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Directorate-General for Energy
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EXECUTIVE SUMMARY

Context

At the Paris climate conference (UNFCCC COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The deal has been ratified by over 180 countries, and has entered into force in November 2016. The EU has been a key player in reaching this agreement, which aims at keeping temperature increase to well below 2°C above pre-industrial levels and pursue efforts to keep it to 1.5°C. The EU's nationally determined contribution (NDC) reflects its objective to reduce EU's greenhouse gas emissions by 40% by 2030 compared to 1990, and is consistent with the then-objective to reduce emissions by 80 to 95% by 2050 (in the context of necessary reductions of the developed countries as a group).

As a response to its commitments under the Paris Agreement, and in order to pursue its objectives of modernising the design of electricity markets, the European Commission has published a number of policy proposals in November 2016, the so-called Clean Energy Package for all Europeans (CEP). The political compromise that has been reached, which includes updated objectives for 2030 (at least 32% renewable energy target, at least 32.5% energy efficiency target) and governance mechanisms to plan, report and monitor as well as coordinate how the efforts shall be distributed and objectives achieved amongst Member States through National Energy and Climate Plans (NECPs), results in new rules that progressively enter into force from 2019 on.

In December 2019, the European Commission has presented the "European Green Deal"[1], a set of policy initiatives aiming at ensuring the EU becomes climate neutral by 2050. In March 2020, the EC has proposed to enshrine this objective into the "European Climate Law"[2]. The Climate Law includes measures to keep track of progress of the decarbonisation of Member States and includes proposals on the way to analyse the pathway to meet the 2050 target.

In line with the objective of reaching carbon neutrality by 2050, the European Commission's Long-Term Strategy[3] describes a number of pathways that reach between 80% and 100% decarbonisation levels. All of them have strong implications for the energy sector, and for the electricity sector in particular. Indeed, in every pathway, a high level of direct and indirect electrification is envisaged, supported by a large-scale deployment of RES. The level of renewable energy sources (RES) varies considerably from one pathway to the next since indirect electrification, enabled by power-to-gas (P2G) technologies, requires substantial amounts of electricity to produce hydrogen and/or methane to decarbonise sectors such as industry, heating and some mobility applications. All pathways have in common that they require a more flexible energy system, in order to integrate variable RES technologies (mostly solar photovoltaic, and onshore and offshore wind power) cost-efficiently while maintaining adequate levels of security of supply.

A strong deployment of flexibility solutions is required to provide the power system with the ability to adapt to the dynamics of the residual load, on all timescales: from frequency response to inter-year flexibility. The main candidate solutions to provide flexibility are networks, demand-response, dispatchable and flexible power generation technologies, and energy storage. Furthermore, the very coupling of the industry, heating and mobility sectors to the power sector makes their flexibility potentials available to the power markets. These new flexibility sources are the flexibility of the demand of the various end-uses and of the processes involved in their direct and indirect electrification (e.g. electrolysis, interaction between gas and electricity infrastructure, etc.).

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[2] https://ec.europa.eu/info/files/commission-proposal-regulation-european-climate-law_en

[3] https://ec.europa.eu/clima/policies/strategies/2050_en

Energy storage will participate in the provision of flexibility on all timescales. Indeed, the typical discharge time of batteries is measured in hours, the one of pumped-hydro storage and seasonal hydro storage in a few hours to several months, and system integration (when seen as a storage solution) has a discharge time allowing it to contribute to meeting seasonal flexibility needs.

Therefore, an appropriate deployment of energy storage technologies is of primary importance for the transition towards an energy system that heavily relies on variable RES technologies to be a success. It is key to understand which of the technologies are the most likely to have an important role to play in the future, to detect the potential barriers to their development (regulatory, lack of innovation programmes, etc.), and finally to propose an updated regulatory framework and policy actions to allow the relevant flexibility solutions to successfully penetrate the market.

Objectives of the study

The study is organised in three main parts: we begin by presenting the current state of play of storage technologies (deployment in Member States and key characteristics), then proceed to identify the need for various types of flexibility solutions at the 2030 and 2050 horizons, and finally examine the regulatory conditions that should be put in place to enable the market to deliver the appropriate level of energy storage technologies.

The three objectives can be summarised as:

- The first objective of this study is to provide a picture of the European energy storage environment, in terms of (i) existing facilities and projects and (ii) policies and regulatory frameworks so as to identify barriers and best practices.

- The second objective is to explore deployment potentials and actual needs for energy storage, at EU and Member State level, in order to design a cost-efficient flexibility portfolio to ensure adequate levels of security of supply for all Member States at the 2030 and 2050 horizons, in the context of a total decarbonisation of the energy sector by 2050.

- Finally, based on the identified barriers and best practices, given the role for energy storage in the decarbonisation of the electricity sector of the Member States, a set of recommendations are proposed to update the regulatory framework that applies to energy storage technologies and to design a set of policy actions to speed up the market penetration of storage technologies, at EU and national level.

Main findings of the study

1. Data collection of current energy storage facilities and future projects[4]

Throughout our data collection work, we have noticed some important points that can be summarised as follows:

- The main energy storage reservoir in the EU is currently, and by, far Pumped Hydro Storage. As their prices plummet, new batteries projects are rising.
- Lithium-ion batteries represent most of electrochemical storage projects. The recycling of such systems should be strongly taken into consideration, as well as their effective lifetime: such theoretical specifications submitted to grids may be relatively optimistic compared with their use at nominal conditions.
- In the EU, the segment of operational electrochemical facilities is led by UK and Germany. We have noticed an important number of projects in the UK, and to a lesser extent in Ireland.
- Behind-the-meter storage is still growing. It is quite heterogeneous, depending on local markets and countries: as a new market, it is still driven by political aspects and/or subsidies. Overall data availability is relatively poor.

A recommendation emerging from our work is to ensure an appropriate monitoring and follow-up of storage facilities at both Member States and European level is put in place. We have noticed through the study that data about energy storage are sometimes difficult to obtain or with a level of precision lower than for power generation databases. A convergence, both in terms of quality and coverage, of storage facilities public data and databases towards power plant existing public data could be define as a key objective.

2. Quantification of the contribution of energy storage to the electricity security of supply

The objective of the quantitative assessment was to determine what would be the optimal flexibility portfolio for the power system in different prospective scenarios, and analyse the place of storage technologies among other flexibility solutions, taking into account the specificities of the power system in each Member State. Three different scenarios adapted from the pathways designed by the EC in the context of its Long-Term Strategy are used: one 2030 scenario (METIS-Baseline) which is in line with the policies already agreed as today, and two long-term scenarios for 2050 (METIS-1.5C and METIS-2C-P2X), with an objective of a deep decarbonization, in order to keep the temperature “well below 2°C by 2100”.

In order to determine the optimal flexibility portfolio, the methodology proposed in the Mainstreaming RES study[5] has been extended to cases with system integration (and thus P2G) and applied to the three aforementioned scenarios. It consists in the following steps:

[4] Stakeholders have been consulted regarding the national and EU-level data and analysis. A number of national stakeholders, including national contact points of the European Commission Electricity Coordination Group (ECG), have provided inputs for the storage project database and the Member States storage policy fiches. A stakeholder policy workshop was held in December 2019, and further comments on the policy analysis draft and national policy fiches were received through written feedback afterwards, including from the ECG national contact points.

[5] https://ec.europa.eu/energy/sites/ener/files/mainstreaming_res_-_artelys_-_final_report_-_version_33.pdf

- Quantification the flexibility needs on different timescales (hour, week, season),
- Identification and characterisation of potential flexibility solutions,
- Determination of the optimal deployment of energy storage capacities and other flexibility solutions at the MS level in light of the Long-Term Strategy scenarios,
- Quantitative assessment of the contribution to the provision of flexibility and security of supply by energy storage technologies and other flexibility solutions on different timescales at the MS level.

Our results reveal that in 2030 a large share of the required levels of flexibility can still be provided by conventional power plants and by using the power networks to trade electricity between the different European countries. However, for the provision of daily flexibility, storage technologies such as batteries or pumped storage appear to be relevant solutions in our scenarios. Up to 108 GW of electricity storage (batteries and pumped hydro storage) would be necessary for the EU-28 (97 GW for EU-27), with a large development of stationary batteries. At the 2030 horizon, electrolysers do not appear to be competitive solutions to provide flexibility to the power system. However, if a deployment of electrolysers were to materialise already in 2030 (e.g. driven by indirect electrification of end-uses in the industry or heating sectors), they could provide flexibility on all timescales.

In the assessed 2050 scenarios, the deep decarbonisation of the different sectors, such as industry, mobility and heating, the Long-Term Strategy assumes that an important amount of "decarbonised" hydrogen (produced by water electrolysis with decarbonised electricity), and synthetic fuels[6] will be produced. This hydrogen is generated from electricity coming for large-scale wind and solar power plants, and then converted into hydrogen with electrolysers. To satisfy this demand, around 550 GW of electrolysers would be required in our different 2050 scenarios. Combined with the flexibility offered by the end-users' of hydrogen and e-fuels, or with direct use of hydrogen or gas storage facilities, electrolysers will able to provide important levels of flexibility to the power system. The potential deployment of electric vehicles using smart charging strategies and of space heating combined with short-term thermal storage also enable the demand-side to provide daily flexibility to the power system. Due to the competition between various flexibility sources, the need for pumped hydro storage and batteries is found to be lower in 2050 than it is in 2030, and reaches around 50 GW in our 2050 scenarios.

To recognise the high level of uncertainty surrounding the configuration of the 2030 and even more so, of the 2050 energy systems, different sensitivity analyses have been designed to assess the impacts of some of the assumptions on the deployment of flexibility technologies. Based on the analysis of the results of the three scenarios (METIS-Baseline, METIS-1.5C and METIS-2C-P2X), three topics have been selected for further analysis since they might substantially impact the optimal mix of flexibility solutions:

- Demand-response: Electricity storage technologies compete with demand-side response, since they both provide daily flexibility services to the power system. In 2030, an optimal use of the flexibility of electric vehicles and of decentralised space heating could reduce the need for stationary batteries by half (67 GW vs 34 GW).
- Costs of electrolysers: In the 2050 scenarios, the large deployment of electrolyser leads to an important drop of their investment costs. In a sensitivity where the prices of electrolysers are significantly higher, the need for pumped hydro storage and batteries rise from 50 GW to 73 GW.
- Flexibility of hydrogen demand: the 2050 scenarios assume an important flexibility of end-uses on the P2X side (hydrogen and e-fuels), that can be provided by direct

[6] e-gas and e-liquids, produced from hydrogen with methanation plants and the Fischer-Tropsch process.

hydrogen storage but also via some flexibility in the end-users consumption (for example for the e-liquids provision for vehicles can be flexible, thanks to current infrastructure for petrol). In a sensitivity with lower flexibility on the hydrogen side, additional investments in methanation plants would be required to benefit from the flexibility offered by the current gas infrastructure.

3. Policy recommendations for energy storage

In order to enable storage technologies to effectively deliver this contribution, different barriers should be addressed, for example regarding public guidance and support, the design of electricity markets or grid aspects. The most important barrier is the lack of a viable business case for many energy storage projects. The cost and technical performance of storage technologies gradually improve their viability, which in the long-term will significantly improve the business case, and already has for several technologies. But in the shorter term, various policy barriers still hamper the development of energy storage in the EU and lead to uncertainty concerning the revenues streams to cover the project costs and risks.

The main responsibility of policymakers is to provide an enabling environment and level playing field to storage. The adequate implementation of the clean energy package should be a priority, in order to enable storage to participate in energy and ancillary services markets as well as in eventual capacity mechanisms, and to be remunerated in a transparent, non-discriminatory way. Positive externalities provided by storage, such as system flexibility and stability, as well as environmental benefits, should be adequately valued, primarily through appropriate remuneration in the different markets, and through cost-reflective network charges and appropriate taxation rules (discussed further below). Adequate energy price signals should also guide the investment and operational decisions of private actors.

The European Commission, ACER and other EU authorities should prioritise policy measures that address barriers to storage identified in the majority or all Member States, and that hinder the deployment of several storage technologies and applications. Relevant barriers specific to only a few Member States should be addressed at the national level. At the EU level, upcoming revisions of EU instruments relevant for energy storage provide an opportunity to address barriers where EU action would be adequate. Actions under the European Green Deal should also consider storage, where appropriate.

Measures addressed by the CEP, but requiring monitoring at EU level to ensure adequate and timely implementation by Member States:

- **Member States should ensure that storage is coherently defined across the national legal framework**. An appropriate definition of storage is provided in the new Electricity Directive. But at present, most EU Member States do not have yet a coherent definition of storage nor have transposed the Directive, and definitions in secondary legislation often are not aligned with the rest of the legal framework.
- **Member States should eliminate the double charging of grid tariffs**. Double imposition of grid tariffs (that is, during storage charge and discharge) on stored energy are especially detrimental and should be eliminated. The current tariffication practices across Member States are still quite diverging, and even if eliminating double charging, do not address all possible cases. For example, concerning the application to existing and new storage facilities, the inclusion of conversion losses, whether the energy is traded in wholesale markets or supplied to end consumers, and the application of tariff rebates on all volumes or only for electricity providing specific services (e.g. balancing).

Measures partially addressed by the CEP, and requiring further actions at EU and/or MS level:

- **Member States should assess barriers and develop a policy strategy for storage**. National (or regional where applicable) authorities should develop a policy strategy for storage based on an assessment of the system flexibility, adequacy and stability needs, and of gaps in national regulatory frameworks. Such assessments of policy gaps have been developed by some Member States. An appropriate identification of the flexibility needs per country and per timescale is key to assess the possible contribution of storage technologies in the future. However, there is still the need to develop robust methodologies to assess and differentiate short- to medium-term flexibility from long-term adequacy needs, complementing the methodology being developed by the ENTSO-E for the European Resource Adequacy Assessment

- **Organisations at the EU level and Member States should weigh network investments vs the procurement of flexibility from other resources.** Additional efforts will be required to develop appropriate methodologies for this, as there is not a robust and widely accepted method at the moment. Network investments and security of supply standards (e.g. N-1 requirements) should be assessed considering the possibility of storage deployment. The procurement of ancillary services should also be conducted in a non-discriminatory way, starting with (more mature) balancing markets and moving onto non-frequency ancillary services. It is also needed to improve the consideration of electricity-gas-heat interlinkages in National Development Plans, the TYNDP and the PCI selection process, and to ensure that investment options are equally considered across sectors.
- **EU organisations (especially the Commission, ACER and ENTSOs) as well as Member States should develop non-discriminatory procurement of non-frequency ancillary services.** At the moment, the possibility of storage to provide non-frequency ancillary services is rare across Europe, especially batteries, which in most Member States cannot provide voltage control nor black-start services. Participation of storage in grid congestion management is at present limited to pilot projects focusing on battery systems, but albeit limited in scale, these projects are taking place in multiple countries. Member States need to provide a level playing field for the procurement of such services. The Commission and Member States should also guarantee locational information in congestion management and other products to foster market-based procurement.
- **Member States should foster dynamic electricity prices and time-of-use grid tariffs.** These are crucial to increase the responsiveness of consumers and the development of behind-the-meter storage, including electric vehicles. Presently, locational grid tariff signals are limited given the zonal approach for European energy markets, while the use of time-of-use grid tariffs or dynamic electricity price signals for residential consumers are still also limited. However, demand-response to electricity prices enabled by heat storage (in e.g. CHP, water gas boilers and heat pumps) is relevant in an increasing number of Member States.
- **Member States should phase out net metering**, in other words, to fully account separately for the electricity fed into the grid and the electricity consumed from the grid. Net metering is another important grid-related barrier to the deployment of small-scale storage, still existing in at least 9 Member States. There is also an opportunity for **improving price signals** through network tariffs. The EU could further assess approaches to develop locational grid tariff signals, and weigh the advantages and disadvantages of such signals at transmission and/or distribution level.
- **EU organisations and Member States should guarantee the interoperability of flexibility resources and access to data.** Specific EU action is to be considered to encourage/develop EU-wide harmonised standards for device communication and system operation. Currently, the digital layer of battery management systems, notably application programming interfaces, is often based on proprietary solutions, and a move to open interfaces would be desirable. In addition, access to data of battery management systems is often limited, depending, among other things, on how data encryption is done. The standards or protocols currently being developed for data encryption and communication (so-called Public Key Infrastructure) between the vehicle and the charging point are proprietary, and created according to specific interests. The relevant developments should be followed to prevent data hoarding and ensure EVs and stationary batteries can be used in "plug-and-play mode".

Finally, energy taxation was not addressed by the Clean Energy Package. EU institutions and Member States should increase the energy and GHG-reflectiveness of taxation, and eliminate the double taxation of stored energy

(that is, when the energy is stored and again when it is consumed). The upcoming revision of the Energy Taxation Directive (ETD) is pivotal, not only for the development of energy storage, but also to foster low-carbon energy technologies in general. The increasing system integration will also require the elimination of diverging taxation levels across energy sectors and carriers, in order to avoid cross-sectoral distortions regarding taxation or the internalization of carbon costs, and to seize the synergies between the electricity, heat and gas sectors. Full or partial imposition of electricity consumption taxes and other levies to stored energy is still common in a majority of Member States. Only storage losses should be subject to taxes (as well as losses in energy production and transport across all energy carriers), in order to stimulate highly energy-efficient processes.

Structure of the report

Section 1: Data collection of energy storage and database for the EU-28

Based on a literature review, this section describes the methodology and the key results of the creation of a database on energy storage. This database is divided in three different parts: the characterisation of the different energy storage technologies, the description of "front of the meter" facilities, and some insights for behind the meter energy storage. The database itself is provided in an accompanying spreadsheet.

Section 2: Quantification of the contribution of energy storage to the security of electricity supply in the EU-28

Based on selected pathways of the European Commission Long-term Strategy, this section details the role of various flexibility solutions at the 2030 and 2050 horizons. A dedicated modelling work at the Member State level and using an hourly time resolution is used to determine the optimal flexibility portfolio for different scenarios. The analysis also provides quantitative results on the contribution of the relevant flexibility solutions to the provision of flexibility, and the contribution to security of electricity supply in Europe.

Section 3: Assessment of energy storage policies, barriers and best practices

This section identifies current barriers and best practices for the deployment of energy storage technologies and assesses the impact of the new market design at the EU and Member States levels. It also provides complementary measures to address the barriers which remain even after the implementation of EU legislation.

Section 4: Policy recommendations for energy storage

Finally, the study provides conclusions and policy recommendations for energy storage at the EU and MS levels to address the identified policy barriers.

Disclaimer

The current study has been elaborated without taking into account the effects of the Coronavirus disease (COVID-19), first identified in December 2019 and resulting in the ongoing worldwide 2019-20 health crisis. However, in view of the results presented in this study, it is important to highlight the relevance of storage as regards security of supply issues that could arise in unforeseeable circumstances, for instance crisis situations such as COVID-19. In addition, the strong investment needs for storage identified in this study could be considered as a supporting element for the recovery of the economy and the creation of high-quality employment.

1. DATA COLLECTION OF ENERGY STORAGE AND DATABASE FOR THE EU-28

1.1. DATA COLLECTION METHODOLOGY

1.1.1. *SOURCES CLASSIFICATION*

The first step of the task was the classification of the sources: it consisted in collecting all the reports about energy storage that could add some value to the study. The Terms of Reference (ToR) provided a large range of documents, and an additional bibliographical research has been led to gather potentially interesting documents.

On this basis, a deep literature review (including all the references mentioned in the ToR) has then been conducted. The data contained in these documents were classified in a table, that list for each report the source, title and date and the technical data that were useful for the development of the various databases. These technical data are:

- The type of energy storage technologies treated.
- The type of data, either general data on technologies, or factual data about energy storage facilities.
- The geographical area covered.

A	B	C	D	E	F
Source	Titre de la publication	Date de la publication	Données générales (études scientifiques, ordres de grandeurs) ou données factuelles (document parlant de sites physiques de stockage) ?	Perimètre géographique couvert	Technologies couvertes
IRENA	ES and renewables : costs and markets to 2030	oct-17	Données générales et factuelles (infrastructures existante	Germany / USA	STEP, CAES, Batteries, Flywheel
IRENA	Renewables and ES, a technologie roadmap for remap 2030	juin-15	Données générales et factuelles (par pays)	California/Italy/Bangladesh/I	STEP, CAES, Batteries
IRENA	Charactesistics of stationary electricity storage systems from 2016 to 2030	2016 ?	Données générales	X	STEP, CAES, Batteries, Flywheel
IRENA	Case studies Battery Storage	2015	Données factuelles	USA/Angola/Japan/China/G	Batteries
IRENA-ETS	Thermal energy storage	janv-13	Données générales et factuelles (installations existantes)	Germany	TES
IRENA-ETS	Electricity Storage	avr-12	Données générales	X	STEP, CAES, Batteries, Flywheel, Supercapacitors, SMES
ESTMAP	Public project summary	févr-17	X	X	X
ESTMAP	ES Data collection report	déc-16	X	X	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors
ESTMAP	Country evaluation	janv-17	X	Europe	X
EASE	European market monitor on ES	mars-19	X	X	X
EASE	Activity report 2018	2018?	X	X	X
EASE	European ES technology development roadmap	2017?	Données générales	X	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors, S
BINE	CAES Power plants	?	Données générales et factuelles	Germany/USA	CAES
CE	ES - the role of electricity	févr-17	Données générales	X	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors, S
CEM	ES system : challenges and opportunities	mai-14	Données générales et factuelles	Germany/USA/Korea	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors, S
DENA	P2Gas system solution	2015	Données générales et factuelles	Germany	Electroysis, Methanation
DOE	ES Handbook	2015	Données générales	X	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors, S
ENEA Cons	Energy Storage	mars-12	Données générales	X	X
CE	Energy research in Europe	mars-13	X	X	X
ES World Fo	ES World Forum	mai-18	Données factuelles (par pays)	USA / EU /UK/France/Germa	X
Eurelectric	Facts of hydropower in the EU	juin-18	Données factuelles (par pays)	Europe	STEP
FCH JU	Commercialisation of ES in europe	mars-15	Données générales	X	STEP, CAES, Batteries, TES, LAES, P2G
JEPE	Renewable Energy Based Grid Connected Battery	2019?	Données factuelles (par pays)	Europe USA China	STEP, Batteries
JRC	Case study on the impact of cogeneration and thermal storage on the flexibility of th	2017?	Données générales	X	TES, P2H
KTH	Costs models for battery energy storage systems	2018?	Données générales	X	STEP, CAES, Batteries, TES
Sandia	ES Overview	2015?	Données générales et factuelles (installations et pays)	Global	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors, S
SETIS	ES in the power sector	>2013	Données générales	X	STEP, CAES, Batteries, Flywheel, TES, Supercapacitors, S

Figure 1 - Extract of the literature review table

This first step allows us to summarize the content of the various sources and to prepare the development of databases on energy storage technologies and facilities.

Based on this initial step, it has been decided to split all the data into **three different databases** dealing with:

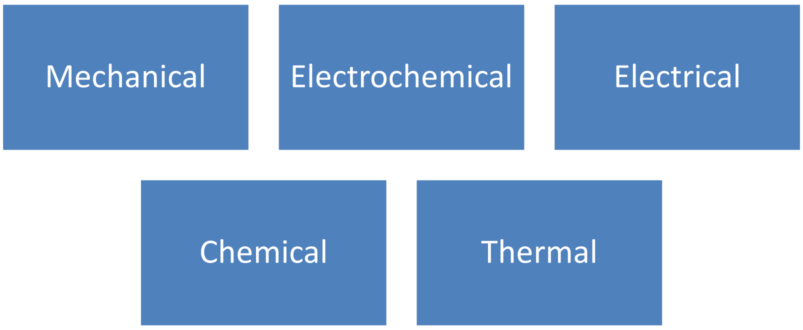
- **Energy storage technologies:** All existing energy storage technologies with their characteristics.

- **Front of the meter facilities:** List of all energy storage facilities in the EU-28, operational or in project, that are connected to the generation and the transmission grid with their characteristics.

- **Behind the meter energy storage:** Installed capacity per country of all energy storage systems in the residential, commercial and industrial infrastructures.

1.1.2. *TECHNOLOGIES DATABASE*

The purpose of this database is to give a global view of all energy storage technologies. They are sorted in five categories, depending on the type of energy acting as a reservoir, and are listed below:



By crossing various data sources, all types of energy storage technologies have been covered. Moreover, relevant types of data for each technology have been highlighted:

- Sub-technology.
- Energy capacity (in kWh, represents the maximum of energy storable in the system).
- Power capacity (in kW, represents the maximum power output of the storage system).
- Storage duration at full power.
- Capex / Opex (€/kW & €/kWh).
- Round-trip Efficiency (in %, represents the ratio of the energy input in the storage facility (before storage) and the energy output of the storage facility (after storage).
- Conversion efficiency (in %, represents the efficiency of the transformation from an energy vector to another).
- Services provided.
- Major technological issues experienced.

Following DG ENER first feedbacks, additional research activities have been carried out, to add characteristics about response time and level of maturity of storage technologies.

1.1.3. *FACILITIES DATABASE*

The purpose of this database is to register all storage facilities across Member States of the European Union, both operational and in project.

The parameters implemented in the database allow an exhaustive description of an Energy Storage System and include data availability limitations. Each facility is described by the following characteristics:

- Country
- City
- Facility name
- Status (Operational, Under Construction, Project)
- Technology
- Sub-technology
- Power installed capacity (MW)
- Energy capacity (MWh)
- Grid connection level
- Grid operator
- Date of commissioning
- Operator

Front of the meter facilities that were targeted for this database are facilities that have a power installed capacity higher than 100 kW. This limit has been set in relation to the lack of data about systems under 100 kW.

Data collection has been conducted through three major steps: first, an integration of national sources & existing databases has been conducted. When they exist, national registers of energy storage facilities have been added to the database. Furthermore, we've used datasets covering a worldwide perimeter, such as the *Global Energy Storage* database of the US DoE, or *Power Plant Tracker*, which is one of the main products proposed by Enerdata, and lists power plants (Operational and Projects) across the world, including Pumped Hydro Storage infrastructures.

The second step was a country-by-country follow up on press updates & articles, in order to have a database that is the most complete possible, by including the last updates on projects, or new facilities that were not included in the previously mentioned databases. This is a well-known process for Enerdata, which is used to conduct power markets monitoring: this methodology has been replicated to track information about energy storage facilities.

Finally, the third step has been to contact ministries and/or TSO for each Member State[7], on the base of a contacts list provided by DG ENER. An extract of the database has been sent to each country, for cross-checking and validation purposes. We have received numerous feedbacks[8] and added them to the facilities database.

The main issue faced for this dataset was the creation of duplicates in the database that results from gathering data from multiple sources. To avoid such duplicates, a verification work has been carried out.

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[7] Norway and Switzerland have been contacted later in the process, in order to get a global overview on European countries.

[8] The feedback rate is 85% (26 out of 30 countries: 28 Member States + Norway + Switzerland). Only Bulgaria, Denmark, Netherlands and Switzerland have not answered as of 2020-03-13.

1.1.4. *BEHIND THE METER DATABASE*

The purpose of this database is to give an overview of Behind-the-Meter storage across Member States of the European Union.

Behind the meter energy storage regroups all energy storage systems that are connected to the residential, commercial and industrial infrastructures. As the name indicates, these systems are placed behind energy meters, and are used to maximise self-use of energy. Because of the diffuse nature of this kind of storage, consisting in very small infrastructures, it is very difficult to compile data and only a few sources are available. As a result, it has been decided to focus on installed capacity at country level.

The data collection has been completed by contacting directly Energy Storage experts and Ministries / TSO of Member States.

1.2. DATABASE RESULTS

1.2.1. *TECHNOLOGIES DATABASE*

The final deliverable for the Technologies database is a table that gathers all technologies / sub-technologies with all relevant characteristics.

	A	B	C	D	E	F	G
1	**Technologies**	**Sub-technologies**	**Use**	**Energy Capacity**	**Power installed capacity**	**Storage duration at full power**	**CAPEX (€/kW)**
2	Mechanical	Pumped Hydro Storage (PHS)	FTM	1-100 GWh	100 MW-1 GW	several hours	500-1500
3		Pumped Heat Electrical Storage (PHES)	FTM	500 kWh-1 GWh	100 kW-200 MW	3-6 hours	350
4		Adiabatic Compressed Air Energy Storage (ACAES)	FTM	10 MWh-10 GWh	10-300 MW	several hours	1200-2000
5		Compressed Air Energy Storage (CAES)	FTM	10 MWh-10 GWh	10-300 MW	several hours	400-1200
6		Liquid Air Energy Storage (LAES)	FTM	10 MWh-8 GWh	5-650 MW	2-24 hours	500-3500
7		Flywheel	FTM	5-10 kWh	1-20 MW	5-30 minutes	500-2000
8	ElectroChemical	Sodium Sulphur batteries	FTM	< 100 MWh	< 10 MW	6 hours	2000-3000
9		Lead Acid batteries	FTM/BTM	up to 10 MWh	Some MW	several hours	100-500
10		Sodium Nickel Chloride batteries	FTM	4 kWh- 10 MWh	Several MW	2- to several hours	150-1000
11		Lithium-ion batteries	FTM/BTM	< 10 MWh	< 50 MW	10 min to 4 hours	150-1300
12		Lithium-S batteries R&D	FTM/BTM				
13		Lithium-Metal-Polymer batteries	FTM/BTM				
14		Metal Air batteries R&D	FTM				
15		Ni-Cd batteries		some MWh	some MW	some hours	500-1500
16		Ni-MH batteries		some MWh	some MW	some hours	500-1500
17		Na-ion batteries R&D	FTM/BTM				
18		Redow flow batteries Zn Fe	FTM	< 100 MWh	< 10 MW	some hours	
19		Redox flow batteries Vanadium	FTM	< 100 MWh	< 10 MW	some hours	500-2300
20		Redox flow batteries Zn Br	FTM	< 100 MWh	< 10 MW	some hours	500-2300
21	Electrical	Superconducting Magnetic Energy Storage (SMES)	FTM	1-10 kWh	100kW-5MW	1-100 seconds	700-2000
22		Supercapacitor	FTM	1-5 kWh	100kW-5MW	<30 seconds	1500-2500
23	Chemical	Power to Gas (H2)	FTM	up to 100 GWh	1kW -1 GW	several hours-several months	2000-5000
24		Power to Ammonia - Gasoline	FTM	1 MWh-several GWh	1 MW-1 GW		
25		Power to Methane	FTM	1 MWh-several GWh	1 MW-1 GW		
26		Power to Methanol + Gasoline	FTM	1 MWh-several GWh	1 MW-1 GW		
27	Thermal	Molten salts	FTM	3 GWh	300 MW	6-10 hours	100-300
28		Sensible Thermal Energy Storage (STES)	FTM	10-50 kWh/t	0,001-10 MW	1-12 hours	3000-4000
29		Phase Change Material (PCM)	FTM	50-150 kWh/t	0,001-1 MW	some weeks	5500-15000
30		ThermoChemical Storage (TCS)	FTM	12-250 kWh/t	0,01-1 MW	some days	Thermal

Figure 2 - Extract of the Technologies database

1.2.2. *FACILITIES DATABASE*

The final deliverable for the Facilities database gathers more than 800 energy storage facilities.

Country	City	Facility Name	Facility Statu	Technology t	Sub-techi	Power installed capac	Energy Capacity	Grid connectio	Grid Operator	Date of commisi	Operator	Source
Belgium	Kraftwerke	TheBattery	Operational	Electrochemical	Li-ion	2	2				Peleman	http://www.energystoragejou
Bulgaria	Sestrimo	Belmeken	Operational	Mechanical	PHS	375	640			1974	NEK	Power Plant Tracker
Bulgaria	Sestrimo	Chaira	Operational	Mechanical	PHS	864	27340			1995 - 1999	NEK	Power Plant Tracker
Bulgaria	Krichim	Orpheus	Operational	Mechanical	PHS	160	13150			1975	NEK	Power Plant Tracker
Bulgaria		Yadenitsa	Announced	Mechanical	PHS	864	5200			2025 - 2030	NEK	Power Plant Tracker
Croatia		Blato	Operational	Mechanical	PHS	4.2					HEP	Power Plant Tracker
Croatia		Busco	Operational	Mechanical	PHS	7.5					HEP	Power Plant Tracker
Croatia		Dubrovnik II	Announced	Mechanical	PHS	304				2022 - 2028	HEP	Power Plant Tracker
Croatia		Fuzine	Operational	Mechanical	PHS	4.6					HEP	Power Plant Tracker
Croatia		Kosinj	Announced	Mechanical	PHS	33.7				2022 - 2028	HEP	Power Plant Tracker
Croatia	Orlovac	Orlovac	Operational	Mechanical	PHS	237				1973	HEP	Power Plant Tracker
Croatia	Obrovac	Velebit	Operational	Mechanical	PHS	276	2340			1984	HEP	Power Plant Tracker
Croatia	Tribalj	Vinodol-1	Operational	Mechanical	PHS	90				1952	HEP	Power Plant Tracker
Croatia	Tribalj	Vinodol-2	Announced	Mechanical	PHS	150				2022 - 2028	HEP	Power Plant Tracker
Croatia	Split-Dalmatia	Vrdovo PHSP	Announced	Mechanical	PHS	540				2022 - 2028	MCC Ekskluzivne	Power Plant Tracker
Cyprus	Nicosie	Nicosie	Announced	Electrochemical	Unknown	5	2.35					https://www.pv-magazine.c
Czech Republic	Dalesice	Dalesice-1	Operational	Mechanical	PHS	120	575			1978	CEZ	Power Plant Tracker
Czech Republic	Dalesice	Dalesice-2	Operational	Mechanical	PHS	120	575			1978	CEZ	Power Plant Tracker
Czech Republic	Dalesice	Dalesice-3	Operational	Mechanical	PHS	120	575			1978	CEZ	Power Plant Tracker
Czech Republic	Dalesice	Dalesice-4	Operational	Mechanical	PHS	120	575			1978	CEZ	Power Plant Tracker
Czech Republic	Jesenik	Dlouhe Strane-1	Operational	Mechanical	PHS	325				1996	CEZ	Power Plant Tracker
Czech Republic	Jesenik	Dlouhe Strane-2	Operational	Mechanical	PHS	325				1996	CEZ	Power Plant Tracker
Czech Republic	Mydlovary	Mydlovary	Operational	Electrochemical	Li-ion	1	1.75	Not connected		2018		Akubat
Czech Republic	Obořiště	Obořiště	Operational	Electrochemical	Li-ion	1	1.3	Not connected		2018		Akubat
Czech Republic	Ochoz	Ochoz	Announced	Electrochemical	Li-ion		10					https://alfen.com/en/news/g
Czech Republic	Prakšice	Prakšice	Operational	Electrochemical	Li-ion	1	1.2	Not connected		2017	Alfen / Solar Global	https://alfen.com/en/news/g
Czech Republic	Stechovice	Stechovice-2	Operational	Mechanical	PHS	45				1948	CEZ	Power Plant Tracker
Denmark	Bornholm	BOSS	Announced	Electrochemical	Unknown	1	1					https://www.cee.elektro.dtu.
Denmark	lance - Air Liquide Advanced Busi	Hobro	Operational	Chemical	P2G	1.25					Air liquide	https://www.energystoragee
Denmark	Vestas Lem Kær ESS Demo 400 kW	Lem Kær	Operational	Electrochemical	Li-ion	0.4	0.1				Vestas	https://www.energystoragee
Denmark	r 1.2 MW ESS Demo - Vestas Wind	Lem Kær	Operational	Electrochemical	Li-ion	1.2	0.3				Vestas	https://www.energystoragee
Estonia	Alutaguse	Estonia PSPP	Announced	Mechanical	PHS	50	350		Elering AS	2030	Eesti Energia AS	Eesti Energia AS
Estonia	Paldiski	Paldiski Hydro	Announced	Mechanical	PHS	500	4000			2028	Energiasalv Pakri OU	Power Plant Tracker
Finland	Kuru	Kuru	Operational	Electrochemical	Li-ion	0.3	0.22	DSO	DSO	6/2019	Owner: Fortum Oyj; Operator: Fortum Oyj / Elenia Oy ; Battery provider:	Energy Authority / Fortum Oy
Finland	Lempäälä	LEMENE	Under construction			2.4	1.6	Local micro-grid (?)		2019	Siemens	https://www.businessfinland
Finland	Järvenpää	LIDL Distribution Centre	Operational			2.6	1.6			2019	LIDL / Merus Power	https://www.meruspower.fi/n
Finland	Espoo	Sello Shopping Centre	Operational	Electrochemical	LiNiMnCoO2	2	2.1	Building's internal grid		1/2019	Operator: Siemens; Battery	Energy Authority / Siemens
Finland	Simo	Viinamäki (wind farm)	Under construction	Electrochemical	Li-ion	6	6.6	TSO	TSO	12/2019	Owner and operator: TuuliWatti Oy; Battery	Energy Authority / TuuliWatti
Finland	Järvenpää	Järvenpää Batcave	Operational	Electrochemical	Li-ion	2	1	DSO	DSO	3/2017	Owner and operator:	Energy Authority / Fortum Oy
Finland	Helsinki	Suvilahti	Operational	Electrochemical	Li-ion	1.2	0.6	DSO	DSO	8/2016	Owner and operator: Helen	Energy Authority / Helen Oy
France	Corse	Alata	Operational	Electrochemical	Unknown	2.4	4.32			31/12/2018		https://www.lemoniteur.fr/art
France	Ham-sur-Meuse	BARRAGE HYDRAULIQUE DE HAM	Operational	Mechanical	PHS	0.9			RTE	2017	0	Power Plant Tracker
France	GRID Primary Substation Battery (F	Carros	Operational	Electrochemical	Li-ion	1.1	0.572				Alstom Grid	https://www.energystoragee
France	Aime	CENTRALE DE PONT THIERET	Operational	Mechanical	PHS	0.6			RTE	2001	0	Power Plant Tracker
France	ca 2 MW Storage by Saft and Schn	Corte	Announced	Electrochemical	Li-ion	2	2				Schneider Electric	https://www.energystoragee
France	Carbonne	EDF DPIH CARBONNE	Operational	Mechanical	PHS	0.4			RTE	1997	0	Power Plant Tracker
France	Llo	eLLO Solar Thermal Project	Operational	Thermal	Molten salts	9	36			31/12/2018	SUNCNIM	https://solarpaces.nrel.gov/
France	Alba Nova 1 Solar Power Plant	Ghisonaccia	Operational	Thermal	STES	12	12				Solar Euromed	https://www.energystoragee

Figure 3 - Extract of the Facilities database

The energy capacity is rarely mentioned: it can be explained by a possible general unawareness of the data describing an energy storage system. Facilities must be described by their power and their energy capacity. A description using only one of these two values is incomplete.

In the Facilities database, we have added a section on “Key Projects”, gathering a few facilities that are remarkable by their technology, size, or geographical locations:

- *Huntorf, Germany, 290 MW / 580 MWh:* this is the first **Compressed Air** Energy Storage (CAES) operational facility, and still the only one in Europe.

- *Cottbus (BigBattery Lausitz), Germany, 50 MW / 53 MWh*: this is a recent and major **Li-ion battery** project, to be commissioned in July 2020. Located next to the Schwarze Pumpe power plant, it will help to protect the power grid against fluctuations.

- *Drax Re-Power, United Kingdom, 200MW / Capacity TBD:* this Li-ion project, authorized in 2019, presents an **important power capacity**. It is associated with the repowering of a power plant which would be switched from coal to gas.

- *Cremzow, Germany, 22 MW / 31.6 MWh*: this is a recent battery project, commissioned in May 2019. It provides **frequency regulation services**.

- *Wartsila (Budapest), Hungary, 6 MW / 4 MWh*: one of the few Li-ion projects in **eastern Europe** and outside big European countries.

1.2.3. *ANALYSIS*

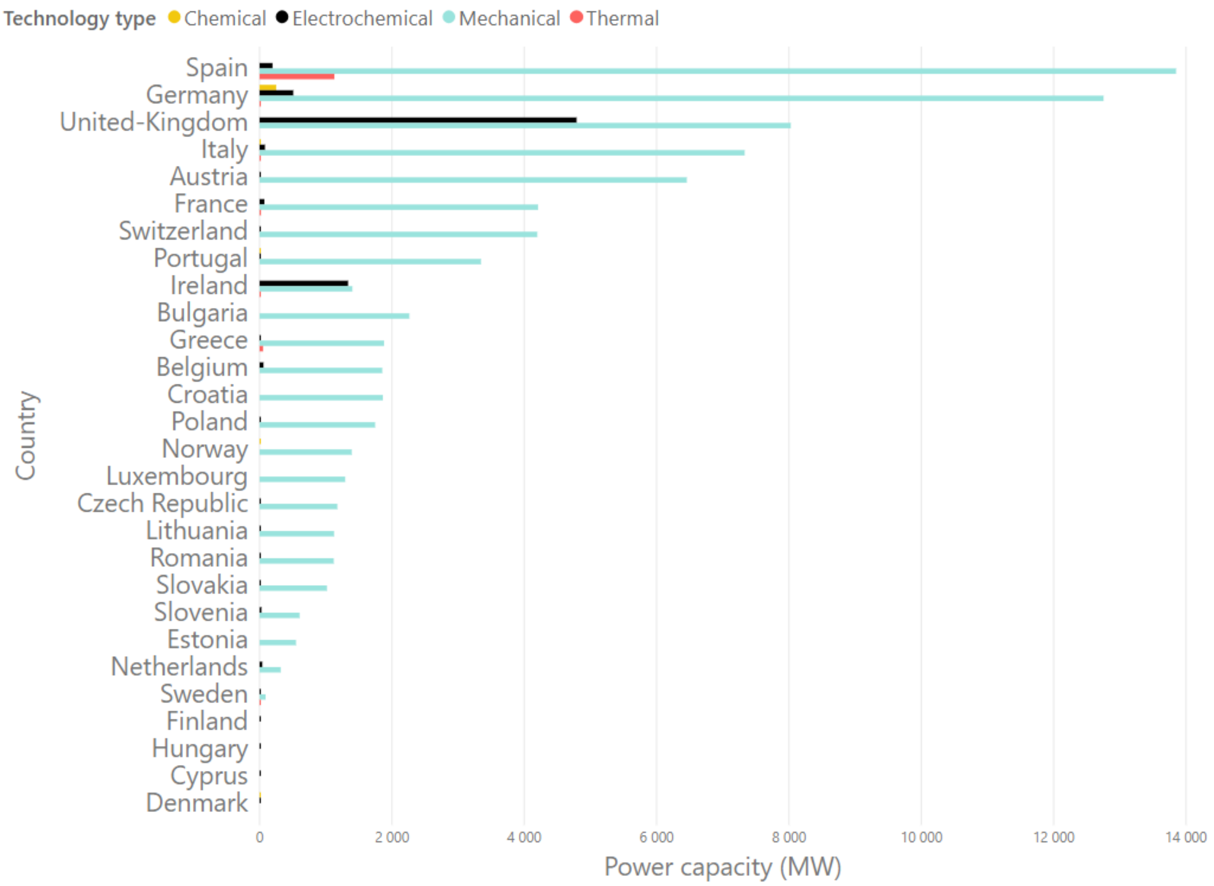

Figure 4 - Power capacity by technology and country (Operational + Projects) (values in Annex 1)

As expected, the **majority of energy storage in the EU (90+% of Power Installed) is brought by the Pumped Hydro Storage (PHS, in blue on this histogram)**: indeed, these systems present huge capacity and power, due to their mechanical characteristics (size, water volumes).

As shown in Figure 5, the number of entries in the database by country is quite heterogeneous. In terms of capacities, **pumped hydro storage dominates the database** but the total amount of facilities per country depends also on smaller facilities, typically electrochemical facilities. In Figure 6 we can see that more than half of the facilities in the database are electrochemical and for UK electrochemical accounts for more 90% of the total facilities.

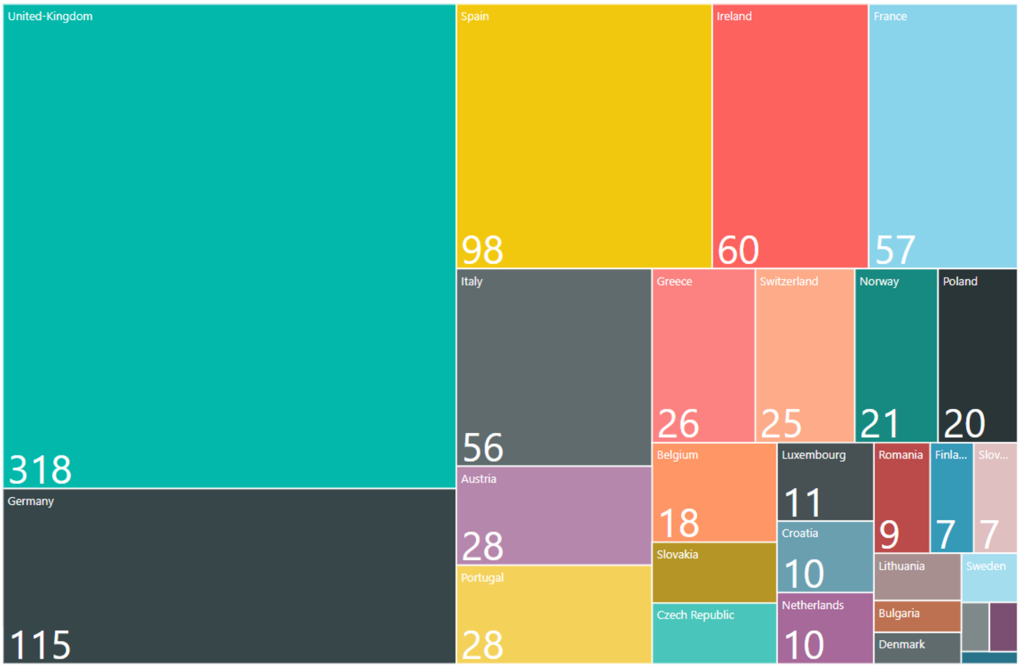

Figure 5 - Entries in the database (Operational + Projects), by country (values in Annex 1)

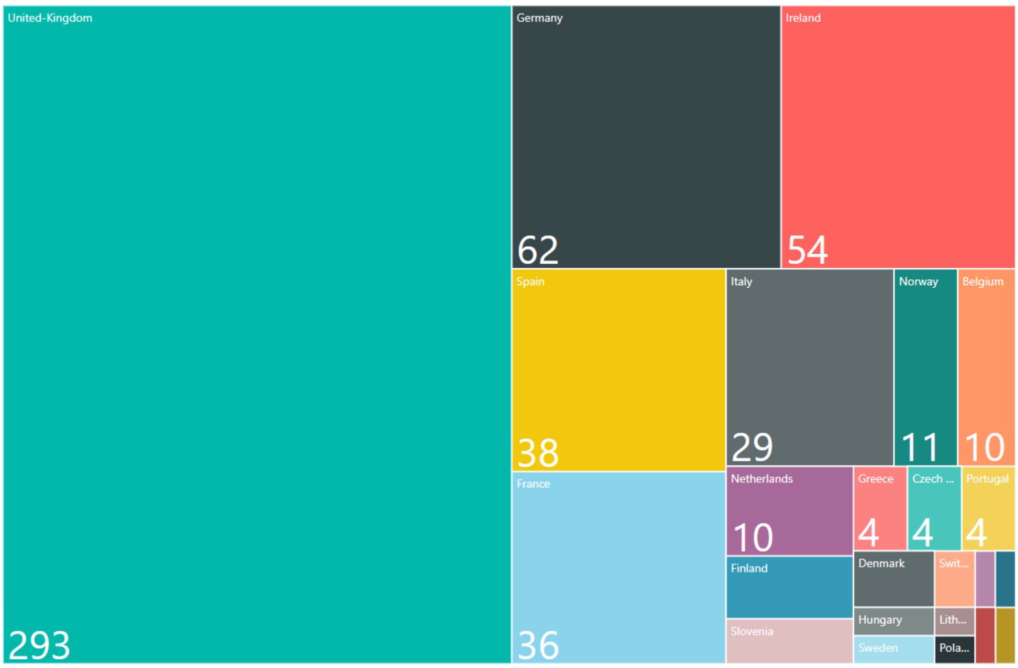

Figure 6 - Entries in the database (Operational + Projects, PHS excluded), by country (values in Annex 1)

The figure below focuses on electrochemical facilities (both operational and in project), which are a rising energy storage alternative. **United Kingdom presents the most important Power Capacity, followed by Ireland and Germany**.

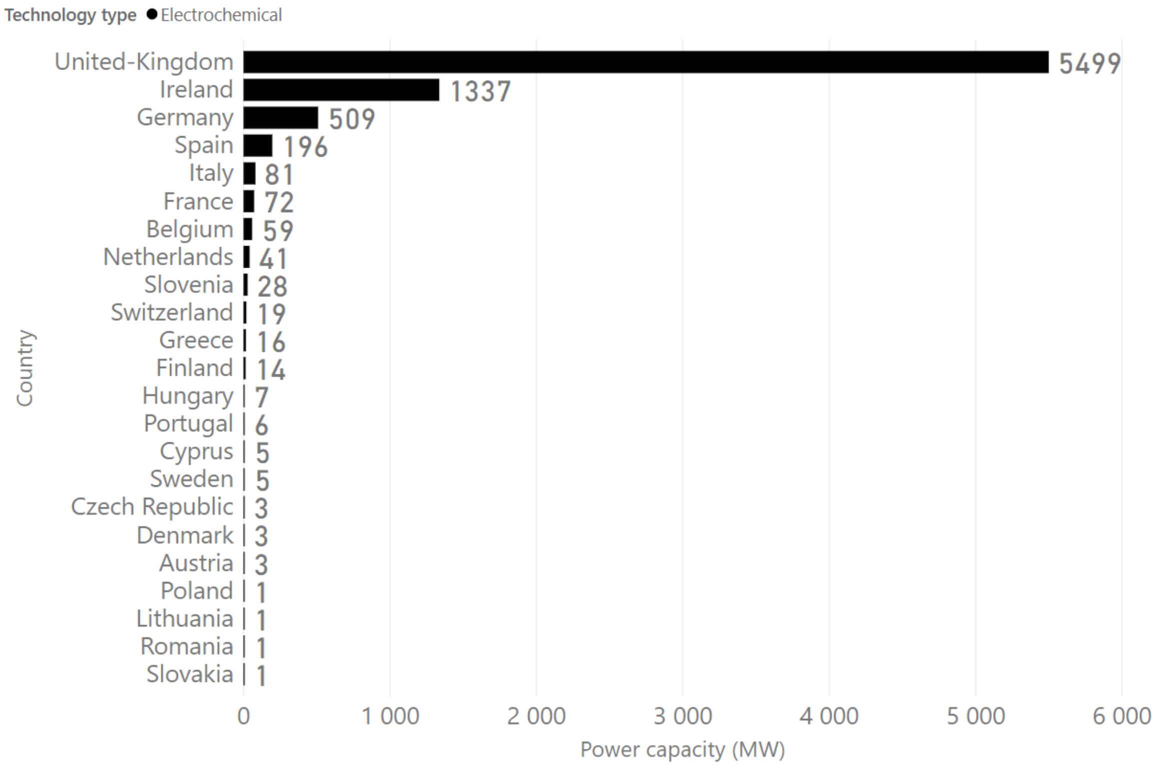

Figure 7 - Electrochemical Storage - Power capacity by country (Operational + Projects) (values in Annex 1)

The analysis of the data collected reveals that **Germany & United Kingdom lead the Batteries Energy Storage Systems (BESS) current market in Europe (**Figure 8**).** Furthermore, the UK has a very important BESS projects pipeline compared to other countries (followed by Ireland, Figure 9).

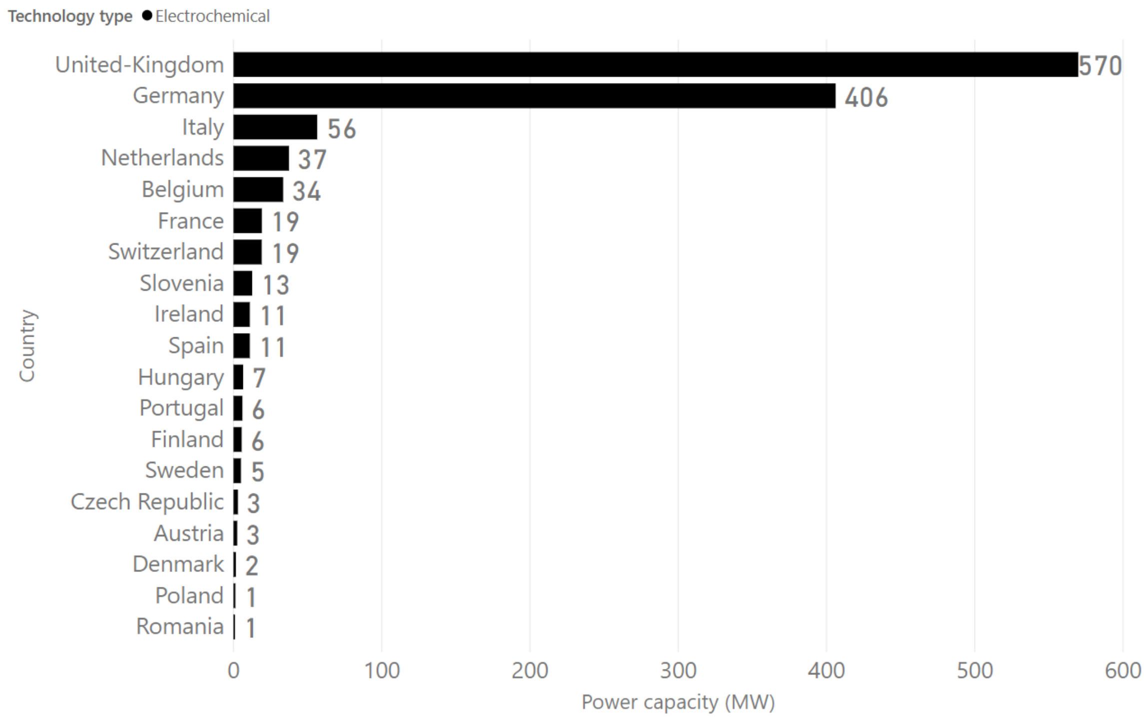

Figure 8 - Electrochemical storage - Operational Capacities by Country (values in Annex 1)

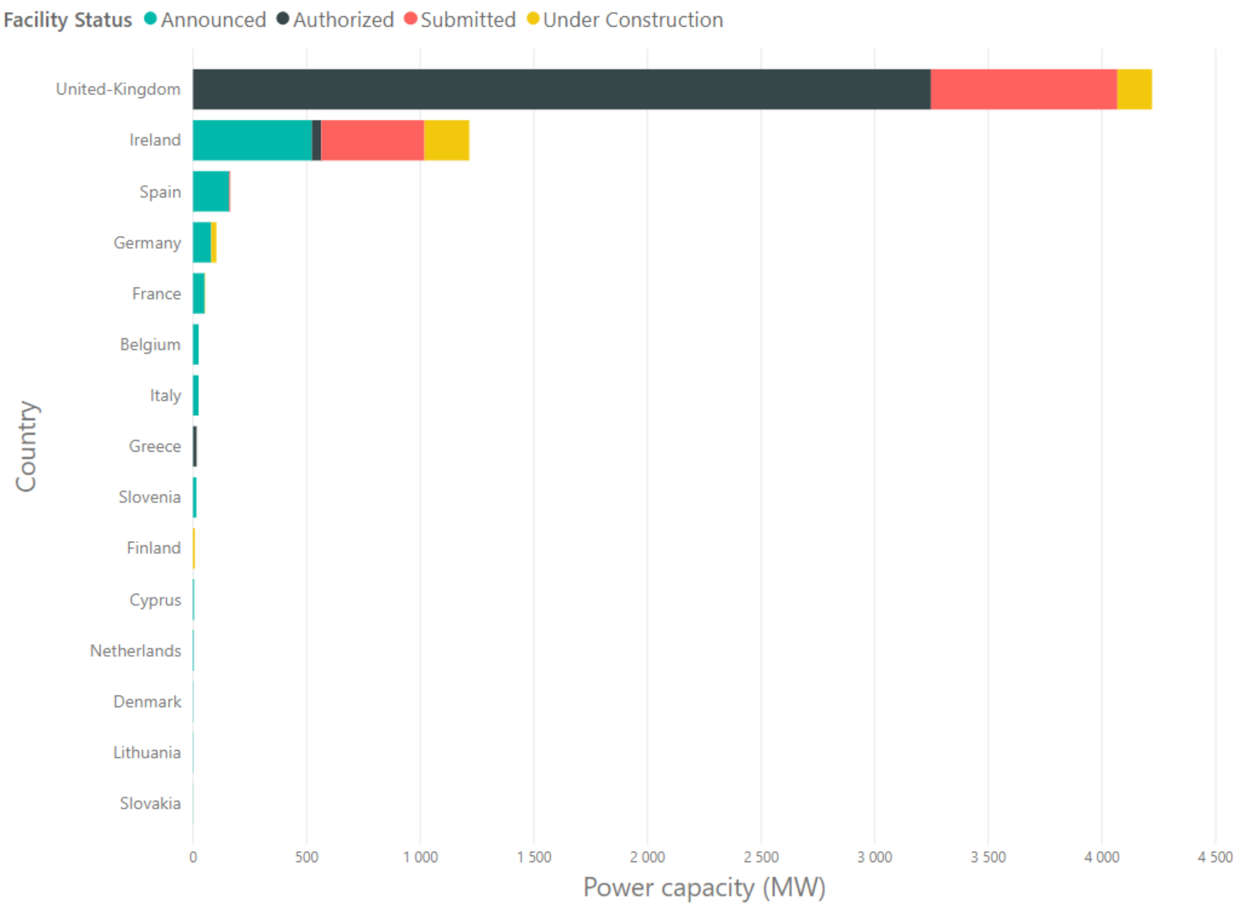

Figure 9 - Electrochemical storage - Planned Capacities by Country

1.2.4. *BEHIND THE METER DATABASE*

The final deliverable for the Behind the Meter database displays the installed capacity per country, when available, based on numbers and assumptions, provided by experts from Ministries and Energy Storage associations.

It is important to note here that **behind-the-meter storage is a growing market with important mid-term potential, but currently presents very poor data availability**. Indeed, we were unable to provide data for an important number of countries, due to lack of data. However, this should be possible to do in the future, with a more mature market.

1.3. CONCLUSION AND KEY MESSAGES RELATED TO THE DATABASE

Energy transition and deep decarbonisation of the power mix will require a strong integration of intermittent renewable sources of power generation. More generally, the main constraint of electricity as an energy vector is that it has always been technically very difficult and relatively costly to store it compared to other vectors such as liquid (oil) or gas. As a result, development of power sector and electricity consumption have been based on massive transmission and distribution networks that account for around one third of the end user bill in most countries.

However, things are changing as batteries technologies becoming more and more mature with significant reduction in their costs. This could facilitate the integration of intermittent power generation and create a large market for electricity storage.

Throughout this data collection work, we have noticed some important points that we would like to summarise with these key messages:

- The main energy storage reservoir in the EU is currently and by far **Pumped Hydro Storage**. As their prices plummet, new **batteries projects are rising**. This type of facilities can be coupled with renewable (wind or solar) farms.

- **Li-ion batteries** represent most of electrochemical storage projects. The recycling of such systems should be strongly taken into consideration, as well as their effective lifetime: such theoretical specifications submitted to grids may be relatively optimistic compared with their use at nominal conditions.

- In the EU, the segment of operational **electrochemical facilities is led by UK and Germany**. We have noticed an important number of projects in the UK, and to a lesser extent in Ireland.

- **Behind-the-meter storage is still growing**. It is quite heterogeneous, depending on local markets and countries: as a new market, it is still driven by political aspects and/or subsidies. Overall data availability is relatively poor.

A recommendation from this study would be to **ensure a monitoring and follow-up of storage facilities** at both Member States and European Commission level. We have noticed through our study that data about energy storage are sometimes difficult to obtain or with a level of precision lower than for power generation databases. A convergence, both in terms of quality and coverage, of storage facilities public data and databases towards power plant existing public data could be define as a key objective.

2. QUANTIFICATION OF THE CONTRIBUTION OF ENERGY STORAGE TO THE SECURITY OF ELECTRICITY SUPPLY IN THE EU-28

2.1. INTRODUCTION

In December 2019, the Commission has presented the "European Green Deal", a set of policy initiatives aiming at achieving a climate-neutral Europe by 2050. In early March 2020, this objective has been addressed by a proposition of the Commission: the European Climate Law. The draft Climate Law includes measures to keep track of progress and to define and update the pathway to get to the 2050 target.

Today, the European Union energy system still heavily relies on fossil energies, and is the main contributor to the overall greenhouse gases emissions (with around 80%[9] of the total emissions, the rest being caused by agriculture emissions, industrial processes and waste management). In order to reach a net-zero system by 2050, the whole energy system will have to be radically transformed. This includes important efforts to increase the level of energy efficiency (e.g. in buildings) and a large-scale deployment of renewable energy sources to enable the direct and indirect electrification of all sectors of the economy.

Ahead of this objective, the European Commission had set out its vision for climate-neutral EU in November 2018, looking at all the key sectors and exploring pathways for the transition. The 2050 visions reflect different possible orientations for the energy system (circular economy, deep electrification, important development of hydrogen), but share a common element to decarbonise the energy system of the European Union: relying on direct and indirect electrification technologies, supported by an important development of electricity generation from renewable energy sources such as solar photovoltaics (PV) and wind power.

The large share of variable energy sources (vRES) in the production will significantly change the dynamics of the power system. The way the flexibility currently being provided by conventional thermal generation technologies (that currently provide a large part of the flexibility on all timescales) will be replaced while ensuring a secure provision of electricity is one of the key questions that has to be addressed. In order to keep the balance between the production and consumption and avoid RES curtailment, additional flexibility solutions will be needed. In this context, storage solutions could play a key role to ensure the integration of renewable energy sources can materialise at the lowest cost, by shifting the consumption to the moment when electricity is available.

The objective of this section is to provide a quantitative assessment of the role of different energy storage technologies at different stages of the energy transition. This analysis is grounded on power systems development plans consistent with the European Commission's Long-Term Strategy and considers all available flexibility solutions (demand and supply sides, storage, interconnectors) in order to robustly meet security of supply criteria.

The methodology of this assessment is based on the recommended framework to establish flexibility portfolios defined in the Mainstreaming RES study of the European Commission[10]. The first step is the definition of the different scenarios and the evaluation of the flexibility needs, then the identification of the possible flexibility solutions and finally the description of the optimal portfolio for each scenario. Three scenarios have been considered in this study, one for 2030 (METIS-Baseline) and two for the 2050 horizons (METIS-1.5C and METIS-2C-P2X). All of them are derived from the pathways described in the Long-Term Strategy, and include the energy and climate objectives of the EU.

[9] Source : Eurostat : https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1180.pdf

[10] European Commission, "Mainstreaming RES - Flexibility portfolios", 2017.

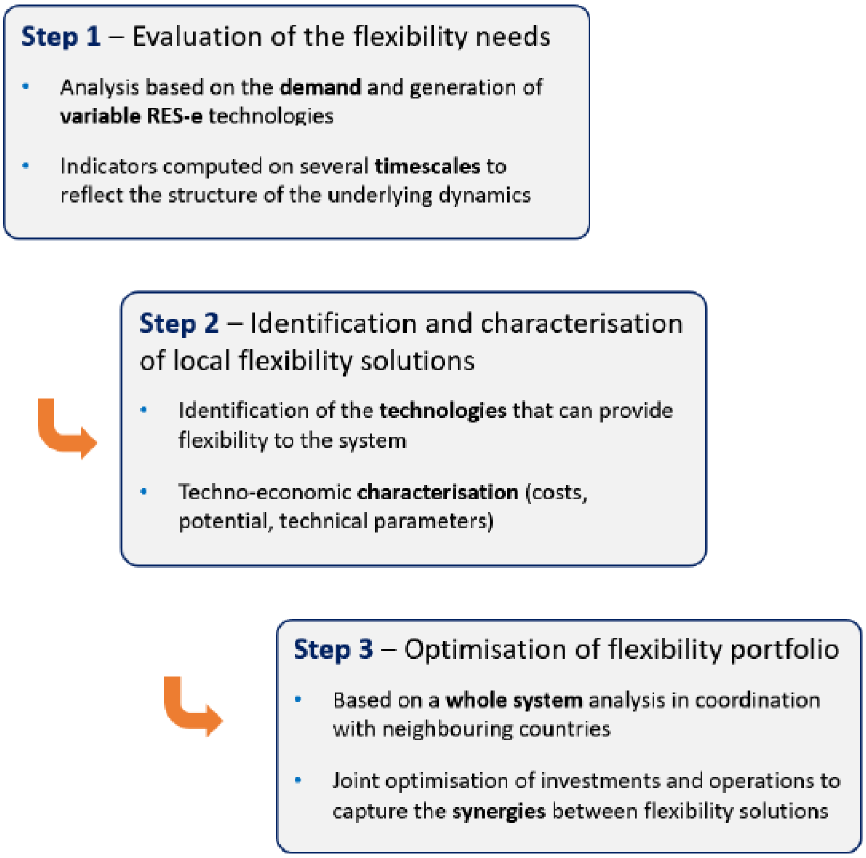

Figure 10 - Recommended framework to establish flexibility portfolios (source: Mainstreaming RES study[11])

In addition to the results of the three central scenarios, different sensitivities have been designed and performed to capture the uncertainties of the evolution of some key elements of the European energy system. Three topics have been selected, based on their potential impacts on the deployment of storage technologies:

- Demand-response: different assumptions were evaluated for the flexibility offered by electric vehicles and smart heating for buildings, since this short-term flexibility directly competes with storage technologies such as batteries.
- Cost of electrolysers: electrolysers were found to provide an important share of the required flexibility services. This sensitivity is designed to understand how the landscape would change if electrolysers were to be more expensive.

Flexibility offered by P2X: this final sensitivity assumption aims at capturing the effect of various levels of flexibility in the consumption of hydrogen (and derived gases and fuels).

[11] https://ec.europa.eu/energy/sites/ener/files/mainstreaming_res_-_artelys_-_final_report_-_version_33.pdf

2.2. DESIGN OF THE DIFFERENT SCENARIOS

2.2.1. *DESCRIPTION OF THE SCENARIOS*

2.2.1.1. Three scenarios adapted from the EC's Long-Term Strategy

The EC Long-Term Strategy has analysed different pathways that can lead the European Union's economy to reach the Paris agreement target of keeping the temperature increase since the pre-industrial era "well below 2°C by 2100"[12].

A first pathway called **Baseline** includes the recently agreed policies, such as a reformed EU emissions trading system and different target for energy efficiency and renewable production. In 2050, this pathway reaches a 60% reduction of greenhouse gas emissions, which is not sufficient to meet the objectives of the Paris Agreement. Five different pathways have been created to meet the objectives of the Paris Agreement, each of them being based on different technological choices on how to decarbonise the EU economy:

- **Energy efficiency (EE):** Pursuing deep energy efficiency in all sectors, with higher rates of building renovation.
- **Circular economy (CIRC):** Increased resource and material efficiency, with lower demand for industry thanks to higher recycling rate and circular measures.
- **Electrification (ELEC)**: deep electrification in all sectors, with large deployment of heat pumps for building heating and faster electrification of all transport modes
- **Hydrogen (H2):** Hydrogen is used in all sectors, and injected into the distribution grids to be used in the building for heating, and for freight transport.
- **Power-to-X (P2X):** Large development of e-gas and e-fuels to decarbonise the different vectors without changing the energy supply type

Based on these different options, three additional pathways are described in the LTS. The first one, **COMBO**, is a cost-efficient combination of the five options described above.

The two additional ones are more ambitious, with a goal of keeping the temperature increase to "around 1.5°C by 2100". Including carbon sinks, these two scenarios reach carbon neutrality by 2050. The **1.5TECH** scenario combines the technologies used in the five different pathways defined above to reach net zero greenhouse gases emissions in 2050. The **1.5LIFE** scenario is also based on the different technological pathways, but with a stronger focus on lifestyle changes leading to a lower energy consumption.

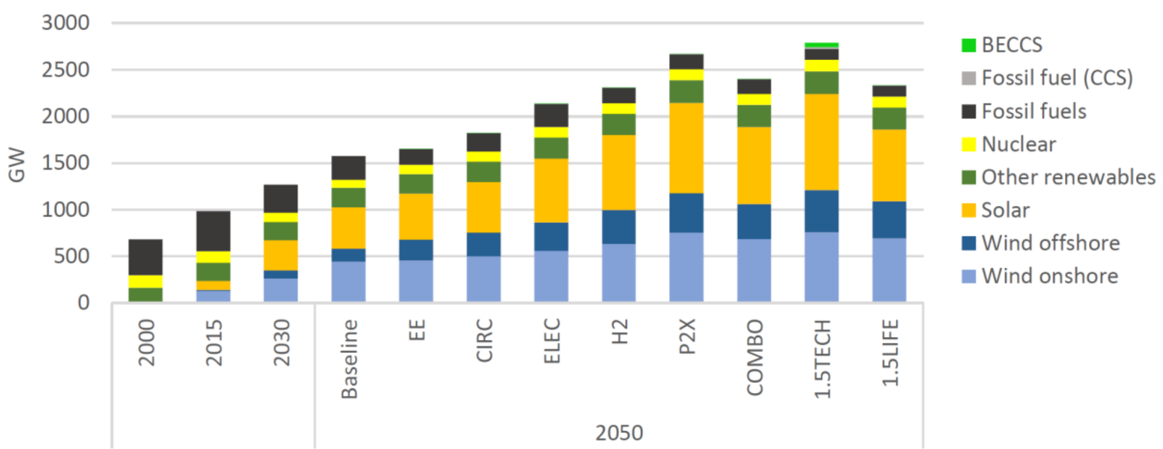

Figure 11 - Power installed capacities in the different pathways of the Long-term Strategy

[12] For more information about the Long term strategy, please refer to the available documentation on the EC website : https://ec.europa.eu/clima/policies/strategies/2050_en

For this study, **three scenarios have been selected** at different time horizons:

- **Baseline** (year 2030)
- **1.5TECH** (year 2050)
- **P2X** (year 2050)

The rationale behind this choice was to have a first 2050 scenario that reaches carbon neutrality in 2050. **1.5TECH** scenario was selected against 1.5LIFE since it was more conservative in terms of behavioural change. **P2X** was then selected because it was the most ambitious pathway in terms of storage potential according to the modelling exercise realized for the definition of these different scenarios. Finally, **Baseline** was selected for the year 2030 since it reflects the currently agreed policies, allowing a comparison of the power flexibility needs between 2030 and 2050[13].

2.2.1.2. Evolution of the energy mix in 2030 and 2050

In the Long-Term Strategy pathways, the decarbonisation of the EU energy system mainly results from a large integration of power renewable energy sources, such as solar and wind capacities, that enable direct and indirect electrification of end-uses. As can be seen on

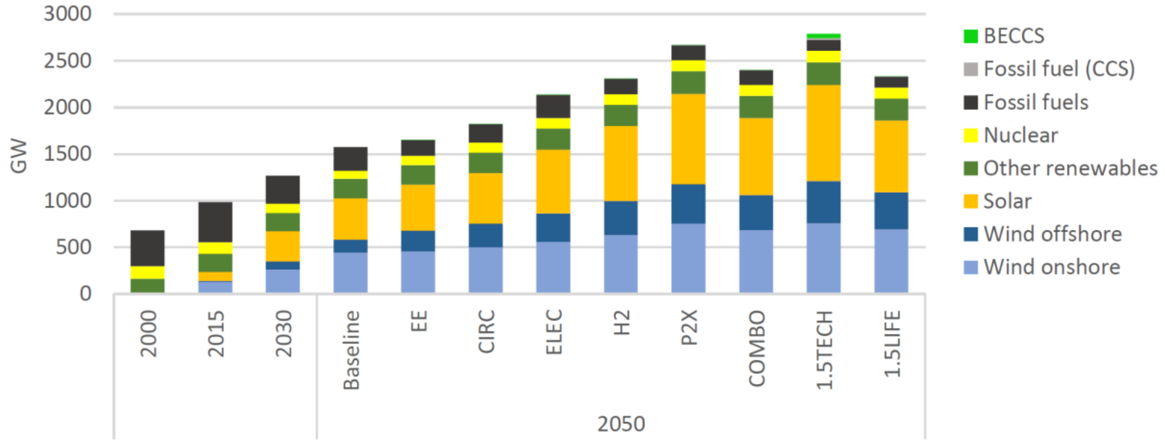

Figure 11, solar and wind capacities soar between 2030 and 2050, rising from 670 GW to 2 140 GW in the P2X scenario and 2 240 GW in the 1.5TECH scenario.

This important decarbonised power production is used to switch from burning fossil fuels to using electricity, both in a direct way and via an indirect electrification route (i.e. via power-to-gas technologies and end-uses using decarbonised gases and fuels). Between today and 2030, this fossil-to-RES switch is driven by direct electrification leading to an increase of the total power production from 2750 TWh in 2015 to 3030 TWh in 2030. From 2030 onwards, the Long-Term Strategy considers an important development of P2X technologies for indirect electrification, leading to the production of synthetic fuels such as e-gases[14] and e-liquids[15] from electrolysis, replacing their fossil counterparts in the industry, heating and mobility sectors.

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[13] At the time of writing, the impact assessment of the 50 to 55% reduction of GHG emissions by 2030 was not available. This scenario has therefore not been included in this analysis.

[14] e-gas refers to e-CH_4, which can be used instead of natural gas in all its applications

[15] e-liquids refers to a large range of complex synthetic hydrocarbons, that could be used instead conventional fuels derived from petrol (gasoline, unleaded, oil, kerosene, etc.)

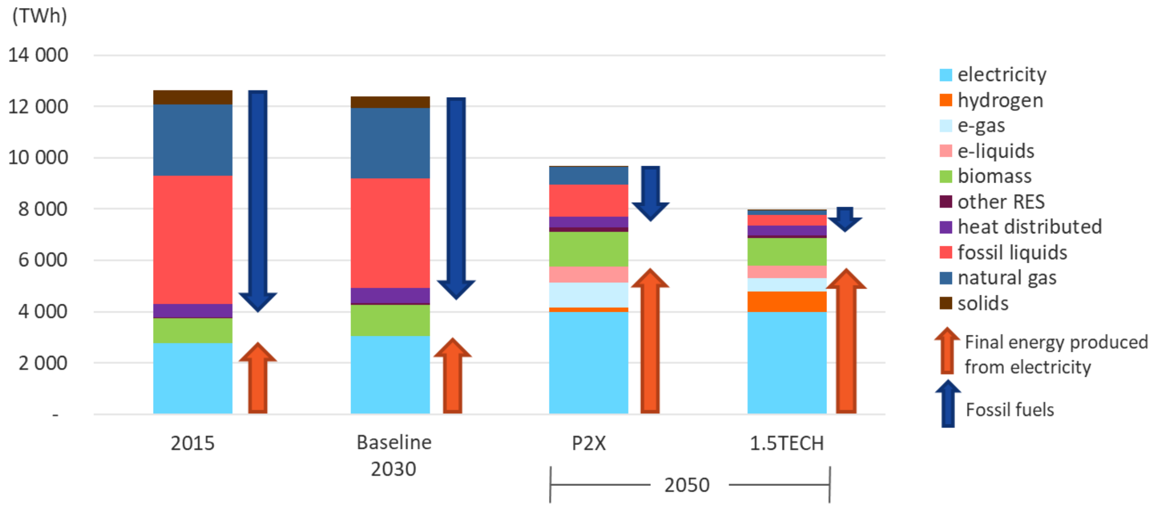

Figure 12 - Share of energy carriers in final energy consumption (TWh)

As a consequence of the large volumes of e-gases and e-liquids being required to decarbonise these sectors, the demand for electricity drastically increases between 2030 and 2050. In 2050, more than a third of the power production is dedicated to electrolysis, in order to produce carbon free fuels (hydrogen, e-gas and e-liquids). Direct electrification also contributes to an increase of the total power demand, raising above 4 000 TWh in both P2X and 1.5TECH scenarios. The combination of direct and indirect electrification leads to a total power demand that will be more than twice higher in 2050 than it is projected to be in 2030. The demand in the 1.5TECH scenario is a little higher than the one of the P2X scenario, since the more ambitious target in terms of reduction of greenhouse emissions requires a deeper decarbonisation of the energy sector.

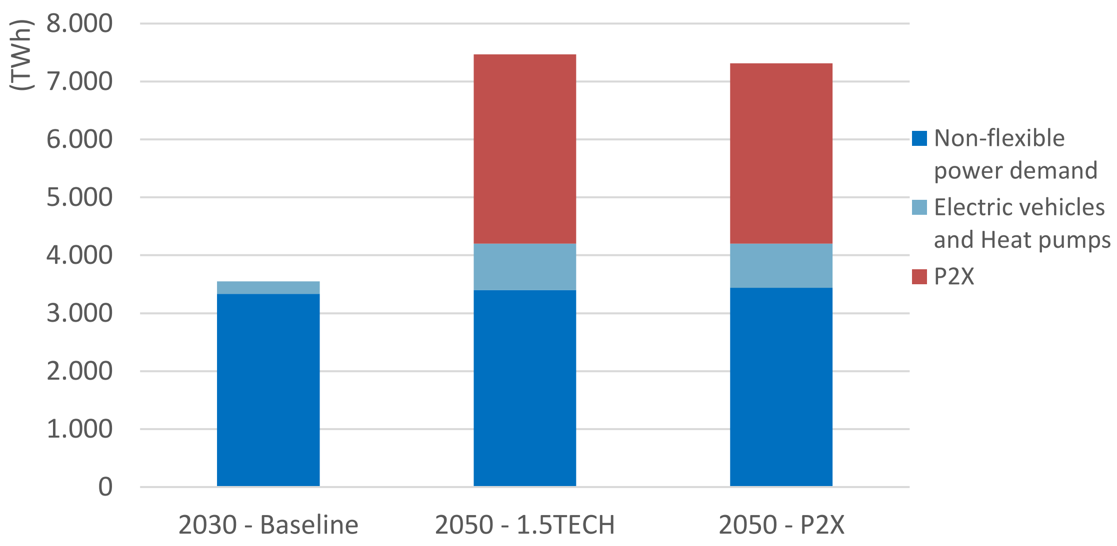

Figure 13 - Power demand of the different scenarios[16] (TWh)

2.2.1.3. Integration of the LTS scenarios in METIS

In order to assess the optimal flexibility portfolio of the European power sector for the different scenarios of the Long-Term Strategy, the main characteristics of these scenarios

[16] The power demand includes the losses of the transmission and distribution grids

have been taken into account in the modelling exercise, carried out using METIS[17]. We present below the list of assumptions that have been directly taken from the LTS scenarios:

- Installed capacities
  - Solar fleet
  - Wind fleet
  - Nuclear
  - Lignite and Coal
  - Geothermal
  - Biomass and waste
  - Other renewables
- Power demand
  - Direct power demand, with a specific distinction of electric vehicles and heat pumps consumption (which can provide flexibility and demand response)
  - Indirect power demand (i.e. electricity dedicated to P2X, in order to produce synthetic hydrogen, e-gas and e-fuels)
- Commodity prices
  - Fuel prices (gas, coal, oil)
  - EU-ETS carbon price

The LTS pathways have been developed and published at the EU level. This study follows this approach, providing EU-wide aggregations of assumptions and results in the following sections.

Note on the scenarios used in the modelling

As explained above, the scenarios that we have built to assess the role of storage are partly based on the LTS pathways, and some structural datasets are directly taken from the LTS assumptions (see list above). However, the modelling of the power system behaviour (described in Section **Error! Reference source not found.**) and the identification of the optimal flexibility portfolio relies on additional assumptions (e.g. potential, capital costs, etc.). Therefore, results can differ from those of the Long-Term Strategy pathways, especially in terms of installed capacities of the flexibility solutions that are optimised in our work (gas-fired power plants, pumped hydro storage, batteries, interconnectors, P2X facilities).

To distinguish the scenarios created during this study from the underlying LTS scenarios, we adopt the following convention throughout this report:

Scenario	Underlying LTS scenario
METIS-Baseline (2030)	2030 - Baseline
METIS-1.5C (2050)	2050 – 1.5TECH
METIS-2C-P2X (2050)	2050 – P2X

In addition to the European Union, 7 neighbouring countries have also been modelled to capture their interactions with the EU member states. These 7 countries are the following:

- Bosnia-Herzegovina
- Montenegro
- Norway

[17] https://ec.europa.eu/energy/data-analysis/energy-modelling/metis_en

- North Macedonia
- Serbia
- Switzerland
- United-Kingdom

For all these countries, their power production capacities and demand are extracted from scenarios developed by the ENTSOs in the context of the elaboration of their respective TYNDP 2018 .

The following scenarios have been selected, as they were assessed to be the closest to the selected EC pathways:

- METIS-Baseline (2030): "Sustainable Transition" (ST) 2030 scenario has been selected, as it was in line with the 2030 objectives of the European Union
- METIS-1.5C and METIS-2C-P2X (2050): "Global Climate Action" (GCA) 2040 has been selected, since it relies as the LTS scenario in large-scale power renewable for both direct and indirect electrification of the EU energy system

2.2.2. *EVOLUTION OF THE FLEXIBILITY NEEDS*

As mentioned above, we have adopted the flexibility framework developed in the context of the Mainstreaming RES study[18]. The first step is to assess the flexibility needs of the power system, on different timescales. The daily, weekly and seasonal flexibility metrics of the study are used here to evaluate the needs in 2030 and 2050 scenarios.

2.2.2.1. Flexibility needs definition

In the following we define daily, weekly and seasonal flexibility needs by analysing the dynamics of the residual load on several timescales, so as to take into account all the underlying phenomena that drive the need for flexibility.

Flexibility is defined as the ability of the power system to cope with the variability of the residual load curve at all times. Hence, flexibility needs can be characterised by analysing the residual load curve.

Daily flexibility needs

On a daily basis, if the residual load were to be flat, no flexibility would be required from the dispatchable units. Indeed, in such a situation, the residual demand could be met by baseload units with a constant power output during the whole day. In other words, a flat residual load does not require any flexibility to be provided by dispatchable technologies.
We therefore define the daily flexibility needs of a given day by measuring by how much the residual load differs from a flat residual load. The daily flexibility needs computed in this report are obtained by applying the following procedure:

1. Compute the residual load over the whole year by subtracting variable RES-e generation and must-run generation from the demand.
2. Compute the daily average of the residual load (365 values per year).
3. For each day of the year, compute the difference between the residual load and its daily average (the light green area shown on the figure below). The result is expressed as a volume of energy per day (TWh per day)
4. Sum the result obtained over the 365 days. The result is expressed as a volume of energy per year (TWh per year).

[18] Source : European Commission, "Mainstreaming RES - Flexibility portfolios," 2017.

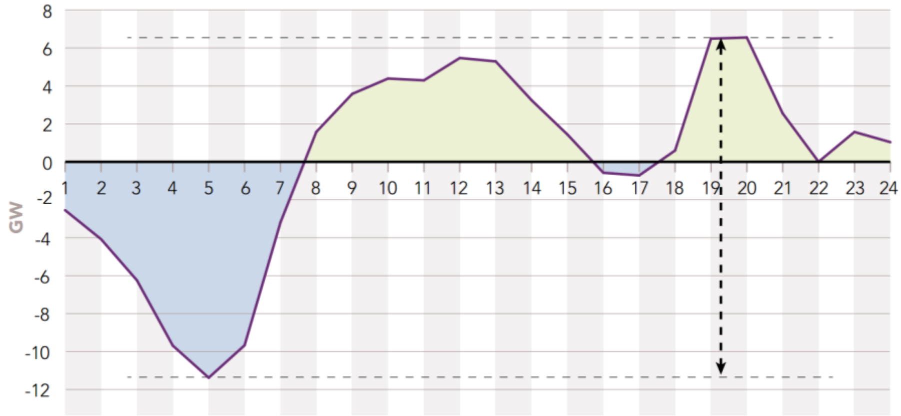

Figure 14 - Illustration of daily flexibility needs (the solid purple line measures the deviation of the residual load from its daily average for a given day). Source: RTE, Bilan prévisionnel de l'équilibre offre-demande, 2015

Weekly flexibility needs

The same reasoning is applied to evaluate the weekly flexibility needs. However, in order not to re-capture the daily phenomena that are already taken into account by the daily flexibility needs indicator, we define weekly flexibility needs as follows:

1. Compute the residual load over the whole year by subtracting variable RES-e generation and must-run generation from the demand with a daily resolution
2. Compute the weekly average of the residual load (52 values per year)
3. For each week of the year, compute the difference between the residual load (with a daily resolution) and its weekly average (the light green area shown on Figure 15). The result is expressed as a volume of energy per week (TWh per week).
4. Sum the result obtained over 52 weeks. The result is expressed as a volume of energy per year (TWh per year).

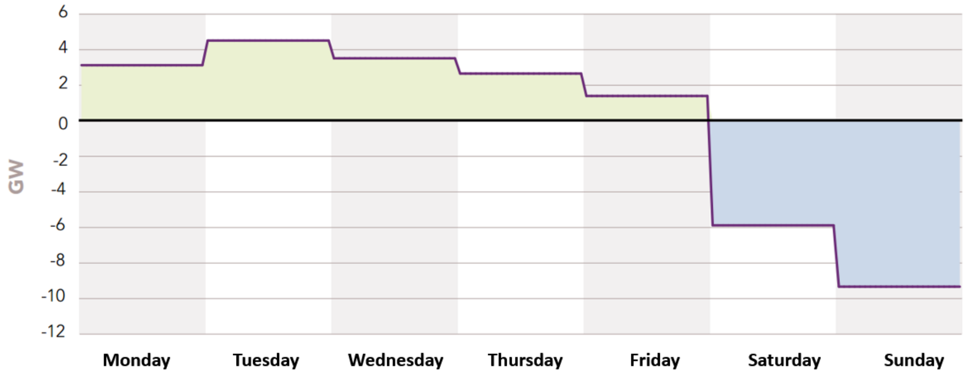

Figure 15 - Illustration of weekly flexibility needs (the solid purple line measures the deviation of the residual load from its daily average for a given week). Source: RTE, Bilan prévisionnel de l'équilibre offre-demande, 2015

Seasonal flexibility needs

Finally, the seasonal flexibility needs are defined in a similar way:

1. Compute the residual load over the whole year by subtracting variable RES-e generation and must-run generation from the demand with a monthly time resolution
2. Compute the annual average of the residual load
3. Compute the difference between the residual load (with a monthly time resolution) and its annual average. The result is expressed as a volume of energy per year (TWh per year).

2.2.2.2. Evaluation of the flexibility needs

Daily flexibility assessment

The daily flexibility needs at the EU28 level are shown for the three reference scenarios on Figure 16 below. From METIS-Baseline in 2030 to METIS-1.5C in 2050 the flexibility needs almost triple, going from 270 TWh in 2030 to 780 TWh in 2050. A small difference can be seen between the two 2050 scenarios, the flexibility needs vary from 780 TWh in METIS-1.5C to 730 TWh in METIS-2C-P2X.

This significant increase from 2030 to 2050 is directly related to the increase of RES installed capacity, in particularly solar power. In all three scenarios most of the flexibility needs is concentrated in a few countries, who have the highest RES installed capacities. Together Germany, France, Spain, United-Kingdom and Italy account for the majority of the daily flexibility needs in all scenarios. The slight difference between the daily flexibility needs in METIS-1.5C and METIS-2C-P2X can be explained by the difference in solar installed capacity in the two scenarios, 1055 GW in METIS-1.5C and 1000 GW in METIS-2C-P2X.

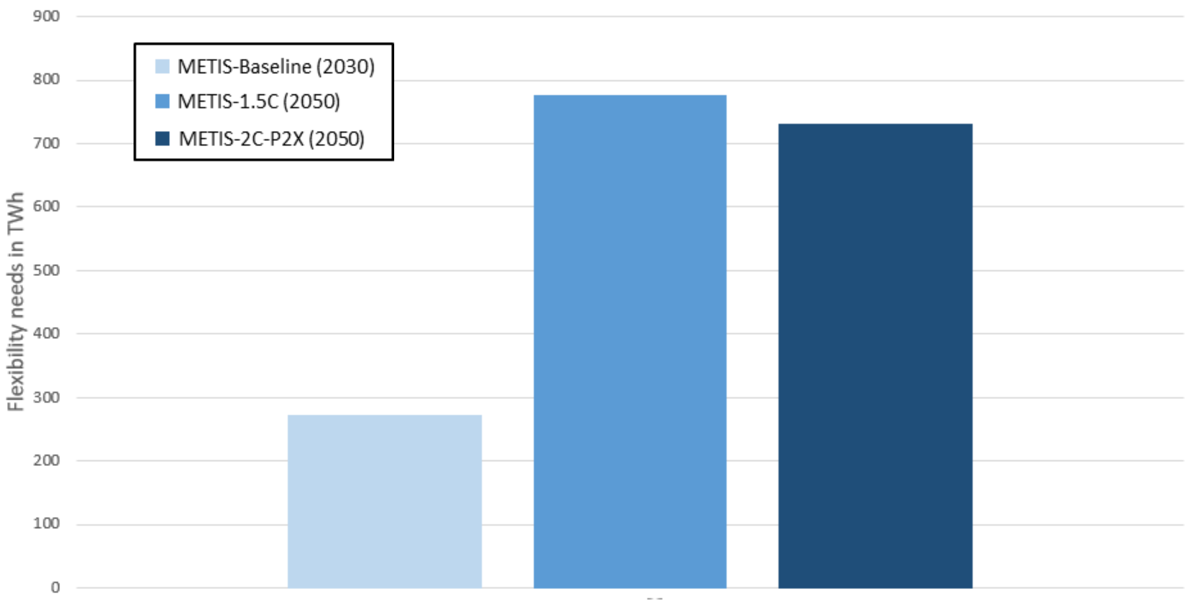

Figure 16 - Daily flexibility needs at EU28 level

A high penetration of solar power can substantially increase the flexibility needs due to hourly generation variability during the day. However, in some cases a smaller amount of solar generation can in fact help decrease the flexibility needs as the daily production is generally correlated to the demand and thus tends to smoothen the residual demand curve throughout the day. This phenomenon, also known as the duck curve, is illustrated by Figure 17, which shows the demand (solid blue line) and residual loads for different solar capacity deployment.

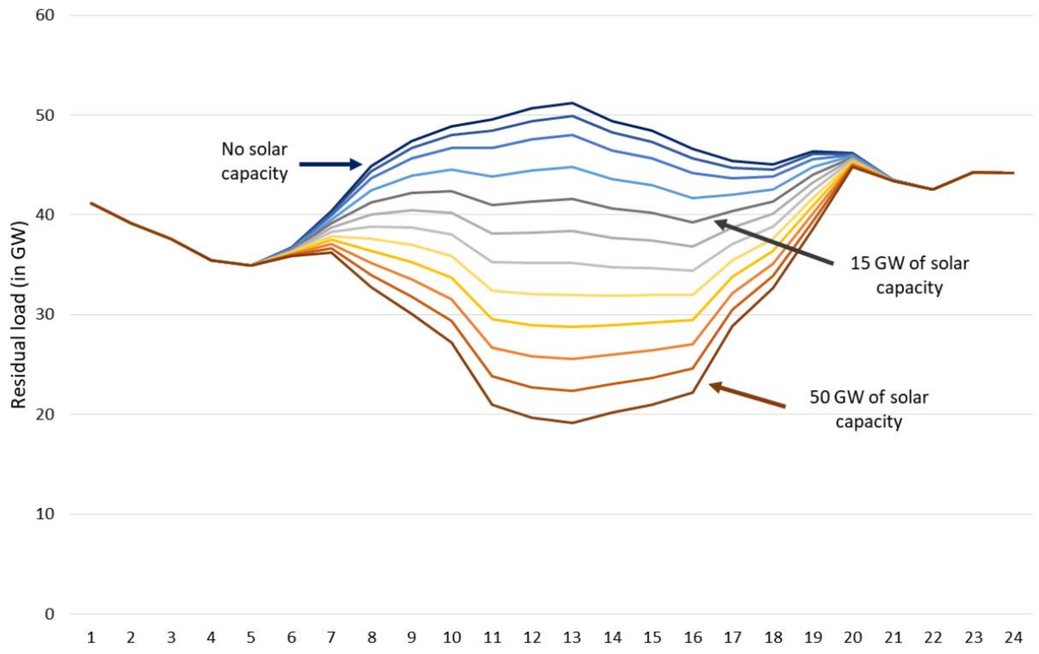

Figure 17 - Illustration of the impact of solar capacity deployment on the residual load[19]

Figure 18 below illustrates the net demand and total generation from a typical summer week in a country with high solar installed capacity.

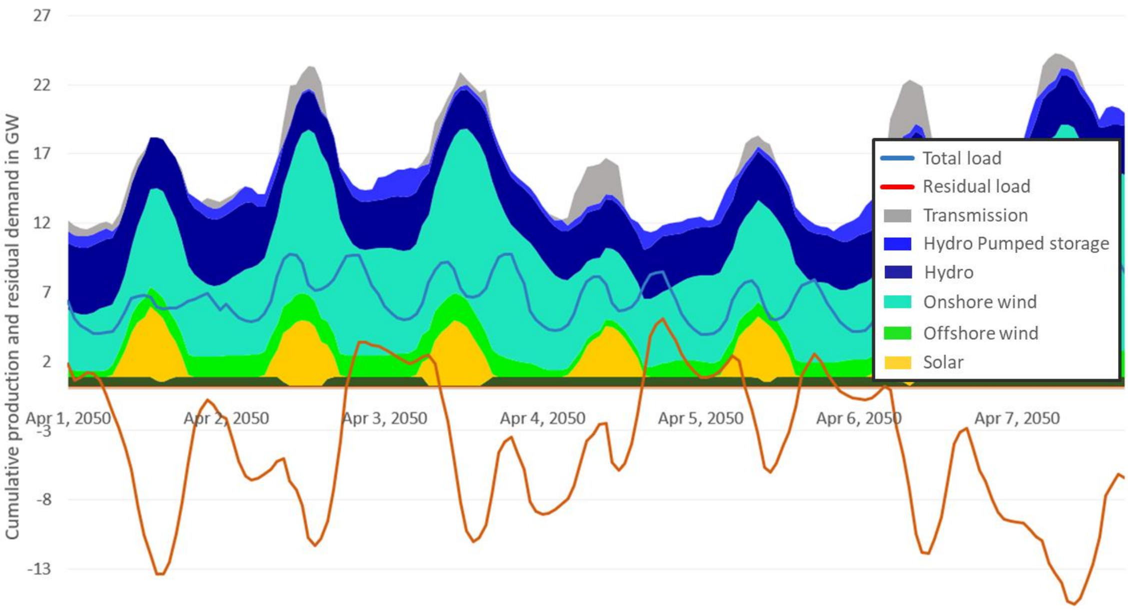

Figure 18 Residual demand and hourly generation
(total load in blue, and residual load in red)

It is possible to see the effects of solar installed capacity on the daily flexibility needs by further analysing a few countries individually. Figure 19 shows the installed capacity of two countries with high solar penetration and two with lower solar capacity and below, Figure 20 shows their respective daily flexibility needs. We can see the correlation between solar

[19] Source: Mainstreaming RES study

capacity and daily flexibility needs, countries with higher solar production have proportionally higher daily flexibility needs.

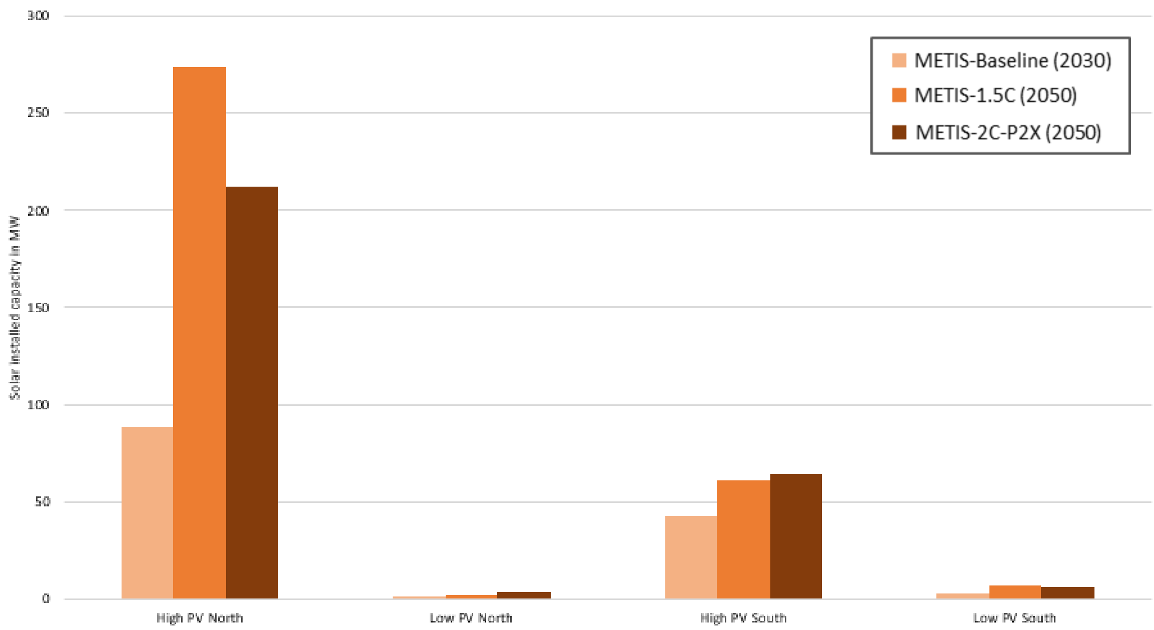

Figure 19 - Solar installed capacities for countries with high and low solar capacity

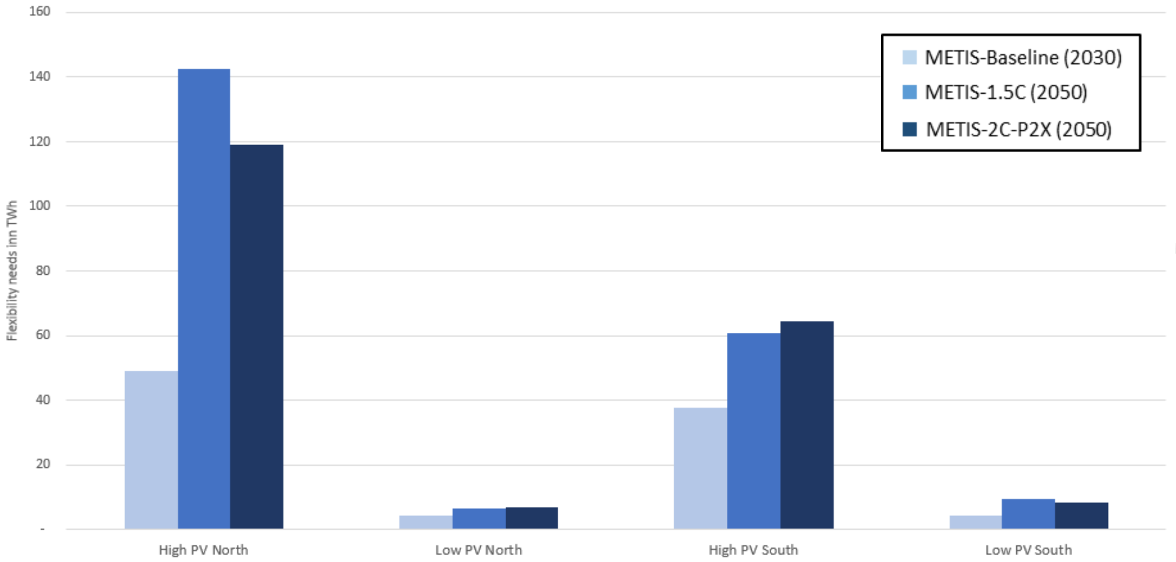

Figure 20 - Daily flexibility needs for countries with high and low solar capacity

Weekly flexibility assessment

Similarly, weekly flexibility needs are also found to be substantially higher in both 2050 scenarios when compared to the METIS-Baseline 2030 scenario. Below, Figure 21 shows the total weekly flexibility needs for all EU28 countries for the three scenarios METIS-Baseline, 1.5TECH and METIS-2C-P2X. The weekly flexibility needs increase from 210 TWh in 2030 to 610 TWh and 600 TWh in the METIS-1.5C and METIS-2C-P2X scenarios respectively at the 2050 horizon.

In this case too, the overall increase of flexibility needs can be explained by the increase of RES capacity from 2030 to 2050. When analysing weekly flexibility needs, one finds that solar capacity has much less impact than wind power since the generation of PV varies mainly throughout the day and show a less important variation from one day to another. Wind power, in contrast, has a significant effect on weekly flexibility, since wind generation tends to have wind regimes that can last a few days, showing a substantial variation during the week.

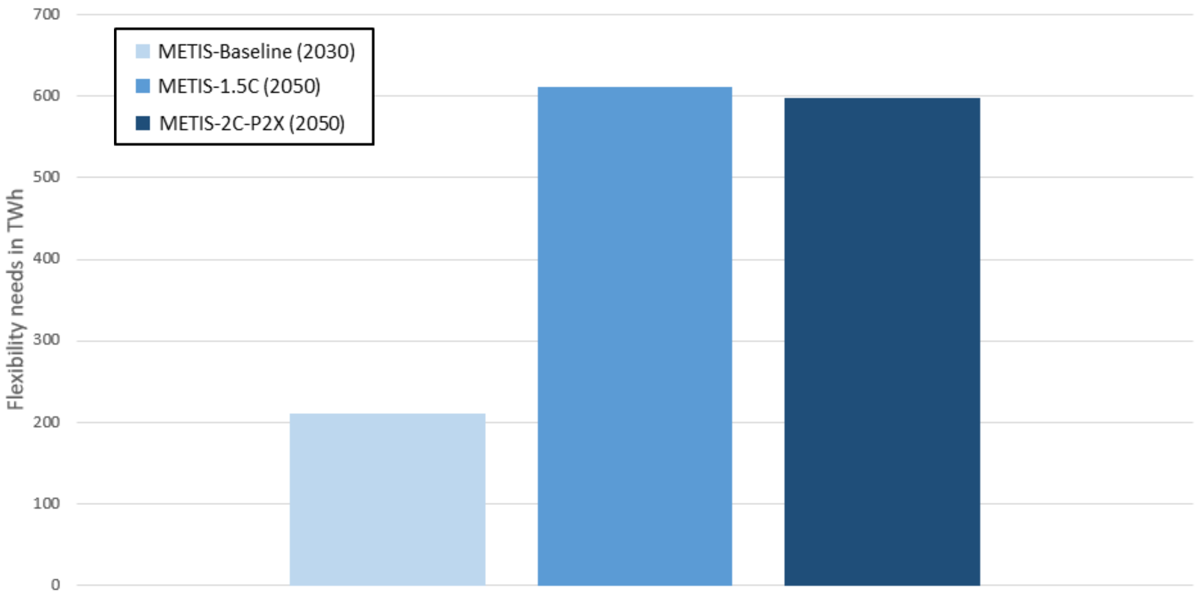

Figure 21 - Weekly flexibility needs at EU28 level

By analysing representative countries, it is possible to assess the impact of wind installed capacity on weekly flexibility needs. Figure 22 shows the installed capacity in two countries with high level of wind installed capacity and two with lower wind capacity and below, Figure 23 shows their respective weekly flexibility needs.

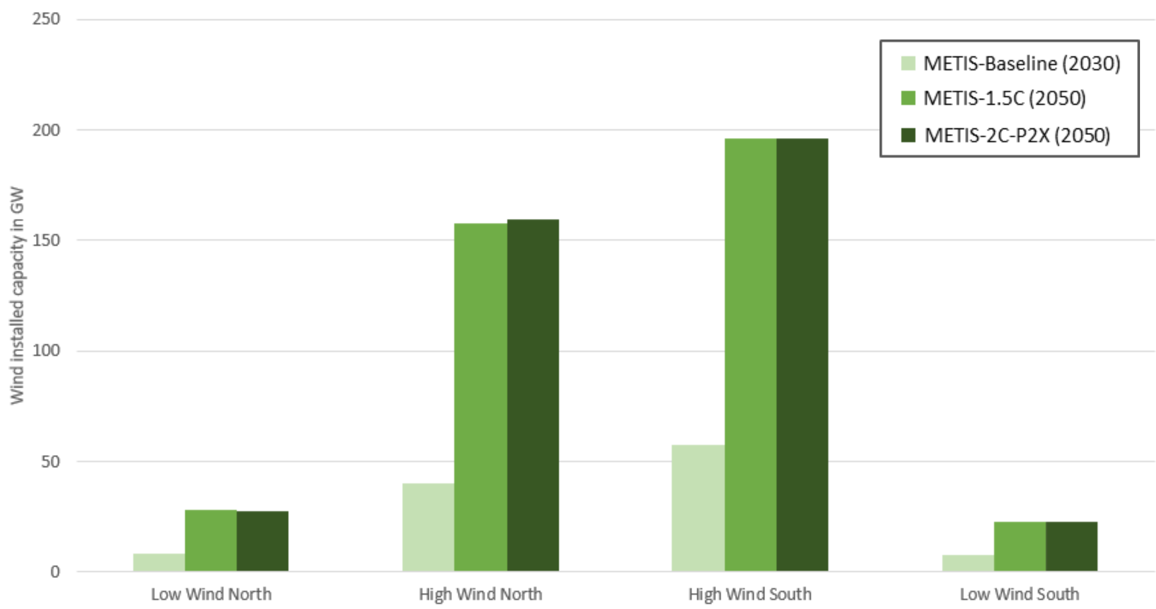

Figure 22 - Wind installed capacities for countries with high and low wind capacity

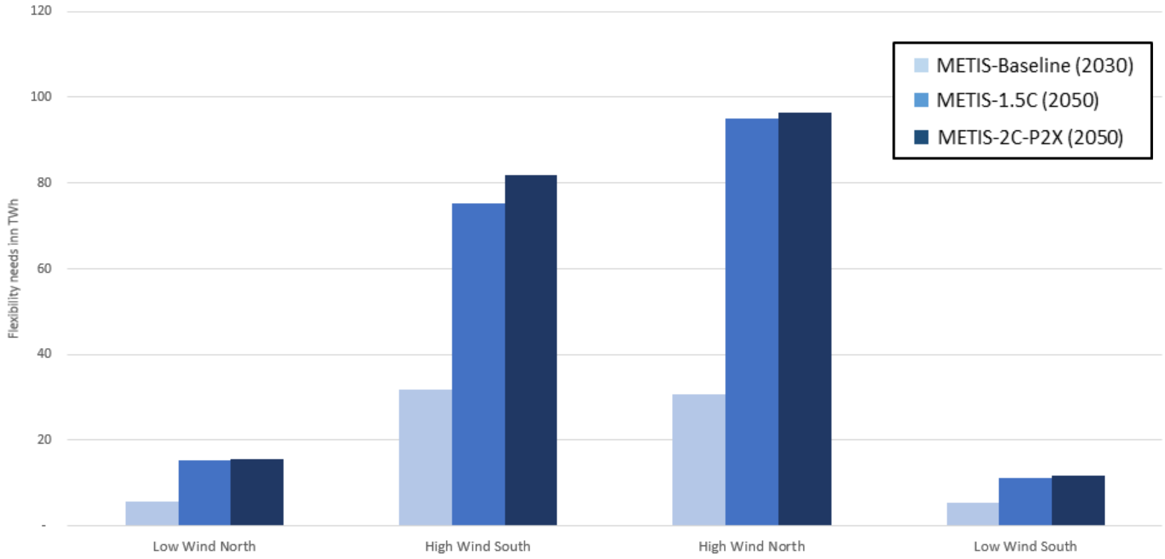

Figure 23 - Weekly flexibility needs for countries with high and low wind capacity

Seasonal flexibility assessment

Whereas solar PV and wind power are clear drivers of the increase of daily and weekly flexibility needs, the seasonal flexibility needs depend on several factors that might have different and sometimes opposing impacts on its value:

- The thermo-sensitivity of power demand (which may vary by country depending on the portfolio of heating technologies, the importance of air conditioning, etc.)
- Solar production (which varies during seasons and therefore can increase or decrease flexibility needs depending on the demand profile of each country). For a country with high demand during summer, solar production can decrease seasonal flexibility needs whereas for countries with lower summer demand it will increase these seasonal flexibility needs.
- Wind production (usually higher during winter so it tends to reduce seasonal flexibility needs for most countries, who typically have higher demand during this time of the year).

The total seasonal flexibility needs of all EU28 countries are shown on Figure 24 for each of the considered scenarios. Compared to the daily and weekly needs, the growth from 2030 to 2050 is found to be less important.

From the METIS-Baseline (2030) to the METIS-1.5C scenario (2050), the seasonal flexibility needs increase by 42%, going from 340 TWh in 2030 to 490 TWh in 2050. A 6% difference can be seen between the 2050 scenarios, with 490 TWh in the METIS-1.5C scenario and 460 TWh in the METIS-2C-P2X scenario. The difference of solar installed capacities between the two 2050 scenarios is the main driver explaining that difference: the 55 GW of additional solar capacity in the METIS-1.5C scenario increase the production during summer, while in most countries the power demand is higher in winter.

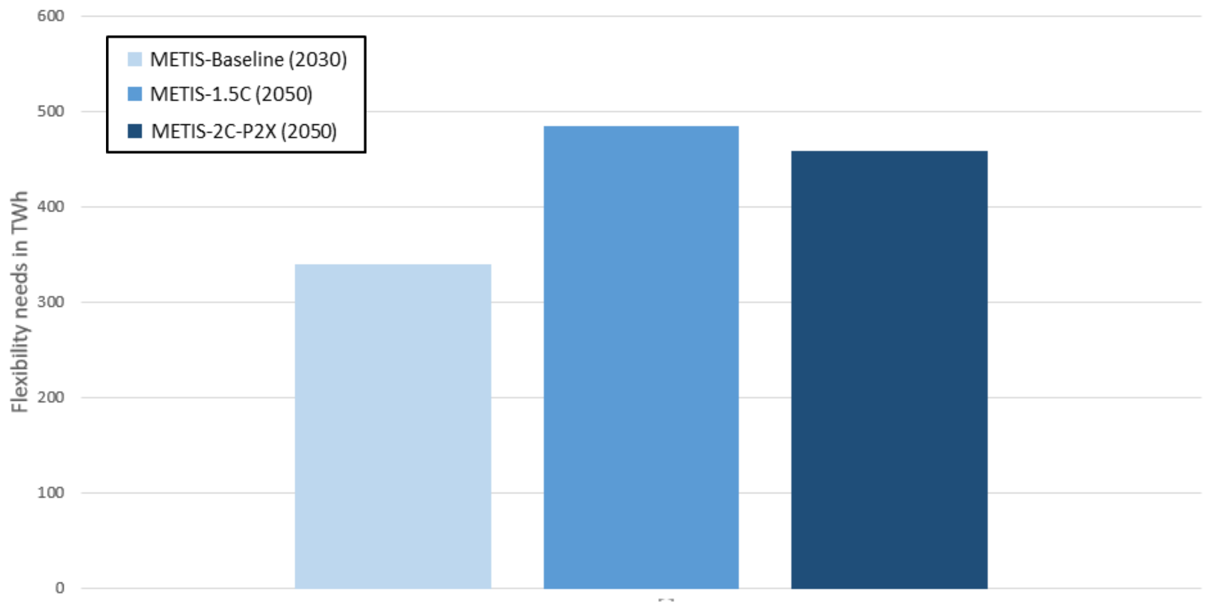

Figure 24 - Seasonal flexibility needs at EU28 level

2.3. CHARACTERISATION OF THE DIFFERENT FLEXIBILITY SOLUTIONS

The second step of the methodology is to characterise the different flexibility solutions. Flexibility can be provided by different technologies, conventional ones such as flexible generation, interconnectors or pumped storage but also less widespread today such as batteries or system integration (via electrolysers and the flexibility of the coupled sectors). This section presents the characteristics of the different technologies that can .

Pumped hydro storage

Pumped Hydro Storage (PHS) is one of the most conventional storage solutions, but its potential is limited by the availability of sites and might therefore vary considerably from one country to another. For all scenarios, PHS were separated in two categories:

- Existing PHS: with existing capacities given by ENTSO-E's TYNDP 2018 scenario "Best Estimate" scenario for the year 2020.
- New PHS: potentials are built from ENTSO-E's TYNDP 2018 Global Climate Action for scenarios METIS-2C-P2X and METIS-1.5C (30 GW) and from TYNDP 2018 Sustainable Transition for METIS-Baseline (15 GW).

A storage of 24 hours is assumed for all added capacities. All technical parameters are listed on Table 1 and Table 2. Below, Figure 25 provides a breakdown of the existing and potential PHS capacity for each country.

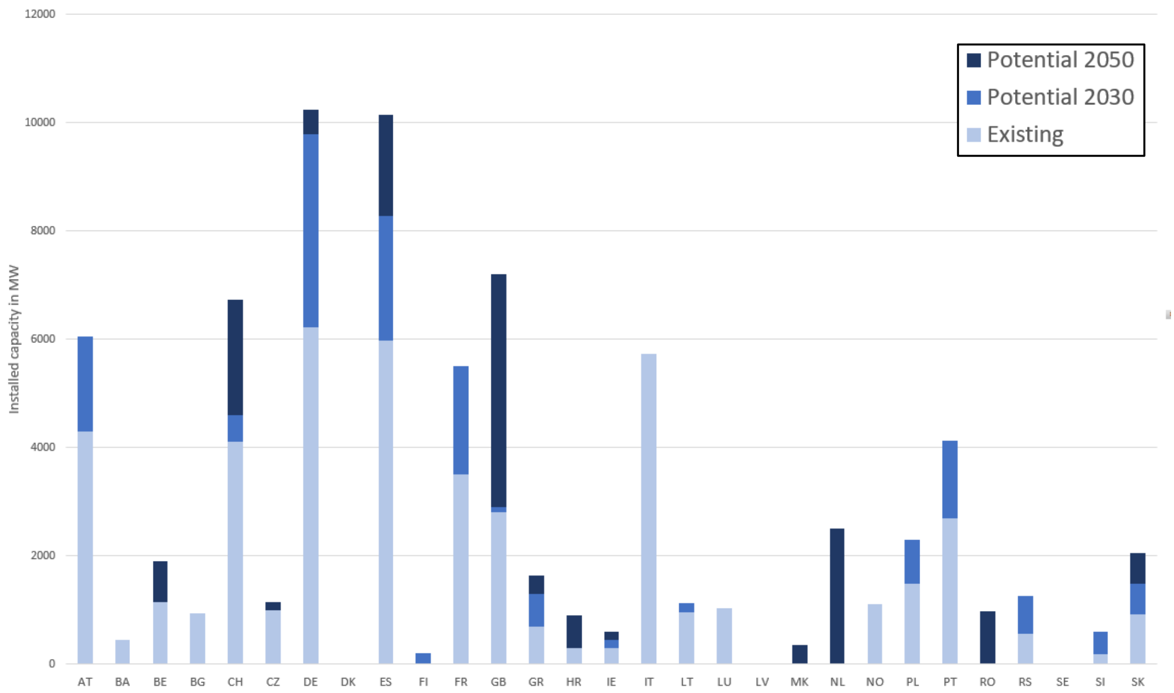

Figure 25 - Pumped hydro storage potential in 2030 and 2050

Batteries

Batteries can be used to provide short-term flexibility to the system. For all scenarios, four types of battery have been considered as potential investment options, with storage duration of respectively 1, 2, 4 and 8 hours. No capacity limit is considered for these assets. Their CAPEX and other technical parameters are specified in Table 1 and Table 2.

Gas-fired plants

Both open-cycle gas turbines (OCGT) and combined-cycle gas turbines (CCGT) can provide additional flexibility and help balance the highly variable generation of RES. While OCGT can provide a quicker response, they have lower efficiency than CCGTs. CCGT with carbon capture and storage (CCS) are also considered, with a capture rate of 90%. All gas-fired plants capacities are optimised without any capacity limits. Their technical parameters are listed in Table 1 and Table 2.

The LTS scenarios foresee limited amount of biogas being available for power production[20] in 2050, but that amount is found to be sufficient to produce electricity with conventional gas-fired units during the hours where the power system is found to be needing such flexibility services. Gas turbines running on hydrogen instead of natural gas did not appear to be economically relevant in our results[21].

Electrolysis and Methanation

Electrolysers and methanation plants are investment options, without limitation on their potentials. The whole power-to-X chain has an important role in enhancing overall flexibility, as electrolysers can serve not only to directly supply hydrogen demand enabling the indirect electrification of a set of end-uses, but also convert the excess of renewable generation into hydrogen that can be stored and later converted to synthetic fuels. In this context, methanation completes the power-to-gas-to-power loop, allowing the production

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[20] C.f. **Error! Reference source not found.** for the potentials considered in the study

[21] This hypothesis has been tested in the sensitivities, with possible investments in hydrogen powered OCGT/CCGT whose CAPEX were assumed to be 20% higher than conventional turbines powered with natural gas. In all three scenarios, the model did not invest in hydrogen OCGTs or CCGTs.

of synthetic gas that can fuel gas-fired plants during peak residual load episodes. All technical parameters of both electrolysers and methanation plants are listed below in Table 1 and Table 2.

Only one type of technology was considered in the modelling. The CAPEX and efficiency are equivalent to the Alkaline Electrolyser, the cheapest technology considered in the Long-Term Strategy. A scenario with higher CAPEX for electrolysers is considered in the sensitivity analysis (see Section **Error! Reference source not found.**).

Interconnectors

Interconnectors have a significant role to play in the provision of flexibility, allowing countries to benefit from each other's resources. They enable exports and imports of energy between countries with different energy prices and levels of RES shares, ensuring the balance between supply and demand can be met at the lowest cost, avoiding curtailments and better exploiting generation and storage technologies.

In all scenarios, interconnectors capacities are optimised based on ENTSO-E's TYNDP 2018 Project List. The existing capacity is based on interconnectors from TYNDP 2018 BE for 2020 and the potential for additional capacities are based on TYNDP 2018 GCA 2040 scenario for scenarios METIS-2C-P2X and METIS-1.5C (170 GW potential) and on TYNDP 2018 ST 2030 for METIS-Baseline (74 GW potential)[22]. Figure 26 shows the existing installed capacities and the potential for additional capacity for each country.

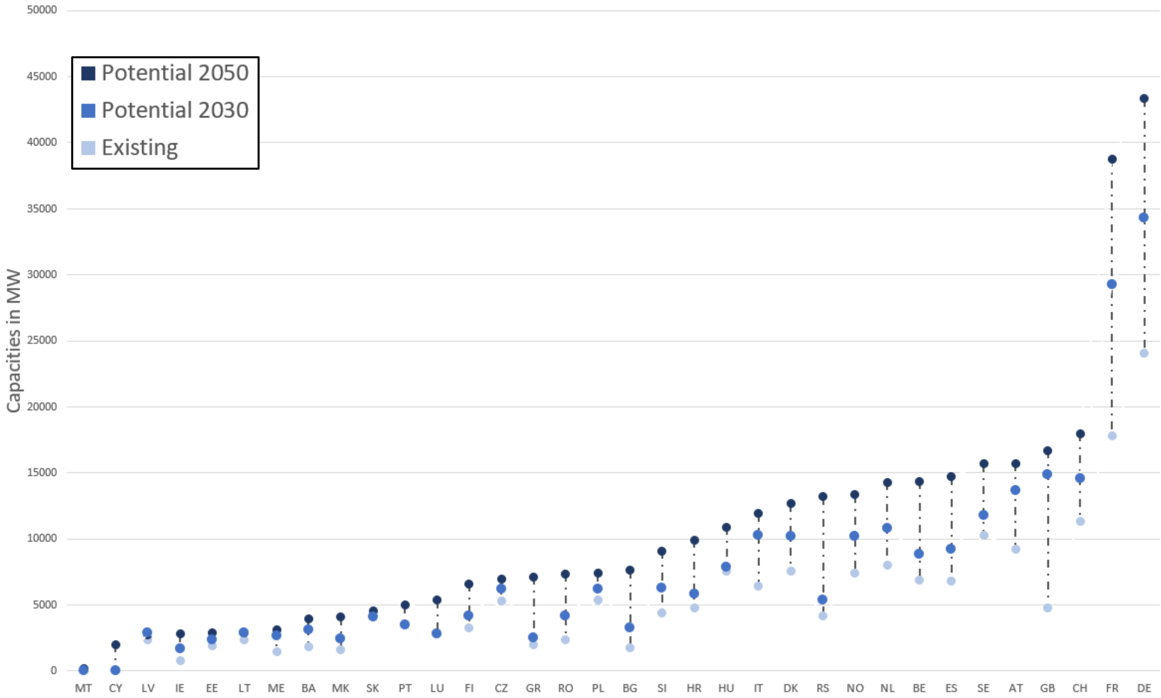

Figure 26 - Interconnectors potential for EU countries

[22] Please note that the capacity of a transmission is counted in this total for each direction of the interconnexion flow. Then, if an interconnexion has an NTC value of 1 GW in one side and 2 GW in the other side, the total capacity would be 3 GW.

Table 1 - Technical parameters for flexibility solutions used for METIS-Baseline 2030

		Potential	Optimised capacity	Investment cost (€/kW)	Fixed O&M costs (% CAPEX)	Efficiency	Lifetime
Interconnectors	Additional capacities	+ 74 GW	✓	Based on line-by-line projects		-	50
Back-up power plants	OCGT	-	✓	700	3%	40%	25
	CCGT	-	✓	770	2%	63%	30
	CCGT with CCS	-	✓	1625	2%	49%	30
Storage capacities	Pumped Hydro	+ 15 GW	✓	1212	1,20%	81%	60
	Batteries	-	✓	120€/kW + 120€/kWh	4,30%	90%	10
Power-to-X technologies	Electrolysis	-	✓	300	6,50%	82%	20
	Methanation	-	✓	633	3,50%	79%	25

Table 2 - Technical parameters for flexibility solutions used for 2050 scenarios

		Potential	Optimised capacity	Investment cost (€/kW)	Fixed O&M costs (% CAPEX)	Efficiency	Lifetime
Interconnectors	Additional capacities	+ 170 GW	✓	Based on line-by-line projects		-	50
Back-up power plants	OCGT	-	✓	600[23]	3%	40%	25
	CCGT	-	✓	750	2%	63%	30
	CCGT with CCS	-	✓	1500	2%	49%	30
Storage capacities	Pumped Hydro	+ 30 GW	✓	1212[24]	1,20%	81%	60
	Batteries	-	✓	120€/kW + 120€/kWh[25]	4,30%	90%	10
Power-to-X technologies	Electrolysis	-	✓	180[26]	6,50%	82%	20
	Methanation	-	✓	263	3,50%	79%	25

Electric Vehicles and Heat Pumps

Electric vehicles and heat-pumps can play an important role in the provision of short-term flexibility. The behaviour of electric vehicles with smart charging or vehicle-to-grid capabilities, and heat-pumps combined with short-term storage (2 hours in the model), can be optimised as a hours with highest renewable generations and lower demand, therefore smoothing the residual demand profile.

At the 2030 horizon, 30% of electric vehicles and heat pumps are considered as being able to offer flexibility services, while in 2050 this percentage is assumed to rise to 70%.

[23] CAPEX source: "Technology pathways in decarbonisation scenarios", 2018
[24] CAPEX source: ETRI and METIS S8
[25] Sources: ETRI and METIS S8
[26] CAPEX and efficiency sources: "Technology pathways in decarbonisation scenarios" and METIS S8

2.4. DESIGN OF THE OPTIMAL FLEXIBILITY PROTFOLIO

The last step of the methodology is the optimisation of the flexibility portfolio. For each of the 3 scenarios described in the previous sections, the objective is to jointly optimise the investments in each of the different flexibility solutions described in section **Error! Reference source not found.**, and the hourly operations of the whole power system (flexible generation, demand response, P2X, exchanges). Thereby, the optimisation takes into account the interrelation between electricity prices and profitability of the different flexibility solutions.

The next section describes the results obtained for the 3 different scenarios, in terms of installed capacities focusing on the selected flexibility solutions. We complement the analysis with deep dives on the hourly dynamics of the different flexibility solutions.

2.4.1. *DESCRIPTION OF THE MODEL USED TO OPTIMISE THE FLEXIBILITY PORTFOLIO*

The METIS model

The METIS model is developed by Artelys on behalf of the European Commission. METIS is a multi-energy model covering in high granularity (in time and technological detail, as well as representing each Member State of the EU and relevant neighbouring countries) the whole European power system and markets.

METIS includes its own modelling assumptions, datasets and comes with a set of pre-configured scenarios. These scenarios usually rely on the inputs and results from the European Commission's projections of the energy system, for instance with respect to the capacity mix or annual demand. Based on this information, METIS allows to jointly perform capacity expansion and hourly dispatch simulations (typically over entire years, i.e. 8760 consecutive time-steps per year). The result consists in the investments in selected technologies (flexibility solutions in this case, but METIS can also optimise RES investments, etc.) and the hourly utilisation of all technologies: generation, storage and cross-border capacities as well as demand side response facilities.

Modelling of the different scenarios

The modelling of the different scenarios is based on the METIS power system models and its capacity expansion module. Each scenario represents the projection of the power system for a given year in the future (2030 or 2050), at the Member State level with an hourly time resolution. Exchanges between countries are represent by interconnections, whose flows are bounded by NTC values. The adequacy between the power demand (and P2X demand in the 2050 scenarios) and the power production is ensured by a joint optimisation of the hourly power supply and investments in flexibility solutions, with the objective of minimising the total costs of the European system[27]. For more information about the METIS model, please refer to the EC METIS website : https://ec.europa.eu/energy/data-analysis/energy-modelling/metis_en.

Assumptions from the Long-Term Strategy

The three scenarios (METIS-Baseline, METIS-1.5C and METIS-2C-P2X) are partially based on the pathways elaborated in the context of the EC Long-Term Strategy. We provide below

[27] The total costs of the system include annualised investment costs (for optimised capacities), fixed operation and maintenance costs, variable operation and maintenance costs, fuel costs and carbon taxes.

the main input data from the LTS scenarios that have been integrated into the METIS model:

- Power demand, with the following end-use decomposition:
  - Direct power consumption:
    - Heat pumps
    - Electric vehicles
    - Other
  - P2X (hydrogen, e-gases and e-fuels)
- Power installed capacities:
  - Variable renewable energy sources (wind and solar)
  - Other renewables (mainly hydro, biomass and waste)
  - Nuclear
  - Coal/lignite
- Carbon taxes projection:
  - METIS-Baseline 2030: 28 €/t_{CO2}
  - METIS-1.5C 2050 and METIS-2C-P2X 2050: 350 €/t_{CO2}
- Biogas potential dedicated to power production:
  - METIS-Baseline 2030: 280 TWh
  - METIS-2C-P2X 2050: 450 TWh
  - 1.5TECH 2050: 560 TWh

To represent the variability of the wind and solar production and of the power demand, 3 different climatic years have been used: a cold year, a warm year and a year with an average temperature profile. The optimisation is performed jointly for these 3 climatic years, in order to obtain a flexibility portfolio that is robust to the different possible climatic configurations.

Optimised investments

The model performs a joint optimisation of the operations of the whole power system, and of the investments in the considered flexibility solutions. The optimised capacities/investments are the ones described in section **Error! Reference source not found.**:

- Back-up power plants: gas capacities (OCGT, CCGT, CCGT+CCS)
- Interconnectors
- Storage capacities (Pumped hydro and stationary batteries)
- Power-to-X technologies (electrolysers and methanation)

The flexibility of the power systems can be provided by these additional capacities, but also by the other flexible technologies whose capacities are directly coming from the LTS scenario (nuclear, hydropower, coal/lignite, biomass) or demand-side response (smart charging of electric vehicles and heat pumps with thermal storage).

The following figure illustrates the interactions between the different parts of the system we have modelled, and highlights the technologies in which the model is allowed to invest Since it is central to the analysis at hand, we emphasise the power-to-gas-to-power loop.

It should be noted that, in our scenario, the whole P2X demand (hydrogen, e-gas and e-liquids) is represented by an aggregated hydrogen demand. Since the possible flexibility on the end-user side is difficult to predict (possible storage of hydrogen, refurbishment of existing network and storage to be compatible with e-gases, flexibility of the fuel supply for vehicles, etc.), we have assumed a large flexibility on the demand-side of hydrogen, e-gas and e-fuels, with limitations on the annual volume that should be provided, in line with the values of the Long-Term Strategy pathways. Several sensitivity analyses have been performed to assess the impacts of a lower flexibility of the hydrogen demand.

In the different scenarios, hydrogen production from electrolysis can be complemented by hydrogen produced by SMR (steam methane reforming) combined with CCS (carbon capture storage) when RES generation is not high enough to produce all the required hydrogen. The associated production cost is 90€/MWh.

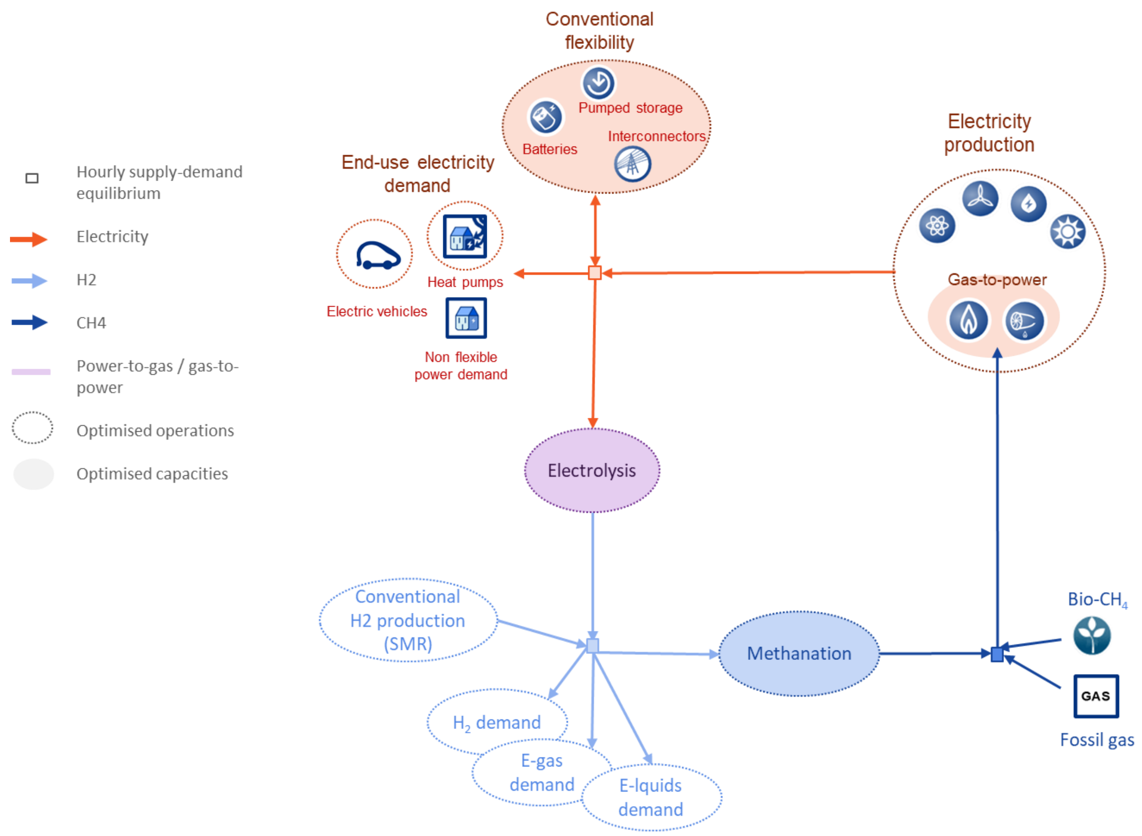

Figure 27 - Description of the model used in the study[28]

[28] Source: adapted from METIS study S1

2.4.2. *OPTIMAL PORTFOLIO FOR THE 3 SCENARIOS*

In this section we present the results of the optimised flexibility portfolio for the three considered scenarios, with different illustrative examples to more precisely assess how the different flexibility solutions interact to deliver a secure source of electricity.

2.4.2.1. METIS-Baseline 2030

Installed capacities

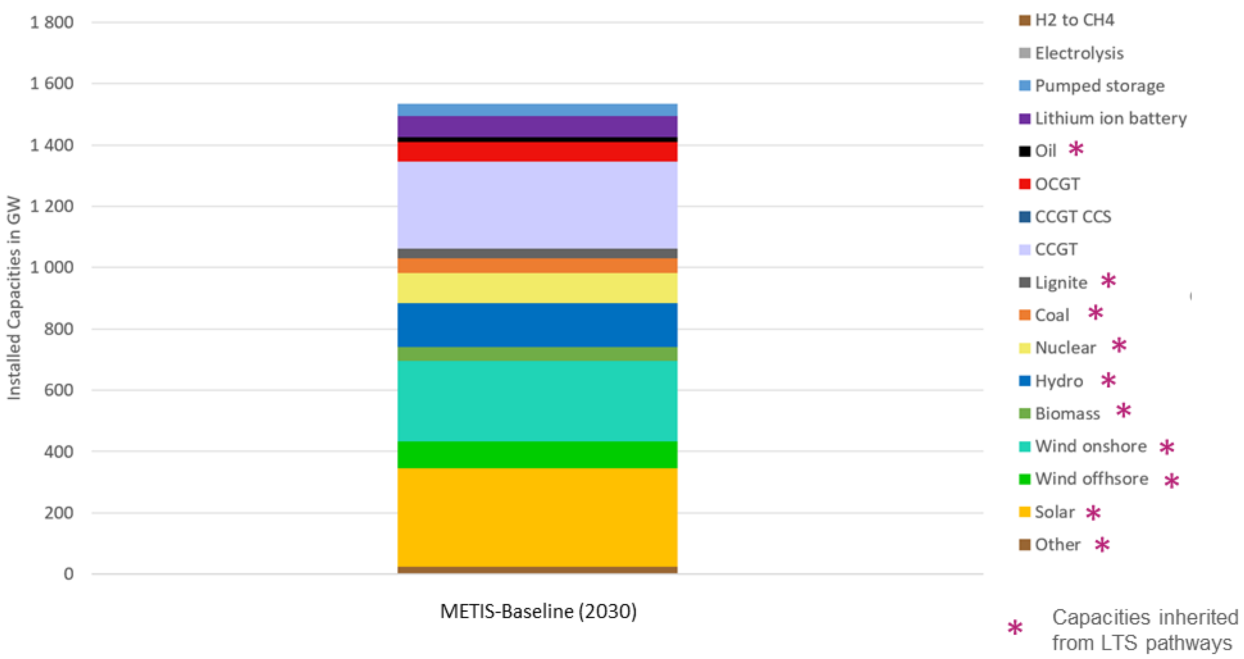

Figure 28 - Total installed capacities for EU-28 for power production, storage and METIS-2C-P2X for METIS-Baseline 2030

In 2017, 279 GW of variable renewable energy sources (109 GW of solar and 169 GW of wind) were installed in EU-28[29]. In the METIS-Baseline scenario of the Long-Term Strategy these capacities more than double by 2030, reaching 320 GW for solar and 352 GW for wind. This important increase of variable generation technologies requires an evolution of the flexibility solutions to enable the system to match the demand at all times. The optimal portfolio of flexibility solutions enabling a least-cost integration of these RES capacities is described in the following paragraph.

Focus on the optimal flexibility portfolio

Figure 29 shows the installed capacities of all optimised flexibility solutions in the METIS-Baseline 2030 scenario. A large part of the optimised flexibility portfolio is composed of gas capacities, with 285 GW of CCGTs and 63 GW of OCGTs. There is also a substantial investment in batteries that reach a total capacity of around 67 GW (31 GW with a 4-hour discharge time, 36 GW with a 2-hour discharge time). In this scenario, there are limited investments in new PHS capacity, as they are generally found not to be competitive with batteries for a few hours of storage. In 2030, electrolysers and methanation plants do not appear to be competitive flexibility solutions, mainly because of their capital costs, which are higher than those of other technologies that can provide similar flexibility services.

[29] Source : Eursotat (online data code : nrg_in_epc)

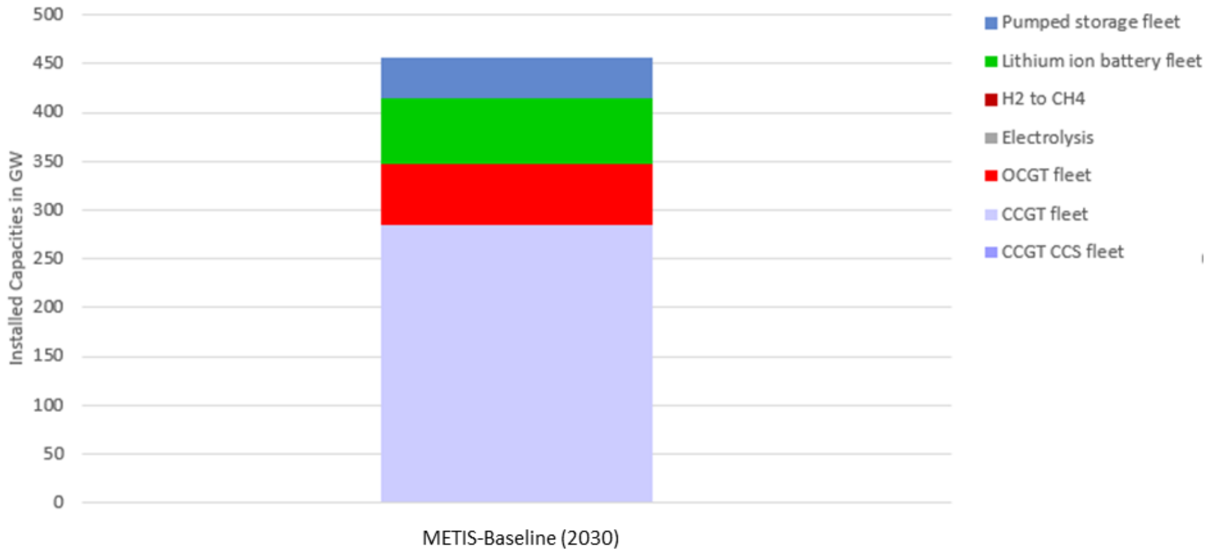

Figure 29 Installed capacities for EU-28 optimised flexibility solutions for METIS-Baseline 2030[30]

Batteries provide short-term flexibility

When looking at the detailed results, one can notice that the investments in batteries are concentrated in a few countries, more specifically countries with the highest PV installed capacities. This result is in line with the analysis of flexibility needs that has been presented in the previous section: solar PV drives the need for short-term flexibility, and batteries are well adapted technologies to provide such services.

A thorough analysis of the hourly results reveals how batteries can supply short-term flexibility. Figure 30 and Figure 31 below show respectively the residual demand and hourly generation for a country with high vRES share during a week. Typically, batteries are used the most during the hours of peak residual load. The surplus of renewable generation is stored throughout the day and then used during the morning and evening peaks, when the total RES production tends to be low and demand tends to be high.

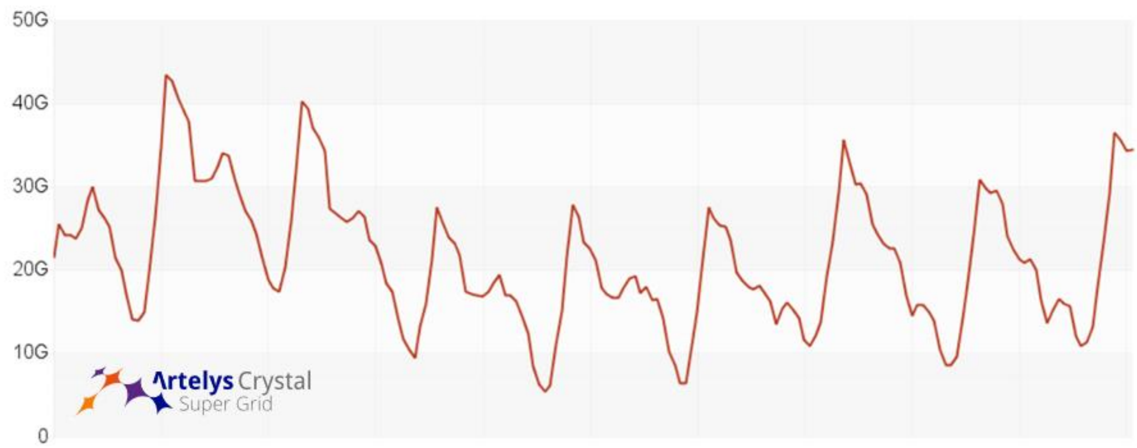

Figure 30 Example of residual load in third week of May for METIS-Baseline 2030 scenario

[30] **METIS-Baseline (2030) -** CCGT: 285 GW; OCGT: 63 GW; Batteries: 67 GW; Pumped storage: 41 GW; Electrolysers and methanation: 0 GW

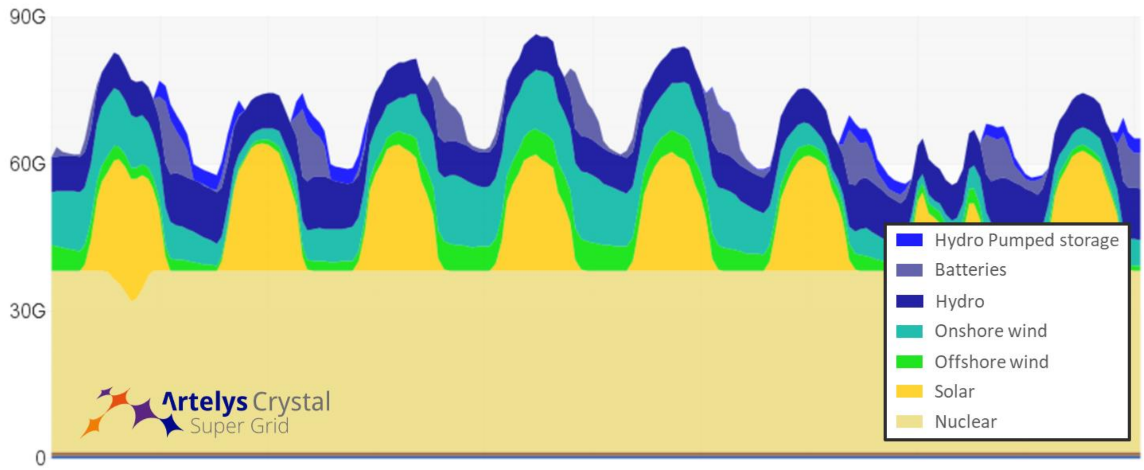

Figure 31 Example of cumulative production in third May for METIS-Baseline 2030 scenario

Figure 32 shows the average daily profiles for batteries with 4-hour discharge time. Batteries are consuming power around midday when the solar production is the highest and releasing energy at later times, to meet the early evening power demand peak. To a lower extent, batteries are also used to store energy during the night in order to release energy during the morning demand peak.

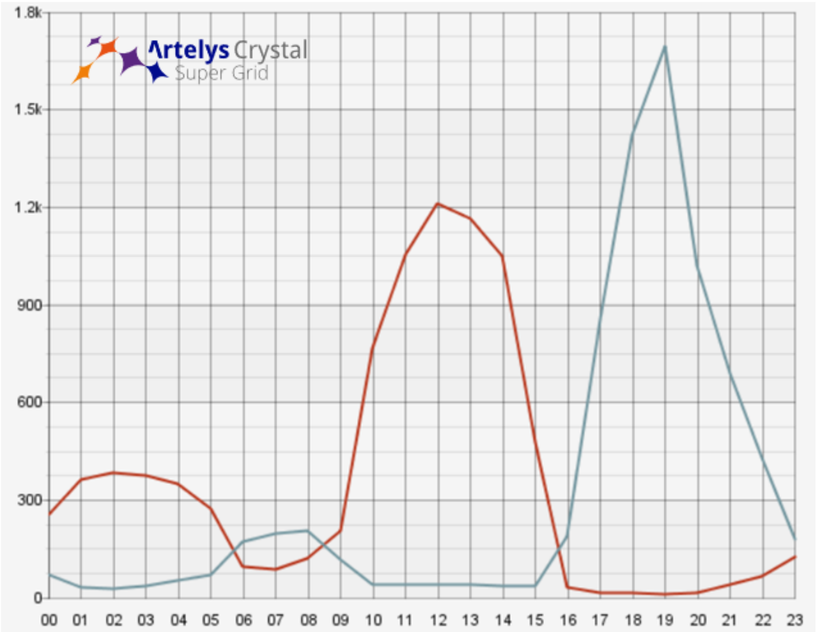

Figure 32 Daily utilisation profiles of 4-hour batteries
The blue curve represents the power production and the red curve the power consumption of the batteries

In METIS-Baseline 2030 scenario, demand-response plays a limited role as a source of flexibility, since only 30% of electric vehicles and heat pumps are considered as being flexible. Figure 33 shows a comparison between the power demand, as it would be without demand-side response, and the power demand after the use of electric vehicles and heat-pumps has been optimised. Demand-side response helps reduce evening demand peaks, by shifting it to hours with lower demand during the day, when the PV production is higher.

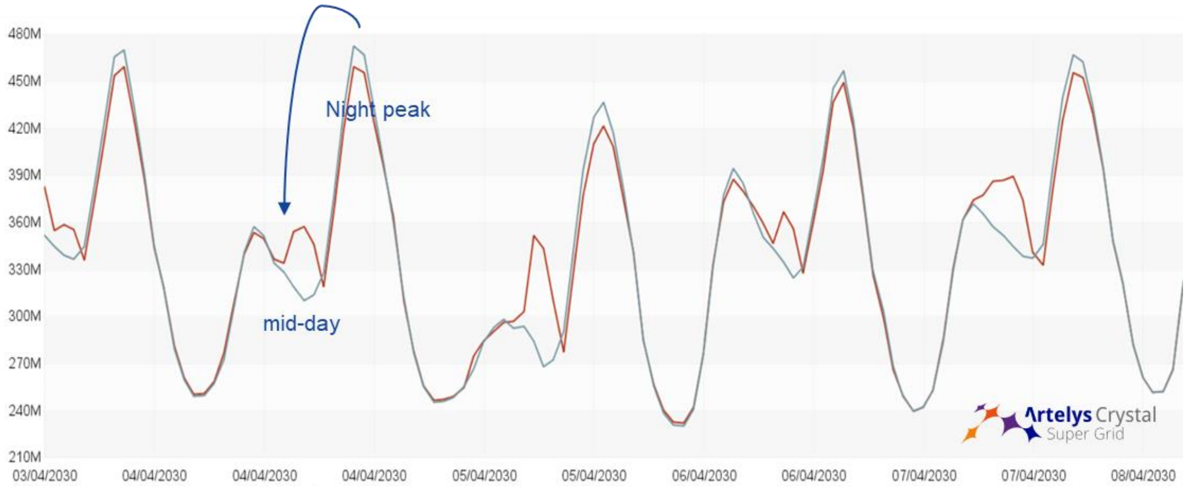

Figure 33 Demand without demand-response (in blue) and optimised demand (in red) during four days in April

In the 2030 scenario, investments in interconnectors were found to add 41 GW to the 2020 grid. Typically, interconnectors are used to export exceeding PV production from countries with high solar generation or to balance wind generation from countries with extremely different profiles. Figure 34 shows on the left the total installed capacity in 2030 and on the right, the detailed results per member state. Some countries like France, Italy, Spain and the UK invest almost up to the maximum of the available capacity. This behaviour is mainly driven by their high shares of vRES, that require flexibility services such as those that can be brought by interconnectors.

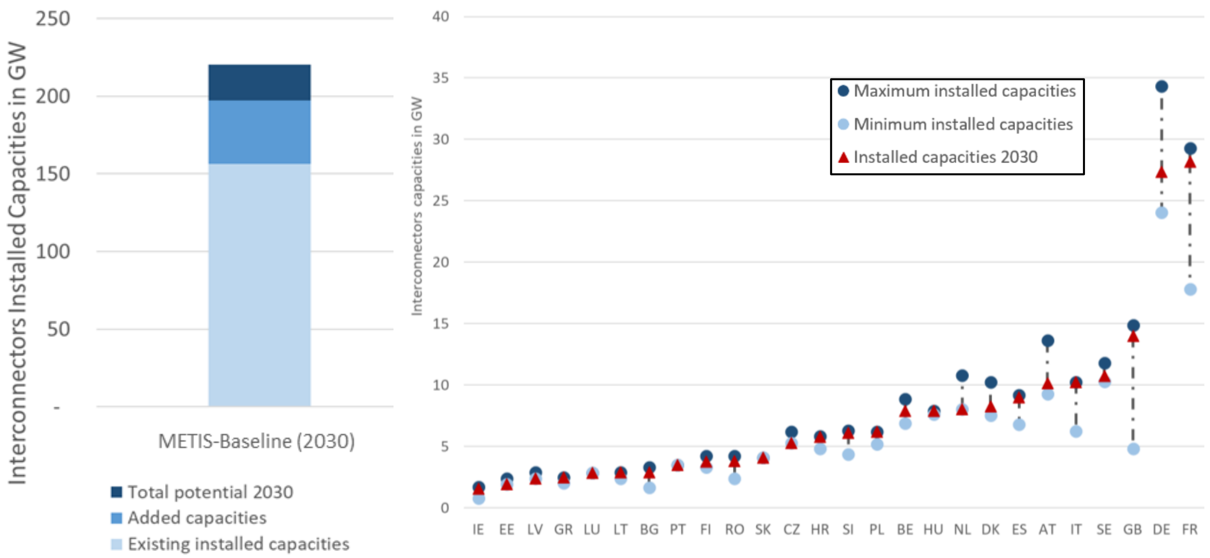

Figure 34 Installed capacities of transmissions[31] in EU-28 in METIS-Baseline 2030 with minimum and maximum bounds

Figure 35 and Figure 36 illustrate a situation of cooperation from a country with high wind generation combined with the use of storage. The exceeding production is stored in batteries during periods of high wind generation and then exported to a neighbouring country with a different generation profile. In this case we can see that the use of storage solutions can be useful even when the national demand has already been met by the national production. The interconnections combined with batteries help balance generation

[31] Please note that the capacity of a transmission is counted in this total for each direction of the interconnexion flow. Then, if an interconnexion has an NTC value of 1 GW in one side and 2 GW in the other side, the total capacity would be 3 GW.

in countries with different wind profiles, smoothing surpluses and shortages in both countries.

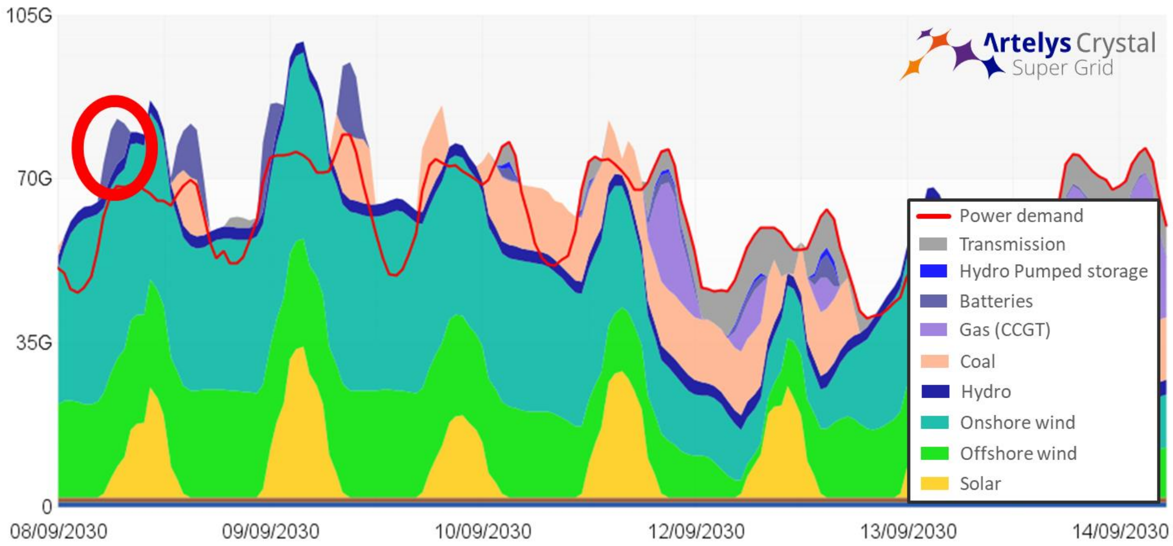

Figure 35 Example of cumulative generation of country A in a period of RES surplus

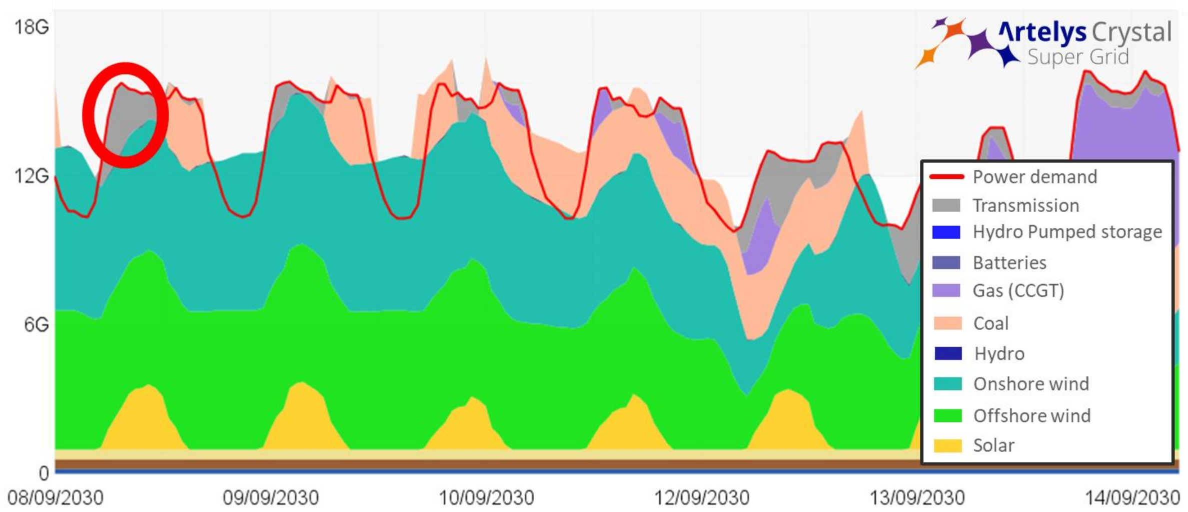

Figure 36 Cumulative generation of country B with moment of imports from country A (cf. Figure 35)

2.4.2.2. 2050 scenarios: METIS-1.5C AND METIS-2C-P2X

Installed capacities

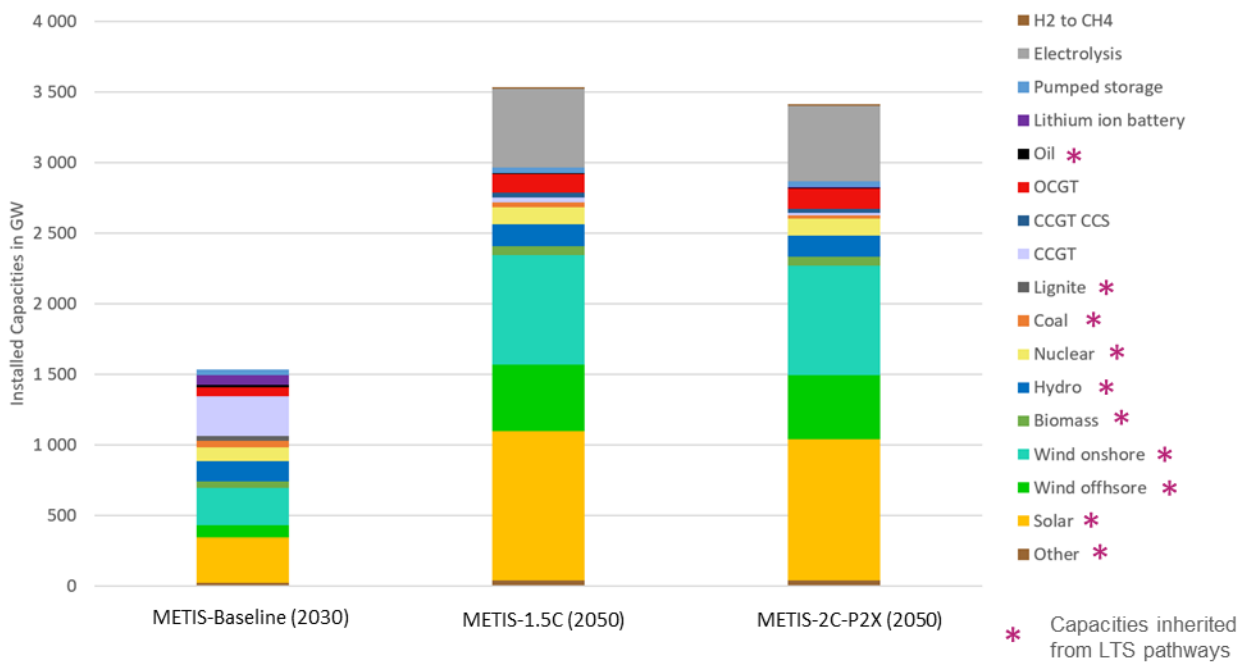

Figure 37 - Total installed capacities for power production, storage and P2X for METIS-1.5C, METIS-2C-P2X and METIS-Baseline scenarios

In both the considered 2050 scenarios, the power generation mix is considerably transformed compared to the 2030 METIS-Baseline scenario. Variable renewable capacities (solar and wind) rise to 2 302 GW for METIS-1.5C, and 2 227 GW for METIS-2C-P2X, to be compared with 672 GW in 2030 METIS-Baseline. Most of the power production in 2050 is coming from wind and solar capacities, for direct production of electricity but also for indirect electrification of end-uses via P2X processes.

Focus on the optimal flexibility portfolio

At the 2050 horizon, the flexibility portfolio changes drastically compared to the one found for the 2030 horizon. With almost half of the power production dedicated for P2X, electrolysers become the first flexibility solution in term of installed capacity. Electrolysers are not only used to supply the demand of hydrogen, e-gases and e-fuels but also provide flexibility to the electricity system.

In 2050, gas-fired plants continue to have an important role in the provision of flexibility. Their fuel supply is however totally different than the one of 2030: while in 2030 gas-fired plants were mainly using natural gas[32], in 2050 gas-fired plants are mainly using biogas, and to a lower extent e-gases coming from the power-to-gas-to-power loop. Another important difference is the split between CCGTs and OCGTs: while CCGTs represent the largest share of gas-fired power plants in 2030, they only represent a small fraction of the plants in 2050 (Figure 38). This is mainly due to the small number of full load hours during which these units run at the 2050 horizon. As a consequence, the model favours not paying for the extra cost of a combined cycle compared to an open cycle. In 2050, CCGT with carbon capture storage are found to emerge. Indeed, with a CO2 prices reaching 350 €/tonneCO2, the lower efficiency of these plants and their greater costs is often offset by the savings in term of carbon taxes.

[32] A limited potential of biogas is also present in 2030 (c.f. section 2.2.1.3), but only covers a small fraction of the total consumption of gas.

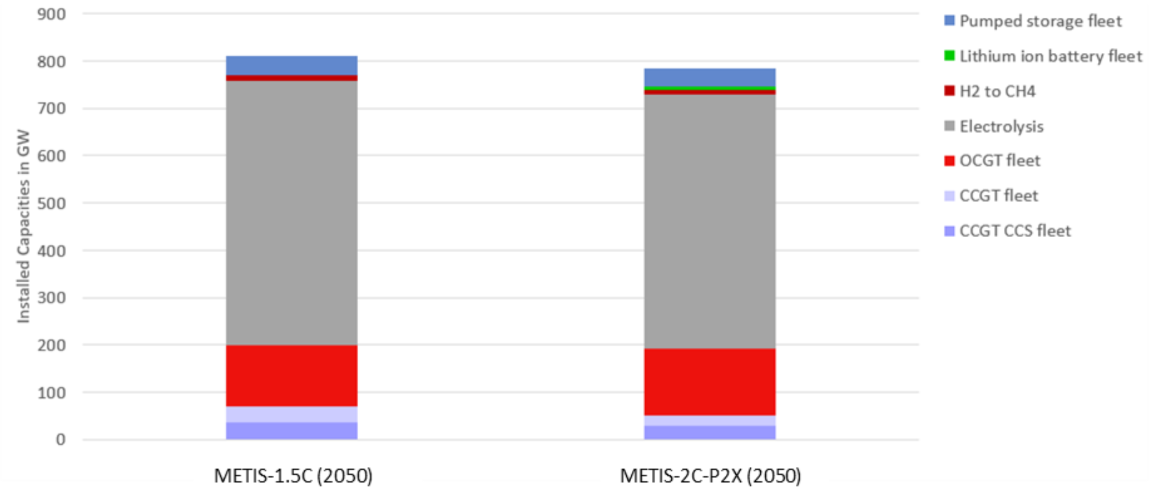

Figure 38 Installed capacities for flexibility solutions for METIS-1.5C[33] and METIS-2C-P2X[34] in 2050

Investments in batteries and pumped-storage capacities are rather low in 2050, since they directly compete with electrolysers that are needed for the provision of hydrogen, e-gases and e-liquids. Indeed, electrolysers connected to power markets can be operated in a smart manner to provide flexibility to these markets. Therefore, the capacity of pumped hydro storage is found to remain close to its current value, and investments in batteries are limited to 6 GW in METIS-2C-P2X scenario, and below 1 GW for METIS-1.5C scenario. Since electrolysers emerge as the most important flexibility solution (in terms of capacity), we devote the next paragraphs to the analysis of their operational behaviour.

Electrolysers

The flexibility provided by the hydrogen demand[35] allows electrolysers production to adapt to different situations. A country with high wind share, for example, will be able to produce hydrogen in moments of power surplus that are correlated with its wind profile. In Figure 39 and Figure 40 we can see how the electrolysers' operations adapt to the generation pattern of wind power, producing to their maximum during these moments.

The daily pattern of the electrolysers' operation is mainly driven by the solar production. Electrolysers will produce most in moments of low demand, typically during the day when solar production is at its maximum and residual demand is negative.

Figure 39 Example of electrolysers usage during the second week of May for METIS-1.5C 2050

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[33] **METIS-1.5C (2050)** – CCGT with CCS: 37 GW; CCGT: 33 GW; OCGT: 129 GW; Electrolysers: 560 GW; Methanation: 12 GW; Batteries: <1 GW; Pumped storage: 40 GW

[34] **METIS-2C-P2X (2050)** – CCGT with CCS: 30 GW; CCGT: 22 GW; OCGT: 140 GW; Electrolysers: 537 GW; Methanation: 11 GW; Batteries: 6 GW; Pumped storage: 40 GW

[35] We remind here that the flexibility on the P2X side (hydrogen, e-gas and e-liquids) is modelled as an annual demand of hydrogen that can be supplied without any additional constraint.

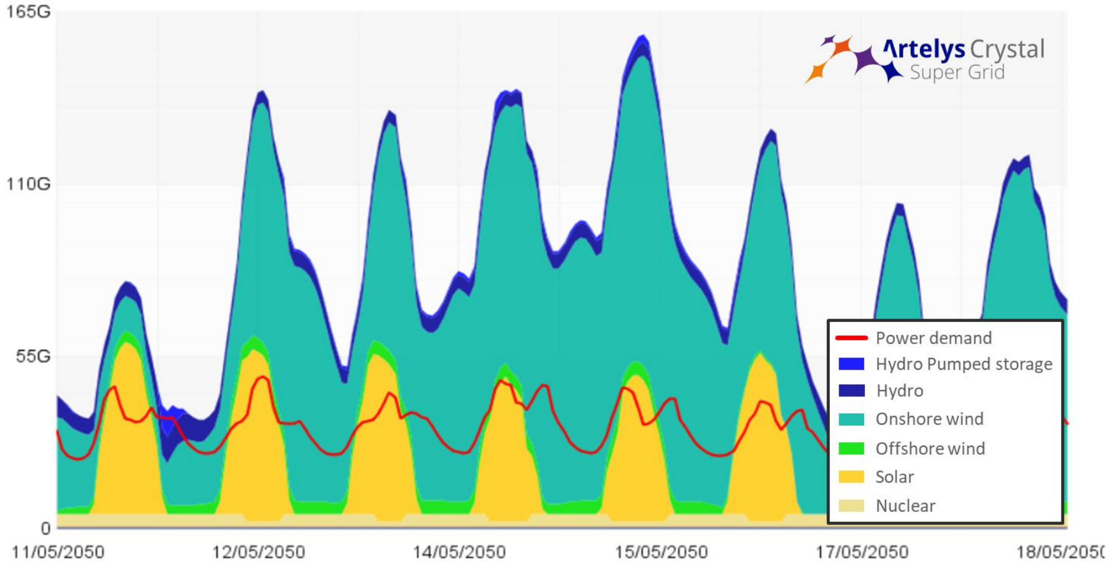

Figure 40 Example of cumulative generation during the second week of May for METIS-1.5C 2050

Methanation[36] (for power-to-gas-to-power)

Electrolysers are found to provide a large part of the flexibility in 2050 scenarios, thanks to the important flexibility offered by the hydrogen demand side (for direct use, and for the production of e-gases and e-liquids). In this context, methanation plants allowing to close the power-to-gas-to-power loop do not appear to be an important flexibility solution, since electrolysers can already absorb the power surplus of variable RES, and limit or stop their production of hydrogen when the residual load is positive.

Even though methanation plants are not providing much additional flexibility, in both the METIS-1.5C and METIS-2C-P2X scenarios, investments in these plants appear to be relevant for some countries with significant RES surpluses. In total the installed capacities dedicated to power-to-gas-to-power loop[37] is 12 GW in METIS-1.5C scenario, and 11 GW in METIS-2C-P2X scenario.

Interconnectors

Interconnectors appear as an even more important provider of flexibility at the 2050 horizon that it was at the 2030 horizon. The total investments in interconnectors represented a total of 142 GW in both METIS-1.5C and METIS-2C-P2X, three times higher than in 2030, where the added capacity was only 47 GW. Interconnectors are an important source of flexibility as they help balance generation from countries with different RES generation patterns. Figure 41 shows on the left the total installed capacity for both METIS-1.5C and METIS-2C-P2X and on the right, the detailed results per country.

[36] Conversion of hydrogen to e-CH4

[37] Please note that these capacities only refer to additional methanation plants used to provide flexibility on the power system via the production of e-gas used in gas-fired plants. Capacities used for the production of e-gas for other sectors are not counted here and are not represented directly in this study (the associated hydrogen consumption is however taken into account in the modelling, please refer to section **Error! Reference source not found.** for more information).

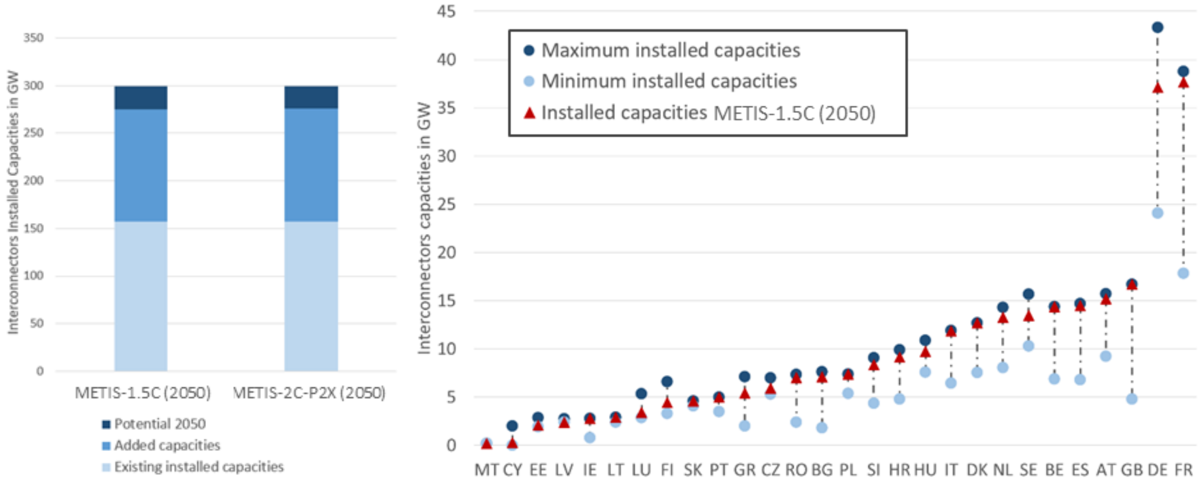

Figure 41 Installed capacities of transmissions[38] in EU-28 in 2050 with minimum and maximum bounds

Western European countries like France, Belgium and Germany are found to invest heavily in interconnection capacities. In countries with a highly renewable mix, imports and exports prove to be essential to balance supply and demand, in a way that avoids over-dimensioning local flexibility solutions such as thermal plants or storage units.

2.5. CONTRIBUTION TO THE PROVISION OF FLEXIBILITY

In other to quantify how each flexibility solution provides flexibility on different timescales, we present in the following section an indicator that characterises the contribution of a given technology to the provision of daily, weekly and seasonal flexibility.

2.5.1. *DEFINITION OF THE CONTRIBUTION TO THE PROVISION OF FLEXIBILITY*

The provision of flexibility of a given technology is calculated by comparing the flexibility needs based on the residual load (as explained in section 2.2.2.1) to residual flexibility needs. The latter are based on the residual load minus the specific technology generation profile.

Figure 42 illustrates the computation of the provision of flexibility by a given technology.

Step A – Compute the daily flexibility needs based on the ***residual load***
Step B – Compute the residual daily flexibility needs based on the ***residual load – technology X generation profile***

The difference between the two quantities is the contribution of technology X in the provision of flexibility. The contribution of each technology is then computed by iteratively removing all technologies to the residual load.

[38] As mentioned in the last sub-section, the capacity of a transmission is counted in this total for each direction of the interconnexion flow.

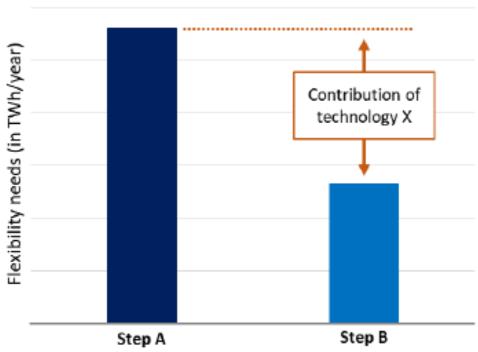

Figure 42 - Methodology to assess the contribution of a technology to flexibility needs

2.5.2. EVALUATION OF THE CONTRIBUTION TO THE PROVISION OF FLEXIBILITY IN THE DIFFERENT SCENARIOS

Provision of daily flexibility

As daily flexibility needs typically originate from the variation of PV generation during the day, short-term flexibility solutions (such as batteries, PHS, CCGTs and demand flexibility of HP and EVs) are the technologies that are best suited to respond to this need. Figure 43 shows the contribution to daily flexibility needs for each of the three scenarios.

In METIS-Baseline 2030, most of the daily flexibility is provided by CCGT plants and interconnections. Batteries are also an important provider of short-term flexibility in 2030, since they enable to shift PV production to hours with higher demand, smoothing demand peaks. Although there was only little investments in PHS in this scenario, the existing PHS also prove to be an important provider of daily flexibility.

At the 2050 horizon, batteries are mostly substituted by other flexibility solutions in the provision of daily flexibility services. As expected from the previous results, electrolysers become the main daily flexibility provider, followed by interconnections. In both the METIS-1.5C and METIS-2C-P2X scenarios, the flexibility in heat-pumps demand and EVs charging becomes essential in the provision of daily flexibility. Gas-fired plants continue to help meeting the needs for daily flexibility, but to a much lesser extent than at the 2030 horizon.

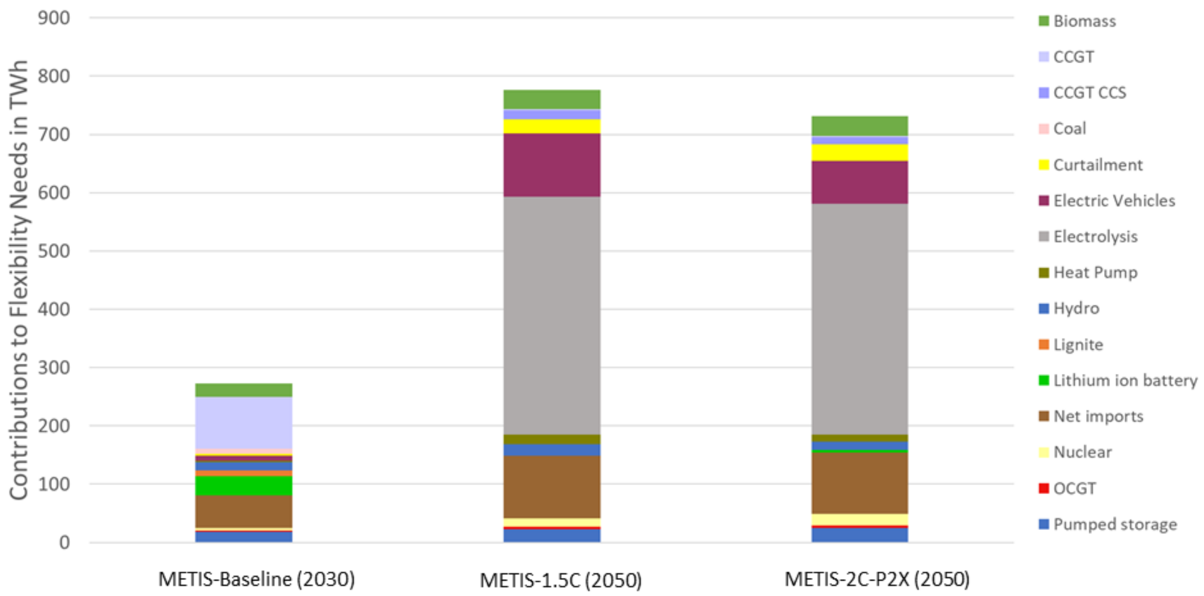

Figure 43 Contributions to daily flexibility needs in Europe

Figure 44 compares the normalised[39] daily flexibility needs of countries with different levels of PV shares. In countries with high solar penetration such as Ctry1 and Ctry3, daily flexibility needs are particularly high and in these cases batteries, CCGTs and interconnections appear as the main flexibility providers in 2030. In 2050 electrolysers provide a large part of the flexibility for almost all countries, especially for countries with high share of PV such as Ctry1, Ctry2 and Ctry3.

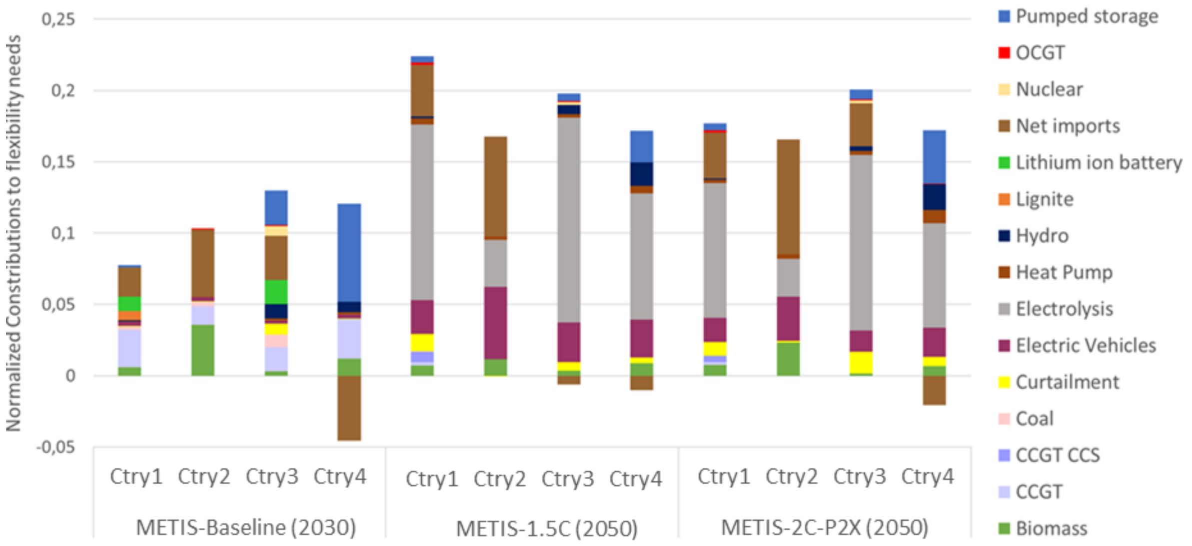

Figure 44 Normalised contributions to daily flexibility for 4 different EU countries

Provision of weekly flexibility

Weekly flexibility needs typically derives from the wind power variations between days. Interconnections in this case, are important flexibility providers, since they allow countries with different wind patterns to exploit synergies between their electricity systems.

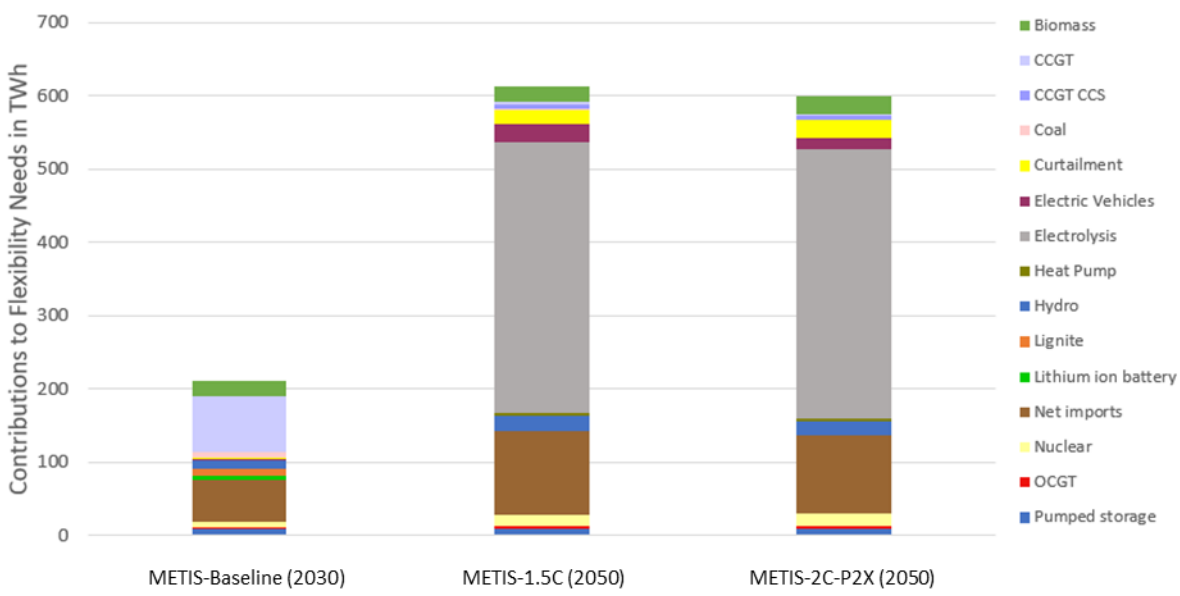

Figure 45 Contributions to weekly flexibility needs in Europe

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[39] This normalization is based on the annual demand of the given country

In 2030, as was the case for the daily flexibility needs, most of the flexibility is provided by CCGT plants and interconnections. Batteries, however, have a less significant contribution to weekly flexibility needs, as they have at maximum an 8-hour discharge time. By 2050, once again, electrolysers substitute gas and batteries as the main flexibility provider. Interconnections are also a key provider of weekly flexibility and demand flexibility (EVs and HPs) become less significant for weekly flexibility, as they typically enable flexibility within a day.

Provision of seasonal flexibility

Seasonal flexibility needs are a result of different factors and it captures mostly inter-seasonal variations in demand and RES generation profiles. Figure 46 shows the contributions of each technology to the seasonal flexibility needs in the three central scenarios.

As explained in section 2.2.2.2 the total difference between 2030 and 2050 is less important than for daily and weekly needs. However, the flexibility providers differ substantially between the METIS-Baseline scenario and the two scenarios at the 2050 horizon. In 2030, thermal plants are the primary providers of seasonal flexibility (mostly CCGT plants, followed by nuclear, coal and biomass plants). Interconnectors and hydro plants provide the rest of the seasonal flexibility services. By 2050, electrolysers are found to be the main seasonal flexibility providers, followed by curtailment and thermal plants (CCGT, nuclear and biomass).

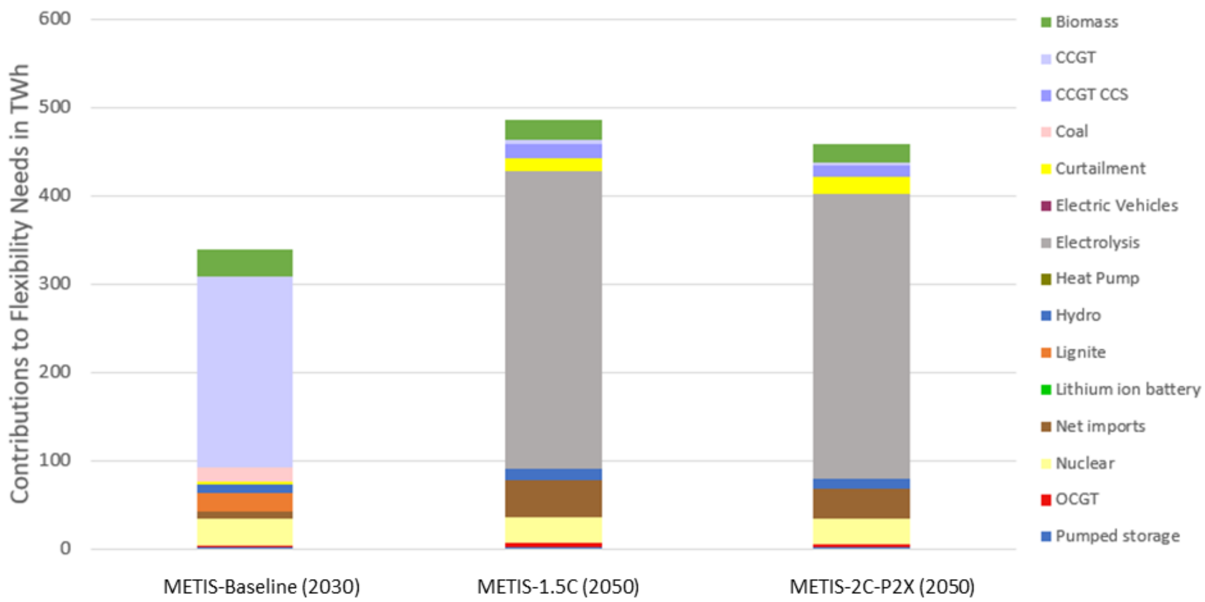

Figure 46 - Contribution to seasonal flexibility needs

2.6. Contribution to electricity security of supply

2.6.1. *Definition of the contribution to electricity security of supply*

In order to analyse the potential contribution of storage technologies to security of supply we have analysed the operational behaviour of these technologies during the periods of stress of the electricity system.

For each scenario and Member State, the 100, 200 and 400 hours where the residual demand is the highest are identified. Then, the production of each technology is calculated during these hours. The three sets of hours (100, 200 and 400 hours of highest residual load) were selected in order to identify the contribution of the various technologies as a function of the stress on the system.

Finally, the contribution is calculated by averaging the hourly contribution over the 100, 200 and 400 hours of stress of the given scenario. This result of this calculation is interpreted as the contribution of each technology to the electricity security of supply at the Member State level.

2.6.2. *Evaluation of the contribution to electricity security of supply in the different scenarios*

Figure 47 illustrates the contribution to security of supply of European countries for the three scenarios, and for the three set of hours defined in the previous sub-section. In 2030 METIS-Baseline scenario, during the hours of stress of the power systems, CCGT capacities provide most of the power production. However, when comparing the contributions between the 400 and 100 hours sets, it is possible to see the large increase of the participation of three technologies: OCGT, batteries and pumped hydro storage. During the hours with the highest power demand and the lowest variable renewable generation, storage technologies along with open cycle gas turbines appear to be crucial for the adequacy of the power system.

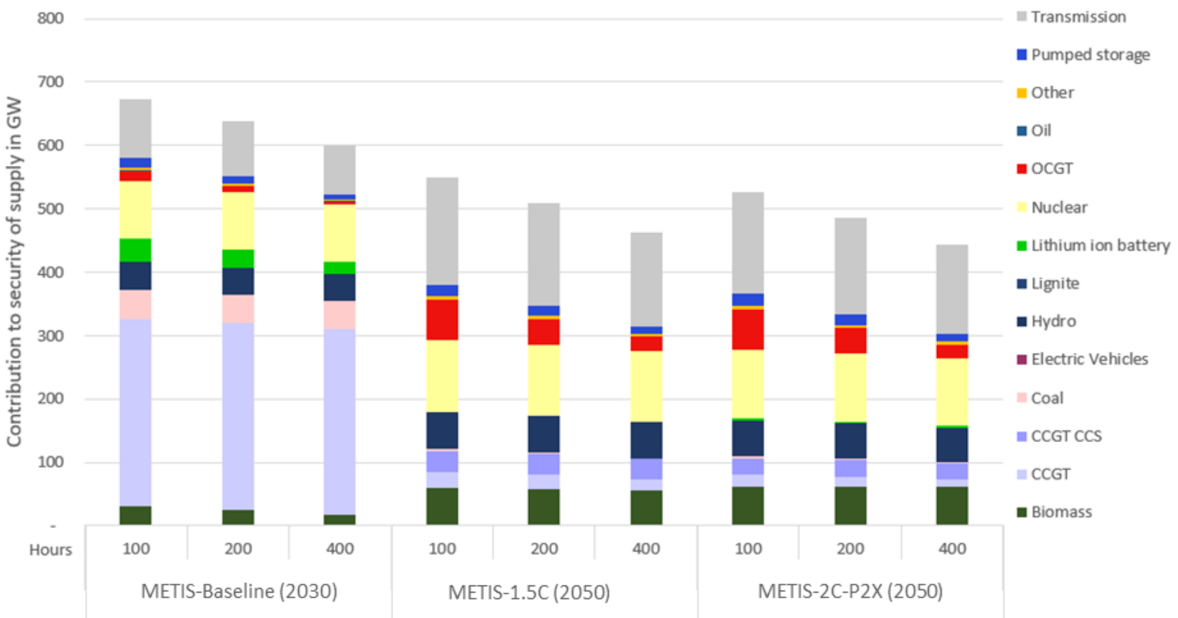

Figure 47 - Contributions to electricity security of supply in EU-28

In the two 2050 scenarios, the production during the hours of stress of the power systems is more balanced than in the 2030 METIS-Baseline scenario, with the notable importance of electricity transmissions that represent around a third of the provision of security of supply. This evolution is correlated to the important development of interconnections in the 2050 scenarios (see optimisation results in section 2.4.2.2), and of the high level of assistance between different countries to achieve the desired levels of security of electricity supply.

2.7. SENSITIVITIES: CAPTURE THE UNCERTAINTIES OF THE FUTURE SCENARIOS

Considering the high level of uncertainty surrounding the configuration of the 2030 and 2050 energy systems, different sensitivity analyses have been designed to assess the impacts of some of the assumptions on the deployment of storage technologies. Based on the analysis of the results of the three central scenarios, three topics have been selected:

Demand-response

Storage technologies such as batteries and pumped hydro storage are mainly providing flexibility to the system on a daily timescale, as shown in Section 2.5.2. These technologies therefore directly compete with demand-side response (smart charging of electric vehicle and smart heating for buildings). Different sensitivities have been created to test the influence of higher/lower level of demand-side response on the role of storage technologies.

Cost of electrolysers

In 2050 scenarios, electrolysers provide most of the flexibility of the power system. This sensitivity aims at testing the influence of a higher capital costs of electrolysers on the installed capacities of power storage technologies.

Hydrogen flexibility

In 2050 scenarios, the flexibility of electrolysers is coming from the possibility to modulate the production of hydrogen for the end-users (direct hydrogen consumption, or e-gas and e-liquids production). Some sensitivities were then created to limit this flexibility and see the influence in term of installed capacities of power storage.

For each topic, one or several variants were created, with for example different level of demand-response in the power system. These variants are presented in section 2.7.1, and the results in section **Error! Reference source not found.**.

2.7.1. *DESCRIPTION OF THE DIFFERENT SENSITIVITIES*

Demand-response

Our analysis has shown that additional sources of flexibility are required in order to balance the increasing share of RES in the energy mix. In this context, demand-response appears to be a complement to traditional storage solutions, bringing short-term flexibility to the system. The smart use of flexible demand will help shift demand peaks to hours with lower demand and higher RES generation. In our study, demand-response is represented by electric vehicles (EVs) with dynamic charging and heat-pumps (HPs) combined with thermal storage.

As the number of EVs is expected to increase significantly in the coming decades, EVs can become a significant source of flexibility depending on the availability of smart charging strategies that can help smoothen residual demand peaks. Likewise, the optimisation of heat-pumps' consumption patterns (when coupled with thermal storage) can also shift residual demand peaks, bringing more flexibility to the electricity system.

In the 2030 METIS-Baseline scenario, 30% of the demand of EVs and heat-pumps are assumed to be flexible. In the 2050 scenarios, 70% of these demands are considered to be flexible. In both 2030 and 2050 scenarios, EVs can only optimise their charging behaviour, without the ability to inject power back into the grid. Power-to-grid behaviour is explored in one of the sensitivity analyses.

In other to capture the impacts of different levels of demand flexibility, three variants have been created:

Low demand-response

In this sensitivity analysis, we consider a scenario where there is no demand flexibility, meaning that electric vehicles are recharged as soon as they arrive at the charging location, and heat pumps do not have any thermal storage.

High demand-response

In this sensitivity, 100% of EVs and heat-pumps have flexible demand. This means that the charging of electric vehicles is optimised for all electric vehicles, and that all heat pumps have a short-term thermal storage.

High demand-response + V2G

In this sensitivity, in addition to 100% flexible demand of EVs and heat-pumps, we also consider that EVs can use the energy stored in their batteries to inject electricity back into the electricity grid (vehicle-to-grid capability).

Cost of electrolysers

As can be seen in the results presented above, electrolysers are expected to play an important role in the considered 2050 scenarios. They are a key element in the European transition towards full decarbonisation, as they enable indirect electrification of end-uses in sectors such as industry, heating and mobility. In our scenarios, they have been found to be one of the main flexibility providers.

Electrolysers are a rather mature technology, but the evolution of their costs and efficiencies is rather uncertain, since it mainly depends on the overall deployment of electrolysers (in particular outside Europe). Since the provision of flexibility in the 2050 scenarios displays a high dependence on electrolysers, a sensitivity analysis considering different techno-economic parameters for this technology has been performed.

High electrolysers CAPEX

In this sensitivity all electrolysers are considered to have a higher CAPEX but their efficiency is assumed to remains the same. The new CAPEX of 600 €/kW and 5% of fixed O&M costs is comparable to the ones of Solid Oxide Electrolysers cell (SOEC) from the Long-Term Strategy. This CAPEX is around three times higher than the one used in the central scenarios.

Hydrogen flexibility

As the demands for hydrogen, e-gases and e-liquids (P2X) are central elements in both 2050 scenarios, three sensitivities have been carried out to better assess how the dynamics of the P2X demand can affect the investments in different flexibility solutions.

P2X demand is driven mainly by the industrial and transportation sectors. At the 2050 horizon, the use of power-to-hydrogen technologies can be an effective solution to decarbonise fuels consumed in these sectors. However, substantial uncertainties remain concerning the extent of the flexibility of the hydrogen demand.

In the model, the whole demand for hydrogen, e-gas and e-liquids is represented by a common demand for hydrogen, with an annual volume to be supplied, without further constraints on the dynamics of the hydrogen demand. The flexibility of the hydrogen demand can be used to balance RES generation throughout the year, since electrolysers production can adapt to residual load profiles. Below, we provide the definitions of three other scenarios with different levels of flexibility that have been considered with various levels of flexibility of the hydrogen demand.

Monthly hydrogen demand

In this sensitivity we consider the annual hydrogen demand to be equally spread between months throughout the year. We also consider that no storage of hydrogen would be possible between months. The hydrogen demand can therefore only offer intra-monthly flexibility.

Hourly hydrogen demand

In this sensitivity, the volume of hydrogen to be supplied is supposed constant throughout the year. We also assume that no storage of hydrogen is possible. This sensitivity should be seen as a rather extreme scenario where no flexibility would be possible on the hydrogen side, i.e. without any conversion of current gas storage infrastructure.

Dedicated off-grid hydrogen production

In this sensitivity, a part of RES capacity is assumed to be directly connected to power-to-hydrogen installations and separated from the rest of the electricity grid. This configuration is similar to what is proposed in some of the ENTSOs' TYNDP 2020 scenarios.

In this scenario we considered that 15% of the solar PV fleet, 22% of wind onshore fleet and 59% of wind offshore fleet total capacities are solely dedicated to the production of hydrogen. These percentages of RES dedicated to hydrogen production are inspired by ratios used in TYNDP 2020 scenarios. The equivalent hydrogen production was then subtracted from the total hydrogen demand.

In such a configuration, the lower hydrogen demand will require fewer electrolysers connected to the electricity grid[40]. This lower capacity will decrease the ability of electrolysers to adapt their hydrogen production, and thereby the flexibility that can be offered to the power system.

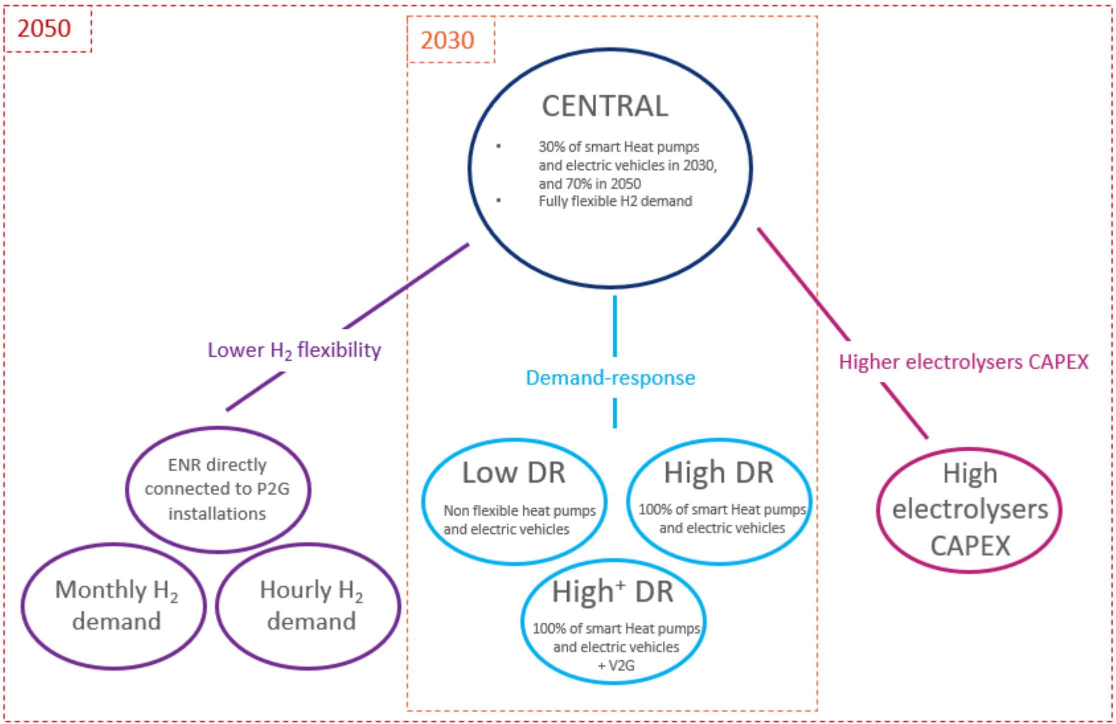

Figure 48 Schematic representation of sensitivities applied to central scenarios

[40] The remainder of the hydrogen demand being supplied by off-grid RES capacity connected to electrolysers as explained above.

2.7.2. *INSTALLED CAPACITIES FOR THE DIFFERENT SENSITIVITIES*

2.7.2.1. Demand-response sensitivities

In order to evaluate the effect of different levels of demand-side flexibility in the 2030 METIS-Baseline and METIS-1.5C central scenarios, three different sensitivities have been performed. The three scenarios include different levels of flexibility for EVs and heat-pumps.

Figure 49 shows the installed capacities of the central METIS-Baseline scenario in 2030, where only 30% of EV and HP demand are flexible, compared to the three sensitivities applied to demand flexibility:

- Low demand response (EVs and HPs' demand are inflexible);
- High demand response, with completely flexible demand (100% of EVs and HP demand is flexible);
- High demand response, with completely flexible demand plus vehicle-to-grid capbility (100% of EVs and HP demand is flexible and V2G is possible for all EVs).

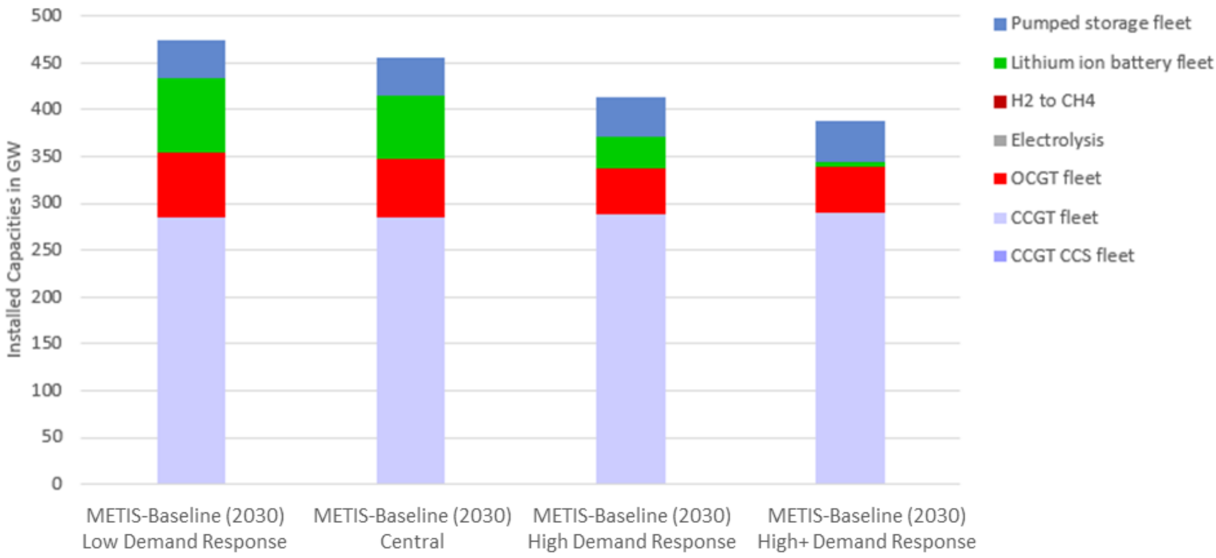

Figure 49 Flexibility solutions installed capacities in METIS-Baseline with demand-response sensitivities

By reducing demand-response availability, the main consequence is an increase in investments in batteries, to compensate for the corresponding loss of flexibility on short timescales. In METIS-Baseline Low Demand Response, we can see an addition of 12 GW (2-hour and 4-hour discharge time batteries only) in comparison with the central METIS-Baseline scenario. The reduction of demand-response also leads to an increase of 7 GW of OCGT capacity.

In the two other sensitivities, which assume higher levels of demand-response, the effect is in the opposite direction. In the scenario with high demand-response, only 34 GW of batteries are required, corresponding to half of the installed capacity in the central METIS-Baseline scenario. In the scenario which assumes that vehicle-to-grid is available, we see a much more drastic reduction of the deployment of batteries, with only 4 GW of batteries remaining. Furthermore, V2G reduces the investments in PHS by 4 GW and in OCGT by 17 GW. As EVs and HPs mainly provide short-term flexibility, investments in short-duration batteries are the most affected in these sensitivities.

Figure 50 shows, for a given country, the hourly EV charging demand if EVs were to recharge when plugged at home (blue solid line) and the actual charging behaviour when EVs can adapt to price signals (either with smart charging behaviour or including V2G capabilities). In a case without flexibility, charging follows exactly the EVs charging demand while in the cases where charging is flexible, charging happens mainly in early-morning before vehicles leave home and the total demand is lower, or in early afternoon, when EVs return home and can still profit from PV generation. By optimising EVs charging, the system can reduce demand night peaks and shift consumption to hours when the sun still shines.

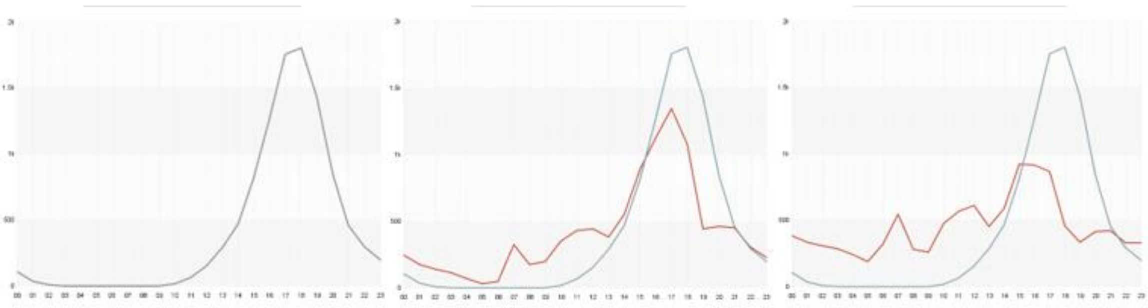

Figure 50 – Average recharge of electric vehicles at home per hour of day
Blue in the three graphs: immediate charging at arrivals
Red in the centre: smart charging
Red on the right: smart charging + V2G

Similar patterns can also be noticed in the usage of heat-pumps. Figure 51 shows the daily utilisation of heat pumps in a scenario where the demand is flexible. It is possible to see how their consumption is adjusted to hours with lower demand and of high PV production, which allows night and early-morning demand peaks to be reduced.

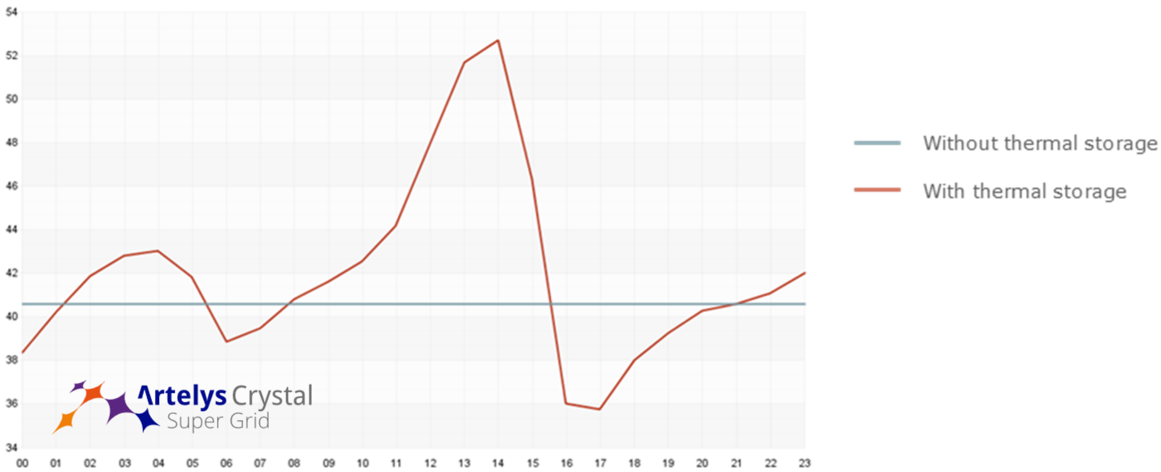

Figure 51 – Average Heat pumps electricity consumption per hour of day

Figure 52 shows the original and optimised demands in the scenario with high demand response, during a week in November. In this case, the flexibility offered by batteries can be replaced by demand-side flexibility. By optimising the use of demand-response, peak demand, that previously required the use of batteries, can be shifted to hours with lower demand. This reduces the need for batteries since they are providing the same kind of services.

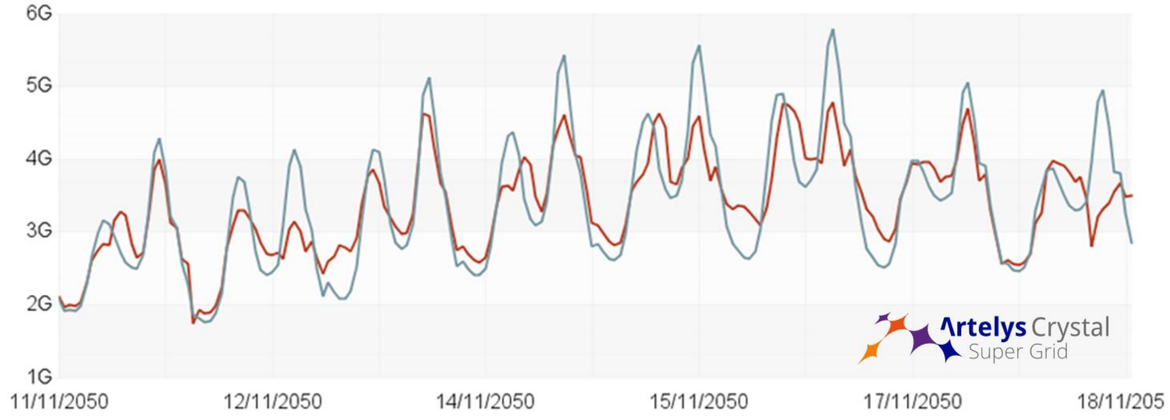

Figure 52 - Comparison between the optimised demand (in red) and the power demand as it would be without demand-response (blue)

The same three sensitivities were also applied to the METIS-1.5C scenarios in 2050. The installed capacities of all scenarios compared to the central METIS-1.5C can be seen on Figure 53.

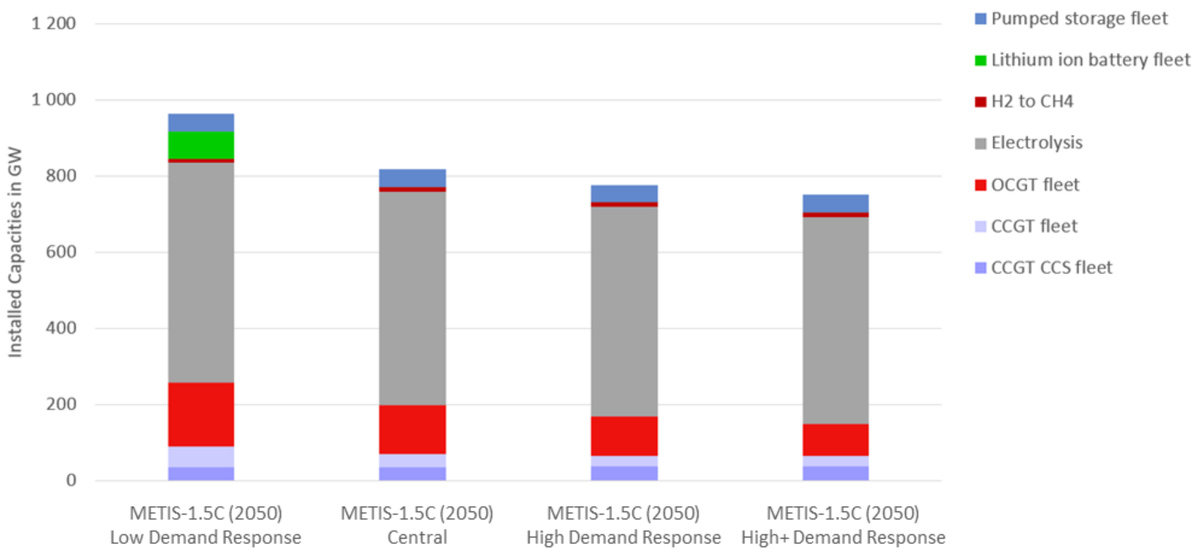

Figure 53 - Installed capacities for the different demand-response sensitivities

In 2050 METIS-1.5C scenario, 70% of electric vehicles and heat pumps are assumed to be flexible, providing a significant part of the daily flexibility. In the Low Demand Response variant, demand-response is assumed to develop in rather limited way, therefore the flexibility offered by the demand has to be compensated by other technologies. This leads to an important increase of investments in batteries (70 GW, with 2-hour and 4-hour discharge time batteries only), and an increase of 60 GW of investments in gas-fired plants. Marginally, a small growth of 16 GW in electrolysers installed capacities can also be seen in this scenario to benefit from the flexibility offered by the hydrogen demand.

In the two other sensitivities with higher demand-response the effect is the opposite. The demand flexibility replaces the need for alternative solutions providing short-term flexibility services, reducing investments in batteries, gas-fired plants and even electrolysers. In the scenario with high demand response the total gas-fired installed capacity is 169 GW, 30 GW lower than in the central scenario, while in the scenario with vehicle-to-grid the reduction is even higher (50 GW). No batteries remain in either scenario. Moreover, vehicle-to-grid provides even more flexibility, reducing investments in PHS by 1 GW. The decrease in electrolysis capacity is not very significant (10 GW in the high demand-response scenario and 16 GW in the sensitivity with vehicle-to-grid).

2.7.2.2. Electrolysers sensitivities

Figure 54 shows the comparison between the installed capacities of flexibility solutions in the central METIS-1.5C scenario and the METIS-1.5C scenario with higher capital cost for electrolysers. The main difference is, as anticipated, a decrease in the total investment in electrolysers. With an investment cost almost three times higher, investments in this technology are considerably reduced, the total capacity in now 451 GW, 19% lower than in the central METIS-1.5C scenario. Although electrolysers still act as the main flexibility provider in this sensitivity, with the decrease in electrolysers capacity, the need for other sources of flexibility to complement the contribution of electrolysers appears.

In this sensitivity, investments in batteries rise to 11 GW as opposed to the 1 GW in the central scenario. A significant increase in PHS installed capacity can also be noticed, the total PHS capacity now rises to 63 GW of which 46 correspond to existing PHS and 17 GW correspond to new added capacity.

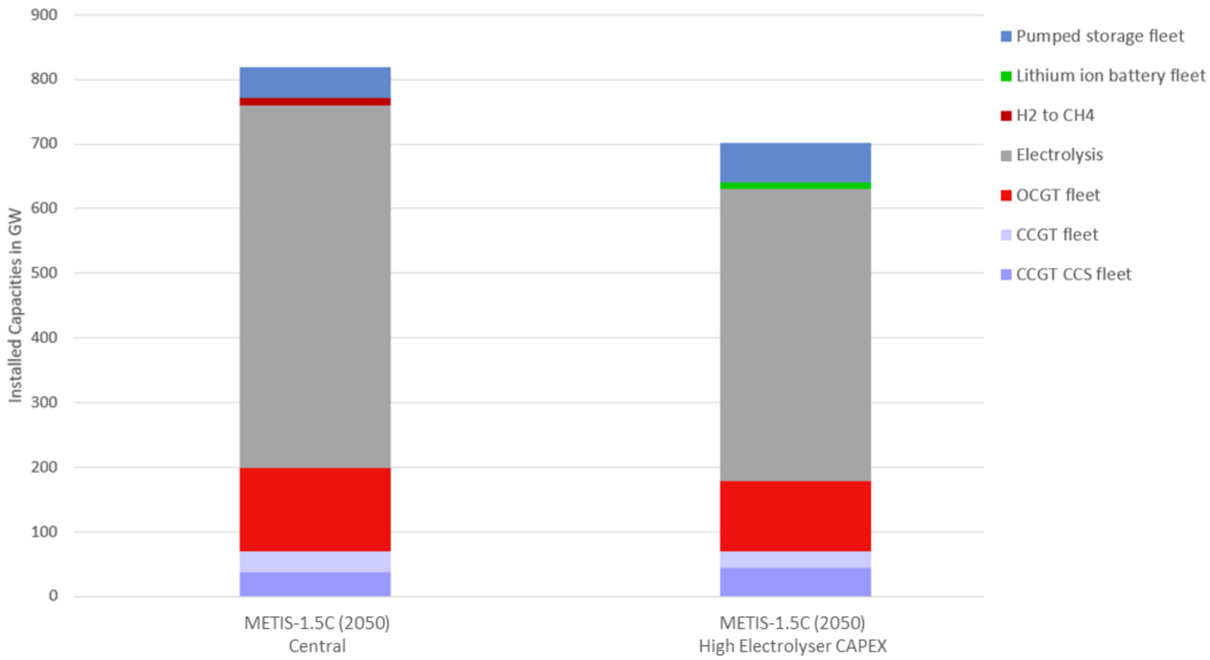

Figure 54 Flexibility solutions installed capacities in METIS-1.5C with high electrolysers Capex

In both scenarios, hydrogen production from electrolysis is complemented by hydrogen produced by SMR combined with CCS plants. The share of hydrogen being produced by SMR combined with CCS is found to be more important in the scenario with higher electrolysers costs. Indeed, exploiting the last MW of RES production during high RES generation episodes will not be economically profitable in a situation with higher cost of capital for electrolysers.

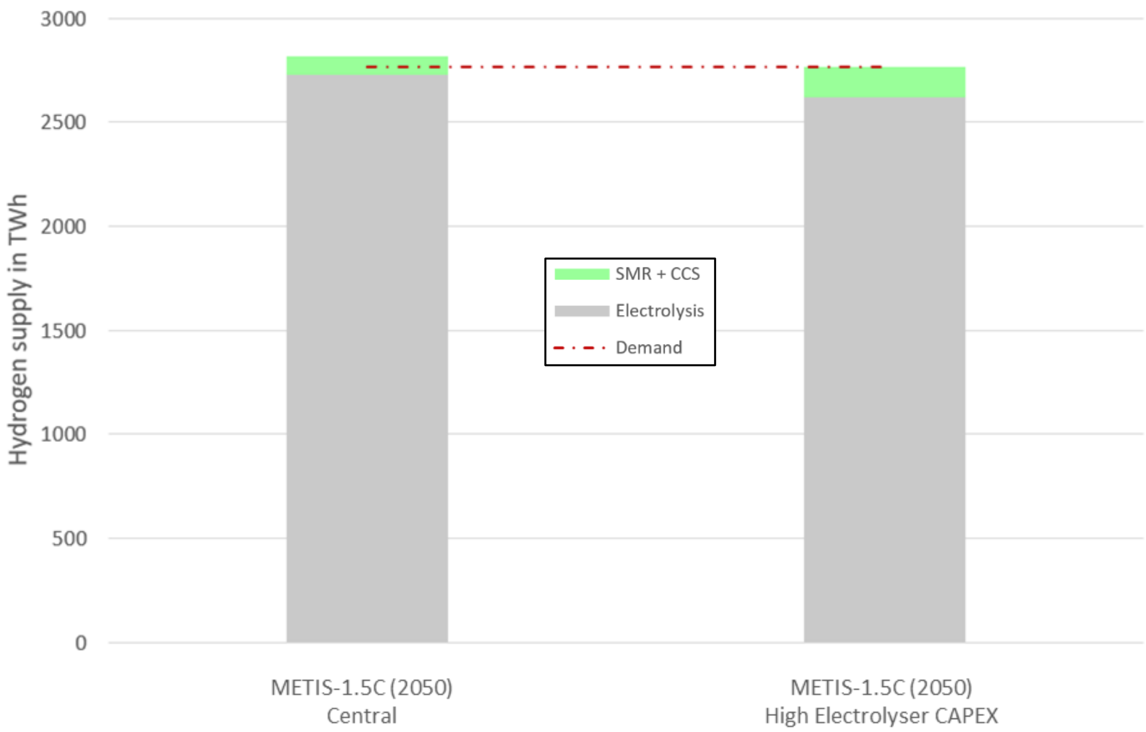

Figure 55 Hydrogen supply in METIS-1.5C with high electrolysers CAPEX[41]

Also, to compensate for the difference in electrolysers installed capacities, as shown in Figure 56, we can see that they have a higher capacity factor throughout the year. In the central scenario capacity factors average at around 56% (even though a part of production is also used for methanation) while in the sensitivity with higher electrolysers capital cost this average is 65%.

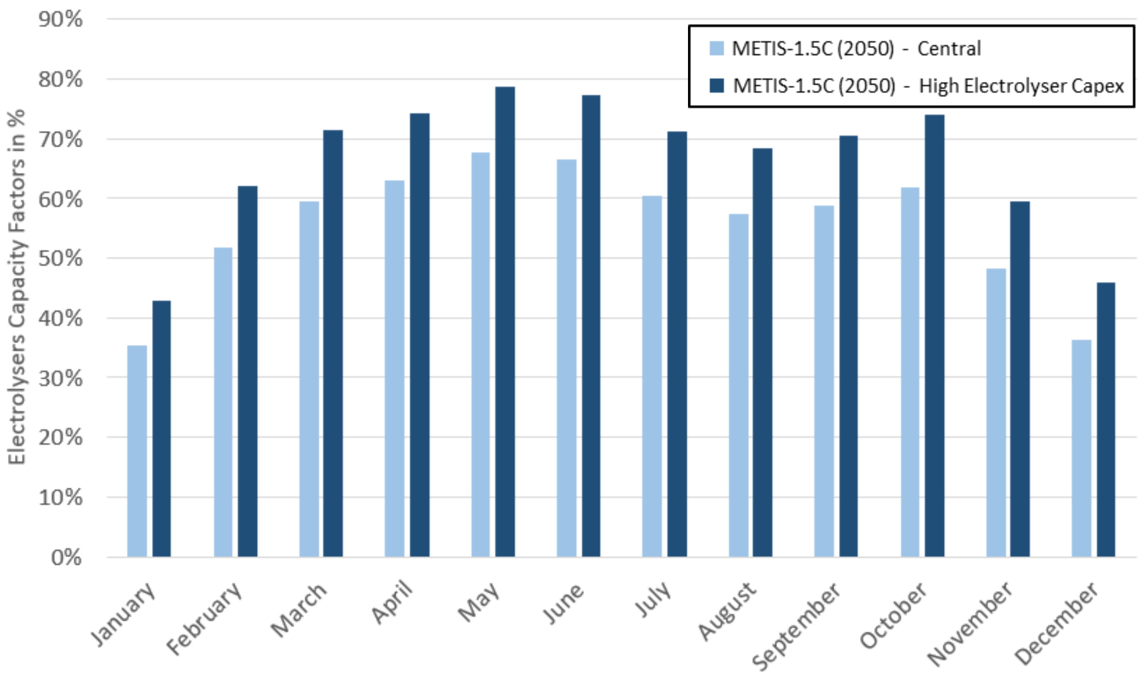

Figure 56 Monthly capacity factors for electrolysers in Europe for scenario with high capex electrolysers

[41] The slight difference in term of hydrogen supply between the two scenarios is driven by the power-to-gas-to-power loop : for METIS-1.5C central scenario, additional hydrogen is produced to be converted in e-gas by methanation plants, and then used later in time by gas-fired plants when the renewable production is low.

2.7.2.3. Hydrogen demand sensitivities

In order to assess the effect of hydrogen demand in the provision of flexibility, three different sensitivities have been carried out. The three scenarios assume limitations, at different levels, of the flexibility that the hydrogen demand can bring to the system.

Figure 57 shows the installed capacities of the central METIS-1.5C scenario compared to the three sensitivities applied to hydrogen demand:

- Monthly hydrogen demand;
- Hourly hydrogen demand;
- Dedicated off-grid hydrogen production

In the central METIS-1.5C scenario, hydrogen demand is considered to be completely flexible and can adapt to different residual demand profiles. On the three sensitivities proposed here, hydrogen demand flexibility is limited, which causes the need for alternative flexibility providers.

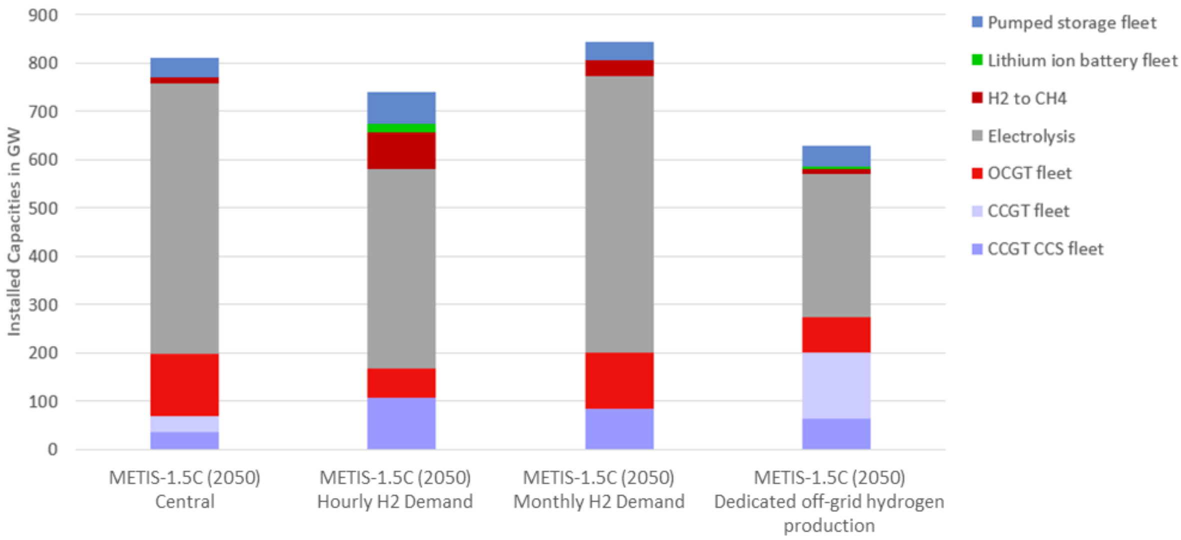

Figure 57 Flexibility solutions installed capacities in METIS-1.5C with hydrogen demand sensitivities

The hourly hydrogen demand scenario is the one with the most constrained flexibility, here we assume an extreme case where hydrogen demand is constant during the whole year. As a result, this is the variant where investments in storage solutions are highest. We can see a total installed capacity of 20 GW in batteries (mostly 4-hour and 8-hour discharge time batteries) and a total of 73 GW of PHS, of which 26 GW correspond to new PHS capacity.

To compensate this loss in flexibility provision, methanation plants also become a profitable option as a flexibility provider, since during periods where renewables produce the most, their generation is more than sufficient to supply the hourly hydrogen demand. RES generation surplus is then used by methanation plants and the resulting methane can be stored for later use using the current important storage capacities of the gas system.

It is also noticeable in this scenario that the total electrolysers installed capacities are lower than in the central METIS-1.5C scenario. Their installed capacity reaches 412 GW, which represent 55% of the total flexibility solutions installed capacities. This decrease in electrolysers installed capacities can be better understood when looking at their capacity factors in Figure 58. It is visible that this variant – which assume a constant hydrogen demand - is the scenario where electrolysers have by far the highest capacity factors, which allows them to produce enough hydrogen to meet hydrogen demand and feed methanation plants.

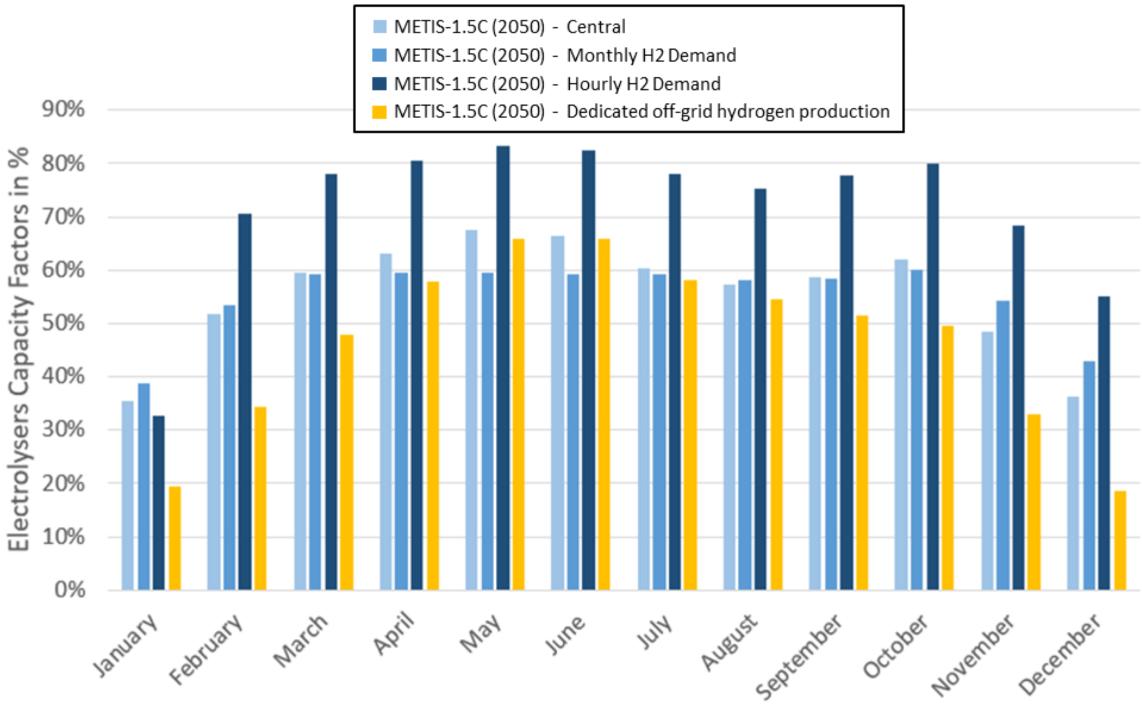

Figure 58 Monthly capacity factors for electrolysers in Europe for hydrogen demand sensitivities

In the scenario with dedicated off-grid hydrogen production, electrolysers installed capacities are considerably lower than in the central METIS-1.5C scenario, due to the reduced hydrogen demand[42]. When looking at other storage solutions, however, we can see an increase in the total installed capacities, in particularly of batteries, PHS and CCGT plants.

Since a part of RES generation is separated from the grid together with electrolysers that are solely dedicated to hydrogen production, the system loses the flexibility needs from RES and flexibility provision provided by electrolysers. To compensate for this decrease in flexibility provision, we can see an increase in batteries installed capacity, now rising to 5 GW and a total of 51 GW of PHS installed capacity, of which 5 GW correspond to new PHS capacity.

Another important impact of changes in the hydrogen demand flexibility is the level of investment in OCGTs and CCGTs, that are much higher than in the central scenario. Their total installed capacity is now 273 GW, 37% higher than in the central scenario. This shows that hydrogen demand flexibility can greatly reduce the need for gas-fired plants in the provision of flexibility.

By looking at Figure 59, we can see that electrolysers supply almost 100% of hydrogen demand in this variant, with a small part complemented by hydrogen produced by SMR with CCS.

[42] Please note that we only refer here to electrolysers capacities connected to the electricity grid. For the scenario with dedicated off-grid hydrogen production, off-grid electrolysers are also installed.

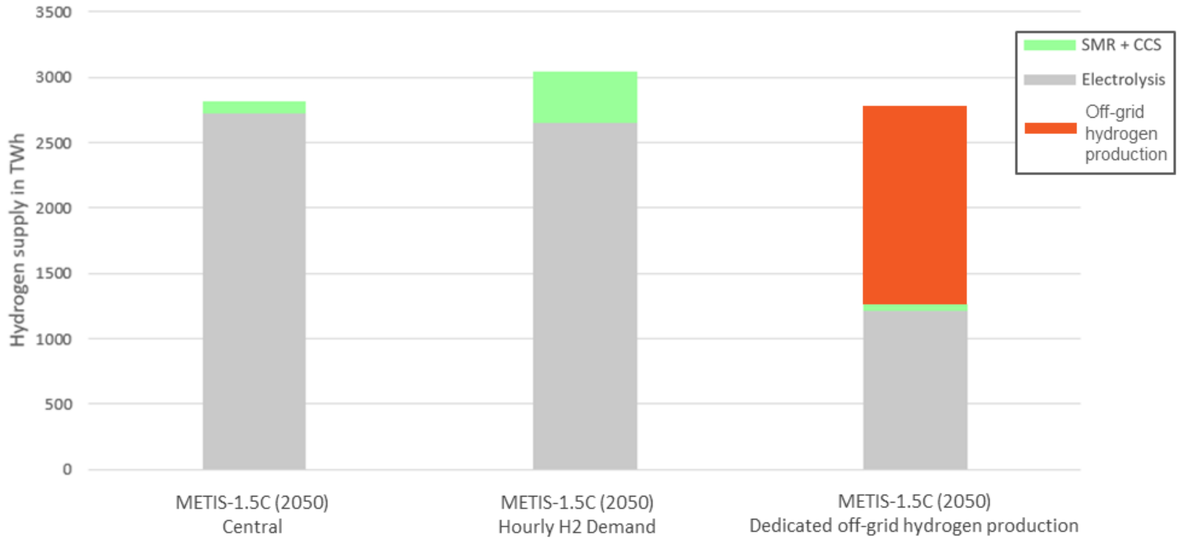

Figure 59 - Hydrogen supply for METIS-1.5C 2050 sensitivities about hydrogen flexibility

2.8. CONCLUSION TO THE QUANTIFICATION OF THE CONTRIBUTION OF ENERGY STORAGE TO THE SECURITY OF SUPPLY

Our results reveal that in 2030 a large share of the required levels of flexibility can still be provided by conventional power plants and by using the power networks to trade electricity between the different European countries. However, for the provision of daily flexibility, storage technologies such as batteries or pumped storage appear to be relevant solutions in our scenarios. Up to 108 GW of electricity storage (batteries and pumped hydro storage) would be necessary for the EU-28 (97 GW for EU-27), with a large development of stationary batteries. At the 2030 horizon, electrolysers do not appear to be competitive solutions to provide flexibility to the power system. However, if a deployment of electrolysers were to materialise already in 2030 (e.g. driven by indirect electrification of end-uses in the industry or heating sectors), they could provide flexibility on all timescales.

In the assessed 2050 scenarios, the deep decarbonisation of the different sectors, such as industry, mobility and heating, the Long-Term Strategy assumes that an important amount of “decarbonised” hydrogen (produced by water electrolysis with decarbonised electricity), and synthetic fuels[43] will be produced. This hydrogen is generated from electricity coming for large-scale wind and solar power plants, and then converted into hydrogen with electrolysers. To satisfy this demand, around 550 GW of electrolysers would be required in our different 2050 scenarios. Combined with the flexibility offered by the end-users’ of hydrogen and e-fuels, or with direct use of hydrogen or gas storage facilities, electrolysers will able to provide important levels of flexibility to the power system. The potential deployment of electric vehicles using smart charging strategies and of space heating combined with short-term thermal storage also enable the demand-side to provide daily flexibility to the power system. Due to the competition between various flexibility sources, the need for pumped hydro storage and batteries is found to be lower in 2050 than it is in 2030, and reaches around 50 GW in our 2050 scenarios.

To recognise the high level of uncertainty surrounding the configuration of the 2030 and even more so, of the 2050 energy systems, different sensitivity analyses have been designed to assess the impacts of some of the assumptions on the deployment of flexibility technologies. Based on the analysis of the results of the three scenarios (METIS-Baseline,

[43] e-gas and e-liquids, produced from hydrogen with methanation plants and the Fischer-Tropsch process.

METIS-1.5C and METIS-2C-P2X), three topics have been selected for further analysis since they might substantially impact the optimal mix of flexibility solutions:

- Demand-response: Electricity storage technologies compete with demand-side response, since they both provide daily flexibility services to the power system. In 2030, an optimal use of the flexibility of electric vehicles and of decentralised space heating could reduce the need for stationary batteries by half (67 GW vs 34 GW).

- Costs of electrolysers: In the 2050 scenarios, the large deployment of electrolyser leads to an important drop of their investment costs. In a sensitivity where the prices of electrolysers are significantly higher, the need for pumped hydro storage and batteries rise from 50 GW to 73 GW.

- Flexibility of hydrogen demand: the 2050 scenarios assume an important flexibility of end-uses on the P2X side (hydrogen and e-fuels), that can be provided by direct hydrogen storage but also via some flexibility in the end-users consumption (for example for the e-liquids provision for vehicles can be flexible, thanks to current infrastructure for petrol). In a sensitivity with lower flexibility on the hydrogen side, additional investments in methanation plants would be required to benefit from the flexibility offered by the current gas infrastructure.

3. ASSESSMENT OF ENERGY STORAGE POLICIES, BARRIERS AND BEST PRACTICES

3.1. INTRODUCTION

The objectives of this chapter are to:

- Identify current barriers and best practices at the Member State level for the deployment of energy storage;
- Assess the impact of the new market design at the EU and Member States levels, identifying which barriers will be addressed with its full implementation, and which are left untouched;
- Provide complementary measures to address the barriers which remain even after the implementation of EU legislation.

The present chapter allows to develop the policy recommendations for energy storage, in combination with the analysis of the contribution of energy storage to the security of electricity supply of this study.

As clearly stated in the Clean Energy for All Europeans Package, **storage is recognised as a competitive activity**, meaning that all policies and regulations should respect this principle and take all measures to ensure a level playing field. Investors will respond to the need for storage only if they are **able to build a strong business case**. In the energy sector, business cases are commonly built on expectations rather than on current circumstances, due to the long lead-times and lifespans of investments. These expectations are affected by several factors, described next.

Given current energy transition trends, awareness of the potential of storage is increasing for many potential applications, from large pumped-hydro storage to the behind-the-meter battery at home. Trends include decentralising energy production (mainly from renewable sources), empowering energy consumers and increasing the share of intermittent renewable electricity production into the energy system. However, this is not enough to ensure the market uptake of storage applications, as in most of the situations the business case still remains difficult for these investments, even when they are coupled with other assets (at the production or consumption side).

Regarding technology readiness, the Levelised Cost of Storage and the technical performance of the different technologies are gradually improving, with capital costs playing a central role in the case of storage, while operational costs are more limited. Logically, the confidence of investors would gradually improve as the readiness increased for certain technologies and specific application.

Storage business cases could also become challenging or even inviable according to some stakeholders, if they depend on revenue streams from the provision of services in multiple energy markets, in a fast changing environment. The volatility of electricity market prices (affected by the increasing share of intermittent renewable energy sources) and the reaction of market actors for providing the required flexibility will have an important impact on the deployment of storage. As a capital-driven investment, a storage unit does need reasonably secure long-term revenue streams to ensure its viability. Low carbon prices could also disincentivise storage deployment, as they negatively affect its competitiveness vis-à-vis flexible fossil-based resources.

However, the majority of the consulted stakeholders emphasize the fact that **regulatory barriers, which for example hinder participation in electricity markets, are an important issue hampering the profitability of storage investments.** Unclear frameworks jeopardise the use of storage, as uncertainty increases the risks and therefore the financial expectations of the investors. Storage could become a relevant option, if the two following issues are addressed: ensure a level playing field for all users and applications, and increase the security of investors.

This chapter is organized as follows:

- **Section 3.2** introduces the 2013 paper and 2017 strategy of the EU on energy storage;
- **Section 3.3** presents the barriers and best practices per policy category, summarizing the current status across the Member States;
- **Section 3.4** focuses on the new EU electricity market design (recast Electricity Directive and Regulation) as well as other EU legislation related to energy storage, indicating potential remaining barriers.

Various stakeholders have been consulted regarding the national and EU-level data and analysis. A number of national stakeholders, including national contact points of the European Commission Electricity Coordination Group (ECG), have provided inputs for the Member States storage policy fiches presented in Annex 4. A stakeholder policy workshop took place in December 2019, and further comments on the policy analysis draft and the national policy fiches were received through written feedback afterwards, including from the ECG national contact points.

3.2. Background on energy policies impacting storage

The European Commission released in 2013 its **working paper 'The future role and challenges of Energy Storage'**[44]. The paper addressed the state of play and importance of storage for the energy system, existing barriers and policies to address them, particularly regarding the role of the EU. The working paper aimed to bring greater attention to storage, recognizing its importance to support decarbonisation of the electricity system, while acknowledging limited deployment of electricity storage at the time.

The most important barrier to energy storage indicated in this working paper is the lack of a business case which adequately values its benefits, both from the energy system and the storage investor perspectives. This economic barrier is affected by a number of underlying technical, economic, regulatory and strategic aspects discussed in the working paper.

The working paper highlighted that to address these barriers, the main objective of any regulator or legislator should be to create a clear, level playing field for the development and provision of storage services. This includes non-discrimination among different storage technologies, sizes and location in the system, but also equal access by energy storage to potential revenue streams such as in energy and ancillary services markets. Such a level playing field would improve the business case for storage, by providing new revenues streams and by reducing costs unfairly imposed to storage facilities (such as double charging of grid tariffs, although storage can lead to avoided network investments).

Finally, the paper noted that the EU can play an important role given the differences in the deployment of renewable electricity among Member States, in the cross-border market interactions and potential for distortions, and the need for additional storage R&I to which multiple suitable EU instruments exist.

The need for an EU strategy to energy storage, coherent with the overall energy and climate policies, was hence already highlighted in 2013. The paper listed a number of actions covering the EU strategy, support to consumers, market design, R&I and investments. Overall, a main takeaway from the paper was the need for more attention for electricity storage at the EU level and its integration in all EU energy and climate policies and measures.

In 2017, the Commission published its white paper on **'Energy storage – the role of electricity'**,[45] related to the Clean Energy Package[46] and its new electricity market design. The most adequate storage technologies are in this paper briefly assessed according to

[44] DG Energy (2013) The future role and challenges of Energy Storage

[45] DG Energy (2017) Energy storage – the role of electricity

[46] European Commission (2016) Clean Energy For All Europeans. COM(860)

their potential applications, and policy approaches to address barriers to storage are discussed within the context of the new electricity market design.

Multiple regulatory issues are listed. The first relates to energy policy measures targeting other objectives than storage, such as the cost recovery of renewable electricity support through tariff surcharges. It can unduly burden the business case of storage, as in some Member States storage facilities pay such surcharges despite not actually consuming electricity (except for cycle losses). The existence of regulated retail prices in some Member States is also negatively impacting the business case for storage, as they can discourage the development of behind-the-meter storage.

Another issue, not exclusively concerning storage, is the design of energy, capacity and ancillary services markets. This includes the trading timeframes (bidding window and time resolution), the inexistence of dynamic electricity pricing to end-consumers and the market access for both autonomous storage, demand-side response (with storage) and aggregators. More fundamentally, the establishment of the right of consumers to produce and consume their own electricity would positively impact the development of behind-the-meter storage. Also, the insufficient consideration of energy storage in system planning until then is noted, as well as grid issues such as potential double charging of access fees.

The document discusses not only these issues as affecting the business case for storage, but also highlights differences among Member States and how resulting inconsistencies can lead to cross-border market distortions which also impact storage negatively. It moreover indicates that a number of issues are addressed in the new market design, such as: the right for consumers to produce and consume their own electricity; improved cross-border trading; shorter time frames and opening of markets; and the broader development of dynamic electricity end-user pricing.

The white paper recognizes that energy storage will be developed primarily through private investments, and, in line with the issues listed above and the measures in the Clean Energy Package, sets four principles for supporting the market development for energy storage:

1. Energy storage should be allowed to participate fully in electricity markets
2. Energy storage should participate and be rewarded for services provided on equal footing to providers of flexibility services
3. Energy storage as an enabler of higher amount of variable RESs could contribute to energy supply security and decarbonisation of the electricity system or of other economic sectors
4. The cost-efficient use of decentralised storage and its integration into the system should be enabled in a non-discriminatory way by the regulatory framework

Principles 1. and 2. are closely related to non-discrimination of storage in the energy and ancillary services markets, and in capacity mechanisms. It places the different energy storage technologies on an equal footing with flexible and intermittent generation and demand side response. Given the increasing needs for flexibility to face the growing penetration of intermittent renewable energy sources, non-discrimination would enable the flexibility contribution of storage to be adequately valued.

While also related to non-discrimination, principles 3. and 4. address the fact that the contribution of the different storage technologies arise in multiple centralized and decentralized applications and in various sectors. Hence, a holistic approach is necessary to value both mature and developing storage technologies (from pumped hydro to batteries, compressed air and chemical storage) in the electricity, heating, transport and industry sectors.

Hence, both the 2013 and 2017 papers identify a number of policy issues and resulting barriers in various areas, related to general aspects such as the design of energy and ancillary services, and capacity mechanisms, as well as storage-specific practices such as grid charges. The papers highlight moreover the need to consider storage holistically, in various policy areas (energy, climate, environmental, fiscal) rather than developing a specific regulation targeted at storage. This given the variety of issues, of storage technologies and the potential applications (and considering the relevance of revenue stacking to improve the business case of storage).

Besides the European Commission papers on energy storage, a large number of studies have covered barriers to the development of electricity storage, and policies to address them. A number of selected studies are reviewed in Annex 2. Two main aspects are extensively discussed in these studies, which are apparent also in the Commission documents: the large diversity and interaction of storage technologies and applications, and the resulting large diversity of barriers and corresponding policies for energy storage.

3.3. BARRIERS FOR ENERGY STORAGE

Data on energy storage policies as well as barriers and best practices was collected covering all EU28 countries. The policy barriers and best practices to energy storage covered are classified in the following categories:

- Public support and strategy;
- Permitting;
- Energy markets and capacity mechanisms;
- Ancillary and grid management services;
- Grid aspects;
- Taxes & other levies;
- Involvement of network operators;
- Storage definition and other policy aspects.

The best practices present relevant policy approaches in EU Member States as well as non-EU countries which should be considered for replication, either across the EU or for specific Member States, consider their specificities.

Each of the above mentioned categories starts with a short explanation of the context, followed by the current status across member States and finally (if there is information available) about the best practices.

3.3.1. *PUBLIC SUPPORT AND STRATEGY (PLAN) FOR STORAGE*

Context

This topic addresses the support to storage assets, which can take the form of grants, investment aid or other types of direct or indirect subsidies. Public support reflects the political willingness of authorities to stimulate the development and/or implementation of storage technologies which are considered important to ensure the reliability/stability of the electricity system and to succeed the energy transition. Support can accelerate the penetration of ready-to-market technologies or compensate for the development cost of specific promising technologies in view of their large-scale deployment in the medium or long term. Supports can be either direct (e.g. investment grant) or indirect (e.g. through the support to decentralised renewable production unit like PV).

Storage technologies, such as batteries and compressed air are still at an early stage, while others such as pumped hydro are mature. Public support in the EU Member States is at present mainly focusing on batteries. Pumped hydro is also still facing barriers, but these are not related to the lack of adequate public support for technology deployment, but rather to regulatory and market aspects.

Storage should also be properly considered in investment planning at national level; therefore, planning and determining adequate objectives for storage are considered as an important element in this assessment on how MS address the deployment of storage.

Current status across Member States

A limited number of Member States have implemented direct investment support schemes for energy storage, which generally aim at small systems (usually home batteries). Indirect support for storage mainly results from another policy scheme or practice; prosumers are for instance in several countries incentivized to invest in batteries in order to increase their self-consumption allowing them to avoid low feed-in prices, and/or to reduce grid costs and related surcharges. The absence of a direct support scheme is usually not considered as an important barrier, as storage operators engaged in the electricity market consider eliminating market and regulatory barriers (e.g. discriminatory rules) more efficient and important than granting support. Public support is considered as a measure of last resort, for some applications of strategic interest, which would otherwise not enter the market.

In some Member States, support is specifically addressing isolated systems, such as islands or remote areas. This allows to value the specific contribution of storage to security of supply and system reliability of isolated regions, as opposed to more general support schemes not tailored for the characteristics of such systems. But in contrast, a stakeholder indicates that wherever public service obligation subsidises diesel & heavy fuel oil-based electricity generation options on islands, it needs to be revised to enable hybrid renewable energy sources + storage plants to also qualify and receive such support. This will allow operators to replace their thermal capacity and prioritise the dispatch of hybrid plants, and enable island operators to make a gradual shift to cleaner energy sources, without need to overhaul the system and posing no threat to energy security.

In a few Member States, storage is supported via tenders for pilot projects. Nonetheless, in the majority of countries there is no direct financial support for energy storage. In these Member States investors are often opting for hybrid solutions where energy storage is for instance coupled with variable renewable energy production, which offers a higher overall profitability than separate investments. Energy storage is also increasingly being deployed in the context of sector coupling, such as combined-heat-and-power plants which are storing heat in order to take benefit of the price volatility on the electricity market.

Pumped hydro storage (PHS) is the main electricity storage technology largely deployed across many Member States and has an important role in the electricity system, in particular to provide ancillary services such as black start.[47] A few countries have put into place specific support schemes to PHS (e.g. discount on grid tariffs in BE) and/or have removed some major barriers (e.g. discriminatory rules in capacity mechanisms following contestation by market operators).

In order to analyse the plans of Member States concerning storage, the National Energy and Climate Plans (NECPs) submitted to the European Commission within the framework of the Energy Union Governance were reviewed. All Draft NECPs were considered, with results being updated with the final NECPs for the Member States which had submitted one by February 2020. Therefore, final NECPs were considered for 16 Member States: AT, HR, CY, DK, EE, FI, EL, HU, IT, LT, MT, NL, PL, PT, SK, SE.

According to the NECPs, Member States consider energy storage as an important pillar of the energy transition and of a low carbon economy. It provides flexibility to the energy system and is therefore considered as an enabler for intermittent renewable electricity. But only a few NECPs present a detailed view on the appropriate policy to deploy energy storage at scale and on the types of storage that would best fit the energy system needs. A few NECPs address the barriers to storage and define objectives or measures to strengthen R&D on storage. Next to the specific references to storage in the NECPs, a few Member States have or are preparing a strategy or roadmap specific to or including storage (such as FI, DK, FR, PT). NECPs should provide further details on the deployment pathways for each storage technology as well as the forecasted measures in order to allow market actors to deploy the identified storage capacity needed.

[47] ENTSO-E (2019) Survey on ancillary services procurement, balancing market design 2018

The majority of Member States consider electric vehicles as potential storage units that can offer flexibility to the energy system, while contributing to reducing the need for investments in grid capacity. A limited number of Member States consider storage as a mean to empower consumers (both households and companies). Some Member States mention in their plan that storage should be developed in order to anticipate accelerating energy system changes and to avoid curtailment of variable renewable electricity production.

At present, there is in most Member States no comprehensive national regulatory framework for storage; policy instruments and measures applicable to storage are spread across different legislations and regulations and appear to address storage without a clear and consistent vision. This leads to non-harmonised rules, and in some cases incoherent and complex frameworks. Following the publication of the new electricity market design package, some countries are taking initiatives to specifically address storage in their energy and/or electricity sector legislation or strategy, and are organising or intend to organise consultations on a proposed review of the legal framework for storage. The changes mainly address electricity and ancillary services markets rules, as well as the definition of storage.

A few Member States have clearly identified the technologies and applications that have an interesting industrial potential, and include them in their energy, industrial and/or R&D strategies. Some countries have also a specific budget for storage R&D. Also, some Member States have a specific roadmap which addresses the different applications for storage in households, tertiary buildings, transport (electric vehicles), and others.

In some Member States, the principles of self-consumption and energy communities are currently being implemented in the electricity market legal framework, with the inclusion of energy storage.

There is finally the potential to further incorporate storage in energy efficiency policies and measures. The various energy storage technologies have the potential to increase energy efficiency in multiple ways, such as by reducing transport losses and increasing the (renewable) energy self-consumption in buildings and industry. When advancing energy efficiency targets, investments in energy storage technologies coupled with other measures such as building renovation or waste energy utilisation should be eligible for available support mechanisms.

Best practices

There is no consensus on the importance or need to set up a storage support scheme due to the existence of market failures. Nonetheless, for the majority of the stakeholders, storage should have adequate grid tariffs and levies, non-discriminatory access to all electricity markets and eventual capacity mechanisms, a stable regulatory framework that reflects the long-term lifetime of storage assets. This would enable the competitive development of storage, before any kind of economic support is considered. According to other stakeholders, for specific Member States, economic support can be useful to stimulate the development of non-mature storage technologies, to leverage economies of scale, to stimulate R&I concerning energy storage, or to support pilot or demonstration projects supporting policy learning. For some stakeholders, economic support, especially in countries with low level of cross-border interconnection and immature electricity markets, is recommended, and would also depend on the expected technologies, applications and market penetration.

Member States which do choose to implement a storage support scheme should pay attention to minimising market distortions and the discrimination of other flexibility sources as far as possible. Integrated or indirect support schemes can be considered as the preferred option to stimulate investments in energy storage; such an approach is in general less distortive than direct support (see section 1.2.1). National support schemes for small scale PV can indirectly incentivize behind-the-meter small scale storage units, if the support scheme is properly designed and implemented. Net metering is considered as a distortive measure, which disincentivizes investment in behind-the-meter storage. Several Member

States (e.g. AT, DE, GR) have implemented renewable energy support schemes which de facto stimulate local storage and can be considered as best practices. Some countries, like Ireland, have launched a specific pilot micro-generation scheme to support PV installations coupled with home battery storage for self-generation. Other regions such as the US state of Massachusetts (with the SMART program) also increase the support to renewable energy installations through a multiplier, if storage is added.

Member States such as Belgium, Finland, France, the Netherlands, Poland, Portugal and Spain have dedicated R&I budgets for energy storage. Hungary, Italy, Lithuania and Malta on the other hand, highlight storage in their R&I Action Plan, but do not refer to a dedicated budget for storage. R&I strategies are supposed to be implemented in the framework of the 2021-2030 National Energy and Climate Plans (NECPs).

Storage has been addressed in a more holistic way in the draft or final NECPs of Austria, France, Greece and Spain. In these plans, the concerned authorities do not only recognise the need for storage, but they also address the different technologies and applications they intend to focus on. Some plans are more detailed and also contain specific storage objectives, a set of concrete policies and measures, a clear R&I agenda and proposed regulatory changes to address barriers and/or incentivize the deployment of storage at scale.

Looking outside of the EU, California has set in 2013 an energy storage procurement mandate for investor-owner utilities, requiring them to install 1 325 MW of storage by 2020. The targets are separated between front-of-the-meter (sub-divided in transmission- and distribution-connected) and behind-the-meter storage, and covers several technologies (although large hydropower is excluded). Following the mandate, California adopted new regulations to accelerate storage development. It created a independent body to mediate connection disputes, added a new target of additional 500 MW by 2024, and expanded funding incentives to behind-the-meter storage.[48] In 2018, the state of New York also announced a storage target, aiming at 1 500 MW to be deployed by 2025, reaching 3 000 MW in 2030. This target is to be achieved by various mechanisms utility procurement of bulk storage, changes in tariff design and wholesale energy markets, taking storage into account in the criteria for large-scale renewable auctions, and addressing other regulatory barriers.[49]

3.3.2. *PERMITTING & STANDARDISATION*

Context

This topic addresses the permitting rules applied to storage for build up or for operation. Permitting regulation can be specific to storage facilities, depending on their technical characteristics and impact on the environment (including soil), safety, fire hazards, public health and/or landscape. Usually, when there are no specific rules, storage is falling under the standard framework. The lack of specific rules is a priori not considered as a main barrier for the deployment of storage but could in some cases slow down the permitting process. Pumped-hydro storage is due to its high environmental impact a specific case, for which the permitting procedure can act as a barrier.

For large storage facilities, a license to be issued by the national energy ministry according to the electricity legislative framework can be required. This licence (which also applies to large generation plants) does not address connection and access conditions to the grid (which are covered by the agreements to be concluded with the grid operator). It rather allows the installation of the storage assets from an electricity system perspective. In general, this legal obligation is not considered as a barrier to storage, as it was not highlighted by stakeholders, also considering that it generally only applies to larger scale facilities, while small installations are exempted.

[48] The Climate Group (2017) How California is driving the energy storage market through state legislation
[49] NYSERDA et al. (2018) New York State Energy Storage Roadmap

Mandatory compliance with standards related to safety and security (e.g. fire protection), has an impact on the economic and technical feasibility of storage and can hence act as a barrier to specific storage types, in particular batteries. The standards address stationary and mobile applications, inside and outside applications. Although the manufacturing industry is responsible for the production of storage components, the safety of the consumers is to be ensured by the installation companies. Safety and security standards are needed, but they should be based on the real risks and avoid jeopardizing the uptake of storage.

Current status across Member States

Most of the Member States do not have specific permitting rules applicable to storage. New projects must comply with the standard notification, planning acceptance or permitting rules, usually depending on the overall risk level of the installation and its size, environmental impacts and location. Although the absence of specific rules is a priori not considered as a barrier, issues may result from the inadequacy of the standard legal framework to storage projects and/or the lack of enabling specific provisions for storage.

In the Netherlands for instance, the absence of a comprehensive national permitting regulation that also covers energy storage results in local authorities having the possibility to impose very strict conditions to storage units. This leads to diverging rules depending on the location, and uncertainty for potential investors in storage assets. For some other Member States, the lengthy permitting process with different concerned administrations becomes a critical aspect in developing storage projects.

The permitting process should be streamlined, ensuring an appropriate coordination between all the administrations involved. The process should take place according to a timeframe which is not excessively long, while allowing for early and effective public consultation. According to our analysis, if the storage project characteristics do not fit the existing permitting regulations, authorisation bodies (such as municipalities) may be inclined to determine their own regulations, which may increase the permitting complexity.

As far as can be determined, few Member States have yet introduced mandatory standards for the installation of the different relevant battery technologies (incl. lithium). Only some technologies are included in the national normative frameworks. Transport and storage of batteries (incl. lithium) are apparently weakly addressed by Member States, but some Member States are considering enlarging their normative framework to include these issues. The transposition of the Directive 2013/56/EU, amending the Directive 2006/66 on batteries and accumulators and waste batteries and accumulators, was not considered as an issue when addressing the barriers to the use of storage technologies. However, the Directive does not address the issue of utilising the batteries in a 'second life' application,[50] e.g. using EV batteries in stationary applications, which could be considered as a raising issue.

A stakeholder has also indicated that stringent calibration requirements on mobile battery charging stations for EVs in Germany constitute d a barrier to developing the business model, although no further indications of this barrier were identified in other Member States. Also, where applicable, the requirement for operators of charging points to notify or request authorisation for the installation and decommissioning of charging points well in advance could hinder cases where such points would be dynamically placed.

Several Member States face problems when it comes to the delivery of a permit for larger scale storage projects, such as pumped hydro or hot water storage (based in natural rock). Environmental concerns and local opposition can jeopardize or (significantly) delay the permitting process. Although the permitting procedure of large-scale projects comprises

[50] European Commission (2019) Report on the implementation and the impact on the environment and the functioning of the internal market of Directive 2006/66/EC

wide public hearings, public acceptance remains a major hurdle.[51] The lack of public acceptance and understanding of the economic and societal added value of such projects can be considered as the root cause of this barrier. Public acceptance may become a more significant issue also for batteries, as he Renewables Grid Initiative notes that there has been rising opposition in some regions, such as Ireland. Governments should implement best practices for the involvement of the public in the development and operation of storage projects, such as understanding and adequately communicating safety standards for battery projects.[52].

For pumped hydro storage, in the majority of Member States, both a building and environmental permit are required. These permits are usually delivered based on a comprehensive Environmental Impact Assessment study. Even small-scale storage may be affected in this regard, as the JRC notes that 'a consistent and efficient licensing process is particularly important for hydro stations of the small- or mini-scale. Long and complex licensing procedures render such investments not feasible and of high risk.'[53]

Best practices

There are at present no national practices, which can as such be considered as best practices. Austria seems the only Member State that considers storage from a holistic point of view, taking into account all impacts and potential risks related to manufacturing, storage, transport, installation and operation.

3.3.3. *WHOLESALE ENERGY MARKETS AND CAPACITY MECHANISMS*

Context

Forward, day-ahead and to a more limited extent, intraday electricity markets are the most mature and supra-nationally integrated markets in Europe. Also, by the end of 2018 capacity mechanisms existed in 13 Member States, being furthermore under implementation in Italy and Germany.[54] These can form important revenue streams for storage, especially when coupled with other revenue sources from ancillary services markets and congestion management. Storage can provide significant value to energy markets and capacity mechanisms, but its effective participation is strongly influenced by the technical characteristics of the various storage technologies, especially regarding energy and discharge capacity rates as well as the rate of self-discharge. Pumped hydro storage has a long record of participating in energy markets, while newer technologies such as battery storage are only starting.

Market barriers for storage can be separated between barriers to entry and barriers to participation. Barriers to entry comprise for instance market rules not defining storage or excessive pre-qualification requirements (such as minimum nominal capacity), and barriers to participation comprise for example inappropriate market design parameters (for example a minimum bid size of several MWs). Specific market designs may exhibit only barriers to entry or only to participation, with the similar end-result of hindering the deployment of storage. Moreover, besides market barriers specifically affecting storage, other barriers such as market power of incumbents may affect all potential market entrants, including storage.

[51] European Parliamentary Research Service (2019) Understanding public responses to low-carbon technologies
JRC (2014) Hydropower – technology information sheet

[52] Renewables Grid Initiative (2019) Energy Storage – Perspectives from California and Europe.

[53] JRC Low Carbon Energy Observatory (2019) Hydropower Technology Market Report

[54] ACER and CEER (2019) 8th ACER-CEER Market Monitoring Report focusing on 2018. Volume 1: Electricity Wholesale Market Volume

Storage can directly or indirectly (via aggregators) participate in electricity markets via transactions in organized exchanges or over-the-counter (OTC). Over-the-counter trade is still more predominant than trade in exchanges in high-volume markets such as Germany, France and the UK.[55] As long term revenue certainty is important to unlock investments in storage, forward contracts can also be an adequate instrument for storage operators to ensure a certain level of certainty of revenues from these markets.

Market barriers related to energy markets and capacity mechanisms affect not only stand-alone storage, but also hybrid cases where storage is aggregated with other resources such as other storage facilities, renewable energy generation and/or demand response. Another relevant case for this section is the coupling of combined-heat-and-power with heat storage in order to respond to the price volatility in the wholesale energy markets.

Current status across Member States

Participation of storage in the energy market is not indicated as a barrier in most countries with liquid and deep electricity markets. Even when there are no specific provisions related to storage, participation is possible, as the regulatory framework does not foreclose storage, which is then generally considered a producer. There are no indications of undue pre-qualification requirements in countries with developed energy markets.

In Member States with less developed energy markets, participation of storage (and especially technologies other than pumped hydro) is more limited, as lack of specific rules still creates uncertainty and market power sometimes also constitutes a barrier to entry.

Besides barriers to entry in less developed energy markets, specific energy market design parameters act as participation barriers to storage in some countries, such as minimum bid sizes and price caps. However, while minimum bid sizes of e.g. 1 MW are common, these may frequently be met through aggregation of resources, effectively reducing the participation barriers to storage. Nonetheless, aggregation is still not allowed in some energy markets.

A rather technical but still important barrier to participation of storage is the lack of appropriate order (i.e. bid) formats, as storage may be exposed in case of uncertainty in securing simultaneously market orders for the charge and discharge phases (with an energy purchase and sale order, respectively). In this context, EPEX (covering six Member States) introduced loop block[56] orders for its day-ahead market in late 2018, being the first power exchange to do so.[57] Nonetheless, EPEX and other exchanges such as Nord Pool offer linked block orders, which may also be used for storage to secure orders for its charge and discharge cycle.

Participation of behind-the-meter storage in energy markets is still limited. Locational and temporal signals in energy markets play an important role in fostering the participation of distributed resources. However, locational signals are limited given the zonal approach for European energy markets, while the use of temporal signals for active residential consumers is also limited. As recently as 2018, fixed electricity prices were still the dominant type available to households in most Member States, while dynamic end-user price offers were available in 7 Member States.[58] However, demand-side management through heat storage in response to energy market prices is relevant in more and more Member States, especially in Scandinavian and Eastern European Member States.

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[55] DG Energy (2019) Quarterly report on European electricity markets. Volume 12 – Issue 1, Q1 2019.

[56] Loop block orders are a group of one sell and one buy orders at two different trading periods which are accepted or rejected together. They thus reflect the storage cycle, eliminating the risk a sell or buy order is accepted without the correspondent order.

[57] EPEX SPOT (2018) EPEX spot introduces curtailable blocks and loop blocks on all day-ahead markets. Available at http://www.epexspot.com/en/press-media/press/details/Press/show_detail/40116

[58] European Commission (2019) Energy Prices and Costs in Europe. COM(2019) 1 final.

Participation of storage in capacity mechanisms is in general legally possible, but its effective participation and the impact on its profitability is still very limited. Certain national mechanisms were recently contested by market actors due to considered barriers to access for demand side response or storage. While storage is generally eligible for participation in the mechanisms deployed in recent years, specific design aspects such as the derating factors applied to storage can act as a barrier. This occurs for example by including by grouping storage with other technologies, or by applying a generic derating factor to all storage technologies. Some stakeholders indicated that all capacity mechanisms notified by Member States and approved by the European Commission so far have a contracting window of 5 years or less before (eventual) delivery. According to the stakeholders, that would hinder the participation of technologies with a very long lead time, such as pumped hydro storage.

Best practices

Generally, the most important best practice for energy storage regarding energy markets is the development of deep and liquid day-ahead and intraday energy markets in Europe which allow storage to place orders aligned with its technical characteristics. One example are the EPEX and Nord Pool exchanges, where the bid size for the spot market is only 0.1 MW which facilitates participation of storage.[59] EPEX has in 2018 launched loop block orders covering its 6 Member States (NL, FR, BE, DE, UK, AT) which are suited for storage. In addition, EPEX and other exchanges such as Nord Pool offer linked block orders suited for storage. Another important best practice is the allowance of aggregators in these markets, such as in the case of EPEX.

In the US, in 2018 FERC issued order No. 841 to remove barriers for the participation of storage in capacity, energy, and ancillary service markets operated by Regional Transmission Organizations (RTO) and Independent System Operators (ISO) (RTO/ISO markets).[60] The order determines that RTOs and ISOs must define market rules that (1) ensure storage is eligible to provide all capacity, energy, and ancillary services that it is technically capable of providing in the RTO/ISO markets; (2) ensure that storage can be dispatched and can set the wholesale market clearing price as both a seller or buyer consistent with existing market rules; (3) account for the physical and operational characteristics of electric storage resources through bidding parameters or other means; and (4) establish a minimum size requirement for market participation in the RTO/ISO markets that does not exceed 100 kW.

Examples of adequately designed capacity mechanisms, mechanisms which (will) allow for the participation of storage include Belgium (upcoming in 2020, with participation possible including through aggregation), France (minimum capacity of 1 MW, with aggregation possible), Ireland (with derating factors specific to the storage size and duration), and Poland (minimum required provision period shortened to four hours). However, even these capacity mechanisms may have specific design parameters which do not fully provide a level playing field for storage across different time horizons.

Moreover, functioning wholesale markets have led to the development of distributed heat storage (e.g. in CHP plants) in order to react to dynamic prices in countries such as Austria, Czech Republic, Germany, Belgium, Denmark and Finland.

3.3.4. *Ancillary and grid management services*

Context

[59] EPEX SPOT (2018) Trading on EPEX SPOT 2018

Nord Pool (2020) Rules and regulations

[60] Federal Energy Regulatory Commission (2018) Order No. 841 Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators

Ancillary and grid management services form an important potential revenue stream for storage, which can provide much value to such services, given the controllability, fast response and modularity of storage technologies. It is essential as storage investors/operators are more and more considering multiple revenue streams in their business cases. Thanks to its controllability, fast response and modularity, policy makers, regulators and network operators have recognized the contribution storage can bring to system security and stability.

Ancillary services may be separated between balancing and non-frequency services, while grid management services (for congestion management) are a third category.[61] Network operators play a central role in procuring these services as they are tasked with guaranteeing the system security.

Pumped hydro has traditionally been the storage technology most commonly providing balancing and non-frequency ancillary services. Recently, batteries have made inroads in multiple Member States, either through market-based procurement or more rarely experimentation by network operators. Besides front-of-the-meter storage, active customers and behind-the-meter storage have a strong potential to participate in the provision of these services, including via vehicle-to-grid applications.

It is generally acknowledged that storage can provide similar services to the system similar to other flexibility resources and should hence be treated equally in a technology-neutral approach. However, an equal approach may constitute a barrier to entry if the technical characteristics of storage, such as more limited discharge durations, are not properly considered when designing the products to be procured.

National regulators and network operators recognise the increasing flexibility needs which arise from the penetration of intermittent renewables. They are conducting studies to better understand the potential role of storage technologies, estimate future flexibility needs and implement pilots in multiple Member States, even in those where there is at the moment barely any participation of storage in the provision of ancillary services.

Current status across Member States

Ancillary services markets are less developed than energy markets in terms of depth, liquidity and cross-border integration. Moreover, procurement of ancillary services is frequently not market-based or some services are imposed to network users and hence not remunerated (or only partly). This applies especially to non-frequency ancillary services. Participation of storage in ancillary service provision is currently hence limited in many Member States. Participation in balancing services is more advanced, while non-frequency ancillary services present higher barriers to storage.

Concerning balancing services, frequency containment and replacement reserve markets are more frequently accessible to storage, in particular pumped hydro, while batteries are still rarely admitted, except in Central-Western Europe. Also, the limited market size can lead to the dominant participation of few large flexible generators (including hydropower) in detriment of potential market entrants. Moreover, the approach per Member State varies, with storage not being eligible to provide services in at least one of the national balancing markets in almost all Member States. This is partially a consequence of national regulatory frameworks not defining and addressing energy storage consistently.

In addition to these barriers to entry, the design of balancing markets represents barriers to participation. Parameters such as requirements for symmetry in the provision of upward and downward balancing, or minimum balancing energy provision duration are barriers in some Member States. Various stakeholders have indicated concerns regarding the

[61] Balancing actions maintain the electricity frequency within a predefined stability range. Non-frequency ancillary services comprises for example voltage control (to maintain it also within predefined ranges), black start (to recover from a partial or total shut-down of the electric system) or islanded operation (in the case of system splitting) capabilities.

provisions of the recast Electricity Regulation concerning the limit of 12 months to balancing contractual durations, indicating that it would be insufficient to provide the certainty required for long-term investments. However, theoretically storage operators are still able to establish contracts of a larger duration with balancing service providers and/or responsible parties.

The possibility of storage to provide non-frequency ancillary services is even more rare than balancing services. This is especially valid for batteries, which in most Member States cannot provide voltage control nor black-start services due to the way these services are procured. Moreover, generators are in multiple Member States obliged to provide these ancillary services, with the consequent inexistence of organized markets for their procurement.

Finally, participation of storage in grid congestion management is at present limited to pilot projects focusing on battery systems. Albeit limited in scale, these projects are taking place in multiple Member States, in recognition of the modularity and controllability of the technology. Nonetheless, national regulations in many Member States still need to provide a level playing field for the procurement of such services by DSOs, while guaranteeing that all flexibility resources are in network development plans considered equally with network expansion. The implementation of dynamic or time-of-use network tariffs and end-user prices at the distribution level could incentivize distributed flexibility resources including storage, but variable tariff and price signals are not yet common practice.

Best practices

Concerning the access of storage to balancing markets, the best examples are the balancing markets of Central-Western Europe and the British Isles. There, multiple Member States allow storage to provide capacity (and more limitedly energy) frequency containment reserves (BE, DE, FR, UK, IE). In addition, several countries (FR, BE, AT, DE, SL) allow pumped hydro to provide automatic frequency restoration reserves, while the Netherlands allows batteries in this market.

One positive development is the cross-border integration of balancing markets. The Electricity Balancing Guideline sets requirements concerning separate upward and downward balancing procurement, the imbalance settlement period and other aspects which will eventually be implemented across Member States.[62] The Baltic Interconnection Project is also leading to the integration and improvement of balancing markets in the Baltic States.

Multiple projects are ongoing for market-based procurement of balancing reserves, for example in Italy, Finland, Denmark, the Netherlands and Portugal. For example, TenneT and other partners are working on blockchain-based projects to sources flexibility services from EVs and residential storage to the TSO.[63] It is also worthy to note the important participation of storage operators for the provision of balancing services in Hungary, with multiple battery projects in the recent years.

3.3.5. *GRID ASPECTS*

Context

This topic addresses grid charges that are applied to users of transmission and distribution networks. Usually, end-users pay grid charges on the basis of the amount of electricity taken off from the grid (€/MWh), and/or on the basis of their connection capacity or their peak capacity taken off from the grid (€/MW). Generators pay in some countries also grid charges depending on their injection volumes and/or capacity. Energy storage can physically be considered as both producer and consumer, and therefore both types of grid

[62] European Commission (2017). Regulation 2017/2195 establishing a guideline on electricity balancing

[63] Eurelectric (2018) Blockchain in Electricity: a Critical Review of Progress to Date

charges (double grid charging) apply in several Member States as storage is not specified in the regulatory framework, notwithstanding the potential contribution of storage to avoiding or reducing network congestion and investments. This is considered as a distortion and a major barrier to the deployment of storage. However, for some grid operators, network tariffs should cover and reflect the actual use of the network. As a result, storage must pay the off-taking tariff when it takes off energy from the network, as any other consumer site does and pay the injecting tariff when it injects, as any other production site does. Any policy-related levies (such as for supporting renewable energy) recovered through the network tariff component are similarly detrimental.

Storage installations benefit in some Member States of grid charges exemptions, or specific tariff rules. These exemptions can be specific per technology, application or grid service. Due to the variety of storage technologies, potential applications and services, a case by case exemption regime can be complex and difficult to apply in practice. Exemption regimes for storage can apply to transmission or distribution charges only or to both, with some differentiation.

Storage can specifically be addressed in the grid tariff regulation via two approaches: either by incentivizing specific storage technologies to support their uptake or by eliminating distorting practices (e.g. double grid charging) and reflecting in the tariff setting the potential benefits of storage to the network. In the second case, the approach should be the same for all types of storage, independently of the technology, application or service.

More generally, locational or temporal signals in network tariffs could be used to incentivise investment and operational decisions of network users, including of storage operators. However, the benefits of such signals must be weighed against the costs of implementing these measures. It is important to differentiate between locational and temporal signals, between the transmission and distribution levels, and between the network connection and access charges. They must not be confused either with signals for energy prices either. Therefore, the interactions between the different possible signals that can be provided to network users through network tariffs and energy prices should be considered, as well as the current practices across the EU, in order to identify the most appropriate approach balancing benefits and costs.

The deployment of storage can also be hindered by grid connection and access rules, such as technical specifications, agreements or contracts. This might in particular be a hurdle for small scale systems, if they have to comply with the same specifications and procedures as large projects. If grid rules and codes do not properly take into account the specific status and characteristics of storage, the administrative and technical burden for storage can be disproportionate and constitute a major barrier.

Net metering[64] for small scale prosumers (consumers, usually households, equipped with a production unit behind-the-meter) discourages active participation in the market. It also limits the interest to opt for hybrid solutions consisting of a storage and production unit allowing to increase self-consumption. Net metering is hence a major barrier to behind-the-meter storage. The new electricity market Directive introduces limitations to new net metering schemes for active consumers.

<u>Current status across Member States</u>

In multiple Member States, the qualification of storage facilities as both consumer and producer makes the storage operator a “double” network user. This leads to the obligation to pay network charges based on its volumes taken off from the grid as well on its volumes injected into the grid. Awareness about this barrier is increasing among Member States,

[64] Net metering is defined in European Commission (2015) Best practices on Renewable Energy Self-consumption as “a regulatory framework under which the excess electricity injected into the grid can be used at a later time to offset consumption during times when their onsite renewable generation is absent or not sufficient. In other words, under this scheme, consumers use the grid as a backup system for their excess power production”

and some of them are currently implementing changes to address this distortion in the regulation.

According to ACER[65], at the transmission-level, of the 13 surveyed Member States which apply injection charges to electricity network users, 8 apply charges to pumped hydro storage and 5 to non-pumped hydro storage.[66] At the distribution level, 6 Member States which charge injections from distribution-connected pumped hydro storage, and 4 Member States do so for non-pumped hydro storage technologies.[67]

The recent changes in grid tariff principles apply in particular to pumped-hydro storage plants (mainly new projects, or existing plants under certain conditions) and comprise an exemption from or reduction of the grid fee for offtake and/or injection. The off-take of electricity for conversion into hydrogen or synthetic methane is in some Member States also subject to exemption. For batteries installed by end-users, this is not an issue, as they mostly do not (yet) inject electricity into the distribution grid. The deployment of batteries by utilities for balancing purposes might however be hindered in Member States where double grid charging is applied for such installations.

A few Member States have implemented exemption regimes with complex rules which do not address the possible behind-the-meter combinations of storage, with for example generation. Other countries are currently addressing the issue of double charges in the context of the review of their Electricity Market Design framework. But some Member States have not yet taken the initiative to address this issue.

For several stakeholders, exemptions on grid tariffs and taxes / surcharges are commonly introduced when a need to deal with distortions created by the existing grid tariffs and taxes / surcharges is identified. Thus, these exemptions are more about dealing with consequences than with causes and, in addition, significantly complicate the regulatory framework and risk to create further distortions. Therefore, the optimal way to deal with the need identified is to tackle the genuine issue – i.e. redesign the grid tariffs and taxes / surcharges according to appropriate regulatory and efficiency principles.

Usually, self-consumers with net settlement do not pay grid tariffs for the share of their consumption that is covered by own production. This measure stimulates the use of behind-the-meter storage.

As storage facilities are currently considered as producer in most Member States, they have to fulfil the usual generators' obligations such as: be part of a portfolio with balancing responsibility; comply with the technical specifications of network operators; compensate for the provision of primary balancing power in proportion to their injection quantities. In addition, in many Member States, storage facilities that take off energy from the grid have also to comply with end consumer obligations. Both obligations apply if there are no specific grid connection and access rules for storage facilities.

The obligations are in some cases limited to storage facilities above a certain threshold (usually > 1 MW). Smaller storage units do in general not have to comply, as they are usually coupled with either self-consumers (self-consumption schemes) or distributed power generation (mainly renewable energy-based), and hence not directly connected to the grid. Standards for the construction, testing and operation of electrical systems usually also apply to storage facilities.

Concerning tariff signals at the transmission level, ACER[68] also indicates that out of 29 surveyed jurisdictions, 11 had some sort of time-differentiated transmission network tariffs, namely BE, HR, EE, FI, FR, NO, PT, SI, ES, GB, and NI (Northern Ireland). Such

[65] ACER (2019) ACER Practice report on transmission tariff methodologies in Europe

[66] Charges pumped hydro: AT, BE, FR, IE, PT, RO, ES, UK (GB). Charges other storage technologies: BE, FI, FR, IE, UK.

[67] Charges pumped hydro: AT, DK, PT, RO, ES, UK (GB). Charges other storage technologies: DK, FI, SE, UK.

[68] ACER (2019) ACER Practice report on transmission tariff methodologies in Europe

signals were mostly applied to the withdrawal charges, either the energy component (8 cases) or the power component (5 cases). Only in 5 cases were such signals applied to the injection component. Dynamic pricing was much less common than seasonal, day/night or peak/off-peak signals. Regarding transmission locational signals, out of the 29 jurisdictions surveyed by ACER, 6 had some kind of locational signal. Most often this applied to both injection and withdrawal (NO, SE, GB), and less often to withdrawal (AT) or injection (IE, NI). In the consideration on the harmonisation of electricity tariff structures through a network code by ACER, a study[69] indicated that given the difficulties of implementing locational marginal pricing in Europe, the use of locational signals in transmission tariffs could be an adequate form of providing incentives for the siting decisions of network users.

For distribution, the use of locational or temporal signals for DSO's tariffs is much rarer. As far as 2015, no tariff schemes with locational nor dynamic price signals were found in the EU in a study for the European Commission.[70] Moreover, the study indicates that such locational signals can be more appropriately conveyed through energy prices for short-term network congestions, while structural congestions may be better addressed through network expansion.

Net metering still exists in multiple Member States and is an important barrier to the deployment of small-scale storage coupled with distributed power generation units.

Only a limited number of Member States have already grid codes addressing specifically storage characteristics. In some Member States, storage is addressed through the smart grid framework, with incentives or specific rules applied to flexible solutions.

Best practices

Several Member States (AT, BE, DE, FR, IT, ES) that dispose of pumped hydro storage capacities that are considered crucial for the stability of their electricity system (balancing and ancillary services), have recently taken measures to reduce grid charges and related costs for these installations. UK is currently considering such a measure. The new rules can be considered as good practices, as they are more cost-reflective and take into account the specific benefits that storage offers to the grid. The current grid tariffication practices across Member States are however still quite diverging: same or different rules for existing and new storage facilities, losses included in tariffs or not, grid tariffs applicable to electricity offtake and/or to injection, tariff rebate on all volumes or only for electricity providing specific services (e.g. balancing). Addressing double charges is hence a highly complex task. Following a multiple year process, the UK is minded to adopt a licence for storage which could help reduce this complexity.

There are currently few Member States having introduced specific connection rules and tariffs for storage, resulting in both generators and consumers' rules potentially being applied to storage projects. In Denmark, the TSO Energinet has published the first grid codes specifically for connection and access of batteries. For some stakeholders, there is need to make connection processes more transparent and simplify technical specifications (DSO/TSO). The approach in France can be considered as a good practice; it has recently included in its legislation a proper definition of energy storage and intends to specifically address the issue of connection rules for storage in a near future.

In Ireland, the TSO EirGrid has recognised that some derogations are required to account for the specific characteristics of energy storage and its potential to offer ancillary services. In the Netherlands, where there is no pumped hydro capacity to ensure system balancing, the TSO TenneT identifies the need to further develop cooperation between TSO and DSOs, the market model and processes for the use of flexibility sources including storage for congestion management. In the UK, the Piclo Flex platform – currently being trialled by several UK DNOs – provides a marketplace for DNOs to tender for and receive bids to resolve anticipated network congestion needs. Ofgem's RIIO-2 price control review,

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[69] CEPA (2015) Scoping towards potential harmonisation of electricity transmission tariff structures

[70] Ref-e et al. (2015) Study on tariff design for distribution systems

currently underway, is also looking at stronger incentives and obligations on DNOs/DSOs to assess the opportunity for flexibility.

3.3.6. *TAXES & OTHER LEVIES*

Context

This topic addresses the specific taxes and levies applied to storage facilities. An electricity generation or consumption tax and/or other levies exist in all Member States.

Besides applying to end-users, they may also apply to storage facilities. Similarly to the double charging of network tariffs, storage plants that are directly connected to the grid, may be considered as both producer (injection) and consumer (offtake). If storage is considered an energy consumer for taxation purposes, energy offtake by storage will constitute a taxable event. Subsequently, the discharge energy will be taxed once again when finally consumed by the end-user. This situation, called double taxation, has a negative impact on investments in and use of storage. It must be noted that as double taxation occurs during storage offtake and then again during the final energy consumption, it differs from double tariff charging, which takes place when storage charges and then discharges.

Storage can be subject to exemptions from or reductions of taxes and other levies. Similar to grid tariffs, these exemptions or reductions can be specific per voltage level (transmission or distribution), storage technology or application.

Current status across Member States

In several Member States, double taxation occurs. This practice leads to a double burden on temporarily stored electrical energy, as the final consumer of stored electricity has also to pay network charges, taxes and levies on the same electricity volumes. Some Member States apply specific exemption or reduction regimes for storage, which can take different forms (exemption under certain conditions like coupling with a renewable energy production facility, technology or size specific,…). Such exemptions or reductions have in several Member States been implemented for pumped hydro storage, while some other Member States plan to implement such measures in the near future. In some Member States, exemptions apply for electricity which is generated with a renewable unit or CHP and then self-consumed, or for electricity which is fed in into the grid to participate in the balancing market.

In some Member States, levies and taxes apply to all electricity consumed irrespective if that energy comes from the grid or from an own production or storage facility behind-the-meter. Such a framework disincentivizes both local production and storage.

The majority of Member States have not yet addressed the double levies applied to both offtake and injection by storage facilities. This is still an important barrier, and it will also hinder the future development of vehicle-to-grid applications.

In some Member States, as storage is not properly defined in the national legislation, the rules applicable regarding levies and surcharges are not clearly defined and remain vague and subject to diverging interpretation.

A few national authorities are providing tax discounts (on taxable income) for the purchase of energy storage equipment, in particular batteries. This support is usually implemented within the broader framework addressing the climate and energy objectives.

Storage has also to be considered when addressing the level of taxes and grid tariffs. Very high tariffs/taxes billed are an obstacle for the development of storage directly connected to the grid (as it is generally the case of big pumped hydro storage plants). However, very high tariffs/taxes can be an incentive to install a storage plant (like a battery) behind the meter of a prosumer. As a result, lowering tariffs/taxes billed to storage could stimulate the development of storage directly connected to the grid and lower the development of behind the meter storage. Hence, the height of the tariffs/taxes billed to storage appears to be a very interesting policy discussion.

Best practices

Austria, Belgium and Germany are exempting pumped hydro storage from paying fees resulting from the cost recovery of support schemes for renewable and/or CHP electricity.

In Luxembourg, the legislative framework foresees the exemption of the electricity tax for "energy consumption used for storage purposes ".

Finland has recently suppressed the double taxation of electricity for large batteries. Electricity can now be transferred to storage sites without the excise duty on electricity, which is due when electricity is transferred for consumption.

Investors in energy storage assets are eligible to a federal tax discount (deduction on the taxable income) in Belgium and Italy (when coupled with PV).

In the Netherlands, there is a tax ruling to avoid double taxation for storage supplying energy directly to end consumers, but this provision does not cover the case of suppliers delivering energy which was previously stored. The government has announced plans to end this double taxation on storage in 2021.

3.3.7. *INVOLVEMENT OF NETWORK OPERATORS*

Context

Electricity storage can provide value both to network users (generators and consumers) and network operators. Hence, the role of network operators in the ownership and operation of storage and the consideration of storage as a competitive activity have been extensively debated in the run-up to the Clean Energy Package, and afterwards.

Proponents of the separation of storage from regulated network activities argue that if allowed to own and operate storage, network operators would enjoy an unfair competitive advantage for several reasons. These include that network operators are responsible for providing connection and access to networks and could hence disadvantage other potential storage operators to favour their own projects. Also, being responsible for the operation of the electricity system, network operators have a better knowledge of the electricity system, which leads to information asymmetry. Furthermore, being regulated, network operators' activities have a lower risk, and thus they have access to capital at a lower cost than market parties. Finally, the combination of network and storage activities could lead to cross-subsidisation and distort competition between storage operators, and between storage and other flexibility resources, such as demand-side response or dispatchable generation, on the other hand.

Arguments in favour of network operators playing a role in electricity storage activities revolve around the still incipient role of storage technologies (especially batteries and power-to-gas) and the need for innovation. Excluding network operators from storage activities would hinder experimentation in new technologies, in a context of potential lack of market interest. Furthermore, regulated investment may drive the deployment of storage technologies, at a faster pace than what would be achieved by the market. Storage technologies can also be combined in multiple network points in order to create 'virtual' lines, in a similar manner to conventional network investments. Moreover, some proponents argue that adequate models exist to leverage the expertise of network operators while guaranteeing that storage remains a competitive activity, with network operators acting as "storage service providers" to the market.

Current status across Member States

Due to the limited deployment of electricity storage in the past, many national regulatory frameworks did not explicitly address the ownership and operation of storage by network operators, and storage was in most countries not defined in primary legislation. This is also partly a consequence of the third energy package which did not address this issue.

When ownership and operation of storage by network operators is addressed in legislation or regulation, it is most commonly not allowed, which was already noted by CEER in 2014.[71] Regulatory frameworks which do allow ownership and operation by grid operators usually do not indicate requirements which need to be fulfilled. However, such requirements are sometimes mentioned, for example maximum storage or discharge capacities of e.g. 0.5 MW. In rare cases storage may be considered a regulated activity such as for pumped hydro in isolated systems such as islands, in one Member State. CEER indicates that in the few cases where storage is considered exclusively as a regulated rather than competitive activity, regulators set disclosure obligations to network operators so that the knowledge from the development and operation of storage is shared with market actors.

Regardless of unbundling requirements in Member States, in practice, network operators do not own nor operate storage in most countries, as was also acknowledged by CEER.[72] Also, given the uncertainty and the proposed unbundling requirements already in 2016 in the Clean Energy Package, only a limited number of system operators actually developed such projects since 2016.

Nonetheless, Lithuania, France, Germany and Italy are developing pilot storage projects with the involvement of network operators. For some, it is argued that these projects respect the unbundling requirements as they are operated as 'virtual power lines' and only intervene during a few seconds when a problem crops up, for instance due to network elements faults.[73] Further analysis and guidance from the Commission might be appropriate to guarantee the unbundling rules set in the new electricity market design are respected.

A particular question on the role of network operators for storage concerns the ownership and operation of power-to-gas facilities, which is related to the question of whether the technology is considered storage or not (this point is discussed in the next section). At the moment, national definitions are divided on this aspect. Providing certainty for the investments in power-to-gas will thus require clearly addressing these interrelated aspects: whether network operators are allowed to own and operate storage, and whether power-to-gas is considered storage. Currently, power-to-gas projects are limited to a handful of countries, with participation of both TSOs and DSOs in some projects.

Multi-service business cases are when "multiple stakeholders are together involved in the ownership, development, management, and/or operation of an energy storage facility in order to maximise its social welfare by fully deploying all services storage can deliver".[74] Multi-service business cases could allow individual storage facilities to provide storage services clearly separated between markets and regulated actors, through adequate contractual arrangements between the parties. These cases are at this moment restricted to a handful of explorative projects.[75] The two regulatory conditions of successful multi-service business cases are likely not fulfilled by the current national frameworks in the EU. Namely, a clear separation between market and regulated storage activities, and the possibility to combine both in an individual storage project.

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[71] CEER (2014) Development and Regulation of Electricity Storage Applications.

[72] CEER (2014) Development and Regulation of Electricity Storage Applications.

[73] See IRENA (2019) Innovation Landscape for a Renewable-Power Future – Solution V.

BMWI (2020) What is a grid booster?

[74] EASE (2019) Maximising Social Welfare of Energy Storage Facilities through Multi-Service Business Cases.

[75] EASE (2019) Maximising Social Welfare of Energy Storage Facilities through Multi-Service Business Cases.

Generally, national regulatory frameworks are consistent in the approach for transmission and distribution system operators: where unbundling requirements exist, they are applied for both TSOs and DSOs. Conversely, where the national regulatory framework does not explicitly address the issue, this is the case for both the transmission and distribution activities.

Best practices

The existence of clear national rules regarding the possible role of network operators in storage can as such be considered as best practice. At the moment TSOs and/or DSOs are not allowed to own and operate storage in AU, HR, CZ, FI, NL, SI. Many national regulatory frameworks do however not address whether and under which conditions, network operators are allowed to own and operate storage. One example of an explicit reference to possible involvement of network operators is Hungary, where ownership and operation of storage is allowed for DSOs, but limited to a certain capacity (0.5 MW). Alternative approaches to the involvement of DSO ownership of storage can be identified in the US, where the rules for states such as New York or California vary in how much involvement is allowed.[76]

3.3.8. *STORAGE DEFINITION, FINANCING, SECTOR COUPLING AND OTHER ASPECTS*

Context

The main aspect in this section is the definition of storage in primary legislation of the electricity sector, which most often has a large impact on policies and barriers for storage in a given Member State. The definition determines for instance whether storage operators are a specific and different market actor than generators and/or consumers. This differentiation should result in greater certainty for the participation in electricity markets and guarantee that storage is not burdened with undue costs such as double network tariffs, electricity consumption taxes or RES surcharges. These barriers to entry in electricity markets and undue costs applied to storage have a direct impact on investment decisions.

A particular question concerning the definition of storage is whether it requires the energy conversion back to electricity (such as in the case of pumped hydro and batteries) or whether conversion to another energy carrier without re-conversion to electricity is allowed (as in the case of power-to-gas or most heat storage technologies).

In the case of conversion technologies between electricity, gas and heat vectors, conflicting definitions my arise in the primary legislation of each sector. For example, in the case of power-to-gas definition in the primary legislation of the gas and electricity sectors.

Even though funding some low carbon projects (like wind and PV) becomes relatively easy to obtain, private investments on other clean technologies like storage is still considered difficult. The main barrier comes from the difficulty to reach a viable business case due to all related regulatory barriers. Another barrier comes from the difficult access to finance, which is gains relevance as we approach a potential large-scale deployment of storage technologies and applications.

The access to finance depends on the business case of an investment and on the stability of the regulatory and policy framework. It is of paramount importance to ensure this stability and to send the appropriate signal to the financial institutions and investors in order for them to understand correctly the risk associated to storage investment.

Sector coupling was previously understood as the electrification of end-use applications (e.g. self-production of electricity by consumers). Currently, this definition has been

[76] CERRE (2019) Smart consumers in the internet of energy – Flexibility markets and services from distributed energy resources

broadened to energy systems' integration, which is the increased interaction between energy vectors and sectors, e.g. interaction between electricity, gas, and heat vectors by using 'new' supply and demand technologies, such as power-to-X, gas-to-power, and others.

The increasing share of intermittent renewable electricity (mainly wind and solar power) leads to higher price volatility, and specific challenges to balance electricity demand and supply at any moment as well as to ensure the supply adequacy. This creates multiple opportunities for sector coupling in different sub-sectors, e.g. x-to-power can be used at moments of scarce electricity supply availability (and high prices), while power-to-x can be used at moments of high availability (low prices).

Through sector coupling the storage of energy carriers other than electricity can provide services to the electricity system and increase the security of electricity supply. The first important possibility is that of sector coupling through heat storage. Examples include thermal storage coupled with a CHP plant, a borehole thermal energy storage (BTES) combined to a heat pump, or recovery of waste heat from industry, datacentres and others. These solutions employing storage respond to price differences on the electricity market (daily to seasonal) and allow an industrial process, a district heating network or a building to deliver services to the electricity market more cost-effectively than employing electricity storage.

Current status across Member States

Most national regulatory frameworks do not contain a definition of storage (the deadline for the transposition of the Electricity Directive is the end of 2020). In such cases, storage is commonly considered as a generator when participating in electricity and ancillary services markets. For grid tariffication and taxation purposes, storage is frequently considered as both a consumer and generator. Consequently, storage may be faced with market rules which do not take into consideration its specific characteristics and is furthermore burdened with non-reflective costs which significantly affect its business case.

Furthermore, even countries where the primary electricity sector legislation has recently been updated, may not have provided a definition for storage in it. And in at least one Member State, storage has recently been defined in primary legislation, but secondary legislation and in the design of electricity markets have not been adjusted, due to the time needed to update all relevant provisions.

In a few Member States storage is defined only in secondary legislation (e.g. regarding active consumers, renewable energy or taxation). In this case, the definition does not reduce the uncertainty for storage in topics not directly related to the concerned secondary legislation. In some Member States storage definitions are not fully consistent, such as if both energy and electricity storage are defined in different secondary legislative acts in an incompatible manner.

Also, the definitions across Member States differ concerning whether conversion of electricity into another carrier and use without re-conversion is considered as storage. Most of the existing definitions require re-conversion of energy into electricity, thus excluding power-to-gas. This leads to inconsistent approaches across the EU and might have a negative impact on the business case of power-to-gas which injects hydrogen or synthetic methane into the gas grids. In particular, if such power-to-gas projects would be considered as electricity end-user and hence have to pay the "full" grid costs and surcharges. The majority of the existing definitions also require storage to be connected to the grid (as part or not of a user facility, i.e. including behind-the-meter storage).

Another point is whether the definition explicitly refers to certain storage technologies, while de facto excluding other options. This is the case in at least one Member State. Also, when cycle losses are defined in legislation or regulation, they may be defined following typical values for pumped hydro of 75%, thus not being adapted to round-trip losses of other technologies such as batteries (where losses are typically lower).

Many definitions do not address the specific issue of the combination of storage with generation, either front-of or behind-the-meter, and the case of active consumers with storage. More generally, the variety of applications of storage in combination with the diversity of policies affecting storage (from electricity market design to network tariffication and taxation) are complex. This in turn increases the risk of inconsistencies in how storage is addressed in legislation and market rules.

For one stakeholder, the definition of energy storage[77] in the recast Electricity Directive could also evolve. To the stakeholder, the definition bundles different steps in the energy supply chain: the energy conversion activity (e.g. power-to-gas, gas-to-power) and the storage activity itself. Hence, to the stakeholder, should storage receive any *ad-hoc* treatment, it would be needed to differentiate when the activity is genuinely part of a storage system in order to avoid distortions (e.g. opportunistic behaviours causing free-riding, cross-subsidisation, etc). In this sense, temporal and geographical coordination between the conversion (e.g. power-to-gas) and the storage itself (e.g. injection into the storage) would be key. Other stakeholders, however, argue that classifying energy conversion as storage is more appropriate, and thus that the current definition is adequate.

The difficulty to access finance from commercial banks is an increasing barrier as storage applications slowly reach market deployment. Beyond the measures addressing the business case to make it a reality, the regulatory framework should be as simple as possible, providing a coherent and long-term approach. Complexity increases the risk for investors and financial institutions. There is need, for some Member States, to have a stable framework based on a long-term vision and ensuring the coherence and place of storage in the whole energy system.

Currently electricity storage is not included as a subsector in the Directive on protecting European Critical Infrastructures. It could be considered to add it to the Directive, taking into account adequate criteria for the selection only of electricity storage projects which would be 'essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions'.[78]

Concerning **sector coupling**, when considering seasonal storage, power-to-X is currently seen as another relevant option. The bulk storage of hydrogen in underground salt domes, aquifers, rock caverns or mines can provide long-term seasonal energy storage for electricity production or injection in the gas grid. However, these 'new' applications are not yet cost competitive and the energy efficiency of certain processes is still low; further applied research and innovation, including pilot projects, is needed to lower the cost and increase the efficiency.

Another issue to consider will be the interaction of renewable guarantees of origin (GO) for different energy carriers. Based upon the FastGO project, [79] the standard CEN 16325 is being updated to address this issue and avoid problems such as (the perception of) double counting, and lack of trust or understanding. Recent draft rules for the European Energy Certificate System (EECS), the platform for guarantees of origin, address the gas GOs and the conversion of GOs of different carriers.[80]

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[77] " Art. 2(59) of Directive (EU) 2019/944: 'energy storage' means, in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier;

[78] Directive (2008/114) on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection.

[79] FastGO project deliverables at https://www.aib-net.org/news-events/aib-projects-and-consultations/fastgo/project-deliverables

[80] See EECS rules Release 7 v11 at https://www.aib-net.org/eecs/eecsr-rules

Coupling of the electricity and transport sector are another significant opportunity. This can occur through demand response of vehicle charging. Much of the electric vehicles (EVs) charging will occur at night and during weekends, when electricity prices are relatively low and vehicles are less employed, although some EVs will need to charge during the day and even during peak demand periods. Grid-connected EVs could also be used in lieu of or in conjunction with stationary electricity storage to supply energy in scarcity periods as well as ancillary services to the system, i.e. vehicle-to-grid applications.

Stakeholders have indicated there is a need for the development of interoperability standards for communication between and control of the different EV brands as well as charging stations and systems, in order to facilitate EV charging and the provision of services in all electricity markets.[81] This is supported by the European Smart Grids Task Force,[82] with the main EU efforts taking place in the JRC European Interoperability Centre for Electric Vehicles and Smart Grids founded in 2015.[83]

Currently, the digital layer of battery management systems (BMS), notably application programming interfaces (APIs), is often based on proprietary solutions, and a move to open APIs would desirable. In addition, access to data of battery management systems is often limited, depending, among other things, on how data encryption is done. The standards or protocols currently being developed for data encryption and communication (so-called Public Key Infrastructure) between the vehicle and the charging point are proprietary, and created according to the specific interests of the automotive industry.

On top of the need for interoperability between EVs, charging infrastructure and control systems, there is the additional challenge of facilitating cross-border EV travel (e-roaming). While the Alternative Fuels Infrastructure Directive 2014/94/EU established requirements to facilitate e-roaming and led to the development of initiatives to implement this, there is no consensual communication protocol for e-roaming.[84] A stakeholder has indicated also that the facilitation of direct payments could also be a solution to enable cross-border EV travel.

The deployment of mobile and stationary energy storage technologies as well as increased sector coupling can lead in the future to the reduction of energy price differentials between peak and off-peak times. For example, when EVs deployment reach significant levels, the purchase of energy at off-peak times to charge EVs and eventual the energy supply in peak times could be enough to reduce the viability of other applications.

Best practices

The best practice concerning the definition of storage is to address it in the primary legislation of the energy sector, in a technology-neutral approach. The regulatory frameworks of Belgium, France, Hungary include a definition of electricity storage in the primary legislation of the electricity sector. However, these require the re-conversion of the energy into electricity, while the French definition explicitly includes 4 technologies, namely pumped hydro, power-to-gas, batteries and flywheels. Moreover, the definition does not necessarily eliminate barriers to storage in other policy categories.

To improve financing conditions and availability to storage, stakeholders indicate that Member States could support or even coordinate the following actions:

- Creating an asset class for storage, to mainstream into the appropriate financial instruments;

[81] EASE (2019) Energy Storage: A Key Enabler for the Decarbonisation of the Transport Sector.

[82] European Smart Grids Task Force (2019) Expert Group 3 - Demand Side Flexibility Perceived barriers and proposed recommendations.

[83] https://ec.europa.eu/jrc/en/research-facility/european-interoperability-centre-electric-vehicles-and-smart-grids

[84] Ferwerda et al. (2018) Advancing E-Roaming in Europe: Towards a Single “Language” for the European Charging Infrastructure

- Introducing an investment grade warranty, which builds upon the investment grade, to support the risk level assessment;
- Getting the private financial sector (including savings, retail as well as cooperative financial institutions) involved to finance energy storage – this is mainly about increasing awareness, probably using success stories and explaining the regulatory framework;
- Establishing linkages with public financial or investment institutions to defer investment risks: EIB, European funds (like the Innovation Fund), or national institutions;
- Contributing to the EU works on integrating sustainability considerations into the EU financial policy framework in order to mobilise finance for sustainable growth[85] & working on the Green Bonds[86] – mainstreaming storage into these considerations;
- Insuring guarantees: Energy storage units and systems do need to be insured to make the risks of an investment manageable. A reliable guarantee and insurance system will also make it easier to rate energy storage products and energy storage companies. Reliable ratings will facilitate financing for the energy storage sector.

3.4. The EU electricity market design and other legislation related to energy storage

The previous section identified policy barriers and best practices affecting the business case of energy storage around several topics, with a focus on the Member State level. The present section complements this analysis, focusing on the EU level. The first sub-section assesses the impact of the new electricity market design on storage. Then, section 3.4.2 covers other relevant areas and the concerned EU legislation, namely the:

- Energy Taxation Directive
- Guidelines on Environmental Protection and Energy State Aid
- Trans-European Energy Infrastructure (TEN-E) Regulation and the Connecting Europe Facility (CEF) Regulation
- Water Framework Directive
- Hydropower rights granting procedures
- R&I Framework Programmes: Horizon 2020 and Horizon Europe
- Critical raw materials
- Financing

3.4.1. *Impact of the new electricity market design on storage*

In November 2016, the European Commission published the Clean Energy for All Europeans draft package, a collection of eight legislative acts (directives and regulations) touching on different aspects of the EU energy legislative framework. An important part of the Clean Energy Package was dedicated to redesigning the internal electricity market through recasts of the Electricity Directive (2009/72) and Regulation (714/2009).

The EU institutions reached a political agreement in December 2018 and the recast Electricity Directive (2019/944) and Regulation (2019/943) were published in June 2019 after adoption by the EU Parliament and Council (hereafter named the Directive and Regulation).[87] The new Directive must be transposed by the end of 2020 and is applicable

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[85] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance

[86] https://ec.europa.eu/info/publications/sustainable-finance-teg-green-bond-standard_en

[87] Directive (EU) 2019/944 on common rules for the internal market for electricity.

Regulation (EU) 2019/943 on the internal market for electricity.

from the beginning of 2021, while the Regulation is directly applicable from the beginning of 2020. However, multiple provisions in the Directive and Regulation have specific deadlines, for example ACER had to publish a best practice report on transmission and distribution tariff methodologies by October 2019.[88]

The first objective of this section is to analyse the provisions in the new electricity market design which affect storage. In many Member States there are indications that the implementation of the new electricity market design should remove barriers to storage. The second objective of the section is to determine which of the barriers to storage observed at the national level in the previous section would remain after implementation of the new provisions (and whether any new barriers may arise due to the new market design). As analysed below, several provisions in the Directive and Regulation adequately address relevant barriers, but others remain due to not being addressed at all or due to necessary improvements to the new provisions.

As Member States have discretionary room regarding the forms and methods to achieving the goals set in a directive (but less in a regulation), the actual way in which the Directive is implemented will vary from one Member State to the other. Hence, whether the provisions were specified in the Directive or Regulation has an impact on their applicability as well as in the form in which they are implemented.[89] Also, Member States have the ability to further reduce the barriers to energy storage beyond what is required in the EU Directive or Regulation, be it through the implementation of more ambitious rules or faster implementation than what is required.

The Directive and Regulation comprise provisions related to all energy storage policy categories discussed in section 3.3, except to permitting. The addressed topics are detailed in this section, while the barriers which will remain after the implementation of the new provisions in the electricity market design are covered in the following section. The mapping of the categories to the Directive and Regulation articles are presented in Annex 3.

The provisions in the Directive and Regulation with a low indirect impact on storage are not analysed here as they are not directly addressing the main barriers identified previously. These **"Low impact"** provisions include the need to conduct national and European adequacy assessments which consider storage and the obligation for NRAs to monitor the investment in storage capacities. It also comprises the requirement for Member States to consider alternatives such as energy storage when authorizing new generation capacity, and the need for TSOs and DSOs to consider storage in their network development plans. Provisions with "**High impact**" are indirectly or directly addressing the main barriers and are hence considered as priorities. Their proper implementation is supposed to have a high impact on the deployment of storage. Provisions with "**Medium impact**" have a lower impact on the deployment of storage but would provide additional value and improve the global framework for storage.

Direct impact provisions are those that explicitly refer to storage, remove undue costs, such as double charging, or open revenue streams which were foreclosed, e.g. by enabling participation in new electricity markets. **Indirect impact** provisions are those that improve the signals for the investment and operational decisions of (active) consumers (e.g. dynamic pricing), or indirectly open new revenue streams (for instance, through aggregation).

Considering the transposition of these provisions, an adequate formulation does mean the transposition could be straightforward as it does correctly address the issue from a storage perspective. Some provisions, being partially addressed, still need to be further developed and detailed either at Members State level or at EU level. For some of these provisions, clarifications are needed.

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[88] Art. 18(9) of the Regulation.

[89] European Parliament (2018) Transposition, implementation and enforcement of Union law.

Electricity markets

Electricity market design (REG)	**_High direct impact_**	**_Adequate formulation_**

The Regulation requires that all relevant actors (national governments and regulators, system operators and market operators) should ensure electricity markets provide a level-playing field for generation, electricity storage and demand response (art. R3(j)). The requirements are comprehensive, covering energy and ancillary service markets as well as capacity mechanisms, and all forms of trade from over-the-counter to electricity exchanges, as well as all time frames. Furthermore, the market rules should allow for the efficient dispatch of the mentioned market agents as well as for their easy entry and exit.

The provisions require national authorities to assess the design of energy and ancillary services markets as well as capacity mechanisms for the entry and participation of storage, and potentially redesign them as required. However, details on how the level-playing field should be guaranteed and monitored are not provided. Moreover, by being defined in the Regulation, the provisions have immediate effect but actual market design is still left to national regulators, after consultation with network and market operators (some parameters are defined in other provisions, as discussed below).

As the assessment indicated there are in several Member States still significant barriers for storage to enter and participate in energy and ancillary services markets, these provisions will have a high direct impact.

Aggregation (DIR)	**_High indirect impact_**	**_Adequate formulation_**

The Directive aims to guarantee final customers are able to access all electricity markets, including through aggregation, being also entitled to separate electricity supply and electricity service contracts. NRAs or system operators should establish the rules for the participation of aggregators in the markets.

These provisions will have an indirect positive effect on front- and behind-the-meter electricity storage by encouraging aggregation (including with other resources and especially demand response), which is not allowed in specific markets in some Member States. The exact impact of the provisions will depend on the importance of aggregation of multiple energy storage facilities and with other flexibility resources, versus the direct participation of energy storage facilities in electricity markets via the concerned asset operators.

Storage was indicated to interact significantly with resources such as demand side response and renewable electricity generation. By requiring also aggregation for storage to be considered in electricity markets, the provision complements other electricity market requirements which address entry and participation barriers for standalone storage.

Active customers and citizen communities (DIR)	**_High indirect impact_**	**_Adequate formulation_**

The Directive provisions aim to enable the participation of end-users in all electricity markets while forbidding or phasing out network tariffication elements which are not cost-reflective, with several storage-specific aspects. End-users are entitled to non-discriminatory technical and administrative requirements, and network charges. Those end-users which own energy storage are entitled to a timely grid connection and should not be subject to double charging either when self-consuming or providing flexibility services. To further increase the cost-reflectiveness of self-consumption and the provision of flexibility services by end-users, the Directive requires network charges account separately for electricity injection and withdrawal, and prohibits existing metering schemes without such separate accounting of granting new rights after 2023. These requirements also apply to citizen communities, which in addition are financially responsible for their balancing.

The provisions should have an important impact on developing behind-the-meter storage in the future at the residential, industrial and commercial levels. They remove both entry and participation barriers to storage and should reduce both network connection and access costs. At the same time the provisions establish limitations to net metering practices, which are at present still common practice in many Member States and which discourage end-users from developing storage capacities. The Directive does not establish further implementation or monitoring requirements.

Energy markets and capacity mechanisms

Day-ahead and intraday markets (REG)	***High direct impact***	***Partially adequate formulation***

The Regulation requires day-ahead and intraday markets of nominated electricity market operators (NEMOs) to have a maximum bid size of 500 kW and trading period as short as the imbalance settlement period (of 15 minutes from 2021, with potential derogations not longer than 30 min from 2025 on).

The Regulation will have a high impact in reducing barriers to the participation of storage in energy markets. The provisions establish a clear threshold for bid size and duration. Although there are currently already markets with lower bid sizes, these generally occur for developed energy markets, and 500 kW is an improvement on the current maximum bid size observed in Europe (and presents synergies with the requirements on aggregation). Although derogations are possible for the latter, this should nonetheless lead to the harmonization towards shorter trading periods.

However, the Regulation does not include provisions leading to further harmonization e.g. on the definition of market products as recommended in the Smart Grids task force.[90] Different product definitions in each country, such as block or exclusive offers, when combined with other elements (such as aggregation), may hinder participation of storage facilities in multiple countries or in the day-ahead and intraday markets simultaneously.

Dynamic electricity pricing (DIR)	***Medium to high indirect impact***	***Adequate formulation***

Final customers with a smart meter are entitled to a dynamic pricing contract; Member States are responsible that this is offered by at least one supplier, and every supplier with at least 200 000 final customers. This provision has a direct relationship with aggregation and active customer provisions of the new electricity market design.

With the EU roll-out of smart meters to be well-advanced by 2020,[91] this will enable most final customers to access dynamic pricing. As discussed in the assessment of current policies, there is a need for further availability of variable pricing offers for final customers in the EU, in order to provide adequate price signals for demand response and local storage. The impact of this provision will depend on the attractiveness of storage to active customers for load management, self-consumption and participation in electricity markets.

[90] European Smart Grids Task Force (2019) Expert Group 3 - Demand Side Flexibility Perceived barriers and proposed recommendations.

[91] The latest European Commission benchmarking exercise estimated 72% of European electricity and 40% of gas customers would have smart meters by 2020. European Commission (2014) Benchmarking smart metering deployment in the EU-27 with a focus on electricity. COM(2014) 356.

Capacity mechanisms (REG)	**_Medium direct impact_**	**_Partially adequate formulation_**

The Regulation requires capacity remuneration mechanisms to be open to all resources with adequate technical performance, including storage. Any existing capacity mechanisms should be adapted by the end of 2019 (with existing commitments unaltered).

The measure should have a direct impact on storage, but its importance will depend on the relevance of capacity mechanisms revenue streams to storage technologies. Capacity mechanisms are increasingly allowing the participation of storage, although the exact mechanism design can still be contested.[92] As discussed, derating factors can inadequately measure the effective capacity contribution of storage technologies to security of supply, such as if storage is grouped in 'other technologies'.

An adequate capacity mechanism design is difficult due to the varying characteristics of the different storage technologies. As no requirements are set concerning these mechanism design features, further guidance will need to come from the European Commission approval of proposed mechanisms in State aid decisions.

Ancillary Services

Balancing markets (REG/DIR)	**_High direct impact_**	**_Partially adequate formulation_**

Several articles of the Regulation address the design of balancing markets, while the Directive touches on the procurement of balancing services by TSOs. Important requirements besides non-discrimination to (aggregated) storage include the limits on the gate closure time for balancing energy (to occur at or after cross-zonal intraday ones). Also relevant is the separation of upward and downward balancing capacity (except if derogated due to a cost-effectiveness evaluation by the TSO). Moreover, balancing capacity cannot be contracted more than one day before delivery or with a duration longer than one day. However, significant exceptions are allowed, through derogation by the NRA. A minimum threshold of 40% of the standard and 30% of all balancing products, and a period of one month for the rest is still required indefinitely, while longer contractual periods are allowed for a limited amount of time. Finally, national regulators and TSOs should collaborate with market participants to define the balancing market technical requirements.

The measures will have a high direct impact by facilitating access to balancing markets to storage and other flexibility resources, especially by reducing important existing entry barriers caused by undue pre-qualification requirements and through eliminating mandatory provision of symmetric balancing products in most markets. While the shortened duration and procurement periods should reduce market participation barriers for many storage technologies, storage associations have indicated also that the limitation to contracting periods could impact the business case of storage by increasing the balancing revenue uncertainty. Moreover, the maximum provision period of one day may still be too long for many emerging storage technologies, but represents an improvement over current practices.

Non-frequency ancillary and grid management services (REG/DIR)	**_High direct impact_**	**_Adequate formulation_**

The Directive determines the transparent, non-discriminatory and market-based procurement of non-frequency ancillary services by TSOs, unless derogated by the NRA for

[92] In 2018 the General Court of the European Union (press release 178/18) annulled the Commission's decision not to investigate the UK's proposed capacity mechanism. Available at https://curia.europa.eu/jcms/upload/docs/application/pdf/2018-11/cp180178en.pdf

cost-effectiveness considerations. TSOs subject to NRA approval, or NRAs themselves, should specify the non-frequency ancillary services procured, and where appropriate standardised market products at the national level. Similar provisions apply to the grid management services, including congestion management. The Regulation provides further guidance on the allowed exceptions to market-based procurement of redispatching, and establishes reporting and monitoring obligations for the system operators and the NRAs regarding this aspect.

This requirement should have a high direct impact in facilitating market-based procurement of non-frequency ancillary and grid management services, and access of storage to them. These services are currently the services least accessible to energy storage, especially those technologies other than pumped hydro. Standardized market products at the national level should support participation of storage in services such as voltage support and black-start, while storage may also derive important revenues from local services such as grid management which may not count with standardized products. While provisions exist for monitoring and reporting requirements for redispatching, this does not apply for other services discussed here.

Grid aspects and taxes & levies

Connection and access charges (REG/DIR)	***High direct impact***	***Adequate formulation***

Following the Directive, TSOs shall publish procedures for non-discriminatory connection of new energy storage. Moreover, they cannot refuse to connect a new storage facility based on future limitations on available network capacities (close or far to the connection point). TSOs may limit the guaranteed connection capacity or offer connections subject to operation limitations, upon regulatory approval. This shall not apply when costs are borne by the storage facility. The Regulation in turn indicates network charges shall be cost-reflective, transparent and non-discriminatory, and not discriminate either positively or negatively against energy storage or aggregation. Charges shall not include unrelated costs supporting unrelated policy objectives.

The connection provisions should provide clear rules to storage and impede the connection refusal for grounds other than economic efficiency, a relevant provision in a context of potential public acceptance issues for new network projects. It can be expected furthermore that storage aiming to provide grid congestion services would actually increase the available capacity. Further clarifications will be needed regarding whether connection refusal is not allowed when deep connection tariffs are applied to storage.

Regarding access charges, they should lead to a revision to avoid double charging while valuing the system benefits brought by storage (and thus increasing cost-reflectivity), as well as avoid the inclusion of surcharges related to e.g. renewable energy support (related to taxes & levies). The recast Renewable Energy Directive also contains a provision to avoid double charging for storage combined with self-consumption of renewable energy.[93] This is an important contribution to increased cost-reflectiveness for storage. Especially as the assessment of barriers indicated that double charging is still applied in the majority of Member States, while the phase out of double charging often starts with pumped hydro, to the detriment of other storage technologies.

Locational and variable tariff signals (REG)	***Medium direct impact***	***Adequate formulation***

The Regulation indicates the possibility of location signals in transmission and distribution network charges, as well as time-differentiated distribution network charges. Although application is not obligatory, NRAs should consider the latter where smart meters have

[93] Art 21(2) of Directive 2018/2001 on the promotion of the use of energy from renewable sources

been deployed. ACER is also obliged to every two years provide a report on transmission and distribution tariff methodologies best practices.

Locational and temporal signals can to a certain extent improve the business case for storage by incentivising load and generation management of users and by rewarding the provision of flexibility to the system. But signals will also affect the investment and operational decisions of other network users and thus actually decrease the price volatility. Nonetheless, such tariff signals can contribute to reducing the overall system costs and valuing all flexibility resources, including storage and demand side management. This is true especially of temporal signals such as time-of-use tariffs while the suitability of locational signals in network tariffs is contested, as other measures may be more efficient from an implementation standpoint, for instance, at the transmission level, the review of bidding zones where needed.[94] From this point of view, the optionality of such signals is adequately formulated in the Regulation. The ACER report will also provide a better overview of transmission and distribution tariff methodologies across the EU, and base eventual initiatives for harmonisation, if deemed adequate in the future.

Involvement of DSO/TSO

Ownership and/or operation of storage facilities (DIR)	***High direct impact***	***Adequate formulation, clarifications needed***

The Directive states TSOs and DSOs shall not own, develop, manage or operate energy storage facilities. Exceptions comprise fully integrated network components or a regulatory process certifying the lack of market interest at reasonable cost and length and the necessity of the storage system or services for the network. The article includes a phase-out of system operator activities in 18 months in the case of sufficient market interest, with possible compensation.

The storage unbundling requirements for TSOs and DSOs have been recently overviewed by CEER,[95] who welcomes the clear conditions for derogation by regulators, following an appropriate review. While the issue is not without dispute from some system operators, the provisions have been accepted by most stakeholders. The provisions provide certainty for potential storage investors by impeding potential competition issues and should furthermore lead to the exit of system operators presently owning or operating storage.

However, the phase out provision period and potential lack of compensation is considered inadequate by system operators and could ultimately disincentivize experimentation and investment in developing storage technologies. Also, the feasibility of multi-service business cases is made difficult by the provisions, as a pre-requisite for the involvement of network operators with storage is the lack of market interest (for non-integrated components).

Other & General

Definition of storage (DIR)	***High direct impact***	***Adequate formulation***

The Directive includes definitions of energy storage and energy storage facilities. They comprise "deferring the final use of electricity to a moment later than when it was generated", or the conversion and storage in other energy forms, with the subsequent reconversion or not to electricity. This hence should include conversion technologies such as power-to-gas, while remaining technology-neutral. Stakeholders have however indicated that clarifications are welcome on the interpretation of the definition, for example

[94] See for example ECN et al (2017) Study supporting the Impact Assessment concerning Transmission Tariffs and Congestion income Policies; Ref-e et al. (2015) Study on tariff design for distribution systems; and Energy Community (2017) Technical Assistance to Develop Policy Guidelines for the Distribution Network Tariffs.

[95] CEER (2019) Implementation of TSO and DSO Unbundling Provisions - Update and Clean Energy Package Outlook

concerning the temporal and geographical coordination of the power-to-gas facility and actual gas storage facilities.

The transposition of the definitions into national legislation should provide the basis for reducing regulatory uncertainty for storage. The definitions should preferably be incorporated into the primary legislation of the electricity sector and address any incoherence with secondary legislation, also in view of eliminating barriers related to other policies or practices. This includes for example the charging of double network tariffs and of electricity consumption taxes, when storage facilities are considered both as generator (injecting energy into the grid) and as consumer (taking off energy from the grid). Furthermore, the definition should not require storage to be connected to the electricity network, while some existing national definitions do include this condition.

Remaining barriers in the new electricity market design

The analysis indicates that the new electricity market design addresses several important barriers for energy storage, especially by defining energy storage, removing entry and participation barriers to electricity markets, making network tariffs and taxation more cost-reflective (e.g. by removing double network charges), and clarifying the role of network operators. Here the barriers which are not addressed by this new market design are discussed.

The new electricity market design does not contain provisions regarding the permitting of energy storage facilities. This is however not considered a central obstacle for development of storage in the Member States, except in the case of large scale projects such as pumped hydro or depending on natural reservoirs (e.g. heat and compressed air storage).

Energy taxation is also not addressed by the new market design, except for the requirement for network charges not to include costs supporting unrelated policy objectives. The overall absence of taxation-related provisions is due to the fact that taxation in general (and thus including energy taxes) is mostly a prerogative of EU Member States, with the EU institutions having only limited competences. However, in 2019 the discussion on energy taxation has been reopened, with a European Commission communication and the evaluation of the Energy Taxation Directive (ETD).[96] The revision of the ETD is addressed in the following section.

Further aspects that could be addressed at the EU level after the new electricity market design is implemented and the necessary provisions transposed in national legislation include, for instance:

- Harmonizing the day ahead and intraday energy market products to enhance cross-border participation of storage;
- Guaranteeing actual capacity mechanisms design details adequately enable the participation of all relevant storage technologies taking into account their different technical characteristics;
- Facilitating long-term contracts between storage operators and balancing responsible parties (electricity generators/suppliers and aggregators) or TSOs (ancillary services) in order to increase revenue certainty and stability for energy storage investments through market mechanisms;
- Assess the risk of cross-subsidisation via network tariffs between end-users with and without energy storage, and mitigate the risk when it is identified;
- Improving the permitting procedure for large scale storage projects, increasing public involvement and acceptance, while facilitating procedures also for small-scale projects taking into account their more limited impact;
- Guaranteeing locational information in congestion management products to foster market-based procurement;

[96] European Commission (2019) A more efficient and democratic decision making in EU energy and climate policy. COM (2019) 177.
European Commission (2019) Evaluation of the Council Directive restructuring the Community framework for the taxation of energy products and electricity. SWD(2019) 332 final.

- Assuring all provisions on the electricity markets design, grid aspects and taxation are clear and also facilitating cases combining storage with other resources such as demand-side management, self-consumption of (renewable) energy and vehicle-to-grid applications;

It must be noted that the analysis was done considered all provisions in the electricity Directive and Regulation are properly transposed and implemented. However, EU and national policy makers, regulators and network operators should still pay significant attention to implementation of the provisions, as the new electricity market design still leaves room for diverging interpretations and practices.

3.4.2. *OTHER EU INITIATIVES RELATED TO ENERGY STORAGE*

Moreover, the analysis of the previous section focuses on the electricity market design, but other relevant EU legislation should be revised to guarantee barriers to energy storage are removed. These are addressed in this section.

Energy Taxation Directive

At the time of the approval in 2003 of the Energy Taxation Directive (ETD), several electricity storage and sector coupling technologies were not significant yet, as acknowledged by the evaluation of the ETD published by the European Commission in 2019.[97] This leads to possible changes in the ETD arising from the deployment of "new" energy technologies and the specific role of storage in the transition to a carbon-neutral energy system.

For the analysis of these potential amendments, certain principles should be observed by any recast ETD. Energy taxation should in general be technology neutral, stimulate processes with high efficiency, and internalize the externalities of the different technologies. The latter refers especially to negative environmental externalities such as emissions of greenhouse gases and local pollutants, when not internalized through other mechanisms such as the Emissions Trading Scheme.

A distinction needs to be made between on the one hand energy use for intermediate processes, for example storage and conversion technologies such as power-to-gas or gas-to-power, and on the other hand energy end-use. Energy taxation should only apply to end-use of energy products, as is the stated objective of the current ETD. As observed in the analysis of taxation policies, if energy used for the charging of storage is considered as a chargeable event, it leads to double taxation.

Energy losses in the storage cycle could be subject to energy taxation if considered end-use. However, the current ETD states in art. 21(3) that energy consumption in an establishment producing energy products does not give rise to a chargeable event (e.g. electricity consumption in power plants). Following this and to treat storage equally vis-à-vis other energy producers, losses in the storage cycle should not be subject to energy taxation either. Changing this principle and hence taxing all energy end-use, including energy losses in production and conversion processes as well as in the transport/distribution infrastructure, could be considered. It would de facto stimulate technologies with high energy efficiency and hence contribute to the energy and climate objectives.

It must be noted that the value-added tax (VAT) is outside the scope of the ETD and should be applied to the value added by the storage activity. VAT expenses should be paid by the storage operator in the purchasing of necessary goods and services (including energy) being duly credited. Also outside the scope of the ETD are levies such as surcharges for the financing of support mechanisms to renewable energy or capacity adequacy. However,

[97] European Commission (2019) SWD 329. Evaluation of the Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity.

in contrast to VAT, these should be levied exclusively on end consumption, and thus not on energy inputs for storage or conversion to another intermediate energy vector.

Following these considerations, the main recommendations relevant for storage for the review of ETD are:[98]

- **Define taxation levels based on the energy and GHG content**: the ETD does not treat energy products equally, as taxes are not required to be based on the carbon content, nor energy content in the case of fuels. Defining minimum taxation levels based on energy and carbon content is a central step in providing an equal playing field for all energy products;
- **Differentiate energy transfer to storage facilities from end-use consumption** and make the former a non-chargeable event. Currently this is left for Member States, where often electricity used for intermediate storage is subject to electricity consumption taxes. Only the conversion/storage losses could be considered as a chargeable basis;
- **Update the scope** to include products resulting from conversion technologies such as power-to-gas. The use in the ETD of static references to Common Nomenclature codes and the lack of reference to products not significant at the time of the approval of the ETD leads to an outdated harmonized scope for certain energy products, such as hydrogen;
- **Update the products entitled to preferential treatment** to include renewable and low-carbon hydrogen and other fuels of biological and non-biological origin. The ETD does not allow for a preferential tax treatment for those, even though they might bring environmental benefits;
- **Guarantee that storage of energy products does not cause the loss of their preferential treatment rights** (e.g. renewable energy), when they are appropriately tracked using. It is not specified for example whether stored renewable electricity released for end-consumption is eligible for preferential tax treatment;
- **Determine that transfer of energy to behind-the-meter storage facilities intended for subsequent injection in energy networks is a non-chargeable event** and provide guidelines on the differentiation from end-use consumption. Smart meters can be used to differentiate between exempt and non-exempt energy uses e.g. for users with a single connection point to an energy network and with behind-the-meter storage;
- **Update minimum tax rates for energy products** considering technological neutrality and recent developments such as heat pumps and power-to-gas which are increasing competition between energy products. Potential competition between electricity, gas and heat carriers is hampered by e.g. high tax rates for electricity compared to gas;[99]
- **Clarify whether the conditional exclusion of electricity from the ETD scope applies to hydrogen electrolysis**. The ETD scope does not cover electricity, when it accounts for more than 50 % of the cost of a product (considering purchased goods, personnel and fixed capital costs). This could be the case of hydrogen produced from electrolysis but would also depend on electricity prices and electrolyser costs. The threshold could provide perverse incentives to increase the cost share of purchased electricity.[100]
- **Treat losses equally for energy production, storage and transport processes**, preferentially taxing losses in the entire supply chain to stimulate efficient technologies, or alternatively guaranteeing any tax exemptions apply to all the supply chain;
- **Consider including heat in the scope of the ETD, given developments such as in heat-to-power technology.** Heat networks are not significantly integrated at the moment. However, competition between alternative energy carriers for heating, increased sector coupling and integration of heat networks could require minimum harmonization of taxation for heat and other energy carriers (considering

[98] Based on own analysis and issues identified in the ETD

[99] Fortum (2019) Efficient district heating: an enabler of carbon neutral energy system

[100] DNV GL (2018) Hydrogen as an Energy Carrier

energy and GHG content). This includes any potential exemptions for all energy carriers.

State Aid for Environmental Protection and Energy

Still nowadays, the economic feasibility of energy storage systems is generally a major barrier for their development as indicated in the introduction of this chapter, with possibly pumped hydro storage having a smaller profitability gap. Therefore, public support to storage can be justified due to various considerations: of dynamic efficiency (that is, future reductions in the cost of storage due to innovation), lack of internalization of negative externalities of other technologies, such as the cost of emissions, or of positive externalities of storage (such as increased security of supply).

In the EU, such public support by Member States is governed by the Guidelines on State Aid for Environmental Protection and Energy 2014-2020 ("EEAG"). While acknowledging the economic, environmental and security of supply benefits of certain energy projects, the EEAG aims to reduce the cost of state aid to governments, minimize overcompensation to companies and diminish distortions to competition.

The EEAG covers only public support by Member States, and thus does not address cross-subsidization issues related to e.g. net metering or double charging of grid tariffs to storage, which are more adequately addressed in the electricity market design. Hence, issues relevant to storage which fall in the scope of State Aid rules comprise direct support to investment, production and decommissioning of energy projects.

Member States should respect the principle of technology neutrality in their policies. Hence besides state aid not discriminating between energy technologies, exemptions to state aid notification requirements should apply only to support R&D in technologies with low(er) readiness levels and first market introduction to accelerate deployment. Additionally, notification exemptions can be granted to regulated, non-competitive activities such as energy transmission and distribution. However, this should not discriminate against flexibility resources which provide an alternative to network expansion, such as storage (including conversion technologies), dispatchable generation or demand response.

The approach to authorizing state aid set in the EEAG is generally considered adequate and the revision rather to be an update than a thorough change in the approach. In 2019 the European Commission announced the extension of the EEAG until 2023, when an on-going fitness check (due in 2020) and subsequent impact assessment should enable a replacement proposal.

A number of elements indirectly address energy storage in the current Guidelines, as discussed next.

First, important Projects of Common European Interest (IPCEIs) are eligible for public financing, with the European Commission providing guidelines regarding the compatibility with State Aid rules.[101] EASE and EERA have argued for the designation of energy storage projects as eligible IPCEIs, which would enable storage to access multiple support types (such as loans, guarantees, grants), exempted from State Aid requirements of prior notification by Member States and approval by the Commission.[102] Currently, the list of supply chains designated as IPCEIs include batteries; connected, automated and electric vehicles; and hydrogen technologies and systems.[103]

Second, the EEAG cover aid measures to guaranteeing power generation adequacy (i.e. capacity remuneration mechanisms), which should be open and provide adequate

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[101] European Commission (2014) Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest (2014/C188/02)

[102] EASE and EERA (2017) European Energy Storage Technology Development Roadmap

[103] DG GROW (2019) Strategic Forum for Important Projects of Common European Interest (IPCEI) – 3rd Meeting of the members

incentives to substitutable technologies to generation, including storage and demand response, which can directly participate or via aggregation. Capacity mechanisms should also not undermine the internal market nor investment decisions in ancillary service markets.

Third, the EEAG cover aid to energy from renewable energy resources. Renewable energy is defined in Art. 19(11) as coming from renewable energy plants (potentially in combination with conventional sources) and includes renewable electricity used to charge storage systems, but explicitly excludes energy provided by storage systems. The definition could also be interpreted as excluding hybrid renewable energy installations employing storage.

Fourth, the General Block Exemption Regulation (GBER) [104] indicates the exemption cases to the EEAG, when prior notice by Member States and approval by the Commission are not necessary. The GBER exempts investment aid for energy infrastructure from the from the notification requirement of the EEAG, but explicitly excludes electricity storage projects from this exemption, to whom thus the EEAG still apply. Moreover, the definition of electricity storage infrastructures is aligned with the TEN-E regulation, being restricted to facilities connected to transmission lines with a minimum voltage of 110 kV. Hence, even if electricity storage was exempt, a wide range of facilities including all those connected to transmission under 110 kV and distribution networks would fall under the EEAG.

Fifth, the GBER does exempt aid for research and development projects from the notification requirement. There are specific exemption thresholds per undertaking and project for fundamental research (40 mln EUR), industrial research (20 mln EUR), experimental development (15 mln EUR) or feasibility studies (7.5 mln EUR). The Storage at Scale competition by the UK government which set a limit of 15 mln EUR for each candidate undertaking in the projects, is hence exempt from the notification requirement.[105] One stakeholder has indicated that these thresholds limited support and did not sufficiently the potential value of flexibility resources.

The European Commission has indicated the EEAG for the next programming period to be concluded by 2023 will be aligned with the objectives of the Green Deal. The new guidelines should consider recent and future regulatory developments such as the new electricity market design, innovation (such as storage and hydrogen technologies) and market development such as higher penetration of renewables, development of infrastructures and low-carbon mobility. The new guidelines would include simplified approval for small(er) aid amounts.[106]

Therefore, the opportunity exists for a number of improvements in the future guidelines concerning energy storage. Given the above analysis, potential elements for amendment include:

- **Align the EEAG with the new electricity market design and renewable energy directive,** regarding requirements for capacity mechanisms, for example CO_2 emission limits, opening of support schemes and definition of storage;
- Align the EEAG scope with the upcoming, **revised TEN-E regulation**;
- **Consider explicitly support to hybrid projects as an eligible state aid measure** (combining generation and storage of renewable electricity, gas or heat);

[104] Regulation (EU) No 651/2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty

[105] BEIS (2019) Storage at Scale competition. Available at https://www.gov.uk/government/publications/storage-at-scale-competition?utm_source=be02a8e4-bfa8-4666-a669-2f30ecd1e607&utm_medium=email&utm_campaign=govuk-notifications&utm_content=immediate

[106] DG Competition (2019) Presentation on guidelines on State aid for Environment and Energy 2014-2020 (EEAG): Fitness Check

- **Consider explicitly entitling conversion technologies to state aid** (subject to notification and approval). Only use of non-supported renewable energy inputs (e.g. renewable electricity) should be allowed (to avoid double support).

TEN-E and CEF

The Trans-European Networks for Energy (TEN-E) Regulation[107] considers electricity storage projects as eligible for a PCI status and opening the possibility for CEF financing. Projects must contribute to at least one of the criteria of market integration, competition, sustainability or security of supply.

Electricity storage PCIs should be directly connected to high-voltage transmission lines designed for a voltage of 110 kV or more. As most electricity storage projects are located in the territory of a single Member State, these projects should have a significant cross-border impact. Moreover, they should have an installed capacity of at least 225 MW and an annual net electricity generation at or above 250 GWh/y.

PCI status provides certain benefits, including a one-stop shop for the permitting process (which is limited to 3.5 years), risk mitigation incentives, and access to Union financing. PCIs are eligible also for Union financial assistance, that is for financing from the Connecting Europe Facility or the European Funds for Strategic Investments. However, electricity storage PCIs are not eligible for the risk mitigation incentives.

Assistance may be provided for studies or works. All storage PCIs are eligible for Union financial assistance for studies and works, except pumped hydro storage which is not eligible for assistance for works. The TEN-E determination that financial assistance for works requires a cross-border cost allocation decision by the involved NRA(s) does not apply to storage projects. Hence, to qualify for financial assistance for works, storage projects need to "aim to provide services across borders, bring technological innovation and ensure the safety of cross-border grid operation".

The latest (4th) list of electricity PCI projects[108] was published in 2019 and includes 10 (clusters of) projects, mostly focussed on pumped hydro storage, with 2 compressed air energy storage projects.[109] By March 2019 the Connecting Europe Facility had provided financial assistance to one compressed air and three pumped hydro energy storage projects, for a total financing value of 10.6 million €.[110]

Of the 13 electricity storage PCIs of the 3rd PCI list covered in the latest available ACER monitoring,[111] 2 were under consideration (in the NL and LT), 3 were planned but not yet in permitting (in BE, and the UK), and 8 were under permitting (in AT, BG, EE, EL, ES and the UK). Concerning progress, 8 were on time or ahead of schedule, 3 were delayed due to financing reasons, complex negotiations, or delays due to environmental concerns (a hydro project in EL), and 2 were rescheduled due to being in the initial stages.

There is therefore no indication of permitting being a particular concern for electricity storage PCIs, although permitting is the most common cause for delays in electricity PCIs overall. Of the 3rd list of PCIs, 25% of electricity projects (of which the majority are transmission projects) were delayed in 2019, with permitting being the cause for 46% of those. Specific permitting issues comprise environmental problems (3 PCIs), public opposition (3 PCIs), national law changes affecting permitting (1 PCI) and prolongation in obtaining permits for various other reasons (5 PCIs).

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[107] Regulation (E) 347/2013 on guidelines for trans-European energy infrastructure

[108] European Commission (2019) Delegated regulation C(2019) amending Regulation (EU) No 347/2013 as regards the Union list of projects of common interest. Annex.

[109] Pumped hydro: new or capacity increase projects in AT, BE, BG, DE, EE, EL, ES, LT, UK. Compressed air energy storage: new projects in NL, UK.

[110] INEA (2019) Connecting Europe Facility - Energy – Supported Actions, May 2019.

[111] ACER (2019) Consolidated report on the progress of electricity and gas Projects of Common Interest - 2019

An evaluation of the TEN-E regulation was published in 2018.[112] The evaluation highlights the complementary nature of storage, transmission infrastructure and demand response. It furthermore acknowledges the lack of many viable business cases and that limited investments in storage were made so far, except for pumped hydro. It further indicates that the relevance of energy storage has increased compared to 2013, but that most projects are of a local nature and thus are not eligible for PCI status.

The evaluation concludes that the consideration of storage in the scope of the TEN-E regulation will remain relevant in the future. However, it finds no evidence that the TEN-E scope should be enlarged to include local storage projects. The evaluation does indicate that a review of the eligibility criteria could be considered and further assessed. Also, an improved framework for measuring, monitoring and reporting storage PCI benefits regarding innovation would allow a better understanding of it in the future. Nonetheless, there is no need for a change in the regulatory framework to further incentivize innovation.

Additionally, relevant stakeholder contributions to the evaluation indicate that the cost-benefit analysis needs to be improved as it does not capture all benefits of storage projects and may have inconsistencies between regional groups. The need to consider storage capacities in defining interconnection targets for Member States is also mentioned.

In July 2019 the European Commission published a study[113] on improving the cost-benefit analysis (CBA) methodology employed by the ENTSO-E regarding the consideration of benefits of electricity storage. The current CBA 2.0 is used also for the PCI selection process, including for storage. Acknowledging limitations in ENTSO-E's CBA 2.0 methodology, the study details nine benefits of electricity storage for consideration in the PCI selection process.

A mid-term evaluation of the CEF was published also in 2018.[114] However, it does not contain insights or recommendations specific to energy storage. A proposal for the Connecting Europe Facility Regulation for the 2021-2027 programming period was published in 2018. By the end of 2019, interinstitutional negotiations were yet due to be finalized. Nonetheless, it was agreed that the European Commission would by 2020 evaluate the effectiveness and coherence of the TEN-E regulation.[115]

It must be noted that the CEF 2021-2027 proposal includes support for cross-border renewable energy projects. It is important that hybrid projects combining renewable energy and storage are eligible for support in the coming CEF programme. However, the question is whether hybrid projects are allowed under the definition of renewable energy joint projects and schemes in the recast Renewable Energy Directive, and in the cross-border implementation of these by the countries.

Therefore, given the considerations above and the analysis conducted in the present study, appropriate measures concerning energy storage projects within the TEN-E and CEF 2021-2027 regulations are:

- **Assess the TEN-E eligibility criteria and electricity infrastructure categories, and consider enlarging them** regarding the eligibility of electricity storage projects connected at lower transmission voltage or at the distribution level;

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[112] Trinomics (2018) Evaluation of the TEN-E Regulation and assessing the impacts of alternative policy scenarios.

[113] Navigant (2019) Study on an assessment methodology for the benefits of electricity storage projects for the PCI process.

[114] European Commission (2018) SWD 44. Report on the mid-term evaluation of the Connecting Europe Facility (CEF). See also accompanying in-depth documents.

[115] Council of the European Union (2019) Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility – Progress report. 7207/1/19 Rev 1.

- **Align the TEN-E infrastructure categories** for electricity storage to the definition of the Electricity Regulation, concerning especially the inclusion of conversion technologies such as power-to-gas;
- Implement the **relevant recommendations of the study on the benefits of electricity storage** to the CBA 2.0 methodology;
- **Reconsider the exclusion of hydro pumped storage to eligibility for Union financial assistance for works** in line with the technology neutrality principle, as other storage technologies are eligible. Art. 14(2c) already establishes a requirement that projects receiving assistance for work should not be commercially viable. Further weight to innovation could be given in the CEF award process to consider the contributions to innovation of each project;
- Examine **the innovation eligibility requirement for financial assistance to works for electricity storage PCIs**. Although it is desirable that the PCI selection process and Union financial assistance support innovation, this requirement is not applied to other types of projects such as for electricity transmission. Supporting innovation could be added as an explicit objective of TEN-E and CEF, and duly considered in the PCI selection and CEF award processes as for the above recommendation;
- If the innovation eligibility requirement is maintained, assess and improve the framework for measuring, monitoring and reporting the **innovation benefits of PCIs**. This could be aligned with the recommendations of the innovation and security of supply in national regulatory frameworks study[116] regarding a EU guideline on the matter for non-PCI projects at the national level.

These recommendations focus in particular on the energy storage aspects in the TEN-E and CEF regulations. Additionally, further improvements to the regulations as proposed in their respective evaluations and other studies should of course also be addressed.

Water Framework Directive

The Water Framework Directive[117] (WFD) is the main EU environmental legislation affecting existing and new hydropower facilities, including hydro pumped storage. The WFD aims to prevent further deterioration, protect and enhance river basins and ecosystems (partially) located in the EU. The WFD requires the development of river basin management plans by the cooperation of the concerned countries and accompanying appropriate measures. The European Commission was concluding in 2019 a fitness check of the Water Framework and the Floods Directives.[118]

The central point of analysis on the impact of the WFD on hydropower (not only pumped storage) concerns the stated objectives of the WFD of non-deterioration and improvement of water bodies in the EU on one hand, and the environmental pressures placed on water bodies by hydropower on the other. Protection of water bodies in the EU could have an impact both on the deployment of new hydropower capacity as well as on the operation of existing plants, by e.g. constraints on reservoir levels, allowed generation or pumping, and thus interact with policy objectives regarding renewable energy.

The WFD states that Member States should implement measures to prevent the deterioration of all surface water bodies, following Art. 4(1a). Hydropower is indicated as one of the most frequent hydromorphological pressures for river basins, and already an important part of water bodies in the EU is heavily modified due to power generation.[119] Although hydropower is not a 'consumptive' use of water, in that there is no net extraction

[116] Ecorys et al. (2019) Do current regulatory frameworks in the EU support innovation and security of supply in electricity and gas infrastructure?

[117] Directive 2000/60/EC establishing a framework for Community action in the field of water policy

[118] European Commission (2019). Evaluation Roadmap - Fitness check of the Water Framework Directive and the Floods Directive

[119] European Commission (2017). Environmental requirements in relation to hydropower in the context of the WFD. IEA Hydropower TCP – European Commission DG RTD Joint Workshop

of water for hydropower, dams do impound water bodies through reservoirs and alter the river's flow. It is however important to note that not all hydropower projects have the same impact and some may not deteriorate the status of a water body. Also, hydropower promotion should not be based on size, as impacts are not necessarily proportional to size.[120] Dedicated pumped hydro storage may not have the same environmental impacts as other hydropower plants, whether run-of-river or with a reservoir. Generally, run-of-river hydropower is considered to have less environmental impacts than both pumped hydropower and hydropower with a reservoir.[121]

For hydropower plants which do lead to deterioration or impede a water body from recovering, the WFD still allows Member States to proceed with projects, as long as the non-deterioration exemption requirements set in Art. 4(7) are met. These requirements are that:

- All practicable steps to mitigate adverse impacts are taken;
- The river basin management plan includes the projects;
- The project is of overriding public interest and/or benefits outweigh the environmental and societal benefits if no project occurred;
- Other alternatives are not available due to lack of technical feasibility or disproportionate cost.

It is important to differentiate between existing and new projects. Existing projects need to mitigate their impact on river basins to achieve the WFD objectives, and often the most interesting solution for them is modernization or repowering in order to increase energy or capacity, possibly combined with ecological restoration measures. For new hydropower projects, an evaluation of whether the project will deteriorate the water bodies or prevent their enhancement needs to be conducted. In both cases, the requirements of Art. 4(7) need to be met.[122]

Especially for the development of new hydropower, stakeholders agree that a pro-active (i.e. early) and integrated planning as well as **increasing the information availability** (e.g. on potential assessments, impacts and mitigation measures) is the best approach to develop hydropower while considering the objectives of the WFD. It is also important to recognise when pumped hydro has lower environmental impacts than large-scale reservoir hydropower, especially in the case of closed-loop pumped hydro.[123] Additionally, **upgrading and retrofitting existing pumped hydro should be a priority** given the average age of the existing hydropower facilities, and the possibility to improve the operational performance and safety.

A workshop on these issues was conducted in 2011, resulting in an issue paper of the WFD Common Implementation Strategy (CIS).[124] It recalls key recommendations for hydropower development under the WFD:

- Pro-active planning of zones for hydropower should be conducted in collaboration between authorities, stakeholders and NGOs, indicating 'no-go' areas;
- Focus should be placed on the modernization and repowering of existing hydropower;[125]
- The development of new or existing hydropower should be accompanied by an improvement of water ecology;

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[120] Kampa et al. (2011). Issue paper of the Common Implementation Strategy Workshop - Water management, Water Framework Directive & Hydropower.

[121] Melin (2010). Potentially conflicting interests between Hydropower and the European Unions Water Framework Directive

[122] European Commission (2017). Environmental requirements in relation to hydropower in the context of the WFD. IEA Hydropower TCP – European Commission DG RTD Joint Workshop

[123] JRC Low Carbon Energy Observatory (2019) Hydropower Technology Market Report

[124] Kampa et al. (2011). Issue paper of the Common Implementation Strategy Workshop - Water management, Water Framework Directive & Hydropower.

[125] This is also supported by the JRC in its 2019 Hydropower Technology Market Report.

- An analysis of costs and benefits of the project is necessary, although not necessarily with full monetization or even quantification;
- The size of the project is not the relevant criteria for exemption from non-deterioration, as impacts are not necessarily related to the size.

A summary of WFD Common Implementation Strategy guidance and activities concerning hydropower is available.[126] The EU has also issued in 2018 a guidance on the requirements for hydropower in relation to EU nature legislation.[127]

The use of strategic planning to integrate energy, climate, water and other environmental objectives in consultation with all stakeholders is a consensual solution considering the recommendations from the CIS, the hydropower industry and other stakeholders. Activities increasing information on potentials, costs and benefits as well as R&I support in mitigation techniques for hydropower are also generally accepted.

The issue paper of the CIS also provides a number of best practices regarding the non-deterioration exemption process, highly relevant given Art. 4(7) is central to hydropower deployment. Proponents of hydropower development have made proposals on the WFD.[128]

In any future update of the WFD balancing environmental, climate and energy policies will remain central. The WFD could require the **assessment of the impact of river basin management plans and measures on existing and new renewable energy production**. Related to this, the update should weigh whether the consideration of public and private costs and benefits of hydropower projects is adequately formulated, and whether the appropriate balance in approving hydropower projects is achieved. In order not to bias any cost-benefit analysis towards the economic benefits of hydropower, attention should be paid to the challenges in assessing positive and negative environmental externalities.

A second point of consideration relates the WFD Art. 9, which establishes the **principle of cost-recovery of water services through water pricing.** The latest report on the implementation of the WFD[129] indicates a significant number of Member States have broadened their definition of water services to encompass activities which have a significant impact on water bodies, including hydropower. The report notices, however, that the actual use of economic instruments throughout the EU is limited, and that the cost-recovery principle implementation is incomplete. Moreover, recently the European Court of Justice has ruled that Member States may exclude certain water uses from this pricing mechanism.[130] Thus, at present water pricing for hydropower may not be an immediate issue in most Member States. The question in a recast of the WFD is whether to specifically include or exclude hydropower in the cost-recovery principle (or if to leave it to Member States, due to subsidiarity), considering the future evolution of water pricing policies in Member States.

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[126] European Commission (2017). Environmental requirements in relation to hydropower in the context of the WFD. IEA Hydropower TCP – European Commission DG RTD Joint Workshop

[127] European Commission (2018). Guidance on the requirements for hydropower in relation to EU nature legislation

[128] Notably Eurelectric (2018) Water Framework Directive: Experiences & Recommendations from the Hydropower Sector

[129] European Commission (2019) SWD 30. European Overview - River Basin Management Plans. Accompanying the report on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC).

[130] European Court of Justice (2014) Judgment of the Court on recovery of the costs for water services - concept of ‘water services’. Case C-525/12. Available at http://curia.europa.eu/juris/document/document.jsf?text=&docid=157518&pageIndex=0&doclang=EN&mode=req&dir=&occ=first&part=1

Concerning actions on energy policy measures, the CIS[131] recommends that support schemes and other measures to renewable energy should advance criteria for protection of water status when relevant. As dedicated pumped hydro plants do not contribute to renewable energy targets, the recommendation could be broadened, as Member States should consider the water status when developing any support measures to storage as well.

Hydropower rights granting procedures

Given the potential environmental impacts of hydropower, the **use of public resources and the benefits to the energy system as well energy and climate policy objectives**, the rights to explore hydropower resources are generally granted by public authorities. Beyond the Water Framework and State Aid Directives, this granting of rights is also affected by the Services Directive, the EU rules on public procurement and the freedom of establishment and the freedom to provide services.[132]

National legislation and practices for granting exploration rights still differ significantly among Member States, concerning the use of competitive procedures, the types of rights provided according (authorization, concession, license or permit), the duration of these rights (from less than 15 years to unlimited) and the involvement of local or regional authorities.[133] This variety of approaches as well as the legal uncertainty regarding the alignment with EU legislation leads to complexity and uncertainty, which are an important barrier to hydropower development.[134] Moreover, differences between Member States can lead to distortion of the Internal Electricity Market, if not justified by economic and environmental aspects.[135]

Moreover, within the same Member State, the rights granting approach will also frequently vary according to the size of the installation. Also, the definition of small hydropower is not consistent between Member States, varying between 1.5 and 15 MW. While environmental impacts of hydropower are not necessary related to the size of the installations (as indicated in the discussion on the Water Framework Directive), especially for small-scale hydropower developers may not have the resources necessary for the complex granting process, nor benefit from the economies of scale of larger projects. Recent national strategies have focused on smaller scale projects (and especially run-of-river plants) due to the overall lower impact.[136]

In the last 20 years, several European countries have been subject to infringement procedures by the European Commission (and even the European Free Trade Association, EFTA) concerning the procedures for allocating rights for the exploration of new or existing hydropower. However, these infringement procedures have been started by different Commission Services and do not necessarily follow a common approach. [137]

Recently, the European Commission called 8 Member States to comply with EU legislation.[138] The infringement procedures were related to transparency and impartiality in the selection procedures for new hydropower authorisations in five Member States (AT, DE, PL, SE and the UK) and for expired authorisations in IT, while French and Portuguese

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[131] Kampa et al. (2011). Issue paper of the Common Implementation Strategy Workshop - Water management, Water Framework Directive & Hydropower.

[132] Respectively Directive 2006/123/EC, Directive 2014/23/EU and Articles 49 and 56 of the Treaty on the Functioning of the European Union

[133] Glachant et al. (2015) Regimes for granting rights to use hydropower in Europe

[134] JRC Low Carbon Energy Observatory (2019) Hydropower Technology Development Report 2018

[135] Glachant et al. (2016) For a harmonisation of hydropower regimes in European Single Market

[136] JRC Low Carbon Energy Observatory (2019) Hydropower Technology Development Report 2018

[137] Glachant et al. (2015) Regimes for granting rights to use hydropower in Europe

[138] European Commission (2018) Hydroelectric power concessions: Commission calls on 8 Member States to comply with EU law.

laws allow some hydropower concessions to be renewed or extended without the use of competitive procedures.

Glachant et al. (2016)[139] argue for the Commission Services and institutional stakeholders to develop a harmonised approach to granting hydropower rights. This comprises defining recommendations for granting of hydropower rights, as well as coordinating and harmonizing the actions of Commission Services. The latter regarding requesting compliance from Member States and starting infringement procedures, based on the relevant EU law (such as the Water Framework, State Aid and Public Procurement Directives). The authors also call for a harmonised regulatory regime across Member States to reduce market distortions, addressing the variations in grating procedures, unless justified by national environmental or economic specificities.

Research and Innovation Framework Programmes

The current Framework Programme Horizon 2020 has financed over 150 projects researching various aspects of energy storage, from fundamental research in specific technologies to energy system integration or research in associated concepts such as energy communities or electric vehicles. Assessing CORDIS[140] data for Horizon 2020 funding for R&I projects related to storage[141], it can be seen that Horizon 2020 contributes the majority of the total projects funds (as opposed to other sources of funding). Overall, the projects considered in the analysis have been awarded hundreds of million € in Horizon 2020 funds. Albeit determining the exact funding volume is challenging as it requires a detailed analysis of the projects' scope, it should be over 1.5 billion €.

Projects worthy of note include XFLEX (power system flexibility through hydropower), INVADE (RES storage through EVs and batteries), INTENSYS4EU (systems integration), HyBalance (PtH_2 demonstration), SMILE (smart island energy systems) and HORIZON-STE (on concentrated solar power).

It must be noted also that R&I projects at the EU and MS level interact with EU strategic priorities as reflected in the recently founded European Battery Alliance, as well as the SET-Plan platforms BatterRIes Europe.

Horizon 2020 is due to end in 2020, being replaced in 2021 by Horizon Europe. Energy storage is one of the areas of intervention of the cluster 'Climate, Energy and Mobility' of Horizon Europe, and moreover the cluster includes the other related intervention areas of 'Energy systems and grids', 'Smart mobility' and 'Clean transport and mobility'. The climate, energy and mobility cluster has a proposed budget of 15 billion €.[142]

Besides areas of intervention, **Horizon Europe clusters have key orientations**, which provide strategic guidance with a description of impacts, related intervention areas and cross-cluster issues. The key orientations related to storage are:

- 'Cross-sectoral solutions for decarbonisation', aiming (also) at developing the European battery, low-carbon hydrogen and fuel cells value chains.
- 'Develop cost-efficient, net zero-greenhouse gas energy system centred on renewables', aiming (also) to advance the technological readiness of centralised and decentralised energy storage for industrial-scale and domestic applications.

The orientations published by the European Commission towards the first Strategic Plan for Horizon Europe[143] highlight the need for research in storage. This especially on key technologies such as battery, hydrogen and thermal storage. The orientations specifically

[139] Glachant et al. (2016) For a harmonisation of hydropower regimes in European Single Market

[140] Available at https://data.europa.eu/euodp/en/data/dataset/cordisH2020projects

[141] Projects with descriptions containing the following were included: (energy OR electric*) AND storage AND (batter* OR hydrogen OR hydropower OR flywheel OR compressed air). * denotes a free ending to the word.

[142] European Commission (2018) Commission proposal for the next EU Research and Innovation Programme (2021 –2027). Available at https://ec.europa.eu/info/sites/info/files/horizon-europe-presentation_2018_en.pdf

[143] European Commission (2019) Orientations towards the first Strategic Plan for Horizon Europe

indicate that R&I investments in the cluster *climate, energy and mobility* targets impacts in "novel competitive cross-sectoral solutions for decarbonisation such as batteries, hydrogen, and other types of storage (chemical, mechanical, electrical and thermal), as well as sustainable buildings and infrastructure enabling low carbon solutions and other break-through technologies."

The orientations also indicate that a co-programmed partnership with industry and academia is proposed for the European industrial battery value chain, and a reinforced hydrogen Institutionalised Partnership in the form of the Fuel Cells and Hydrogen Joint Undertaking. Other storage types, including thermal storage, also feature very prominently, even if no need for specific partnership has been identified. EU R&I support to battery technologies should be interconnected also to the EU actions on critical raw materials, for instance to reduce or substitute the use of critical raw materials.

Critical raw materials

The large-scale deployment of energy storage may create new dependencies for the EU, according to the exact storage technologies which are deployed. Recent EU initiatives to address the dependency on raw materials include the 2017 list of critical raw materials for the EU[144] and key actions within the Strategic action plan on batteries.[145]

The recent 2018 Report on raw materials for battery applications[146] covers four raw materials for batteries: cobalt, lithium, graphite, and nickel. It focuses on the relevant key action from the Strategic action plan on batteries, which aims to:

- Build on the EU list of Critical Raw Materials, established in 2017, to map the current and future primary raw materials availability for batteries;
- Assess the potential within the EU for sourcing the four battery raw materials;
- Assess the potential in the whole EU for sourcing of secondary raw materials;
- Put forward recommendations aimed at optimising the sourcing of batteries raw materials.

The report on raw materials indicates it is necessary to improve the knowledge on battery raw materials, and confirms these are mainly supplied to the EU from third countries. The report highlights the potential to increasing primary and secondary production of these raw materials in the EU, and that there are few obstacles to using the EU potential. The obstacles include the unavailability of geological data on the deposits (which are difficult to access), the lack of integrated land use planning and mining, public acceptance, and the regulatory heterogeneity across the EU.

Given this assessment, the report makes recommendations grouped in three main categories:

- **Improving knowledge on battery raw materials**
- **Boosting primary and secondary battery materials production in the EU**
- **Ensuring access to battery raw materials on global markets**

Moreover, the Energy Technology Dependence study was finalized in 2019[147] for the Commission. It conducted a broad assessment of 13 energy technologies, selecting 3 for an in-depth assessment, among which battery energy storage (focused on lithium-ion batteries).

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[144] European Commission (2017). Communication on the 2018 list of Critical Raw Materials for the EU. COM(2017) 490.

[145] European Commission (2018) Annex to the Communication Europe on the Move. ANNEX 2 – Strategic Action Plan on Batteries. COM(2018) 293.

See also European Commission (2019). Report on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe. COM(2019) 176.

[146] European Commission (2018) Report on Raw Materials for Battery Applications SWD(2018) 245/2

[147] Trinomics et al. (2019). Study on Energy Technology Dependence

The batteries technology was assessed for the EU external dependence, market concentration, political risk, ease of market entry, availability of substitutes and competitiveness trends. While critical dependencies for lithium, battery cells, cathode substrate and battery recycling were potentially identified on a first moment, a more in-depth look provided no evidence for it. The in-depth assessment focused on cobalt critical dependencies.

The main findings for battery storage technology indicated that raw cobalt is indeed a critical dependency, with a few non-EU third countries supplying the material. Moreover, maintaining the EU refined cobalt industry is strategic as the global market is concentrated and substituting cobalt is challenging. Battery cells are identified as a critical dependency, but with a relatively low risk given stability of security of supply.

The main recommendations of the study to address the dependencies identified in the field of battery storage technology, such as to increase EU funding for the development of new battery designs employing alternative raw materials, to provide further support to investors in battery cell manufacturing (including new entrants), and to develop EU incentives for the battery recycling industry. The study finishes with general recommendations on coordinated policies, integrated energy dependence assessments, the circular economy and the role of EU industrial policy.

EU energy storage financing

To stimulate the market uptake of energy storage, access to finance should be facilitated by **measures that improve the bankability** of storage assets. Hundreds of billions of euros will be needed to finance new energy storage systems and electrolysers in the EU up to 2050, particularly to scale-up deployment from 2030 to 2050. Moreover, some stakeholders indicate that the uncertainty on returns for storage projects and the unavailability of funds with adequate interest rates form a barrier to the deployment of storage.

Financing Under the next MFF (2021-27) all EU access to (risk) finance instruments will be implemented under a single InvestEU Fund. EU instruments which form part of InvestEU can help address the financing challenge, in the categories of sustainable infrastructure, research, innovation & digitalisation, social investments & skills, and SMEs.

As part of the European Green Deal the European Commission aims to start a buildings 'renovation wave' initiative, due in 2020. The aim is to increase the renovation rate, bringing together the different actors in order to develop financing and combine renovation efforts. This initiative could constitute an opportunity in order to develop behind-the-meter storage in buildings. Storage should also be considered within a COVID-19 recovery strategy.

In order to increase the ability of market actors to finance their investments in mature or promising storage technologies, European and national public investment banks and authorities could provide loans and guarantees for project developers and manufacturers allowing them to leverage private finance. At the EU level, mechanisms such as the Connecting Europe Facility or the European Regional Development or Cohesion Funds can be used to leverage other public and private investment. The authorities could also provide guidelines for private investors to include storage in an asset class (e.g. infrastructure) that facilitates access to finance, or to evaluate the bankability of projects. In 2019 the European Investment Bank (EIB) updated its energy lending policy,[148] indicating storage technologies in general have a high alignment with it.

However, storage is still at an early stage of development (with the main exception of pumped hydro) and needs further R&I**.** Due to the large number of storage technologies and applications at various maturity levels, there is generally room to improve many

[148] EIB (2019) Energy lending policy – supporting the energy transformation

aspects. These include cost, conversion efficiencies, weight, size, material use, reliability & durability, supply chain lead times, and environmental impacts.

The EU and MS have an important role to play in providing public funds to support promising technologies in achieving market maturity and supporting low readiness level technologies through fundamental and applied R&I. DG Research & Innovation is involved in two windows of InvestEU: the R&I Window and the SME Window. The R&I window aims to make financing for innovation available across the innovation cycle and corporate development cycle. The challenge will be to develop a window that is both inclusive (accommodating financing for R&I of all types) and at the same time aligned and complementary to the priorities of Horizon Europe. For the SME window, DG Research & Innovation is in charge of the equity sub-window.

In December 2019 the EU Parliament and Council have reach an agreement regarding the EU taxonomy for classifying eligible environmentally sustainable economic activities. However, the actual eligible activities will be defined through delegated acts between 2020 and 202. Given the political agreement did not mention energy storage explicitly, a stakeholder argued that the Taxonomy only partially recognised energy storage as a key player in a carbon-neutral economy. The stakeholder highlighted it was necessary to have a clear framework for the inclusion of storage in the eligible sustainable activities.

This framework was further defined in the final report by the Technical Expert Group on Sustainable Finance,[149] which will be a main input to draft the delegated acts. The report provides criteria for projects contributing to climate mitigation or adaptation, as well as criteria for guaranteeing the projects do no significant harm to the other Taxonomy objectives.

The report indicates that all investments in electricity and thermal storage are eligible under the taxonomy climate mitigation criteria, subject to regular review. However, pumped hydro storage is subject to the criteria for production of electricity from hydropower. The construction of hydrogen storage assets is eligible under the Taxonomy climate mitigation criteria, while the assets may store only Taxonomy-eligible hydrogen (that is, they may not be used to store hydrogen which do not meet the criteria, such as a maximum level of direct CO_2 emissions per ton). Electricity, thermal and hydrogen storage is furthermore subject to standard screening criteria concerning climate adaptation.

Storage projects should, in addition, implement certain measures to avoid harm to the other environmental objectives, such as maximising recycling through the use of best available techniques and ensuring an environmental impact assessment is completed.

4. CONCLUSIONS AND POLICY RECOMMENDATIONS FOR ENERGY STORAGE

The Long-Term Strategy published by the European Commission includes pathways towards a fully decarbonised economy by 2050. One of the key elements to achieve carbon-neutrality is a large-scale deployment of variable renewable electricity sources (PV and wind) for direct and indirect electrification (e.g. via use of synthetic gases and liquids produced with electrolysers). The variability of this renewable electricity production will substantially increase the need for flexibility.

According to our study, energy storage can make a significant contribution to these flexibility needs and to reaching the security of energy supply and decarbonisation objectives at least-cost. Daily and weekly flexibility needs are directly related to the increase of RES installed capacity. In particular, solar capacity drives the need for short-term flexibility, while wind power has a significant effect on weekly

[149] EU Technical Expert Group on Sustainable Finance (2020) Taxonomy Final Report and Technical Annex.

flexibility. By 2030, up to 108 GW of electricity storage[150] would be necessary for the EU-28, with a large development of stationary batteries. By 2050, the decarbonisation of industry, transport and heating will require important capacities of electrolysers (around 550 GW based on our modelling scenarios, c.f. section 2.4.2.2). Combined with hydrogen and methane storage, these electrolysers will be able to provide essential flexibility to integrate the renewable electricity production and to meet the demand fluctuations. Electricity storage will also be necessary at the 2050 horizon, but the required capacities would decrease from 103 GW in 2030 to 50 GW in 2050 due to increasing flexibility services provided by electrolysers and electricity demand response.

In order to enable storage technologies to effectively deliver this contribution in a competitive market-based approach, different barriers should be addressed. The most important barrier is the lack of a viable business case for many energy storage projects. The cost and technical performance of storage technologies gradually improve their viability, which will significantly improve the business case, and already has for several technologies. But in the shorter term, various policy barriers still hamper the development of energy storage in the EU and lead to uncertainty concerning the revenues streams to cover the project costs and risks, but could be removed in the coming years.

The main responsibility of policymakers is to provide an enabling environment and level playing field to storage. The adequate implementation of the clean energy package should be a priority, in order to enable storage to participate in energy and ancillary services markets as well as in eventual capacity mechanisms, and to be remunerated in a transparent, non-discriminatory way. Positive externalities provided by storage, such as system flexibility and stability, as well as environmental benefits, should be adequately valued, primarily through appropriate remuneration in the different markets, and through cost-reflective network charges and appropriate taxation rules (discussed further below). Adequate energy price signals should also guide the investment and operational decisions of private actors.

The European Commission, ACER and other EU authorities should prioritise policy measures that address barriers to storage identified in the majority or all Member States, and that hinder the deployment of several storage technologies and applications. Relevant barriers specific to only a few Member States should be addressed at the national level. The proposed measures are hereafter separated according to whether they are (partially) addressed by the Clean Energy Package provisions:

1. **Tackled by the CEP**, but requiring monitoring at EU level to ensure adequate and timely implementation by Member States:
    - MS: Ensure that storage is coherently defined across the national legal framework
    - MS: Eliminate the double charging of grid tariffs
2. **Partially tackled by the CEP,** and requiring further actions at EU and/or MS level:
    - MS: Develop a policy strategy for storage
    - EU+MS: Weigh network investments vs the procurement of flexibility from other resources
    - EU+MS: Develop non-discriminatory procurement of non-frequency ancillary services
    - MS: Foster dynamic electricity prices and time-of-use grid tariffs
    - MS: Phase out net metering
    - EU+MS: Guarantee the interoperability of flexibility resources and access to data
3. **Not tackled by the CEP,** and requiring actions at EU and/or MS level:
    - EU+MS: Increase the energy and GHG-reflectiveness of taxation across the electricity, gas and heat sectors
    - EU: Eliminate the double taxation of stored energy

[150] Electricity storage includes pumped storage and stationary batteries. Current capacities represent around 40 GW.

Specific conclusions and policy recommendations

This below section provides specific conclusions and policy recommendations to address the identified policy barriers. At the EU level, upcoming revisions of EU instruments relevant for energy storage provide an opportunity to address barriers where EU action would be adequate. Actions under the European Green Deal should also consider storage, where appropriate, for example within the smart sector integration strategy and the 'renovation wave' initiative. The proposed actions at the EU and Member State level[151] per policy topic are discussed next in detail, with further details provided for the EU in Table 4-1 and for Member States in Table 4-2.

1. Energy storage requires a clear strategy addressing system flexibility and stability needs as well as policy barriers, accompanied by support adapted to the different technological maturities

National (or regional where applicable) authorities should develop a policy strategy for storage based on an assessment of the system flexibility, adequacy and stability needs, and of gaps in national regulatory frameworks *[MS action]*. Such assessments of policy gaps have been developed by some Member States (e.g. FR and FI), in particular within studies assessing barriers for developing smart grids. An appropriate identification of the flexibility needs per country and per timescale is key to assess the possible contribution of storage technologies in the future. Power storage technologies, such as pumped storage or batteries, can only provide short-term flexibility (daily and to some extent weekly flexibility). For most of the weekly and for all seasonal flexibility needs, other solutions are required. In our analysis, conventional technologies such as thermal power plants and interconnectors provide most of this flexibility at the 2030 horizon, while in our 2050 scenarios a large part of this flexibility is provided by electrolysers. However, there is still the need to develop robust methodologies to assess and differentiate short- to medium-term flexibility from long-term adequacy needs, complementing the methodology being developed by the ENTSO-E for the European Resource Adequacy Assessment.[152]

The National Energy and Climate Plans are a central instrument for Member States to provide transparency and visibility to market actors regarding the objectives for increasing the flexibility of the national energy system, including the deployment of storage technologies, and to signal the main policy actions to be undertaken *[CEP implementation]*. NECPs which comprehensively address energy storage include for instance AT, FR, EL and ES; they comprise specific policy actions to remove barriers and provide forecasts of technology-specific storage deployment that can guide investment decisions of market actors. The European Commission is expected to thoroughly assess the NECPs in view of Member States' targets, policies and measures reaching the EU energy & climate objectives *[CEP implementation]*. Member States with less detailed NECPs could be stimulated to provide further details in their future progress reports. The update of the NECPs in 2024 will allow the European and national authorities to take stock of the advances made on storage policies and to chart further actions necessary in the medium- and long-term *[EU+MS action]*.

The EU and Member States should continue providing R&I guidance and support to promising storage technologies *[EU+MS action]*. The upcoming EU Framework Programme of Horizon Europe highlights the need for research in storage, including on key technologies such as batteries, hydrogen and thermal storage. Further actions should be undertaken regarding raw materials, especially for batteries, given the significant deployment in the 2030 and 2050 horizons. Actions identified at the EU level comprise mainly improving knowledge on battery raw materials, boosting primary and secondary battery materials production in the EU, and ensuring access to battery raw materials on global markets [*EU action, batteries*]. These actions are interconnected to the EU R&I

[151] Indicated as an *[EU action]*, *[MS action]*, *[CEP implementation]* or *[EU+MS action]*. Specific affected storage applications or technologies are also indicated, otherwise, the action affects all or most.

[152] ENTSO-E (2019) European Resource Adequacy Assessment - Methodology Proposal

support to battery technologies, for instance to reduce or substitute the use of critical raw materials.

There is still uncertainty on the mid-term deployment of electrolysers; according to our assessment, investments in electrolysers would be limited in the 2030 time horizon, while after 2030 the decarbonization of the energy sector would strongly rely on P2X, and hence on electrolysers (around 550 GW estimated installed capacity in 2050, c.f. section 2.4.2.2). For storage technologies, stationary batteries appear to be an interesting solution to provide daily flexibility for the mid-term (up to 67 GW in 2030, c.f. section 2.4.2.1). But their profitability will be challenged in 2050, with direct competition with the daily flexibility provided by electrolysers, and the important development of electricity demand response (smart charging of electric vehicles, heat pumps with thermal storage). Given the large range of storage technologies and applications at various maturity levels, there is room to improve several aspects, including cost, efficiency, weight, size, material use, reliability & durability, supply chain lead times, and environmental impacts. Some Member States, e.g. DE and NL, are already setting up pilot projects using 'new' conversion and storage technologies. Storage is part of the R&I agendas of several Member States; they have specific budgets to support energy storage related R&I, either directly or in the context of system integration and smart grid technologies (e.g. FR, IE, HU, NL, PL and SK).

The EU and Member States may furthermore consider providing economic support to higher readiness-level storage technologies based on dynamic efficiency considerations *[EU+MS action]*. Specific support for storage investments exist for example in FI, BE and NL, often in the form of reduced grid tariffs. Nonetheless, achieving business case viability for energy storage projects should primarily be based on market revenues; most EU countries effectively do not grant specific economic support to energy storage. As the combination of energy storage and renewable energy generation offers in general also system benefits, support mechanisms to renewable energy should not exclude such hybrid projects [*MS action, generation+storage]*. For example, support mechanisms in AT, DE, GR consider storage, e.g. through an adder or multiplier in support levels. Therefore, the State Aid Guidelines on Energy and the Environment (EEAG) may consider including support to hybrid projects (combining generation and storage of renewable electricity, gas or heat) as an explicitly eligible state aid measure *[EU action, RES generation+storage]*. The EEAG could explicitly entitle conversion technologies to state aid (subject to notification and approval). Only use of non-supported renewable energy inputs (e.g. renewable electricity) should be allowed (to avoid double support) *[EU+MS action, RES generation+storage]*.

To stimulate the market uptake of energy storage, access to finance should be facilitated by measures that improve the bankability of storage assets *[EU+MS action]*. Between 100 and 300 billion € will be needed to finance new energy storage systems and electrolysers in the EU up to 2050, including to scale-up deployment of electrolysers from 2030 to 2050. In order to increase the ability of market actors to finance their investments in mature or promising storage technologies, European and national public investment banks and authorities could provide loans and guarantees for project developers and manufacturers allowing them to leverage private finance. The authorities could also provide guidelines for private investors to include storage in an asset class (e.g. infrastructure) that facilitates access to finance, or to evaluate the bankability of projects *[EU+MS action]*.

EU instruments can help address this financing challenge, such as the Connecting Europe Facility or the European Regional Development or Cohesion Funds *[EU action]*. To enable the Connecting Europe Facility to provide support to a large range of storage projects, the TEN-E eligibility criteria and electricity infrastructure categories should be re-assessed, and if appropriate enlarged to storage with a cross-border impact connected to lower transmission voltages and/or at the distribution level. This along with other necessary changes to ensure non-discrimination of alternative flexibility resources such as demand response, for example those eligible for the TEN-E smart grids thematic area *[EU action, front-of-the meter storage]*. Moreover, innovation requirements are at present not applied in a technology-neutral way in TEN-E, discriminating electricity storage, and particularly hydropower, against transmission projects *[EU action, pumped hydro storage]*. It is therefore recommended to examine and adapt where necessary these innovation requirements, and to assess the opportunity to add innovation as an explicit objective of TEN-E and Connecting Europe Facility *[EU action, front-of-the meter storage]*.

2. Member States should address permitting barriers, while further action at the EU level is warranted for standardisation, such as regarding safety and EV interoperability

Permitting of energy storage is in general not considered a major obstacle for the development of storage, except for larger scale projects such as (pumped) hydro or compressed air energy storage. Most Member States do not have specific permitting rules applicable to storage, only in some Member States specific national legislation and practices apply that can hinder storage. National action addressing permitting barriers may hence be more adequate than at the EU level [*MS action, large- and medium-scale storage*].

Interoperability is central to leverage the potential of behind-the-meter and EVs storage. Specific EU action is to be considered to encourage/develop EU-wide harmonised standards for device communication and system operation. Currently, the digital layer of battery management systems, notably application programming interfaces, is often based on proprietary solutions, and a move to open interfaces would desirable. In addition, access to data of battery management systems is often limited, depending, among other things, on how data encryption is done. The standards or protocols currently being developed for data encryption and communication (so-called Public Key Infrastructure) between the vehicle and the charging point are proprietary, and created according to specific interests. The relevant developments should be followed to prevent data hoarding and ensure EVs and stationary batteries can be used in "plug-and-play mode".

Adequate safety and security standards are also needed, based on actual risks and without jeopardizing the uptake of storage *[EU+MS action].* Few Member States have yet introduced mandatory standards for the installation of the different relevant storage technologies, particularly for batteries. The disposal of batteries is addressed by only a few countries, requiring further measures *[MS action, batteries]*. Austria adresses storage from a holistic point of view, considering all impacts and potential risks related to manufacturing, storage, transport, installation and operation.

Member States should implement the best practices identified in the context of the Water Framework Directive for advancing hydropower development, including pumped hydro storage. These best practices include pro-active planning in collaboration with stakeholders, focus on modernisation and repowering, and conducting always a cost-benefit analysis.[153] Permitting should be facilitated by increased public involvement and consider the differences between large- and small-scale projects. *[MS action, pumped hydro storage]*. Although the permitting procedure of large-scale projects comprises wide public hearings, public acceptance remains a major hurdle across the EU. Increased public participation may be warranted for not only large-scale projects such as pumped hydro but also other technologies, for instance batteries.

3. Member States should prioritize the full implementation of the new electricity market design, and address remaining barriers, especially regarding adequate price signals and access to ancillary services markets

Member States should ensure that storage is coherently defined across the national legal framework *[CEP implementation]*. An appropriate definition of storage is provided in the new Electricity Directive. But at present, most EU Member States do not have yet a coherent definition of storage nor have transposed the Directive, and definitions in secondary legislation often are not aligned with the rest of the legal framework. BE, FR

[153] Kampa et al. (2011). Issue paper of the Common Implementation Strategy Workshop - Water management, Water Framework Directive & Hydropower.

and HU are examples of countries with a definition of storage in their primary legislation of the electricity market. A few stakeholders have indicated moreover that clarifications are welcome on the interpretation of the definition, for example on the inclusion of the various power-to-gas possibilities.

Member States should facilitate active participation of storage in electricity markets and eventual capacity mechanisms by properly implementing the Electricity Directive and Regulation. This including the provisions regarding market prequalification and bidding parameters, which are at present in some Member States still hindering the participation of storage in e.g. ancillary services procurement *[CEP implementation].* Rules for electricity and ancillary services markets as well as capacity mechanisms should not discriminate between technologies nor between large and small-scale installations. Adequate design parameters for trading and procuring energy, capacity and ancillary services are crucial in order not to hinder participation of storage. Allowing aggregation of storage with other flexibility resources is key to facilitate the deployment of (especially behind-the-meter) storage. Likewise, market rules should allow the behind-the-meter combination of storage with other resources such as renewable energy generation or demand response for participation in electricity markets and capacity mechanisms *[CEP implementation, storage+generation]*.

Dynamic electricity price signals as well as time-of-use grid tariffs should be provided in order to guide investment and operational decisions of market actors towards system-optimal decisions. The development of time-of-use grid tariffs and dynamic retail prices (and the limitation to new net metering schemes discussed below) are crucial to increase the responsiveness of consumers and the development of behind-the-meter storage, including electric vehicles [*CEP implementation, behind-the-meter storage*]. For instance, at the 2030 horizon, we find that enabling vehicle-to–grid services could enhance the provision of flexibility and stability by the mobility sector, and avoid up to 25 GW of large-scale storage investments. Presently, locational grid tariff signals are limited given the zonal approach for European energy markets, while the use of time-of-use grid tariffs or dynamic electricity price signals for residential consumers are still also limited. As recently as 2018, fixed electricity prices were still the dominant type available to households in most Member States, while dynamic end-user price offers were available in only 7 Member States. However, demand-response to electricity prices enabled by heat storage in e.g. CHP, water gas boilers and heat pumps is relevant in an increasing number of Member States, especially in Scandinavian and Eastern European Member States.

Participation of storage in wholesale electricity markets is properly being addressed in most EU countries with liquid and deep markets, but requires further initiatives in less developed markets. Specific energy market design parameters still act as participation barriers to storage in some countries, such as minimum bid sizes and price caps. While minimum bid sizes of e.g. 1 MW are common, they may frequently be met through aggregation of resources, effectively reducing the participation barrier to storage. While implementing the new electricity market design, Member States should set thresholds which effectively enable the participation of storage *[CEP implementation, aggregated resources]*. Moreover, at supra-national and EU level, the implementation of harmonized day ahead and intraday wholesale electricity market products should facilitate the (cross-border) participation of storage *[EU+MS action]*. Different product definitions in neighbouring countries, such as block or exclusive offers, when combined with other elements (such as aggregation), may hinder participation of storage facilities in multiple countries or in the day-ahead and intraday markets simultaneously.

Participation of storage in national capacity mechanisms is in general possible, but its effective participation and the impact on its profitability are still limited. Certain national capacity mechanisms were recently contested by market actors. Specific design aspects such as the derating factors applied to storage can act as a barrier, including by grouping storage with other technologies, or by applying a generic derating factor to all storage technologies. Member States should carefully design capacity mechanisms in order not to discriminate, in practice, storage against other technologies *[CEP implementation].*

The new Irish capacity mechanism for example has specific de-rating factors for pumped hydro and other storage technologies considering the storage size and duration.

The increasing maturity of balancing markets (energy and reserve) will help to adequately remunerate storage for its contribution to system flexibility and stability. One such positive development for the participation of storage technologies is the cross-border integration of balancing markets. Balancing markets should allow for the aggregation of flexibility resources. Besides providing adequate prequalification rules and bidding thresholds, Member States are considering new approaches to improve the remuneration of flexibility and stability resources in balancing markets *[MS action]*, which may eventually be deployed at the EU level *[EU action].* Fees (and eventual penalties) for residual imbalances should be set at an appropriate level in order to stimulate balancing responsible parties to reduce their residual imbalances by using flexible assets, including storage. Multiple projects are ongoing for improving market-based procurement of balancing reserves, for example in IT, FI, DK, NL and PT. These measures should allow to generate additional revenue streams for storage and thus avoid the need for specific economic support for mature storage technologies. Moreover, the development of fast response balancing markets for frequency regulation reserves may allow to take advantage of the very short activation times of some energy storage technologies. Real-time scarcity pricing in balancing markets, as is being considered in BE, could also incentivise capacity availability, providing additional remuneration to resources that specifically contribute to security of energy supply.

Implementing enabling rules in non-frequency ancillary services markets may require more medium-term efforts. At the moment, the possibility of storage to provide non-frequency ancillary services is rare across Europe, especially batteries, which in most Member States cannot provide voltage control nor black-start services. Moreover, large conventional power plants are in multiple Member States obliged to provide such ancillary services, with the consequent inexistence of organized markets. Participation of storage in grid congestion management is at present limited to pilot projects focusing on battery systems, but albeit limited in scale, these projects are taking place in multiple countries. Member States need to provide a level playing field for the procurement of such services, while guaranteeing that all flexibility resources are considered equally with network expansion in network development plans *[CEP implementation].* The Commission and Member States should guarantee locational information in congestion management and other products to foster market-based procurement *[EU+MS action].*

4. <u>Double charging of network tariffs</u> and <u>net metering</u> (partially tackled by the new electricity market design) as well as network codes (to a lesser extent) are still a major barrier to storage

Some specific grid tariff aspects both hamper market participation and distort price signals. Double imposition of grid tariffs (that is, during storage charge and discharge) on stored energy are especially detrimental and should be eliminated [*CEP implementation*]. The current tariffication practices across Member States are still quite diverging. For example, concerning the application to existing and new storage facilities, the inclusion of conversion losses, whether the energy is traded in wholesale markets or supplied to end consumers, and the application of tariff rebates on all volumes or only for electricity providing specific services (e.g. balancing).

Member States should ensure a proper implementation of the grid related provisions in the new electricity market design, considering also cases where storage is combined with generation or consumption, front- and behind-the-meter *[CEP implementation].* The new electricity market design makes network tariffication more cost-reflective (e.g. by removing the double network charges). It also comprises the requirement for network charges not to include costs supporting unrelated policy objectives. Only few countries such as DE and NL (the latter by introducing capacity-based network tariffs at DSO level) have already wholly or partially addressed the double charging issue.

Net metering is another important grid-related barrier to the deployment of small-scale storage, still existing in at least 9 Member States. Member States should prioritise the phasing out of net metering schemes *[MS action]*. The new electricity market design already introduces limitations to new schemes, and Member States should implement these preferably ahead of the 2023 deadline *[CEP implementation].* Net metering of not only network charges should be avoided, but also of the energy, taxes and levies components.

There is also an opportunity for improving price signals through network tariffs. EU and national authorities could assess the feasibility and opportunity to implement further locational and/or time-of-use signals in transmission tariffs, also based on lessons learned from current practices in EU Member States. The advantages and disadvantages of introducing time-of-use signals in distribution tariffs could also be evaluated *[EU+MS action]*.

Adequate network rules for storage connection and access should also be developed. Network codes usually do not explicitly address storage, which can then be treated as generation or consumption (or both). Only a limited number of Member States have already grid codes addressing specifically storage, such as DK or shortly FR. In some Member States, storage is addressed through the regulatory framework for smart grids. The Commission, ACER and ENTSO-E could consider updating the electricity network codes in this regard, also taking into account the combination of storage with front- and behind-the-meter generation *[EU action].*

5. The revision of the taxation, principally through the Energy Taxation Directive (ETD), is pivotal to eliminating undue burdens to stored energy, such as double taxation, and reducing cross-energy vector distortions

Full or partial imposition of electricity consumption taxes and other levies to stored energy is still common in a majority of Member States. In some Member States, as storage is not properly defined in national legislation, the rules applicable regarding levies and surcharges are not clearly defined and remain subject to diverging interpretation. Member States should review and adapt the taxation rules for stored energy, considering also the specific cases of behind-the-meter storage and the combination with generation *[MS action]*. Only storage losses should be subject to taxes (as well as losses in energy production and transport across all energy carriers), in order to stimulate highly energy-efficient processes. Only a few Member States (including AT, FI, NL and SE) have taken measures to address this barrier.

The revision of the Energy Taxation Directive (ETD) is pivotal, not only for the development of energy storage, but also to foster low-carbon energy technologies in general. This by introducing a carbon component in the energy taxation, and to reduce cross-border market and cross-energy vector distortions (within the EU and with its trade partners). In addition to that, storage-specific updates to the Directive would be useful in the upcoming revision, as storage technologies are largely unaddressed in the current version. It is necessary to differentiate in the ETD energy transfer to storage from end-use consumption, and make the former a non-chargeable event. Only storage losses should be subject to taxes *[EU action]*.

The increasing system integration will also require the elimination of diverging taxation levels across energy sectors and energy carriers. Taxation signals have been eroded since the publication of the Energy Taxation Directive (ETD), which also does not require taxes to be based on the carbon nor (for fuels) on the energy content, and whose coverage of energy products is outdated. A revision of the ETD is needed to avoid cross-sectoral distortions regarding taxation or the internalization of carbon costs, and to seize the synergies between the electricity, heat and gas sectors *[EU action]*. These synergies are potentialized by new technologies and the increased participation of consumers in energy markets. In the 2050 scenarios, large installed capacities of electrolysers are expected to be used for the production of synthetic gases and liquids. Thanks to the flexibility on the end-use side and dedicated gas storage (hydrogen and others), the operational management of electrolysers can be adapted to match with the system conditions.

According to our assessment, 50%-65% of the daily flexibility, 60%-70% of the weekly flexibility and 70%-80% of the annual flexibility could in 2050 be provided by electrolysers. Heat pumps with thermal storage also make significant contributions to flexibility requirements in our scenarios, highlighting the interactions of the electricity and heat sectors. Stakeholders have indicated other thermal energy storage such as underground (UTES) or in aquifers (ATES) have also a significant potential.

6. Competitive flexibility resources should be considered on an equal footing to network investments, across all energy vectors

Energy storage is primarily a competitive activity and the possible role of network operators in storage investments and operations should be clearly defined in the national regulatory frameworks, following the new electricity market design *[CEP implementation]*. The EU (e.g. through ACER) could provide recommendations for national regulators to decide on derogations for unbundling requirements, and on the definition of fully integrated network components *[EU action].* Due to the limited deployment of electricity storage in the past, most national regulatory frameworks did not explicitly address the ownership and operation of storage by network operators, and storage is in most countries not defined in primary legislation. In the cases where ownership and operation of storage by network operators is addressed in national legislation, it is most commonly not allowed. National frameworks which do allow ownership and operation by grid operators usually do not indicate requirements which need to be fulfilled. In rare cases storage may still be considered a regulated activity, reserved to network operators. But regardless of actual unbundling requirements in Member States, network operators do in practice not own nor operate storage in most countries.

National regulators should require network operators to weigh network investments against the procurement of flexibility resources by market actors, following the provisions in the new electricity market design. Additional efforts will be required to develop appropriate methodologies for this, as there is not a robust and widely accepted method at the moment *[CEP implementation]*. Security of supply standards (e.g. N-1 requirements) should be assessed considering the possibility of storage deployment *[MS action]*. The procurement of ancillary services should also be conducted in a non-discriminatory way, starting with (more mature) balancing markets and moving onto non-frequency ancillary services *[CEP implementation]*. Improvements need also to be made regarding the provision of information on e.g. network congestions to market actors in order to guide their decisions to investing and providing flexibility resources to prevent or reduce congestion *[MS action]*.

Improving the integrated cross-vector planning and operation of the energy system will likewise be crucial. Member States need to improve the consideration of electricity-gas-heat interlinkages in National Development Plans, and need to ensure that investment options are equally considered across sectors, which requires transparent modelling methodologies, tools and data *[MS action]*. These interlinkages should similarly be increasingly considered in the electricity and gas Ten-Year Network Development Plans (TYNDP) and the PCI selection process, ideally leading to the employment of a single EU electricity-gas investment and operation model *[EU action]*. The TYNDP should moreover adequately value all benefits of storage, considering the recommendations made in the study on the benefits of electricity storage to the CBA 2.0 methodology *[EU action]*.

Table 4-1 EU-specific policy measures to address energy storage barriers[154], with ***priorities highlighted in bold***

Topic	Issue	Measure	EU Instrument	
Support	A limited number of MSs address storage holistically in their NECPs.	Thoroughly assess the NECPs in view of providing recommendations to MSs regarding the development of storage and stimulate MSs to provide further guidance to storage in future progress reports.	-	-
		Take stock of the advances made on storage policies and chart further actions in the medium- and long-term with the 2024 update of NECPs.		
	The TEN-E scope excludes storage at lower transmission voltages or the distribution level, does not treat storage equally, and is not aligned to the storage definition in the new electricity market design.	Assess the TEN-E eligibility criteria and electricity infrastructure categories, and consider enlarging scope to storage connected to lower transmission voltages or at the distribution level. This along with other necessary changes to ensure non-discrimination of alternative flexibility resources.	TEN-E and CEF regulations, others	TEN-E Annex 2, art. 1
		Align the TEN-E infrastructure categories for electricity storage to the definition of the Electricity Regulation.		
		Reconsider the exclusion of hydro pumped storage to eligibility for Union financial assistance for works.		TEN-E Art. 14 (2)
		Examine the innovation eligibility requirement for financial assistance to works for electricity storage PCIs. Supporting innovation could be added as an explicit objective of TEN-E and CEF.		
	New energy storage systems and electrolysers in the EU up to 2050 will require hundreds of billions of Euros, particularly to scale-up deployment from 2030 to 2050	Use EU financing instruments such as loans and guarantees to leverage private investments	CEF Regulation, others	-
		Provide guidelines for private investors to include storage in an asset class that facilitates access to finance, or to evaluate the bankability of projects.		-
	Further actions should be undertaken regarding raw materials use and dependence, especially for batteries.	Develop actions in the categories identified in the Commission 2018 Report on Raw Materials for Battery Applications.	-	-
	The combination of storage with renewable energy in support schemes is possible under state aid rules, but not explicitly addressed by the EEAG.	Consider including support to hybrid projects (combining generation and storage of renewable electricity, gas or heat) as an explicitly eligible state aid measure.	EEAG	Section 3.3
	The EEAG's scope on energy infrastructure excludes storage at lower transmission voltages or at the distribution level.	Align the EEAG scope with the upcoming, revised TEN-E regulation.	EEAG	Art 1.3, point 31.iii
	The EEAG does not consider conversion technologies such as power-to-gas eligible to support.	Consider explicitly entitling conversion technologies to state aid (subject to notification and approval). Only use of non-supported renewable energy inputs (e.g. renewable electricity) should be allowed (to avoid double support).	EEAG	Art 1.3 or new article.
	The EEAG in several provisions do not refer to storage as a potential capacity provider.	Align the EEAG with the general principles (art. 21) and design principles for capacity mechanisms (art. 22) of the Electricity Regulation.	EEAG	Article 3.9, several provisions.
	There is a lack of visibility on small-scale installed storage capacity in MSs	Maintain and expand the study's storage project database, above all for behind-the-meter storage.	New instrument	-
Permitting & standardisation	There is no consensual standard for interoperability of flexibility resources. Despite the DAFI, gaps remain for e-roaming.	**Support EU-wide harmonised standards for device communication and system operation, e.g. for vehicle-to-grid technologies.**	DAFI, new instrument	-
		Cooperate with market actors for developing a consensual communication protocol for e-roaming.		-

[154] DIR = Electricity Directive; REG = Electricity Regulation; DAFI = Directive on Alternative Fuels Infrastructure, CEP imp. = implementation of the Clean Energy for All Europeans Package.

Topic	Issue	Measure	EU Instrument	
CEP implementation and market design	Wholesale energy market products may not be fit for (cross-border) energy storage participation.	Advance harmonized day-ahead and intraday market products that facilitate participation of storage.	CEP imp.	REG Art. 7-8
	The multiple possible combinations of storage with other technologies are not all addressed in EU or national electricity market designs.	Monitor the implementation of the new electricity market design, including for cases combining storage with other resources, such as local production and self-consumption of (renewable) energy.	CEP imp.	DIR/REG several articles.
	Market-based procurement of non-frequency ancillary services needs to be fostered and derogations minimized.	Provide clarity on criteria for granting derogation from market-based procurement of non-frequency ancillary services to TSOs and flexibility services to DSOs, considering decentralised storage.		DIR Art. 40
	Mature balancing markets can help to adequately remunerate storage.	Consider approaches to improve the remuneration of flexibility and stability in balancing markets, such as real-time scarcity pricing or fast response markets.	CEP imp.	REG Art. 6
	Markets for non-frequency ancillary services and the participation of storage are incipient in most Member States.	Promote the availability of locational information in congestion management and other products to foster market-based procurement.	CEP imp.	DIR art. 40
Grid / role of network operators	Further temporal/location signals in network charges may be beneficial but overtly complex.	Assess the feasibility and opportunity to implement further locational and/or time-of-use signals in transmission and distribution tariffs, also based on lessons learned from current practices in EU Member States.	-	-
	Behind-the-meter energy storage deployment may shift network costs to passive network users.	Assess the risk of cross-subsidisation via network tariffs between end-users with and without energy storage, and mitigate the risk when it is identified.	-	-
	Network codes usually do not explicitly address storage, which can then be treated as generation or consumption (or both).	Commission, ACER and ENTSO-E could consider updating the electricity network codes in this regard, also taking into account the combination of storage with front- and behind-the-meter generation.	New instrument	-
	National regulatory frameworks may diverge in the implementation of the storage definition and unbundling requirements.	Provide recommendations for national regulators to decide on derogations for unbundling requirements, and on the definition of fully integrated network components.	CEP imp.	DIR art. 36, 54
	The ENTSOs cost-benefit analysis methodology does not consider all benefits of storage.	Increasingly consider sector coupling in the electricity and gas Ten-Year Network Development Plans (TYNDP) and the PCI selection process.	DIR/REG, TEN-E	Several articles.
		Implement the relevant recommendations of the study on the benefits of electricity storage to the CBA 2.0 methodology.	ENTSO-E CBA 2.0	Various provisions.
	Double charges for storage (in the charge and discharge cycle) are still applied in most Member States, at the transmission and/or distribution level	**Ensure the adequate implementation of the Electricity Regulation art. 18 regarding non-discrimination and cost-reflectivity of network charges lead to the elimination of double charges.**	CEP imp.	REG Art. 18
Taxation	The Energy Taxation Directive does not provide adequate signals to market actors and generally does not consider energy storage.	**Increase the energy and GHG-emission reflectiveness of taxation across the electricity, gas and heat sectors.**	ETD	Various articles.
		Differentiate in the ETD energy transfer to storage from end-use consumption, and make the former a non-chargeable event. Only storage losses should be subject to taxes.		New art.
		Update the ETD scope to include new energy products (including storage-related), and use dynamic references.		Art. 2(1)
		Guarantee that storage of energy products does not cause the loss of their preferential ETD treatment rights (e.g. renewable energy), when they are appropriately tracked.		Art. 2(4b)
		Exempt energy stored behind-the-meter subsequently injected back to the network, and provide guidelines.		New art.
		Treat losses equally for energy production, storage and transport processes, preferably by taxing them similarly to end-use to stimulate the implementation of highly-efficient technologies.		Art. 21(3)

Table 4-2 MS-specific policy measures to address energy storage barriers, with ***priorities highlighted in bold***

Topic	Issue	Measure
Support	The majority of MSs recognize storage as a key enabling solution in energy and climate policy but a limited number address storage from a broad perspective and with concrete objectives and measures addressing all barriers	**Develop an assessment of national policy barriers to storage and accompanying policy strategy (supported by the study's MS fiches).**
		Ensure storage is properly addressed in the NECP and recognised as key enabling solution for the energy system, including in future progress reports and the 2024 NECPs update.
		Develop a strategic research agenda for storage, if missing, as part of the R&I dimension of NECPs and aligned with priorities established at the EU level.
	Frequently, RES support mechanisms do not consider the interaction with storage	Ensure support mechanisms to renewable energy do not exclude hybrid projects combining storage and RES generation.
Permitting & standardisation	Among storage technologies, permitting barriers may affect especially medium- to large-scale storage, and batteries	Implement the Water Framework Directive identified best practices for advancing hydropower development, including pumped hydro storage.
		Improve permitting for storage projects, by increasing public involvement and properly considering the differences between large- and small-scale projects.
		Consider defining mandatory standards for the installation of the different relevant battery technologies.
Market design	The correct implementation of the new electricity market design should be the priority of Member States to address existing policy barriers to storage.	**Ensure storage is coherently defined across the regulatory framework.**
		Implement the new electricity market design with adequate parameters for participation of storage in all markets, as well as eventual capacity mechanisms. Also considering aggregation, hybrid generation+storage, and behind-the-meter storage projects.
	Temporal signals in retail energy prices are a central instrument to accelerate the development of energy storage.	**Facilitate where possible dynamic/ToU price signals in retail energy prices.**
	Storage technologies and increasing participation of consumers in energy markets are accelerating sector coupling and augment the benefits of heat storage.	Address regulatory barriers for heat storage (e.g. coupled with CHP), including for participation in wholesale electricity and ancillary services markets.
	Mature balancing markets can help to adequately remunerate storage.	Consider approaches to improve the remuneration of flexibility and stability resources in balancing markets, such as real-time scarcity pricing or fast response markets.
	Markets for non-frequency ancillary services and distribution flexibility services, as well as the participation of storage are incipient in most Member States.	**Implement market-based procurement of non-frequency ancillary services with standardized products, minimizing the use of derogations and permitting the participation of storage.**
		Foster the market-based procurement of flexibility services at distribution level, with standardized products, minimizing the use of derogations and allowing the participation of storage.
		Use pilot projects to advance the contribution of decentralised storage to congestion management, using standardized products when possible and sharing best practices between MSs.
		Guarantee the availability of locational information in congestion management products to foster market-based procurement.
Grid / role of network operators	Double charging and net metering schemes are important specific grid barriers to energy storage tackled in the new electricity market design, requiring Member State action.	**Suppress double grid charging where existing.**
		Phase out net metering schemes.
	Further provision of signals in network charges may be beneficial but potentially overtly complex.	**Approaches to develop transmission locational and time-of-use signals could be assessed. Advantages and disadvantages of introducing time-of-use signals in distribution tariffs could also be evaluated.**
		Assess the need to develop specific rules in the network code for storage connection and/or access (compared to those applying to consumers and producers).
	Clean Energy Package requirements for network planning and service procurement by network operators are central to weighing network investments vs the procurement of flexibility resources.	**Require network operators to weigh network investments against the procurement of flexibility resources by market actors, e.g. in National Development Plans.**

ANNEX 1: INSTALLED CAPACITIES OF CURRENT STORAGE FACILITIES

Figure 4 - Power capacity by technology and country (Operational + Projects)

(MW)	Chemical	Electrochemical	Mechanical	Thermal
Austria		3	6456	
Belgium		59	1854	
Bulgaria			2263	
Croatia			1863	
Cyprus		5		
Czech Republic		3	1175	
Denmark	**1**	3		
Estonia			550	
Finland		14		
France		72	4207	21
Germany	**250**	509	12754	4
Greece		16	1881	52
Hungary		7		
Ireland		1337	1402	5
Italy	**1**	81	7331	5
Lithuania		1	1125	
Luxembourg			1294	
Netherlands		41	320	
Norway	**3**		1392	
Poland		1	1746	
Portugal	**1**	6	3345	
Romania		1	1120	
Slovakia		1	1017	
Slovenia		28	605	
Spain		195	13850	1130
Sweden		5	91	10
Switzerland		19	4197	
United-Kingdom		4790	8027	

Figure 5 - Entries in the database (Operational + Projects), by country and Figure 6 - Entries in the database (Operational + Projects, PHS excluded), by country

Number of entries	All	PHS excluded
Austria	28	1
Belgium	18	10
Bulgaria	4	
Croatia	10	
Cyprus	1	1
Czech Republic	11	4
Denmark	4	4
Estonia	2	
Finland	7	7
France	57	36
Germany	115	62
Greece	26	4
Hungary	2	2
Ireland	60	54
Italy	56	29
Lithuania	6	1
Luxembourg	11	
Netherlands	10	10
Norway	21	11
Poland	20	1
Portugal	28	4
Romania	9	1
Slovakia	11	1
Slovenia	7	5
Spain	98	38
Sweden	4	2
Switzerland	25	2
United-Kingdom	318	293

Figure 7 - Electrochemical Storage - Power capacity by country (Operational + Projects)

	Electrochemical Power Capacity (Operational + Project) - MW
Austria	3
Belgium	59
Cyprus	5
Czech Republic	3
Denmark	3
Finland	14
France	72
Germany	509
Greece	16
Hungary	7
Ireland	1337
Italy	81
Lithuania	1
Netherlands	41
Norway	6
Poland	1
Portugal	6
Romania	1
Slovakia	1
Slovenia	28
Spain	196
Sweden	5
Switzerland	19
United-Kingdom	5499

Figure 8 - Electrochemical storage - Operational Capacities by Country

	Electrochemical Power Capacity (Operational) - MW
Austria	3
Belgium	34
Czech Republic	3
Denmark	2
Finland	6
France	19
Germany	406
Hungary	7
Ireland	11
Italy	56
Netherlands	37
Norway	6
Poland	1
Portugal	6
Romania	1
Slovenia	13
Spain	11
Sweden	5
Switzerland	19
United-Kingdom	570

ANNEX 2: REVIEW OF SELECTED DOCUMENTS ON ELECTRICITY POLICY BARRIERS, BEST PRACTICES AND RECOMMENDATIONS

This annex reviews selected studies on energy storage policies, focusing on studies which are recent than the Commission papers on energy storage, or which were conducted by other EU institutions. Two main aspects are extensively discussed in these studies: the large diversity and interaction of storage technologies and applications, and the resulting large diversity of barriers and corresponding policies for energy storage.

Diversity and interaction of storage technologies and applications
One aspect which is apparent from the studies is the important interaction of electricity storage with generation, transmission, distribution and consumption. This interaction may occur in two levels. First, storage may be deployed together with power generation projects (especially based on renewable energy) or at the end-user level (especially when combined with self-production of renewable electricity). The studies discuss a number of barriers and associated policies arising from the hybrid nature of projects combining generation and storage. The second level of interaction between storage and the rest of the electricity system is that, being essentially a provider of flexibility services, storage interacts on a system level with these segments of the energy system which affect the demand and supply for flexibility, in a way which may be complementary or competitive to storage.

Another common aspect in the studies is the acknowledgement of the diversity of storage technologies and associated characteristics. Despite differences in technologies, studies consistently support technology-neutral policies, not only regarding storage technologies but generally all potential flexibility resources. This taking appropriate consideration of the differing technology readiness level of the technologies and the need for corresponding support instruments in line with the SET-Plan and national priorities.

The reviewed studies also acknowledge the multiple potential applications of energy storage. A frequently addressed aspect is the importance of stacking of revenues from multiple applications in order to achieve a viable business case for storage, while considering appropriate technology-neutral requirements for the provision of storage services in each application. An aspect which is more rarely discussed is how to avoid conflicts in the provision of services in multiple markets and guarantee the delivery of the contracted services, in particular in the ancillary services and capacity mechanisms. While the issue is sometimes acknowledged, it is less clear how it could be dealt with.

The fact that the energy system and mix (including deployment of renewable electricity sources) and resulting flexibility needs vary across EU Member States, adds a further complexity dimension, as not only technologies and applications vary, but also the storage needs per Member State.

Barriers and policies for energy storage
The reviewed studies conclude that barriers and policies for energy storage cover a wide array of topics, from electricity market design to grid tariffs, taxation and power market structure to the legal classification of assets.

The first aspect is the lack of coherence across Member States concerning policies for or affecting energy storage. Regardless of the different storage needs of Member States, there is a frequent observation of important disconnection among national legislation and regulation, which can lead to cross-border distortions in investment and operational decisions by market participants. This involves multiple aspects such as electricity market design, double charging of grid fees and electricity consumption tax and ownership rules for system operators.

These cross-border interactions already hint that there are not only policy gaps regarding storage, but also that existing policies and regulations often constitute barriers themselves. This comment refers to storage-specific policies (e.g. inadequate definition of storage) and also to policies targeting related aspects such as aggregation, RES support mechanisms, grid tariffication or taxation. Poorly designed policies may have been developed in a time where the deployment levels of storage and/or renewable energy were still low and hence led to only limited distortions in electricity markets. A fitting example are inadequate support schemes incentivizing renewable energy producers to still produce in moments of negative prices, which in turn increase the need for system flexibility and hence inadvertently improve the business case of storage.

Furthermore, the studies indicate a strong interaction between the EU and Member State levels. Within the boundaries set by EU legislation, Member States have an important role to play in policies for storage, especially considering the national differences in renewable energy deployment and available flexibility options. Besides national competences regarding storage and energy policies, the transposition of EU directives and guidelines also leaves room for specific policies at national level.

The more recent studies do indicate that multiple barriers to energy storage are due to be addressed with the changes brought by the new electricity market design. In line with the European Commission papers, changes such as the right for self-production of electricity, furthering the deployment of a time component in electricity end-user prices and the introduction of a definition of energy storage are highlighted as addressing important issues. Nonetheless, the variety of barriers implies not only that no study discusses them all, but also that not all barriers are covered by the new electricity market design, according to the studies surveyed.

Study	Policies discussed	Policy barriers/best practices	Selected policy recommendations
DG energy, **“Energy storage – the Role of electricity”** 2017	1. Support 3. Energy markets 4. Ancillary services 5. Grid aspects 7. Involvement TSO-DSO 8. Other & General	- Regulated prices to end-consumers - RES support surcharges applied to storage - Lack of a common regulatory framework across MSs - Insufficient consideration in grid planning - Availability of EV refuelling infrastructure (electricity/hydrogen) - Cost and performance of some storage technologies - Best practice: Early development of storage in intra-day markets which have larger volumes - Best practice: Use of second life batteries	- Definition of storage - Inclusion of storage in PCI selection process - Guarantee of right to electricity self-generation - Recognition and support of aggregators - Non-discriminatory access to the grid at the national level - Removal of price caps and regulated prices at the EU level - Consideration of storage as a market activity - Opening of electricity markets to storage, with standardised products - Cost recovery for system operators of storage service procurement - Revision of the ETS with the Market Stability Reserve providing adequate investment signals

Study	Policies discussed	Policy barriers/best practices	Selected policy recommendations
European Smart Grids Task Force Expert Group 3, "Demand Side Flexibility - Perceived barriers and Proposed recommendations" 2019	1. Support 3. Energy markets 4. Ancillary Services 5. Grid Aspects 7. Involvement DSO-TSO 8. Other & General	- General lack of customer awareness about DSR opportunities. The diversity and complexity of offers complicates this. - Business case for DSR is often negatively impacted by the lack of opportunities. - Standardization and prequalification for market access differs across Europe, and limitations for bids need to be justified - Lack of framework for DSR providers concerning allocation of energy volumes and balancing responsibility, baseline methodology and remuneration vs other technologies - Although data access and sharing is agreed on a generic level, it is not implemented satisfactorily - No clear EU product definition other than for balancing markets - Locational information is not provided in any kind of bids except if introducing in balancing following the balancing guidelines - The interaction of long- vs short-term products has not been addressed regarding DR availability, liquidity and TSO-DSO coordination - Market access for flexibility services could be limited depending on location, voltage, service and asset type - The variety of markets and products can lead to market fragmentation - There is low observability in the low voltage grid	- NRAs could ensure TSO and DSO revenue regulation and network tariffs structures take into account costs and benefits of flexibility for the system and are non-discriminatory - There is a need for harmonisation of market rules and energy products - A comprehensive aggregator framework should be implemented, following the new electricity market design and electricity balancing guidelines - Locational information in flexibility products should be mandatory for congestion management products, with minimum granularity to the extent necessary - An EU framework shall be developed to ensure an equal and transparent level playing field for all service providers - TSOs and DSOs, in coordination with all market actors, should strive for efficient coordination, especially in designing, buying and settling flexibility products. - Categorise best practices and develop a methodology for selecting and validating a baseline methodology to value flexibility services against a counterfactual - Share and develop best practices for value stacking - Develop market monitoring, at national level or potentially at EU level, to provide a view how much flexibility is active in the market, and to monitor and prevent strategic behaviour and gaming by market players. - Improve forecasting at distribution level - Develop other options for mitigating grid constraints with MS studies/national codes - Regulators across sectors should collaborate more and consider relevant updates to license conditions in order to address the new complexities that flexible electricity services will bring

Study	Policies discussed	Policy barriers/best practices	Selected policy recommendations
BRIDGE initiative, Horizon 2020 working group on regulations, "Recommendations on Selected Regulatory Issues" 2018	2. Permitting 4. Ancillary Services 5. Grid Aspects 6. Taxes & Levies 7. Involvement DSO-TSO 8. Other & General	- Storage unbundling not addressed in 3rd energy package - Barriers for self-consumption + storage, e.g. "sun tax" in Spain or impossibility to create islands in black-outs - Power-to-gas plants still classified as chemical instead of energy industry - Lack of MS ancillary services markets or access for storage - Best practice: multi-building storage in Germany and Switzerland	- MSs and Commission to clarify possibility to combine RES + storage - Explore and draft safety regulations for less mature technologies (e.g., P2G, CAES) - Support development of local microgrids - Promote grid flexibility through support for smart meters, pricing mechanisms - Define ownership regime, with potential regulatory sandboxes (potentially with sunset clause) - Allow flexible interpretation of storage definition in new Electricity Directive - Incentive for grid operator to purchase storage services, including through ambitious transposition at MS level
CROSSBOW, "Legislation and Regulatory Frameworks" 2018	1. Support 3. Energy Markets 4. Ancillary Services 7. Involvement DSO-TSO	- Lack of rules on ownership, procurement of storage by TSO/DSO and support measures for storage in South East Europe (SEE) - Existing regulation covers only pumped hydro - Some form of price regulation still exists in all SEE countries - Developing cross-border integration of day-ahead markets, more limited for balancing	- Main recommendation is implementing regulations from 3rd Energy Package, supported by further cross-border interconnection in the region and the rest of Continental Europe, as the report focuses on South East Europe countries (including Member States of Croatia, Bulgaria and Romania)
EASE, "European Energy Storage Technology Development Roadmap" 2017	1. Support 4. Ancillary Services 5. Grid Aspects 6. Taxes & Levies 7. Involvement DSO-TSO 8. Other & General	- Regulatory complexity prevents viability of critical demonstration projects - Fair market design is lacking for energy storage - Lack of clarity on the rules for ownership and operation of storage by system operators - Unwarranted double-charging of grid tariffs - Confusion over the classification of energy storage - Certain "requirements in the Network codes" identified as unduly onerous	- Fund further demonstration projects - Clarify market access and unbundling requirements for system operators - Exempt storage from double grid charges in a coordinated approach, consider further exemptions for new techs - Establish storage as a separate asset class to prevent it being considered either generation, T&D or loads - Remove regulatory barriers to enable innovative projects, by after due consideration waive ownership and/or connection requirements - Establish a definition of energy storage in the EU regulatory framework - Designate energy storage as an Important Project of Common European Interest (IPCEI) - Ensure the procurement of all energy and ancillary services is market-based, subject to a cost-benefit analysis - Allow system operators to own storage upon approval of the NRA only for regulated infrastructure services, in the absence of market interest or for promotion of new technologies, on a temporary basis

Study	Policies discussed	Policy barriers/best practices	Selected policy recommendations
NETfficient, "Social, socio-economic and regulatory measures for local/small storage market uptake" 2017	2. Permitting 3. Energy Markets 4. Ancillary Services 5. Grid Aspects 6. Taxes & Levies 7. Involvement DSO-TSO 8. Other & General	- Trend of increasingly complex regulation on RES and storage systems - Unbundling requirements impedes grid operators of maximizing utilization of storage from grid perspective - Historic asset classes not adequate anymore for storage - Not all EU markets fit for the participation of storage, aggregated or not - Complex technical and contractual process for aggregation of distributed storage Heterogeneity of national rules and regulations, e.g. definitions on balancing market products and rules for self-consumption	- Technical and non-technical standards, regulations and requirements should be formulated as simple and understandable as possible - Translation of regulations and requirements to small businesses and households - Legal and regulatory requirements should be scaled depending on the technical system size - Adapt regulations to specific nature of energy storage (generator and load) and interaction with self-production - Evaluate current market produces for ease of access to storage - Consider unconventional market products (e.g. incorporating delivery probability) - Simplification of regulatory and technical requirements for storage aggregation - Develop technical and legal requirements for shared ownership of storage, e.g. in apartment complexes - Common European tax principles, e.g. exemption of final electricity consumption tax - European standardization of rules and products
SQ Consult, Fraunhofer et al. for the European Parliament, "Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?" 2015	1. Support 3. Energy Markets 4. Ancillary Services 5. Grid Aspects 6. Taxes & Levies 7. Involvement DSO-TSO 8. Other & General	- Technological maturity - Lack of definition in Electricity Directive - Double charging of grid fees in specific MSs - Lack of common EU regulatory approach to decentralized self-production + storage - Regulation at MS level of net metering, feed-in tariffs and self-production and consumption - Exclusion of pumped hydro from Europe Infrastructure Package - Decentralized production + storage risk of resulting in grid defecting and affecting grid operators' business case	- Public support to storage R&D technologies aligned with Energy Union strategy, to industrial structures and smart grids/cities - Common approach to incentives to storage + RES, combined with access/connection priority rules - Improved merit order, e.g. through better scarcity pricing - Technology-neutral balancing markets and storage definition in new market design - Clarify unbundling rules and allow grid operators to own and operate storage for balancing and other ancillary services - EU guidance to MSs for harmonized stimuli to storage at end-user level

ANNEX 3: PROVISIONS ON THE ELECTRICITY DIRECTIVE (2019/944) AND REGULATION (2019/943) RELATED TO ENERGY STORAGE

	Directive (EU) 2019/943
	Regulation (EU) 2019/943

Policy category	Topic	Article	Description
Electricity markets	Non-discrimination in all electricity markets	**Art. 3(j)**	Generation, energy storage and demand response shall participate on equal footing in markets for electricity, including over-the-counter markets and electricity exchanges, markets for the trading of energy, capacity, balancing and ancillary services in all timeframes, including forward, day-ahead and intraday markets.
		Art. 3(m)	Market rules shall enable the efficient dispatch of generation assets, energy storage and demand response.
	Aggregation (including with other resources)	**Art. 12**	Customers are entitled to independently contract electricity supply and electricity services (including aggregation).
		Art. 17(1)	Final customers should have equal access to all electricity markets including for ancillary services, whether or not aggregated (including independent aggregators).
		Art. 17(5)	NRAs or system operators should establish the technical requirements for participation of demand response (including aggregated) in all electricity markets.
	Active customers	**Art. 15(1)**	Enables active customers and impedes disproportional or discriminatory requirements (technical, administrative and related to network charges).
		Art. 15(2)	Active customers should be: - Subject to cost-reflective, transparent and non-discriminatory network charges that account separately for the electricity fed and consumed; - Existing net metering schemes that do not account separately for the electricity fed into the grid and the electricity consumed from the grid should not grant new rights after 2023. Customers under such net metering schemes should be able to opt to a scheme that accounts for injections and withdrawals separately; - Financially responsible for imbalances if they are a BRP or delegate their balancing responsibility.
		Art. 15(5)	Active customers owning an energy storage facility should: - Have the right to a timely grid connection if requirements are fulfilled; - Are not subject to double charges for self-consumption or when providing flexibility services; - Are not subject to disproportionate licensing requirements or fees; - Are allowed to stack services if technically feasible.
	Citizen communities	**Art. 16(3)**	Citizen communities should be: - Able to access all electricity markets (including through aggregation); - Financially responsible for balancing; - Treated like active customers regarding self-consumption;

	Directive (EU) 2019/943
	Regulation (EU) 2019/943

Policy category	Topic	Article	Description
Energy markets and capacity mechanisms	Day-ahead and intraday market design	**Art. 8(3)**	Nominated electricity market operators shall provide products for trading in day-ahead and intraday markets with minimum bid sizes of 500 kW or less
		Art. 8(4)	Nominated electricity market operators shall provide products for trading in day-ahead and intraday markets with a period at least as short as the imbalance settlement period. This amounts to 15 minutes from 2021 on, with possible derogations not being longer than 30 minutes from 2025 on.
	Dynamic pricing	**Art. 11**	The national regulatory framework should enable suppliers to offer dynamic electricity pricing, including monitoring and reporting obligations to Member States.
	Capacity mechanisms	**Art. 22(1h)**	Capacity mechanisms need to be open to energy storage and demand side management.
Ancillary services	Balancing markets design	**Art. 6(1)**	Balancing markets (include pre-qualification processes) shall not discriminate energy storage, whether individually or aggregated.
		Art. 6(4)	Balancing energy gate closure times shall not be before the intraday cross-zonal gate closure time.
		Art. 6(9)	Upward and downward balancing capacity procurement shall be carried out separately, unless derogation is given by the NRA.
		Art. 6(9)	Contracting window and contract duration are set to one day, unless derogation is given by the NRA.
	Procurement of balancing services by TSOs	**Art. 40(4)**	TSOs should procure balancing services in a transparent, non-discriminatory and market-based procedures from qualified electricity undertakings and market participants, including energy storage facilities and aggregators.
	Procurement of non-frequency ancillary services by TSOs	**Art. 40(5)**	TSOs should procure non-frequency ancillary services in a transparent, non-discriminatory and market-based procedures from qualified electricity undertakings and market participants, including energy storage facilities and aggregators, unless the NRA derogates this obligation due to lack of economic efficiency.
		Art. 40(6)	TSOs or NRAs should specify the non-frequency ancillary services procured, and where appropriate standardised market products at the national level.
	Redispatching	**Art. 13(1)**	Redispatching market shall be objective, transparent and non-discriminatory, and open to energy storage.
		Art. 13(2)	Redispatching markets shall use market-based mechanisms and financially compensate market actors (with defined exceptions).
	Procurement of grid management services by DSOs	**Art. 32(1)**	Regulatory framework should ensure DSOs procure flexibility services in a non-discriminatory, effective way from providers including storage and demand response when economically efficient.
		Art. 32(2)	DSOs or NRAs should specify the flexibility services procured, including standardized market products at least on a national level when appropriate.

	Directive (EU) 2019/943
	Regulation (EU) 2019/943

Policy category	Topic	Article	Description
Grid aspects	Connection of storage to the transmission system	**Art. 42(1)**	The TSO shall publish transparent and efficient procedures for non-discriminatory connection of new energy storage facilities.
		Art. 42(2), 42(3)	The TSO is not entitled to refused the connection of a new storage facility based on future limitations on available network capacities (close or far to the connection point). TSOs may limit the guaranteed connection capacity or offer connections subject to operation limitations, upon regulatory approval. This shall not apply when costs are borne by the storage facility.
	Non-discrimination in network charges	**Art. 18(1)**	Network charges shall be cost-reflective, transparent and non-discriminatory, and not discriminate either positively or negatively against energy storage or aggregation. Charges shall not include unrelated costs supporting unrelated policy objectives.
	Locational signals in network charges	**Art. 18(2)**	Where appropriate, the level of the tariffs applied to producers or final customers, or both, shall provide locational signals.
	Time-differentiated network charges	**Art. 18(7)**	Where Member States have implemented the deployment of smart metering systems, NRAs shall consider time-differentiated network charges.
Involvement DSO/TSO	Ownership and/or operation of storage facilities by TSOs and DSOs	**Art. 36 Art. 54**	TSOs and DSOs shall not own, develop, manage or operate energy storage facilities. Exceptions comprise fully integrated network components or a regulatory process certifying the lack of market interest at reasonable cost and length and the necessity of the storage system or services for the network. The article includes a phase-out of system operator activities in 18 months in the case of sufficient market interest, with possible compensation.
Other and general	Definition of storage and storage facilities	**Art. 2(59)**	Definition comprises “deferring the final use of electricity to a moment later than when it was generated”, or the conversion and storage in other energy forms, with the subsequent reconversion or not to electricity. Thus includes power-to-gas technologies.

ANNEX 4: MEMBER STATE STORAGE POLICIES FICHES

Austria

Topic	Austria - Policy description
1. Public Support	Austria plans to integrate storage within the energy system in the next 5 to 10 years through: * Energy consumption optimization for photovoltaic systems: Home storage, swarm solutions, district storage * Mobility : Storage at electric vehicle fast-charging stations, increasing electrification of the transport sector * Heating / cooling supply in buildings : component integration, load balancing in smart grids, power-to-heat * Industry & commercial : Waste heat utilization, load management for heat and electricity, power-to-heat / power-to-power * Storage in the heating / cooling supply : Large water storage in combined heat and power plants at the interface of electricity / gas / heat networks, buffering of power peaks in critical network areas, use of the heat network as storage for load management, seasonal large-scale storage with undergrounds storage / geothermal fields * Storage in the electricity supply : Balancing fluctuating demand and generation (short-term and seasonal), buffering of performance peaks in critical areas of the network, short-term compensation for forecast deviation, provision of system services The final 2019 NECP version refers to electricity storage * small-scale photovoltaic and storage system programme * Increase the share of efficient renewable energy sources and district heating/cooling for heating, hot water and cooling, including component activation, active use of hot water storage tanks and buildings as reservoirs for load balancing and load flexibility Investments in storage facilities, including heat storage facilities, rewarding storage facilities for system capacity * Storage (including hydrogen technologies) is currently addressed as a high priority cross-cutting issue with cross-references to the mission-oriented priorities and the broad implementation initiatives * Increase of pumped storage capacity in Kaunertal * The countries of the Pentalateral Energy Forum address the impact of the implementation of flexibility options, including the role of demand response, PTX and hydrogen as well as the role of storage and electro-mobility, and analyse specific electricity-related barriers to sector coupling * In addition to storage and pumped storage, a particular role is played by high-efficiency combined heat and power (CHP) plants, which are necessary to maintain the supply of electricity (for balancing purpose) and heat, particularly in agglomerations. * Activation of components, the active use of hot water storage tanks and the use of buildings as reservoirs for load balancing and load flexibility increase or adapt investments in storage infrastructure (from short-term storage to seasonal storage) and transmission and distribution networks to increased demand * *Digital and smart energy*: Ensuring system integration of new energy storage and energy supply system flexibility technologies as basic enablers for a high proportion of renewable energy, coupled with security and resilience * particularly in the interests of the system, to establish as far as possible the control and controllability of decentralised small and medium-sized storage units * The long-term storage of electricity by hydrogen is to be made possible and encouraged. * The 100.000 roofs of photovoltaics and small-scale storage are intended to stimulate the increased use of roofs through photovoltaic modules for individuals and economic operators. There will also be implicit guidance to combine photovoltaics and storage by implementing self-supply as a ranking criterion for investment support * In future, buildings should not only have high energy standards, but above all play an active role in the supply of energy and its storage for self-consumption * Photovoltaics and small-scale storage : Prolongation of support for a further three years, taking into account self-consumption ; a total of EUR 108 million in investment support (per year PV:EUR 24 million, storage: EUR 12 million) ; production limits for electricity storage is 50 kWh * Significant investments in storage infrastructure and transmission and distribution networks, adapted to increased needs, will be made * Electrochemical energy storage is to be accelerated, as these are large-scale or small-scale storage units as a solution to compensate for the demand-driven production characteristics of renewable energy (for mobile and stationary applications) * As new storage technologies make a vital contribution to the transformation of the energy system, their flexibility in the design of network tariffs will be rewarded. Storage

	facilities should be exempted from end-use charges and benefit from support for green electricity * The availability of competitive energy storage facilities that can store electricity from renewable energy sources on a larger scale and for longer periods of time will be of great importance. Particular attention will therefore be given to the promotion of such applied research projects with pilot plants demonstrating the market maturity of scalable storage technologies * Key elements of a new electricity market law : Definition of new actors: Storage facilities, PTX facilities, aggregators, … * Austria already has an important position in storage, which is to be developed and strengthened through research and development * Technology Roadmap[155] – Energy Storage Systems in and from Austria (2018).
2. Permitting	* Lithium battery storage standards are foreseen in the OVE guideline R20. Although the industry is responsible for the production, consumer safety is the responsibility of installers. The current standard ÖVE EN 50272 covers lead-acid batteries and nickel-cadmium storage. * The Electrical Engineering Ordinance sets binding standards for the construction, testing and operation of electrical systems. However, storage is not explicitly treated but is arguably within the ordinance scope. * The transport of batteries is subject to hazardous goods legislation and have to be labelled accordingly (highly flammable), there is no specific legislation for the storage and transport of lithium batteries. * In the area of fire protection, the ÖVE guideline R11 must be supplemented with storage in internal and external environments.
3. Energy Markets and Capacity Mechanisms	* Storage facilities can participate in the electricity markets (including intraday and balancing). In 2018 the EPEX energy exchange introduced loop block orders, where two block orders are executed or rejected together, representing for example the storage cycle. * Heat and electricity systems are integrated in several ways, e.g. in co-generation of electricity and heat, or when DH is produced with electric boilers or heat pumps. Heat is stored more easily than electricity, and thermal storages are used to improve the system balancing of variable power generation. By utilising co-generation, heat pumps and thermal storages, a DH supplier can respond to price signals on the electricity market. In times of high electricity prices, DH production can be adjusted to maximise the power generation and thermal storage used to cover heat demand, and in times of excess power, DH suppliers can utilise more heat pumps. These large water storage tanks in CHP and district heating will increase in the future.
4. Ancillary Services	* Pumped hydro participates in the provision of aFRR/mFRR services; * batteries are under the same requirements (such as prequalification) as other units eligible to provide services * In distribution networks, storage will provide additional services such as voltage control, reactive power or used as a phase shifter
5. Grid Aspects	* The qualification of storage facilities as consumer and producer makes the storage operator a network user, who is obligated to pay system usage fees twice (according to SNE-VO 2012 as amended in accordance with § 51 ff ElWOG 2010) * Being considered generators, storage has the following obligations: join a balance group; comply with generator technical specifications of the network operators including maximum balance deviation, fault tolerance, frequency and voltage control (reactive power capability); pay fees for the provision of primary balancing power in proportion to their annual production quantities, provided that the generating plant has a capacity of over 5 MW; have a metering point; follow data exchange obligations above a certain size * No new grid usage fee or network loss fee is payable for new installations of pumped-storage power plants and plants for the conversion of electricity into hydrogen or synthetic natural gas, and for the purchase of electrical energy until the end of 2020 (ElWOG 2010). * For existing pumped hydro storage power plants, § 4 Z 8 SNE-VO 2012 as amended provides for preferential regulation in the form of a lower charge for electricity consumption * Providers of the reserve services (including storage) are exempted from paying grid usage fee * (battery) storages are to be operated as integrated grid assets for non-frequency ancillary services * (battery) storage can be used at meshed grid nodes (Quartierspeicher) and at Energy Communities * Market-sourced (battery) storages services can/will be used for congestion management to avoid curtailment of local renewable generation. Alternatively, they must undergo the procedures laid out in Art. 36/54 of the IEM-Directive

[155] https://www.klimafonds.gv.at/wp-content/uploads/sites/6/Technologieroadmap_Energiespeichersysteme2018.pdf

6. Taxes & Levies	* Storage operators also pay renewable electricity sources support surcharges, which are paid by the end-users connected to the network. * Storage operators, with the exception of pumped hydro, pay the surcharges for the promotion of CHP systems, which are paid by all end-users connected to the network, according to the CHP Act.
7. Involvement of TSO/DSO	* System operators are currently testing/running (battery) storages in the framework of scientific research projects for frequency and non-frequency ancillary services * System operators run (battery) storages as integrated grid assets for congestion management of meshed (medium voltage) nodes and to balance the power fluctuation of energy communities (in the framework of scientific research projects)
8. Other & General	* There is no general definition of the term 'storage' in the electricity and heat sectors. * All electricity traders and other suppliers who supply end customers in Austria are legally obligated to inform the end customers of the primary energy sources of the power generation (with proof of origin). A special provision is made in the Electricity Labelling Ordinance for those quantities of electricity that are delivered by pumped storage power plants (adjusted with an efficiency of 75%)
9. Barriers	* There is no common definition of energy storage in the regulatory framework * There is no separate standard for lithium-ion storage * Storage should be included in the ÖVE guideline R11 (fire protection) * There is a need for legal certainty for power-to-gas plants in Austria * The unbundling provisions of the recast Electricity Directive need to be transposed in national law * Development of regional hydraulic-thermal models for overall concepts of groundwater management in areas with high degree of utilization of geothermal fields or groundwater wells as heat storage * (battery) storages shall be acknowledged as grid integrated assets for (non-frequency ancillary services) system operation
10. Best practices	* A special provision is made in the Electricity Labelling Ordinance for those quantities of electricity that are delivered by pumped storage power plants (adjusted with an efficiency of 75%), so the impact of storage is considered in the energy labelling value chain. * Electricity consumption tax for PV has been abolished, according to the recently adopted government programme the electricity consumption tax shall be removed for all RES (previously suppliers and consumers had to pay the electricity consumption tax, except for self-produced renewable electricity up to a limit of 25 MWh/y, following § 2 of the Electricity Supply Act (Elektrizitätsabgabegesetz)) * (battery) storages (also used in regulatory sandboxes) which are used for frequency ancilliary services (e.g. Prottes battery) and non-frequency ancilliary services as meshed node integrated grid asset (e.g. Quartierspeicher, Heimschuh battery, Lichtenegg battery) and for Energy Communities (e.g. Südstadt Battery).

Belgium

Topic	Belgium - Policy description
1. Public Support	* Support for R&I projects for energy storage : the law of 28 June 2015 has created a legal basis to set up specific funding, financed by the tax on nuclear electricity production, to support R&I projects related to energy production and storage, as well as energy demand. In this context, several publicly funded R&I projects which also include storage, are being performed by Belgian research centres. The funding for energy related R&I projects in 2019 amounts to 30 million €. * The Government of Flanders has in May 2019 approved a budget of 6 million € to subsidise home batteries. The subsidy amounts to 250 € per kWh, with a maximum of 3,200 € per connection point or 35 % of the investment costs. The subsidy scheme will be available until end 2020. * In addition to the National Energy and Climate Plans, there is no national strategy addressing storage from a holistic perspective The draft NECP 2018 refers to electricity storage * Storage will be one of the solutions in addressing need for flexibility in internal energy market * Greater emphasis will be placed on flexibility (including storage and demand management) and interconnections to ensure security of supply * Different levels of government will ensure the continuous development of new centralised and decentralised storage systems * The regions are working on a clear regulatory framework, intended to place storage behind-the-meter or at the neighbourhood level * Objective to create energy storage potential as means to integrate intermittent, decentralised renewable energy into the grid * Residential, SME, local, electric vehicle storage methods expected to increase further by 2030 * Legal frameworks revised to different regional contexts to allow prosumers to choose whether generated energy should be fed back into the grid at peak times, or a battery storage system should be used * Clear regulatory framework needed to govern installation of individual home or neighbourhood batteries * 2018 National Investment Pact with private sector to foster public-private partnerships within six strategic sectors, including 'the development of storage facilities for heat and electricity' * Particular area of focus for research in Wallonia (i.e., energy storage technologies): expertise developed in batteries, phase-change materials, compressed air storage, accumulators, hybrid batteries, storage management tools
2. Permitting	* For stationary batteries a notification OR permit (depending on the overall risk level of the concerned company) is necessary if the installed capacity is higher than 10.000 VAh. For pumped hydro storage, both a building and environmental permit (based on an environmental impact assessment are always required.
3. Energy Markets and Capacity Mechanisms	* Storage facilities in Belgium can participate in the electricity spot and balancing markets, either directly (with a minimum bid volume increment of only 0.1 MW), or via aggregators. * In 2018 the EPEX energy exchange introduced loop block orders, where two block orders are executed or rejected together, representing for example the storage cycle. * A new CRM will be implemented in 2020 (law of 22 April 2019); energy storage will be eligible for participation, either directly (if concerned capacity > threshold) or indirectly (via aggregation). The introduction of a CRM could be positive for the development of storage. However, there are no incentives for low-carbon emissions flexible units * Net metering during 15 years is in place for existing and new PV installations < 10 kW commissioned until 2020 * Despite the fact that the concept of storage has been recently defined in the electricity law, the grid cost exemption mechanism that is foreseen in the transmission tariffs (and the CREG tariff methodology) remains difficult to implement and is more constraining than in neighbouring countries. * Storage applications like heat storage (e.g. water as a heat storage medium, powered by cogeneration or electrically powered), borehole thermal energy storage (BTES), storage heater (accumulator) are already implemented in Belgium
4. Ancillary Services	* Pumped hydro as well as batteries are eligible to provide FCR and aFRR/mFRR services. * The rules for procurement of ancillary services by the TSO have been adapted (lower threshold for direct participation and aggregation possibility) to allow battery storage to also participate. At the present, batteries provide FCR services, either directly or via aggregators, but other reserve services are open to these resources. * Pumped hydro as well as batteries are eligible to provide voltage control services.

	* Pumped hydro as well as batteries are eligible to provide black start services subject to their technical ability to provide the service. * Pumped hydro has historically had an important role in the procurement of ancillary services.
5. Grid Aspects	* Double charging is applicable for end users with an energy storage installation or energy storage installation that is (directly) connected to the low-voltage and medium-voltage distribution grid that have separate distribution tariffs for off-take and injection. This will probably partly be solved due to the transposition of Directive (EU) 2019/944 article 15 5 b) which states that ”Member States shall ensure that active customers that own an energy storage facility: (b) are not subject to any double charges, including network charges, for stored electricity remaining within their premises or when providing flexibility services to system operators;” * Exemption mechanism is already available. Art. 4. of the Electricity Law of 2017: For storage facilities connected to transmission or networks with a transmission function, the tariff methodology contains incentives that encourage the storage of electricity in a non-discriminatory and proportional manner. A separate tariff regime for the storage of electricity may be determined by the CREG (Federal Regulator). The first special transmission tariff has been implemented for storage plants commissioned 1) After 1 July 2018: exemption from network tariffs during first 10 years or 2) before 1 July 2018: can benefit from 80% reduction in transmission tariffs during 5 years if they increase both the energy stored volume and capacity by at least 7.5%. * National/regional connection requirements and tariffs contain no specific connection tariffs for storage assets. For production and storage facilities with an injection capacity above 1 MW, specific technical connection requirements apply * For small scale storage connected to DSO grids, no specific grid tariff measures exist * The new transmission tariff structure applicable since 1 January 2016 (tariff period 2016-2019) has slightly improved access conditions for transmission-connected storage * Compensation of avoided transmission network losses is under consideration * in Flanders, the network tariff structure will change in 2022 and will be both based on kWh-use and kVA (peak-use), which is supposed to provide additional incentives to storage.
6. Taxes & Levies	* Double taxation for energy storage installation connected to the distribution grid where the energy storage is used as an intermediate is the general rule for all storage * Since 2018 electricity consumption by storage is exempt from the federal electricity contribution, following art. 7(1bis) of the Electricity law (2017): 'Electricity withdrawn from the network for the purpose of supplying an electricity storage facility shall be exempted from the federal contribution' * Exemption of electricity storage from the green certificate federal levy is under consideration. * Investors in energy storage assets are eligible for a federal tax discount; for physical persons the deduction on the taxable income amounts to 20% of the eligible investment amount, versus 13.5% for companies. * All consumers are obliged to submit regional green certificates (directly linked to the volume consumed). In Wallonia, all storage is now exempted with the order of 11/04/2019 (art 10.6°). It was previously the case only for pumped hydro located in Wallonia * No further exemptions exist for electricity storage with regard to taxes, surcharges and other obligations imposed on off-take and injections
7. Involvement of TSO/DSO	* In Wallonia (=<70kV), the DSOs are allowed to own and operate storage systems but only if it is for strict support of the grid and only after the market fails to provide * At federal level (>70kV), the regulator does not allow the TSO to own and operate storage
8. Other & General	* 'Electricity storage' : any process whereby, through the same installation, electricity is withdrawn from the grid for the purpose to be completely re-injected into the system later on, subject to efficiency losses. (Electricity Law of 13th of July 2017, modifying the 29th of April 1999 Electricity Law)
9. Barriers	* The profitability of Belgian pumped hydro was impacted by transmission tariffs (before the recent law providing investment incentives)
10. Best practices	* 2018 National Investment Pact with private sector to foster public-private partnerships within six strategic sectors, including 'the development of storage facilities for heat and electricity' * Notification OR permitting requirement depends on storage capacity * CRM design allows the participation of storage directly or through aggregation * Regulatory framework explicitly allows the regulator to provide specific tariffs to storage * Storage is exempted from some electricity taxes * Storage is exempted from the obligation to submit green certificates

Bulgaria

Topic	Bulgaria - Policy description
1. Public Support	* The national energy strategic documents do not address nor recognize the importance of new energy storage technologies. * The potential and regulation of electricity batteries, electric vehicles, power to gas, other innovations are not yet a subject of any policy and legal documents. * The renewable energy projects in Bulgaria developed between 2007 – 2014 were incentivised by way of a FiT. As a result, in the times of curtailment of production or offtake (due to grid-related or balancing reasons) developers were incentivised to develop electricity storage facilities. Since the changes to the Renewable Energy Act, which entered into force in 2014, there is a cap of the electricity produced under FiT and therefore this indirect support mechanism has been eliminated. The draft NECP 2018 refers to electricity storage * Intent to increase the flexibility of the national energy system, partly by increasing electricity and natural gas storage capacity (developing existing storage facilities as well as building new ones) * Project underway to expand the capacity of underground gas storage (completion scheduled for 2024) * PCI Bulgaria-Yadenitsa hydro-pumped storage project - considered key to balance the system * Need to use energy storage systems identified as important measure from 2021-2030 * 'From 2021 to 2030, Bulgaria will benefit from [...] investment support [...] from the Modernisation Fund and the option for funding projects related to [...] energy storage' * REM: the NECP does not include policy and measures to ensure the non-discriminatory participation of energy storage in the energy market. There is no provision to cover aspects of energy storage and the services they can provide to the energy system.'
2. Permitting	* Licensed activities (generation license) are explicitly listed in the Energy Act. Those are for example production, trading, distribution, but storage is not addressed. The production license is required for a capacity above 5 MW, and as legislation does not distinguish between technology types, any production above 5 MW must have a license, including e.g. pumped hydro. * Licensing reported by stakeholders as a costly and time-consuming process
3. Energy Markets and Capacity Mechanisms	* There are various small projects where consumers utilise battery storage technology for domestic purposes, such as reducing the demand charges of large energy users * There are currently three operational pumped hydro storage projects in the Republic of Bulgaria. Their combined capacity is around 1.4 GW, operated by the National Electricity Company EAD * Electricity storage is not economically competitive in Bulgaria, and there is revenue uncertainty. Despite recent efforts, electricity is still cross-subsidised in Bulgaria, hampering price signals to investors.
4. Ancillary Services	* According to the electricity market rules, pumped hydro shall be considered as dispatchable load when in a pump regime * Storage is not allowed to provide any services as they are not regulated by the market rules and thus not listed as an eligible market participant * The DSO cannot procure services in the market * Stakeholders indicate TSO procurement procedures are not transparent
5. Grid Aspects	* There are no specific rules for connection or access charges for storage facilities * Consumer network charges are based on energy consumption and capacity to all consumers (households only pay network charges based on consumption) . The RES pay grid taxes on injected energy, as well. * All producers network charges are based on energy injected (kWh).
6. Taxes & Levies	* No specific rule identified on exemption, meaning storage charging is subject to the electricity consumption tax
7. Involvement of TSO/DSO	* Regulation does not address ownership and/or operation of storage by network operators.
8. Other & General	* Energy storage is regulated under the Energy Act (of 9 December 2003). But while gas storage is specifically regulated by the Energy Act, the electricity storage is not addressed in the legislative framework.
9. Barriers	* There is no common definition of energy storage in the regulatory framework * There is a large variation between summer and winter as well as daily electricity loads. Heating is primarily based on electricity, with low penetration of gas for households and lack of use of district / building complex heating. * Multiple regulations need to be adapted, like the Energy Act, market rules, permitting. It is of importance also to introduce clear rules for service procurement, the rules for cost recognition and cost coverage of the grid operators in case such services are procured.

10. Best practices	* The PCI Bulgaria-Yadenitsa hydro-pumped storage project is considered key to balance the system

Croatia

Topic	Croatia - Policy description
1. Public Support	* Electricity storage is not specifically regulated or supported by Croatian law. The Renewable Energy Act prescribes that renewable energy demonstration projects shall not be supported through market premium or feed-in tariff incentive models but through general research and development and innovation support programmes. * Pumped hydro storage (PHS) should be supported through a scheme which would guarantee recovery of the investment cost, with feed-in tariffs – for instance – which would guarantee payment for discharging wind-originated power as a reward for boosting the integration of renewable energy sources (RES). Electricity Market Act (OG 22/13, 102/15, 68/18, 52/19) The final 2019 NECP version refers to electricity storage * Two to three large hydropower plants are expected to be built up until 2030, a few hydro power plants (both in watercourses and water supply systems) and a pumped-storage power plant. The regeneration of existing plants is expected to extend their lifetime with a slight increase in hydro power * Among the national energy security objectives are, comes the increase of storage capacity of gas and energy in the electricity system * Energy storage in the EES will allow for the construction of pumping plants, thus also providing more flexibility for the system and greater integration of variable renewable energy sources, mainly solar and wind. * Croatia will increase (by 2030 and 2050) investment in research, development and innovation in low carbon technologies, among which advanced energy storage systems * Existing legal solutions need to be complemented by the development of a regulatory framework for active customers, aggregators, energy communities, renewable energy communities (participation in local energy production, distribution, storage, supply and provision of energy and aggregation services) and own-account production of energy, in accordance with the provisions of the Directive on the promotion of the use of energy from renewable energy sources, the electricity directive and the regulation on the internal market for electricity * In order to increase the energy storage capacity of the system and the increased control power of the electricity system, the development of battery tanks, the introduction of recharging points for electric vehicles and the use of other innovative energy storage technologies (financed by EU funds) are planned.
2. Permitting	* Behind-the-meter installations of battery storage are allowed (for self-production or hybrid storage and renewable energy projects).
3. Energy Markets and Capacity Mechanisms	* Market barriers include a minimum bid capacity of 1 MW in wholesale markets, availability requirements, and limiting the price spread.
4. Ancillary Services	* Pumped hydro can participate in provision of FRRm services; * Storage plants (incl. batteries) are allowed to provide ancillary services to the TSO * Storage plants (incl. batteries) can be used to guarantee the N-1 criterion for a limited amount of time to radial networks, but are not deployed in practice.
5. Grid Aspects	* There is double charging of network charges for storage * There is no regulatory framework for procurement of flexibility services allowing for the deferral of network investments.
6. Taxes & Levies	* electricity consumption for charging is taxed like other consumers.
7. Involvement of TSO/DSO	* TSOs and DSOs are prohibited from owning storage assets.
8. Other & General	* Energy storage is not defined in the national regulatory framework.
9. Barriers	* There is no common definition of energy storage in the regulatory framework
10. Best practices	

Cyprus

Topic	Cyprus - Policy description
1. Public Support	* In Cyprus, the framework for storage is still at the initial stages of development. The Cyprus Energy Regulatory Authority (CERA) has issued a decision titled "Principles of the regulatory framework regarding participation of electrical storage in the whole sale electricity market" addressing the storage systems installed in-front-of-the-meter. * There is no public support until now in Cyprus for energy storage. * Storage is considered a positive insertion in the system in support of the net metering and the net billing tariff systems. Currently PV owners are allowed to cover 80% of their load with the PV production. When operating a storage system, this can increase up to 100%. The National Energy and Climate Plan (NECP) refers to electricity storage. * If Cyprus remains electrically isolated from other electricity networks, the penetration from RES-e will only be increased once RES-e, coupled with storage technologies, materialises. The need of storage systems (both behind and after the meter) is included in the electricity system investments, but their need might be limited if the Cyprus will get electrically interconnected by 2023. * Similarly, the batteries in electric vehicles (with PV), can facilitate the use of higher shares of variable renewables and they might be charged when there is an increase in generation. This enables the grid operator to use them as demand response and a means of electric storage from which it can draw (together with selective load shedding) in cases of generation shortage or to smoothen out fluctuations in electricity demand * The pumped hydro storage facility was used as an option, but its deployment is delayed until 2027 (estimated 130MW pumped storage potential by 2030 in Cyprus) * The objective to deploy an Advanced Metering Infrastructure, including the roll-out of 400.000 smart meters by January 2027 will enable the optimization and control of the distribution system, increase the penetration of distributed renewable sources, enable aggregation of RES, demand response and storage and increase direct final customer participation in all market stages (active customers) * the use of Interconnector can help the RES to further penetrate earlier, while in the WEM scenario it seems that more RES will be introduced in the post 2030 period with technologies that using storage behind the meter. These technologies, based on the existing available data, include Concentrated Solar Thermal (CSP) and other storage technologies like Li-Ion Batteries and Pumped Hydro. A detailed overview of Storage technologies that can be deployed in Cyprus was made under an SRSS study by University of Cyprus[156] and JRC[157] * The country is 'exploring ways to introduce smart grids in the national network. * Possibility to use batteries in electric vehicles to offset the variability of renewables (Vehicle to Grid). * In its scenario modelling, several storage options play a role in the further penetration of RES due to the absense of Electricity Interconnector, including: pumped hydro storage; lithium-Ion battery storage; concentrated solar power storage (thermal Storage that is converter to electricity). * Enabling participation of storage is one of five objectives to promote competitively-determined electricity prices & increase system flexibility: 'revise the regulatory framework to enable the participation of storage in the electricity market'. Ensure that generators, aggregators and consumers will be allowed to own and operate storage systems, buy on the day-ahead market, and sell stored energy on the forward and day-ahead markets; also enable participation in the balancing market. *Storage Technologies, can be used also as a support for conventional power generating units and limit the start-up and shut-down cost. This will increase both the performance and the efficiency of the conventional power generating units.
2. Permitting	* No specific requirements have been put forward for authorization permits at the moment. Stakeholders indicate that once network codes are finalised regarding e.g. battery storage, special environmental requirements will be developed especially concerning fire hazard. * Ground contamination by leakages is already covered in the law for the environment, requiring appropriate measures.
3. Energy Markets and Capacity Mechanisms	* Cyprus currently has approved new market rules but not yet operational (a transitional arrangement is in force until the new market rules take place). A regulatory decision (03/2019) has been issued by Cyprus Energy Regulatory Authority (CERA) so that by mid of 2020 the Transmission System Orerator Cyprus (TSO Cyprus) submit adaptations

156 http://www.mcit.gov.cy/mcit/EnergySe.nsf/All/4CFADF62B303D228C22584D6004AAB42/$file/JRC%203-%20Storage.pdf

157 JRC study for storage

	to market and network codes to facilitate the connection, and participation of front-of-the-meter storage in all electricity markets, including through aggregation. The new market rules and updated network codes are expected to become operational by end of 2021, so when in operation storage facilities in-front-of-the-meter will be able to participate in all electricity markets. Behind-the-meter installations can be licenced with existing framework. * There are no rules for the participation of behind-the-meter storage and active customers in wholesale markets. * Currently there are no capacity remuneration mechanism. * Presently the only service of storage for end-users is to increase self-consumption to 100% when using the net metering and net billing tariffs. The time of use tariff for net billing users provides an additional signal.
4. Ancillary Services	* Current market design does not allow for the provision of ancillary services by storage. * A regulatory decision by CERA 03/2019 has been issued so that by mid of 2020 the Cyprus TSO will submit adaptations to markets and network codes to facilitate the connection, and participation of front-of-the-meter storage in all electricity markets, including through aggregation. The new market rules and the updated network codes are expected to become operational by the end of 2021, so when in operation storage facilities in-front-of-the-meter will be able to participate in all electricity markets. Behind-the-meter installations can be licenced with existing framework.
5. Grid Aspects	* There are no specific connection rules for storage, so same connection rules for other generators and/or loads apply. Upcoming regulatory changes should not change this. * According to regulatory decision by CERA 03/2019 in-storage is currently excempt from network tarriffs.
6. Taxes & Levies	* The regulatory framework does not address storage in relation to taxation, thus there are no specific levies or taxes on storage * A levy per kWh consumed is charged from the end-user in the net billing tariff (i.e. for dispersed installations), irrespective of whether it is supplied by the network or self-produced, and of whether it is directly consumed or supplied at a later time by a battery system.
7. Involvement of TSO/DSO	* By law the TSO is unbundled from the Transmission Grid Owner, which is the EAC, the utility of Cyprus and who functions under the special regime of Functional and Accounting unbundling. The EAC is allowed other roles related to electricity (meaning Generator, Distribution Owner and Operator and Supplier) * According to the latest Directive and Regulations the TSO and/or DSOs are not allowed to own and operate storage systems but only except for strict support of the grid and only after the market fails to provide. * DSO are enabled to procure flexibility services, including congestion management in their service area, especially from distributed generation, demand response, storage and other market participants (including those engaged in aggregation).
8. Other & General	* There are four research projects on storage : StoRES, PV-ESTIA, ERIGENEIA and FLEXITRANSTORE. Through the R&I (with EU partners) there is willingness to diffuse best practice solutions for the deployment of storage in Cyprus
9. Barriers	* With the amendments of the market rules and network codes for the participation of in-front-of-the meter starage in the electricity market a first step for addressing the regulatory framework barrier will be made. Behind-the-meter installations can be licenced with existing framework. Alignment with the requirements of the Clean Package for All Europeans will give the right platform to pursue the match needed storage solutions.
10. Best practices	

Czech Republic

Topic	Czech Republic - Policy description
1. Public Support	* Pumped hydro storage is in the Czech energy law considered as a specific form of power generation and is not considered as storage * The Czech Republic has implemented a specific support scheme for small-scale home batteries as a part of subsidy program for residential PV * The National Action Plan for Smart Grids (NAP SG) includes relevant provisions on storage : 'By 2015/2016, create conditions for gradual deployment of energy storage; By 2017, issue a license for energy storage operations', although this was still not addressed in early 2020. * The Updated State Energy Concept (ASEK) also includes specific references to storage : 'Support for development of energy storage systems (both distributed and centralized); R&I in the field of energy storage' * The Study of the Electricity Market Operator (OTE) assesses four scenarios of possible developments by 2050, two of which count on energy storage (all types) on a daily basis: Conceptual scenario: 4.3 GWh; Decentralized scenario: 19.4 GWh, with electricity storage (batteries) in the range of higher hundreds/lower thousands of megawats. * The Operational Program Enterprise and Innovations for Competitiveness addresses storage in two ways: - Implementation of economic measures, incl. installations of RES and energy storage (2018-2019) - Use of low-carbon technologies, incl. energy storage pilot projects The draft NECP refers to electricity storage * Electric vehicle batteries are acknowledged as potential storage option within the electricity market * 'Electricity storage, including the use of hydropower' is mentioned as a specific sub-area in the national priorities for research, experimental development and innovation
2. Permitting	* There is no specific licence issued by the Regulator for battery storage systems yet. The licence parameters are foreseen to be addressed in the market design of the Energy Act. * Pumped hydro is operated on the basis of a license for production, granted through the standard process as for other power plants.
3. Energy Markets and Capacity Mechanisms	* Storage facilities can participate in the electricity markets (including intraday and balancing) only together with the spinning reserves. Stand-alone batteries are completely forbidden for any kind of use in the energy markets in the Czech Republic, use with RES officially allowed, but technically infeasible. * Storage is used primarily for active customers to avoid network charges. * Large boilers, usually inside of district-heating and power plants, are used for ancillary services
4. Ancillary Services	* Pumped hydro can in the Czech Republic participate in the provision of Frequency Restoration Reserve (FRRm). Facilities can be involved in the provision of ancillary services when (virtually) aggregated with generation. Changes in ancillary service procurement rules according to Commission Regulation (EU) 2017/2195, establishing a guideline on electricity balancing (EBGL). * However, the EBGL did not fully allow batteries to participating in the ancillary services. As mentioned, stand-alone batteries cannot participate in the ancillary services at all, BESS with RES is infeasible. Only installations BESS + spinning reserves (coal and gas power plants). There is growing interest among traditional energy producers due to generous conditions for providing fastest types of ancillary services (FCR, aFRR etc.). * Czech TSO (CEPS) recently indicated the network code should be revised at the end of 2020 in order to allow a broader use of energy storage on the Czech eletricity market.
5. Grid Aspects	* Czech legislation doesn't allow direct connection of batteries to the grid, only together with the generation site. * Network charges are applied only to consumers. Therefore no network (or other) charges are paid for any electricity supply to the system. In the case of storage facilities, no specific discounts on network charges apply, except that some of the distribution-connected pumped hydro storages are partially exempted from transmission-related withdrawal charges.
6. Taxes & Levies	* Support for the development of storage facilities is primarily provided in the form of investment grants. * No tax exemptions or rebates are applied or considered at the moment.
7. Involvement of TSO/DSO	* DSOs and TSOs are not allowed to own storage plants, but can operate them for the time being (the 4 MW project between CEZ and CEPS (Czech TSO) in Tusimice is partially operated by CEPS, but only in the testing regime)
8. Other & General	* The sector did propose some amendments of the Energy Act to address energy storage, but there is finally no mention at all of energy storage. It was considered an important opportunity to integrate storage issues, however, amendments proposed for

	the topic were not accepted. A first proposal of the Energy Act was defining storage as : "Electricity storage means the storage of electricity by storage facilities in the form of energy, which can be stored and subsequently used or converted into electricity or other form of energy and used at a later point in time than when it was produced." This has since been removed. * Works on the completely new Energy Act (not a revision, but brand new law) started and relevant stakeholders participate in its preparation, including the Association for Energy Storage & Batteries AKU-BAT. However, this new act should come into force not earlier than in 2022.
9. Barriers	* Some changes in the ancillary services are not completely addressing storage : stand-alone batteries still cannot provide ancillary services, only in connection with spinning reserves. * Stand-alone batteries can be connected to the grid (only in testing mode), but cannot supply electricity to the grid, their use in hybrid installations is hence limited, except at the same site. * There is no common definition of energy storage in the regulatory framework, and it was removed from the Energy Act amendment draft.
10. Best practices	

Denmark

Topic	Denmark - Policy description
1. Public Support	* The Danish energy policy is strongly focusing on short-term heat storage (which allows CHP producers to balance supply and demand for heat and electricity), while electricity storage is referred to in policy documents but there is no comprehensive policy, also due to the fact that electricity storage is in Denmark currently not competitive compared to other available flexibility options. According to the IEA (country assessment 2017), the double taxation of electricity stored in batteries (when purchased and when resold) is considered as a barrier to a wider use of batteries by district heating companies and end-users. * The Energy Technology Development and Demonstration Program (abbreviated in Danish EUDP), one of the largest public sources of research investment, includes funding for storage projects * On the basis of act No. 121 of 25 April 2019, a budget of DKK 13 million has been made available for grants to development and demonstration projects that facilitate renewable energy storage * Energinet, the national electricity and gas TSO, has included energy storage in its energy system outlook for 2035. Electricity storage is expected to play a role for short-term flexibility (hours, a few days) while seasonal flexibility would be provided by Power-to-Gas coupled with gas storage. Energinet has also included energy storage in its three-year RD&D strategy that aims to catalyse solutions which are to be market-ready in 2020-50. The final 2019 NECP version refers to electricity storage: * Policies and measures adopted with the 2018 Energy Agreement includes, among many others, the energy storage fund of 2019, developing markets for flexibility and ancillary services, * Energy storage could be a useful tool to ensure sufficient supplies of energy, by levelling out demand peaks and by making use of surplus wind energy from times of high wind power generation to store for later times of shortage. Today, the technologies available for storing electricity are rather limited and expensive. Yet, the technologies will possibly continue to be developed and become profitable with time, as current trends in prices of storage technologies are indicating. This means that in the future it is not unlikely that for instance power-to-gas and the hydrogen sector could play a larger role in ensuring supply security and that batteries will become more prominent in the energy markets. * The flexibility of the energy system is expected to be facilitated largely by market-based solutions. Therefore, it is an objective to support structures that favour demand response and energy storage markets. Especially the integration with the district heating sector and its vast energy storage capacity is expected to provide a basis for increasing flexibility through increased demand response and energy storages * The Danish electricity market is open for participation from renewable energy, demand response and storage, including via aggregation * In order to accommodate future needs, the Danish Government has established a fund supporting development and demonstration projects on energy storage. The fund's size is 128 million DKK and it was in December 2019 granted to two Power-to-X-projects * Increased flexibility in energy system is crucial for the green transition and storage can contribute to that flexibility * NER (Nordic Energy Research) has identified seven key areas that could enhance joint Nordic research efforts, among which Energy Storage * While smart grids specifically address the problem of moving consumption to other times during the day and matching supply with demand, system integration is also a growing and very important area. In the future, many factors will be competing to supply this dynamic: electric cars, electric cartridges, heat pumps, etc. system integration also covers aspects relating to energy storage and smart energy * A larger share of intermittent RE leads to greater demand for energy storage solutions. In this context, battery storage, in particular, is expected to play a significant role (including small scale PV) * Furthermore, energy storage could be a useful tool to ensure sufficient supplies of energy, by levelling out demand peaks and by making use of surplus wind energy from times of high wind power generation to store for later times of shortage * Ambitious targets and plans to decarbonise the energy supply : more than 1 million green cars by 2030; a new gas strategy; a roadmap for smart energy, expected to provide increasing flexibility through demand response and energy storage
2. Permitting	
3. Energy Markets and	* Storage devices (including batteries) can participate in the electricity markets. * District heating companies own and operate large thermal storage facilities and are active in the electricity market to respond to short-term changes in electricity prices.

Capacity Mechanisms	
4. Ancillary Services	* Pumped hydro is eligible to provide FCR and FRR services, while batteries are eligible to provide FCR services. * Energinet is running a pilot program allowing electric vehicles to provide balancing services. In the Parker project, specialists and car manufacturers are developing a universal definition for network integration, enabling electric vehicle batteries to support renewables integration and participate in intra-day and balancing markets in the future. * District heating companies own and operate large thermal storage facilities, often equipped with electric boilers. Their fast response is offered to the balancing market.
5. Grid Aspects	* The TSO Energinet has published grid codes specifically for the connection and access of batteries * The DSO Danish Energy has recently participated in several research projects analysing the impact of batteries on distribution systems * Self-producers (companies) shall not pay the grid tariff for the part of their production covering their own consumption * Customers with their own 132 kV transformers with settlement on the 132 kV side pay a reduced grid tariff
6. Taxes & Levies	* There is no exemption of taxation and fees, storage is considered as a common consumer
7. Involvement of TSO/DSO	* While in 2014 stationary Li-ion batteries were installed by TSOs and DSOs on a test basis, it is assumed the grid operators are allowed to own and operate storage plants
8. Other & General	* No definition of storage in the national legislation
9. Barriers	* There is still an absence of technical specifications for how batteries are expected to participate in all of the Nordic ancillary services markets. The Danish requirements for batteries are currently being revised, and a new version is expected in late 2019. * There is a degree of regulatory uncertainty surrounding future grid codes for energy storage devices. EU regulations (RfG and DCC network codes) have omitted specific treatment of energy storage systems, leading to a patchwork of national requirements.
10. Best practices	* Parker project is developing a universal definition for grid integration, enabling electric vehicle batteries to participate in intra-day and ancillary services markets * District heating companies are actively participating in energy markets. * The TSO Energinet has published grid codes specifically for the connection and access of batteries

Estonia

Topic	Estonia - Policy description
1. Public Support	* PCI project 4.6 hydro-pumped storage in Estonia was scheduled to start construction in 2019 and be completed by 2026-2027 * Public R&I budget - Electrical storage (2014): 0.51 M€, Energy storage (2018): 0.51 M€ The final 2019 NECP version refers to electricity storage: * Hydrogen could be one of the main options for the storage of renewable energy and more favourable options for the storage of electricity for days, weeks or even months * seasonality need for temporary storage on the part of the proprietor * Estonia's economy needs investment in the transition to cleaner energy and more sustainable jobs, including the acquisition of wind farms (including national defence aerial surveillance radars), electricity storage solutions, cogeneration plants, transport to biofuels and electricity transfer, electricity railways and modern rental housing funds, renovation of apartment buildings, demolition of buildings that fall out of use, decarbonisation of the cement and lime industries, recycling of industrial residual gases. * Chapter deals with measures to increase the flexibility of the energy system to produce renewable energy, such as smart grids, aggregation, demand response, storage, distributed generation, distribution, redispatching and curtailment mechanisms and real-time price signals, including the introduction of intraday coupling and cross-border balancing markets * As regards independent aggregators and energy storage, the regulation will be complemented by Directive 2019/944 on the EU internal electricity market * The trends of Estonia's renewable energy sector in 2040 viewpoints depend heavily on the megatrends we can see in Europe and also in the world, where carbon-neutral energy production, energy saving and storage and smart consumption are the keywords * To ensure security of electricity supply in Estonia, a combination of renewable energy production facilities and storage solutions (including seasonal storage), … may be used in the future * As regards energy storage, Estonia is already on the world map, with Skeleton Technologies, the leading European producer of super-capacitors, producing facilities in Germany and developing in Tallinn * on RD&I, be at the forefront of next generation renewable energy technologies, storage, smart grid and home solutions, smart cities, buildings neutrality, clean transport, clean carbon capture and utilisation and nuclear energy, building on Horizon 2020.
2. Permitting	* No specific permitting provisions identified.
3. Energy Markets and Capacity Mechanisms	* The Electricity Market Act indicates that the regulator may oblige the TSO to tender new production, energy storage devices or energy efficiency/demand-side management measures if generation reserves fall below requirements or if this is necessary for the promotion, of new technologies * In April 2010 the Nord Pool power exchange started operations in Estonia. Nord Pool day ahead and intraday markets are open to storage. The day ahead products include hourly and block orders, while the intraday market offers 15-minute, 30-minute, hourly and block products.
4. Ancillary Services	* In January 2018 the Baltic common balancing market came in operation, covering mFRR. Storage is allowed to provide mFRR services. For mFRR the product duration is 15 min , the minimum bid size is 1MW. The ENTSO-E ancillary systems survey of 2018 however still indicates storage cannot participate in FRRm markets. * Currently only FRR is used in the Baltic balancing market. The Russian Unified Power System (UPS) provides FCR and FRRa, while Baltic TSOs provide also RR. * Aggregated generation and loads can participate only in the FRRm market. They cannot provide other ancillary services such as black start or voltage control. * Loads use the same market mechanisms and activation procedures as generation to provide balancing services (both capacity and energy) * All power plants that are connected to the main grid must have voltage control capability. The service is partly remunerated by the TSO. * Black start service is provided by power plants which are included in the restoration plan as black start service providers. It is not a mandatory service and is remunerated by the Elering. * The Electricity Market Act indicates that the regulator may oblige the TSO to tender new production, energy storage devices or energy efficiency/demand-side management measures if generation reserves fall below requirements or if this is necessary for the promotion of new technologies
5. Grid Aspects	* According to an Elering 2015 report, a DSO was already then looking at flexibility projects such as energy storage, as it had already 'been forced to curtail the maximum

	output of a wind farm due to local network constraints. In the long term, the DSO is expecting overloaded substations in all types of distribution network areas (rural, suburban and urban).' * The feed-in scheme was kept for installations under 50 kW following the 2018 update of the Electricity Market Act. Net metering is not allowed.
6. Taxes & Levies	* No specific mention of electricity storage in the tax legislation, thus assumed that storage charging pays the electricity consumption tax.
7. Involvement of TSO/DSO	* Regulation does not address ownership and/or operation of storage by network operators. It could be used to compensate network losses.
8. Other & General	* Storage is not defined in the new 2018 electricity market act.
9. Barriers	
10. Best practices	* The Baltic states implemented the Baltic common balancing market, with storage being able to provide the first product, mFRR. * Regulation specifically indicates TSO roles to tender for new flexibility resources including storage due to generation adequacy or innovation considerations

Finland

Topic	Finland - Policy description
1. Public Support	* The Energy Aid government investment programme provides co-financing for projects that (among others) promote the transition towards a low-carbon energy system. Storage is eligible if they involve investments in renewable energy production or energy efficiency. Energy-storage-related costs of a project may not exceed 50% of total costs. * In Mission:Innovation Finland wants to double by 2020 RD&D investments in clean energy (including energy storage) from 2013-2015. The Smart Energy programme provides EUR 100 million for co-funding of Mission Innovation initiatives to fund new opportunities in fields including energy storage. * The 2019 government programmes indicates Finland will improve the security of energy supply together with Finnish industry operators [by among others developing] new possibilities for energy storage. * Public R&I budget for electrical energy storage in 2014 was 2.50 M€ * Ongoing work to create Sectorial Climate Roadmaps may identify barriers. Sector coupling including energy storages will be included in these roadmaps. Thefinal 2019 NECP version refers to electricity storage: * The transition to a low-carbon economy will require additional investments, particularly in bioeconomy, the circular economy, clean energy solutions, energy efficiency, emissions-free forms of energy production, energy storage solutions, carbon recovery and energy utilisation, along with research, development and innovation activities and measures to bring these solutions to market * Among the three most popular proposals of the citizens survey : Promotion of decentralised energy production (electricity, heat, transport, storage) through sustainable and cost-effective measures * As for ensuring generation adequacy in the light of the renewable energy contribution, including demand response and storage, the Finnish strategic reserve system plays a significant role. * Demand response and storage are further promoted by applying the proposals by the Smart Grid Working Group as discussed in Chapter 3.4.3 * In October 2018, the Smart Grid Working Group set up by the Ministry of Economic Affairs and Employment proposed an extensive operational programme to increase the demand-side response of electricity and the opportunities for customers to participate. The working group’s key proposals were: 1/ clarifying the roles of actors in the market-based implementation of demand-side response (e.g. principles for the storage of electricity, discontinuation of the flexibility implemented by distribution networks) ; 2/ highlight the significance of market-based solutions for demand response and storage * Finland committed to doubling public innovation funding for clean energy by 2020. The baseline was the average of the funding granted by TEKES to projects on renewable energy sources, storage of energy, energy systems and energy networks between 2013 and 2015 * Finland is also active in Set-Plan key action no 7. “Batteries for e-Mobility and Stationary Storage”, where Finland is leading the working group related to battery recycling. * Total use of electricity in the transport sector is not more than 1–2 % of the total electricity demand during the assessed period. Its impact on electricity generation is small on a yearly level, but charging batteries and active use of them as two-way electricity storage can affect both the short-term electricity market and the local grid.
2. Permitting	* In Finland there is no specific rules (legislation, procedures) for the storage permitting. * Small-scale batteries need only the city planning acceptance, but when locating battery in the existing industrial site, the permitting is typically only light notification. * Large-scale storages like pumped hydro or hot water storage (based in natural rock) need also permission according the water body legislation when affecting water body/ground water levels or other hydro-morphological issues. The permission of the large-scale projects comprises public hearings as part of permitting procedure. Stakeholders indicate there are also rights for contestation through courts, which can lead to prolonged delays if there is no social acceptance.
3. Energy Markets and Capacity Mechanisms	* In 1998-1999 the Nord Pool power exchange started operations in Finland. Nord Pool day ahead and intraday markets are open to storage. The day ahead products include hourly and block orders, while the intraday market offers 15-minute, 30-minute, hourly and block products. * The government's Smart Grid Working Group recommended in 2018 that independent aggregators should be allowed to operate in all electricity marketplaces. * There is integration between district heating, cooling and electricity both in supply and demand, with extensive use of water boilers and other water heating systems as storage and an estimated 1800 MW of heat storage controllable through smart meters. Night-day-tariffs have been used to shift electricity consumption to night hours, mainly

	due to water heat storages. Large heat storages especially connected with combined heat and power plants supplying district heating networks are common. * In Helsinki there are underground cooling storages. * Heat pumps are used to produce district heating and cooling. * Energy storage use for consumer energy management (e.g. peak shaving) and electric vehicle integration is limited. Small scale storage (also by EVs) is growing in interest but not economical yet.
4. Ancillary Services	* In 2018 batteries could provide FCR services, while loads could provide FCR/FRRm. Dedicated rules to batteries apply to the management of the state of charge and to the restoration of full activation capacity in FCR. * The government's Smart Grid Working Group recommended in 2018 that independent aggregators should be allowed to operate in all electricity marketplaces. * Fingrid is conducting a pilot to allow the participation of independent aggregators in the mFRR balancing market, to last until the end of 2019 at least. * Using storage in non-frequency ancillary services is allowed.
5. Grid Aspects	* There is no separate connection or access rules and/or standard terms of contract for storage. Storage is considered a consumer when charging and a producer when discharging. There is thus double charging of network tariffs to storage. Grid tariff for production is in LV- and MV-networks limited to up to 0.07 €/kWh. * Net metering is not applied. Self-production within a consumption site (behind a meter) is allowed.
6. Taxes & Levies	* Taxation of electricity for large batteries has been eliminated in 2019. Electricity is transferred to large storages without any excise duty on electricity. The excise duty is paid when electricity is transferred to be consumed. * The government programme foresees that taxation on electricity storage for pumped storage facilities and smaller batteries will also be removed.
7. Involvement of TSO/DSO	* The government's Smart Grid Working Group recommended in 2018 that system operators should not be allowed to own or operate storage. * Current Finish regulation does not support DSOs owning storage or contracting it from the market, but instead making network investments. in practice storage is not included in the DSO's regulatory asset base.
8. Other & General	* Electricity storage is defined only in the law concerning electricity and fuel taxes: 'electrical storage' means a functional unit of equipment, machinery and buildings required for the short-term electrochemical storage of electricity.
9. Barriers	* The register of independent aggregators in the mFRR balancing market is slow and has required the extension of the pilot to the end of 2019, at least. * Double taxation for pumped hydro and small batteries still needs to be eliminated. * A stakeholder supports a regulatory framework where DSOs may procure storage capacity from markets and that this is evaluated in equal footing to other solutions such as network investments. * A stakeholder finds the DSO unbundling requirements and the market test of the new electricity market design burdensome, especially for small projects.
10. Best practices	* The government formed a Smart Grids working group, addressing multiple aspects related to e.g. storage, aggregation and active consumers. * Double taxation of electricity for large batteries has been eliminated in 2019, elimination for other storage planned. * The Finnish energy market is generally based on open market driven policies and competition on level playing field. This applies to electricity retail and wholesale markets as well as heating markets. * TSO pro-activity (e.g. with a mFRR pilot project) is seen as a positive aspect, as well as co-operation between TSO, DSOs and market actors. * Using storage in non-frequency ancillary services is allowed. * One of the largest virtual batteries in the EU is located in Finland. It aggregates and controls distributed energy assets (mainly water heaters) owned by customers, for grid balancing purposes.

France

Topic	France - Policy description
1. Public Support	* The Energy Transition for Green Growth Act of 17 August 2015 is a comprehensive legal framework with the aim of tackling climate change and reinforcing energy independence and energy security. One of the five action principles is to develop energy research and innovation, including in energy storage. A specific target has been determined for the development of pumped hydro storage : expansion of 1 to 2 GW in 2025-30. * There is at present no specific support scheme for storage, but storage projects/technologies can be subsidised via other schemes. In isolated and remote areas (non-connected zones, ZNI in French) with small scale, low reliability and stability, and higher electricity production costs, battery storage does already represent an economically interesting solution. * The industrial Branch Strategic Committee for new energy systems was created in 2018 and includes a thematic project on storage The draft NECP 2018 refers to electricity storage * Power systems flexibility tools including storage must be developed on the medium-term, especially due to the penetration of renewable energy * The multi-annual energy plan should anticipate the energy system change and enable the development of energy storage[158] * Storage is identified as a specific R&I need * Storage is a flexibility pillar to handle fast supply and demand fluctuations * The 2018 Low-Carbon National Strategy reference scenario includes storage, including measures to develop geothermal heat storage * Plan to confirm by 2023 the gas storage needs post-2026 * Identify sites for decommissioning in the next multi-annual energy plan * Plan to develop in the first period of the multi-annual energy plan (by 2023) the framework to develop storage as an alternative to grid expansion from 2028 * Plan to continue R&I efforts in storage through various government mechanisms * Plan to study the reutilization of salt caverns for hydrogen storage * Plan to review support framework to enable solar thermal heat storage * Storage needs to 2035 occur only in scenario with faster decrease of nuclear power generation
2. Permitting	* The standard permitting rules for power generation plants apply to energy storage plants e.g. planning permission (which covers environmental issues), power generation licence (*at the moment, electric storage plants have not been submitted to power generation permit application, this question will be discussed in the next few months*) and authorisation to construct.
3. Energy Markets and Capacity Mechanisms	* Pumped hydro and batteries can participate in the electricity markets. * The threshold for direct participation in wholesale markets was lowered to enable other flexibility resources. * A storage unit can individually participate in the CRM if its capacity is above 1MW, or through aggregation for a total of minimum 1MW, for lower capacities. * In 2018 the EPEX energy exchange introduced loop block orders, where two block orders are executed or rejected together, representing for example the storage cycle.
4. Ancillary Services	* French NRA and TSOs are working to open the ancillary services markets to energy storage (especially regarding FCR), including for small-scale storage facilities, in a technology-neutral approach. * Storage operators must sign the same regulated contract to provide ancillary services as other providers. * Pumped hydro can provide a wide range of ancillary services (FCR, FRRm, FRRa and RR), while batteries are eligible to provide FCR. To this end, the Frequency System Services rules are currently being reviewed in order to open the participation to batteries * The DSO Enedis launched a call for contribution of local flexibility products, including storage, in order to introduce market mechanisms in the frame of grid congestion management * The TSO RTE participates in the RINGO project which also aims at introducing market mechanisms in the frame of grid congestion management
5. Grid Aspects	* Storage operators pay 'postage stamp' transmission charges as a consumer (for their offtake) and do not pay injection charges. A discount on the transmission grid tariff up to 50% applies for energy storage plants, if their utilization rate during off peak hours exceeds 0.53 and if their efficiency rate is higher than 70%.

[158] CRE (French regulator) has achieved a review of the regulatory issues for the development of storage. Results, including recommendations and special requests to the system operators are reported in a document available here (in French): https://www.cre.fr/Actualites/La-CRE-publie-sa-feuille-de-route-pour-le-stockage-de-l-electricite

	* There are in France no locational network tariffs. * Rules for grid connection currently applicable for 'utility scale' batteries are considered efficient and do not jeopardize the development of storage. * Network connection procedures for small network users are currently are separate for demand and production. * The specific legal provisions regarding self-production also stimulate flexibility solutions including storage. * Specific tariff exists for multi-locations customers. This tariff considers a unique virtual site, summing all load of the concerned sites, and calculating an annual fee proportional to the necessary length of network to connect these sites. * Industrial customers connected to the transmission grid can benefit from a reduction of their transmission invoice from 5% to 90% depending on whether they have storage capabilities or not, their demand (annual consumption, annual usage duration, usage duration during peak period vs. usage duration during off-peak period) and on the importance of electricity in their process, and the degree of international competition
6. Taxes & Levies	* Storage charging needs to pay for taxes, levies and network tariffs for the electricity consumed (even in isolated systems, ZNI)
7. Involvement of TSO/DSO	* The EU Electricity Directive 2019/944 states that TSOs and DSOs cannot own, develop, manage or operate energy storage facilities because it’s a market-based and competitive activity; except if a derogation is given by the NRA in very specific conditions.
8. Other & General	* A definition of storage exists (order of 7th of July 2016) : 'a set of stationary electricity storage equipment allowing the storage of electric power in one form and its reconversion, while being connected to the public power grids. The technologies of these equipment are [pumped storage], hydrogen, electro-chemical batteries […]. The facility is connected to the public power grid directly or indirectly, through facilities belonging to a user of the grid.' * There is at the moment no legal status of storage
9. Barriers	* Uncertainties still remain regarding the implementation of the new Electricity Directive * There is a lack of a connection framework for batteries conducting to the risk that new existing constraints for other assets (non-synchronous generation) would apply to batteries * A general evolution of the TURPE structure (network tariffs) in the way of a better cost reflectivity should be positive. For example an access tariff mainstreaming per user category the costs it does generate to the network, without considering the final use of electricity. Reinforcement of fixed and capacity component (€/y or €/kW) and a stronger seasonal signal on the energy component (€/kWh) could be considered also. * A simplification of the contractual grid access framework and of connection procedures is necessary for decentralized storage (vehicle-to-grid, residential, commercial and industrial), like a single connection demand.
10. Best practices	* Draft NECP addresses storage extensively, including in R&I strategy, multi-annual energy plan, and industrial strategy. * On-going work by the NRA, TSO and DSOs on pilot projects, including for ancillary services * Many task forces have been set up to discuss storage, one being co-chaired by the NRA and the ministry.

Germany

Topic	Germany - Policy description
1. Public Support	* Power storage facilitates are increasingly built at the same location as renewable energy-based electricity plants (without necessarily being used for self-production), as this combination leads to an advantage in terms of the market premium for EEG installations and improves the profitability. * An energy storage plant which contributes to balancing the system by taking off 'excess' electricity during periods of oversupply and hence relieves the network and prevents curtailment of renewable energy production, is in the current system compensated accordingly. Clarify how The draft NECP 2018 refers to electricity storage * Central strategy in renewable energy: expansion of funding programmes for heat storage systems * The Federal Government has set the goal of building a flexible electricity system consisting of well-developed electricity networks and flexible power plants and consumers. Storage facilities will be integrated into this system wherever appropriate. It has also confirmed its ambition to enhance research into storage technologies. * The market incentive programme for supporting renewable energies in the heating market provides funding for large-scale storage facilities for heat from renewables * The Seventh Energy Research Programme covers five main topics, including 'System Integration,' with a focus on networks, storage reservoirs and sector coupling as a new area of research * Plans exist to set up a new Fraunhofer Institute for Storage Technologies
2. Permitting	* Federal Battery Act (Batteriegesetz – BattG, https://www.bmu.de/en/law/batteries-act/) is transposing Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and repealing Directive 91/157/EWG. The new Act (amendment) deals with the placing on the market of portable batteries containing cadmium and intended for use in cordless power tools, and of button cells with low mercury contents. * Regarding the installation of storage units, the applied legislation is the Federal Building Code (Baugesetzbuch - BauGB) and the Federal Emission Protection Act (Bundes-Imissionschutzgesetz - BImSchG) * Transposed Directive 2013/56/EU on (waste) batteries and accumulators addresses the placing on the market of portable batteries and accumulators containing cadmium intended for use in cordless power tools, and of button cells with low mercury content
3. Energy Markets and Capacity Mechanisms	* The general legal framework consists of three legislative pieces: the Energy Act (Energiewirtschaftsgesetz - EnWG); the Renewable Energy Act (Erneuerbare Energien Gesetz - EEG); the Framework of the prequalification and the provision of the PRL: Eckpunkte Freiheitsgrade bei der Erbringung von Primärregelleistung * There is globally non-discriminatory market access (EEX/EPEX). In 2018 the EPEX energy exchange introduced loop block orders, where two block orders are executed or rejected together, representing for example the storage cycle. * Electricity storage (pumped hydro and batteries) can individually or via aggregation participate in the electricity markets (threshold for direct participation of 1 MW) as long as storage is part of a nomination for which a balancing responsible party exists. * CHPs are using heat storage to take benefits of the electricity market price volatility; this option is in general economically more attractive than storing electricity * Network users increasingly combined PV systems with local storage, to increase self-consumption from 30% to up to 80%, also driven by the low feed-in tariff for new PV installations of 12.31 cents (up to 10 kWp) or 11.97 cents (10-40 kWp).
4. Ancillary Services	* Pumped hydro is eligible to provide FCR and FRRa/FRRm services, while batteries are eligible to provide FCR services.
5. Grid Aspects	* In the German energy Law, there are currently no injection-charges for electricity. However, by February 2020, a new legislative proposal changing, among others, the "Energiewirtschaftsgesetzt" will be presented. The new law would include a provision stating that any generation in Germany which asks for connection will have to pay for the connection. This would not hamper renewable generation installation, as costs would be funded by a surcharge on consumers following an auction system based on the Erneuerbare Energien Gesetz (EEG 2017). But those connection costs will hamper the installation of energy storage, which cannot pass these costs through to the consumer. The sector sees as a possible solution to directly exempt in this national legislative text energy storage * The conditions for connection/access to the grids are regulated through: Technische Anschlussregel Mittelspannung VDE-AR-N-4110 & Technische Anschlussregel Hochspannung VDE-AR-N-4120 (Implementation Network Codes „Requirements for Generators" (RfG)) * Since stored electricity taken off from the grid is considered as final consumption, all final consumer levies must be paid for this offtake (incl. EEG surcharge, grid charges,

	others), and the charge applies a second time when the final consumer off-takes. But some exemptions apply : - Grid charges do not have to be paid for electricity that provides upward balancing energy in the balancing market. In this special case, there are no grid fees for both the injection and the withdrawal. Depending on full load hours, the grid fee has to be at least 10, 15 or 20 % of the 'normal' grid fee. - There are network charge reductions for customer with an exclusive usage of storage (not less than 20% of yearly power price). - Grid-connected storage facilities are exempted from the grid charges for storage for 20 years after commissioning. This applies for pumped hydro storage plants commissioned from August 2011 (or for 10 years when existing plants increased electrical capacity by at least 7,5% or storage capacity by at least 5% after August 2011). - Hydrogen electrolysis plants, like electricity storage systems, are exempted from electricity grid charges for 20 years if they are connected to the grid by 4 August 2026 * Unlike stationary electricity storage devices, storage in electric vehicles does not fall under exemption rules, full network charges are due. * There is a network tariff reduction for energy intensive customers (typically heavy industry customers) with energy consumption that exceeds 7 000 full load hours per year and 10 GWh. Depending on full load hours, the grid fee has to be at least 10, 15 or 20 % of the normal grid fee * For industrial electricity users, the level of grid charges is largely determined by their peak load. To lower their peak offtake and related grid charges, electricity storage is often considered as an option. * A monthly instead of yearly capacity component is offered for final customers with a temporary peak electricity consumption * An individual tariff is available to final customers with a peak load not coinciding with system peak demand. The individual tariff must not be lower than 20 % of the published regular tariff.
6. Taxes & Levies	* Storage is treated as final consumption and thus bears network charges, taxes and levies since 2009. The following exemptions apply: * Battery electricity storage is regarded as a network component, and therefore not subject to the electricity consumption tax (StromStG §5, Abs. 4) * Pumped hydro plants are considered generators. Generators are not subject to the electricity consumption tax (StromStG §9, Abs. 1, Nr. 2 and StromStV §12, Abs. 1, Nr. 2) * Electricity from storage fed into the network for balancing purposes (i.e. upward balancing energy) is exempt from the EEG surcharge, as the electricity is supplied to the balancing group. * A storage facility according to the EEG is treated like an EEG installation. In order for a self-supply constellation to exist, there must be personal identity between the self-supply system, the storage plant and the consumption of the electricity * Self-production plants are existing plants that have already generated electricity for self-production before 1 August 2014. These plants are currently exempt from the EEG surcharge. * Self-consumption systems are all those installed from 1 August 2014. These plants must pay the full EEG surcharge, unless they are combined heat and power plants (CHP) or renewable energy plants (RE), or are not connected to the network. Rebates exist depending on the utilization, use of biogas for self-generation. E.g. Batteries and thermal storage which can prove with a costly measurement system that they only use renewable energy are exempted from levies for renewable energy (below 10 KWp). * The electricity consumed for the generation of green hydrogen has to pay fees, levies and taxes. The long-term stored hydrogen is charged again when it is used by the next end user. However, electricity used for power-to-gas is exempted from charges and levies if hydrogen is transformed directly into electricity again. In this case no state-imposed costs have to be paid. The difference in production costs plus state-imposed costs to other forms of hydrogen can exceed total investment costs. Green hydrogen costs about 6 Ct/KWh. If levies, fees and taxes apply the costs are increasing to 28 Ct/KWh. Hence, electrolysers could be clearly defined as time buffer and facilitator for PtX in the energy law to get the state-imposed costs down and attract investments.
7. Involvement of TSO/DSO	* Due to the unbundling between network operation and the other actors according to the Energy Industry Act (EnWG), the operation of a storage facility for the distribution network operator is only possible for a few services.
8. Other & General	* Electricity storage is not clearly defined in the German Legislation * The Electricity Tax Act defines stationary battery storage: 'a rechargeable storage for electrochemical-based electricity that remains exclusively at its geographical location during operation, permanently connected to the utility grid and not part of a vehicle. The geographic location is a point determined by geographic coordinates' * TenneT and Sonnen are working on blockchain-based projects to sources flexibility services from residential storage to the TSO.

9. Barriers	* There is a regulatory gap concerning the application of EEG dispositions when renewable electricity is stored, for example regulation in § 60 (3) EEG 2014 cannot be applied directly because the electricity was not obtained from the public grid. * In the further development of the electricity market, balancing deviations will be more heavily punished, resulting in suppliers taking their customers under liability. Storage can then be part of the corporate strategy to avoid such deviations * Network tariff exemption does not remove the obligation for storage facilities to pay some other regulatory charges not directly related to TSO activities. There is legal uncertainty as to whether the exemption from the network charges also applies to the concession fee and the levies that are charged. This concerns the CHP surcharge, the §19 surcharge and the offshore liability charge. * There are no feed-in tariffs in the gas network for such installations (§ 118 (6) EnWG). * Delivery to a sister company in a corporation is not considered as self-supply according to the strict interpretation of § 61 EEG by the national regulator. * There is no common definition of energy storage in the regulatory framework. Considering storage as both a consumer and producer has a considerable impact on the economic efficiency of storage projects due to the volume of network charges, taxes and levies. There are also legal differences as to whether the electricity originates from a self-generating or self-supply system or is sourced from the public grid, and whether the stored electricity is fed into the public grid or consumed directly in the site. It would be necessary to have a clear definition about energy storage as time buffer as it has been pointed out in Article 2 Point 59 of the Directive on common rules for the internal market for electricity (EU) 2019/944.
10. Best practices	* In the German energy statistics, stored electricity is considered as removal from the grid and as the return of electrical energy to the grid. The current adaptation of the energy statistics of the Federal Ministry of the Interior (Bundesinnenministerium – BMI) for the determination of the primary energy factor provides factually and statistically accurate results. * Highlight placed on developing a flexible energy system, including through system integration and use of storage * Heat storage for industrial and tertiary CHP is a flexible and cheap option for the indirect storage of electricity * In the further development of the electricity market, balancing deviations will be more heavily punished, resulting in suppliers taking their customers under liability. Storage can then be part of the corporate strategy to avoid such deviations

Greece

Topic	Greece - Policy description
1. Public Support	* Currently, there is no regulatory framework for distinct storage facilities. The Regulatory Authority for Energy (RAE) has published on 2019 a public consultation "for the formulation of a new regulatory framework for the installation, operation and pricing of storage stations in electricity transmission and distribution networks". It will address : relationship between electricity markets and storage; viability of investments on storage; mechanisms for remuneration; energy storage participation in the electricity markets; licensing and permitting for behind-the-meter storage; possible differentiation between small-scale and large-scale storage; other barriers. RAE published its thoughts on the major issues related to such a framework in October 2019, and up to early January 2020 no draft text had been prepared. * In the non-interconnected islands, hybrid facilities are compensated based on a regulated combination of capacity payment for the storage component, plus a feed-in-tariff for the energy from the storage , plus a feed-in-tariff for the energy from the renewable generation. For the three existing commercial hybrid systems installed, special provisions apply. This scheme is due to change, and RAE has submitted to the Ministry of Energy a new compensation scheme. The final 2019 NECP version foresses the addition of aproximately 2.7 GW of electical storage capacity by 2030, split between around 1.4 GW in pumped hydro and 1.2 GW in batteries. Two explicitly named pump storage projects (one of which is a PCI project) are to be implemented by 2025. The NECP contains furthermore the following references to storage: * To achieve high levels of penetration of uncontrollable RES plants, as set out in the NECP, in an economically rational way (sufficiently low cuts in their output), there is generally a need for energy storage. For several decades, pumped storage has been the most widespread international method for large-scale storage of electricity. Today, international developments are rapid in terms of other forms of storage, for large or small installations, especially for batteries of different kinds. The coupling of markets via interconnectors in accordance with the provisions of the new electricity market model is important for achieving high levels of penetration. There is also interest in power-to-gas (e.g. hydrogen) storage applications, in the context of which the interconnection of electricity and gas networks is also investigated. Moreover, given the international interconnections of the Greek mainland system, the investigation of the needs for storage and coverage thereof at a regional level may also prove efficient. * The full regulatory framework for the operation of storage systems in the electricity market will have been developed and it will be possible to develop these systems as part of generation units with simplified administrative procedures to authorise their operation by 2020. Already in the energy offsetting scheme, provision is made to operate storage systems exclusively for the storage of energy generated by self-generation RES systems and for its use by end consumers to meet their electricity needs at a later time. * As regards power generation in particular, RES will be the major domestic source of power as early as in the middle of the following decade, with a share exceeding 65% of the domestic power generation by 2030, by utilising in the most cost-effective manner Greece's high potential especially for wind and photovoltaic plants. A tool in this direction will be the full functioning of the new electricity market model, the simplification and speeding up of the licensing procedure, the digitisation of the energy system and the enhancement and expansion of energy infrastructures to allow for maximum RES penetration in power generation, focusing on storage systems, and in general the gradual electrification and the energy coupling of final consumption sectors to allow for maximum RES share in final energy consumption. Another priority is promoting electromobility, which will now rely heavily on RES power generation. * A further aim is to combine consumption sectors to the greatest and most efficient extent possible, placing emphasis on maximising the use of RES. The electrification of different uses in final consumption is an essential component in achieving this aim. A typical example is heat pumps which, together with the future greater use of energy storage systems and self-production schemes, will make a decisive contribution in this direction. * At a technical level, it is also critical for the following period to develop an appropriate institutional framework for storage units and have them participate in the electricity market. The participation of these units is considered to be crucial for attaining high shares of RES in the electricity market. In this context, plans have to be made immediately also for making possible the deployment of storage units within a RES plant, using simplified procedures. * The main categories of flexibility sources are dispatchable power plants, storage, interconnections and demand response. * For islands that are not expected to be interconnected, a significant reduction in the use of diesel for power generation is also being promoted, with the setup of state-of-the-art RES plants combined with storage technologies

	* in RD&I, Transformation of the transport sector, to be achieved by reducing the cost of small-scale electricity storage technologies and of electromobility * the development of both centralised and decentralised *storage units* is expected to contribute towards the attainment of the goal of optimal integration of RES in electricity networks. * Storage systems are expected to play an important role in reducing RES cuts in the system as a whole, to address local congestion problems and to ensure more adequate capacity and better system flexibility. Combining RES plants with energy storage systems, i.e. where they share a common connection point (storage system installed behind the meter or at a point in the distribution network downstream the same point of connection with the high voltage system), can mitigate the impact of RES plants on system operation, smoothing out variations in generation, provided that there are no operating problems. * Both centralised and decentralised storage units require the development of a comprehensive regulatory and statutory framework for their operation in energy markets and their integration in electricity networks. * The options for coupling the electricity and gas sectors (power-to-gas) through storage applications that include conversion of electricity into renewable gas, such as hydrogen, are equally important. The gas produced by using RES energy may be fed into the existing gas network and used as fuel for heating in buildings or in transport. * A key objective of centrally distributed storage systems is the development of storage units, including existing ones (Sfikia-Thisavros ~ 700 MW) and including projects of common interest (PCIs). The precise additional required power of storage systems, capacity, and technology of storage units will result from relevant studies that will be based on both the economic benefits they provide to the operation of the system and their contribution to power adequacy and flexibility of the System. * Policy measures to promote the installation of electricity storage systems may vary depending on the technology and type (centralised, dispersed) of the storage system (such as pumped storage projects in the area of *Amfilochia and Amari, Crete*). In particular, the promotion of centralised electricity storage systems is possible through the implementation of an appropriate purchasing mechanism, which will motivate the construction of storage systems over other electricity generation plants. * With regard to energy storage, measures will be taken to strengthen the development of new or improved electricity or thermal energy storage technologies with higher efficiency, availability, durability, security and at the lowest cost. Support will be provided for electrochemical energy storage technologies, which relate primarily to RES applications for utilisation in non-interconnected electricity networks or in remote points in the electricity network. * The essential characteristics of the electricity generation system until 2030, in line with the objectives achievement scenario, the NECP indicates 1.4GW Power of new central storage systems (batteries)
2. Permitting	* Permitting process for hybrid facilities (cf. section 8 for hybrid facility definition) follows the same rules which apply for the renewable generation component of the station
3. Energy Markets and Capacity Mechanisms	* The participation of front-of-the-meter storage facilities in the upcoming target model has not yet been announced * In the interconnected system, hybrid facilities participate in the market with the same rules as renewable energy facilities. There is currently neither a market for the storage services nor a special remuneration for hybrid facilities.
4. Ancillary Services	* Electricity storage is not yet eligible to provide ancillary services
5. Grid Aspects	* Stand-alone front-of-the-meter storage is not described as a specific asset in the network code and therefore should comply to the consumer and producer's rules. * Net metering for self-producers allows behind-the-meter storage. No injection to the network is allowed, as defined by the regulatory framework (Law 4513/2018) and corresponding Ministry of Energy regulation 15084/382 (2019).
6. Taxes & Levies	* No specific mention of electricity storage identified in the legislation, assumption is that charging is treated as consumption for the electricity consumption tax and levy purposes.
7. Involvement of TSO/DSO	
8. Other & General	* Storage is a necessary component in the definition of a hybrid installation. According to the national legislation (definition in Law 3468/2006), hybrid installation is one: - Which uses at least one form of renewable energy source. - Where the total energy which the hybrid installation consumed from the grid, should not exceed 30% of the overall energy which is stored, on a yearly basis. - The maximum capacity of the renewable energy generation does not exceed 120% the storage capacity.
9. Barriers	
10. Best practices	* Support mechanisms for renewable electricity in islands addresses and remunerates hybrid installations

Hungary

Topic	Hungary - Policy description
1. Public Support	* For energy storage, a focus in on manufacturing batteries for EVs, due to the economic potential of the electric vehicle industry * The National Energy Strategy 2030 does not recommend new pumped hydro storage, arguing it could be solved more efficiently with regional cooperation. * The Energy & Industrial Development and R&I Action Plan highlights storage as an R&I key field among several other technologies. * The Hungarian Regulatory Office (MEKH) supports pilots and is acquiring experience regarding the market, the technology and the possibilities offered by energy storage. * The Ministry of Innovation and Technology supports storage with tenders for pilots, also in order to gather knowledge (including for the NRA and system operators) on the use of storage and the impact on the transmission and distribution networks. * Pilots established with such support include small ones by DSOs (E.On, NKM in the case of fast charging stations) and larger ones by Alteo and ELMŰ (Innogy), focusing on balancing markets. * The implementation of energy storage projects in Hungary is relatively difficult as Hungary is centrally-located and has a developed electricity network. However recent developments should improve the business case of storage: a. Several fossil–based power plants were shut down, decreasing balancing capabilities b. Electricity imports increased to 30-35% of traded volume c. Renewable energy share is growing d. 3 to 6 GW of PV should be installed in the 10 years, and could amount to 50-60% of the net installed capacity of Hungary e. A minimum 1 GW of additional balancing capacity should be needed to integrate renewables. In 2018 reserve capacity already fell in some hours below the reference reserve level of around 1.3 GW set by MAVIR. The final 2019 NECP version refers to electricity storage * The construction of a new gas turbine power plant at the Mátra power plant site, which is particularly important for the security of supply in the Eastern part, is under investigation, is the construction of a new photovoltaic (PV) power plant and industrial energy storage unit, as well as the energy recovery of non-recoverable waste (RDF).The Mátra power plant site and/or the Northern Hungary region hosting it offers a good opportunity to carry out low carbon energy production and storage projects that can relieve other areas of pressure * Short-term fluctuations in weather-dependent production can be offset today mainly by gas-fired power plants, but there should also be scope for the spread of new innovative solutions such as energy storage and demand response * The Energy Innovation Council (EIT) composed by the Minister for Innovation and Technology, the Hungarian energy and industrial companies, universities, research institutes, professional organisations, the Energy Regulator (MEKH) and several Ministers identified, among the options for intervention areas: Innovative System Balance (Flexibility Storage and Demand Management). * regarding the electricity market, it is essential that the domestic electricity system (including consumers) has controllable capacities guaranteeing safe operation and balancing. (E.g.: generation capacities providing flexibility; new types of flexibility services, DSR solutions, energy storage) * As regards energy storage, Hungary intends to encourage the use of energy storage systems to integrate renewable energy production. In order to ensure cost-effective integration of renewables, it will also be necessary to encourage the uptake of innovative technologies (energy storage, capacity building of existing network elements) and modes of operation (demand response). * The spread of seasonal electricity storage and battery storage, as well as grid developments and grids, will be supported from OPs and Modernisation Fund grants as of 2021 * Investment in energy storage and micro-grid solutions (facilitating single-site operation of renewables and energy storage facilities with regulatory tools) should be encouraged. It is necessary to simplify the authorisation process and regulatory market accreditation of energy storages, to develop regulatory products making better use of the technical potential of storages (e.g. the introduction of artificial inertia-type products), to promote innovative solutions in seasonal storage and to encourage the storage of heat by cogeneration producers. * In order to support the use of the necessary innovative solutions in seasonal energy storage, Hungary is also planning pilot projects: Converting excess electricity into heat and storing it in district heating systems using electric boilers; Development of optimal storage and use of electricity generated hydrogen * It is proposed to launch pilot projects on the distribution and transmission (DSO and TSO) side for energy storage systems

	* The creation of a complex pilot-sized research and development centre to test the systemic interconnection of different renewable energy sources and energy storage technologies is desirable * The aim is to develop complex price regulation that encourages the use of innovative smart solutions and the market procurement of flexibility services (e.g. energy storage, demand response). * Sector coupling is accentuating when the processes of producing different forms of energy (electricity and heat as well as fuels) are interlinked. The gas market and the electricity market are already interlinked on a number of points. However, in the near future, sector coupling could also cover new areas, e.g. replacing gas-based heating/cooling with renewable-based electricity or heat pumps in regions with low-use infrastructure or not connected to the gas network. The convergence of energy systems is also facilitated by the development of energy storage technologies (e.g. battery, heat storage, power-to-gas). * In digitised energy systems, communication between generation, demand, storage and grid is becoming faster * Priority is to improve innovation, with sub-focus on development of household and industrial scale energy storage technologies * Planned measure to develop household-scale small power plants combined with smart metering and electricity storage * The upcoming Energy Strategy will define the regulatory framework for among others electricity storage in batteries
2. Permitting	* The regulator is the competent authority responsible for licensing of all generation facilities. In case of any future development e.g. pumped hydro, it would act as the licensing body. * The Hungarian Act 86/2007 on Electric Energy requires the authorization for the operation of an electricity storage facility with a nominal output capacity of 0.5 MW or more * The Hungarian Act 86/2007 on Electric Energy indicates the provisions (including in secondary legislation) for the authorization of power plants shall apply to electricity storage facilities, mutatis mutandis
3. Energy Markets and Capacity Mechanisms	* There is no specific electricity storage regulatory regime in Hungary. * Legally, all markets are open for large and aggregated consumers, however participation is currently still limited. * Large consumers, retailers and aggregated consumers are allowed to participate in the Hungarian Energy Exchange HUPX. However in 2016 entrance was difficult, expensive and with liquidity problems. The combination of over-the-counter contracts and participation at the exchange was then common.
4. Ancillary Services	* In 2018 batteries could provide FCR services, while loads could provide RR * Aggregators are allowed to provide balancing services, as there is no special restriction or rules for aggregation. * Several battery projects focusing on balancing implemented/planned from 2018 on 1) Alteo project delivered in 2018 for FCR and aFRR services, including to the company's virtual power plant; 2) ELMŰ-ÉMÁSZ Energiatároló Kft; 3) E.ON battery. * Black start is remunerated by the TSO. If the gross installed capacity is more than 500 MW and the power plant is connected to the transmission grid, the service is mandatory. Some of the power plants are able to provide black start capability, but their gross installed capacities are less than 500 MW.
5. Grid Aspects	* There is no specific legislation about tariff discounts, transformation losses, or other grid aspects.
6. Taxes & Levies	* There is no specific taxation regulation for energy storage in Hungary. If energy storage is interpreted as consumption, it could be subject to electricity consumption taxes.
7. Involvement of TSO/DSO	* DSO can install and operate a storage facility of max 0.5 MW to optimize distribution activities, as long as in accordance with the lowest cost principle (Hungarian Act 86/2007 on Electric Energy).
8. Other & General	* Hungarian Act 86/2007 on Electric Energy: 'Electricity storage facility' shall mean an equipment used for storing electricity by way of physical or chemical means, meaning that it converts and stores in-put electricity, then releases it back to the electricity system minus technical waste; * In essence, the current legal situation is that energy storage shares the legal role of generators and are handled by the regulator as such.
9. Barriers	* The National Energy Strategy 2030 provides negative signals as pumped hydro is deemed as not an adequate option. * All potential pumped hydro sites are located close to the River Danube and other environmentally sensitive locations, which are Natura 2000 territories. On one such site the competent authority refused the necessary environmental license, later confirmed in court. * Storage is subject to double charging and to the electricity consumption tax. * Hungary requires the development of a regulatory regime for the participation of storage in energy, capacity and ancillary service markets.

	* The participation of storage in ancillary service markets is very limited, restricting the available revenue streams for storage projects.
10. Best practices	* Electrical energy act contains a definition of storage. * The government, regulator and system operators are actively exploring storage technologies, pilots and system integration. * Samsung SDI has completed in 2017 its battery manufacturing plant in Hungary, focused on the automotive industry. SK Innovation has also announced the construction of plants in the country. * Several stationary battery storage installations in development / operational by both network operators and non-regulated actors

Ireland

Topic	Ireland - Policy description
1. Public Support	* The national report on climate action refers explicitly to storage: 'Storage of electricity through the use of batteries, pumped storage or compressed air storage (amongst others) will be of vital importance both in terms of security of supply and in the switchover to renewable energy sources.' * The government 70% renewable electricity target for 2030 will require significant additional system stability services from fast acting energy storage * In July 2018, a pilot micro-generation scheme was launched to support PV installations coupled with home battery storage for self-production Relevant references in the draft NECP 2018 * Large-scale energy storage is necessary to electrify the heating and transport sectors * New efficient energy storage systems should be incentivised * Policies related to small scale battery storage should be developed to facilitate self-production; moreover a regional approach to strategically located battery storage facilities is suggested to alleviate pressure on national grid * R&I to focus on technologies at advanced readiness levels, prioritising energy storage technologies and solutions * At the present only one large scale energy storage facility is in operation: pumped hydro station at Turlough Hill
2. Permitting	* The standard permitting rules for power generation plants apply to energy storage plants e.g. planning permission (which covers environmental issues), power generation licence and authorisation to construct. The legislation does not differentiate between generation and storage technologies.
3. Energy Markets and Capacity Mechanisms	* Energy storage is allowed to participate in the electricity markets (including intra-day and balancing). The effective participation varies per technology. * Energy storage are allowed to participate in the Irish Capacity Remuneration Mechanism; the derating factors depend on the duration of storage being provided. The CRM offers additional revenues, which may have to be partly reimbursed if the market price exceeds the strike price in the contract (€500/MWh). * Developments in the area of sector coupling are at an early stage. Some companies provide a solution combining heating, cooling, electricity and energy storage
4. Ancillary Services	* Ancillary services are currently both a grid code requirement in terms of capability, and units can also contract under the DS3 System Service programme for availability payments for provision of services. The DS3 programme led by EirGrid (TSO) includes the development of an enhanced market for system services,14 System Services exist which cover both frequency and voltage services, and are open to all technology providers. A separate DS3 fixed 6 year contract for provision of 5 services (fast reserves with response provision within 300ms for a duration of 20 mins) is also in place with a limited number of providers (110MW). The fixed 6 year contracts require a response within 300ms and there is an incentive to respond within 150 ms.
5. Grid Aspects	* An Enduring Connection Policy (ECP-1) was published under which generators can apply for a connection at a particular time (for all types of applications). In the first “gate”, with 1000MW being processed, 400MW was prioritised for connections for DS3 system services plants, predominantly batteries. * There is double charging of tariffs, as currently storage pays connection and access charges on the basis of withdrawal and injection. Some of the transmission-connected pumped hydro storages are fully or partially exempted from withdrawal charges. Also, the Public Service Obligation charge (applied to all energy consumers in Ireland) which is based on Maximum Import Capacity (MIC) will only apply to the portion of the MIC related to house load when it is offline (i.e. neither importing or exporting) and not to the full MIC related to energy injection and absorption to/from the grid. This contrasts with the treatment of self-producers which only have to pay access charges for whichever of their Maximum Import Capacity (MIC) or Maximum Export Capacity (MEC) is higher. * The aspect of the network codes which currently applies to energy storage is a generic Power Park Module (PPM) code which was originally elaborated for wind generators. TSO EirGrid has recognised that some derogations are required the specific characteristics of energy storage and its potential to offer grid stability services. * There is no net metering at the moment
6. Taxes & Levies	* Public service obligation levies are charged only based on the house load consumption. The levy is calculated on the basis of the Maximum Import Capacity (MIC). The Commission for Regulation of Utilities (CRU) determined in 2019 that the MIC for calculation of the PSO for energy storage plants was based on the MIC when importing at 'house load' (i.e. when neither importing or exporting).
7. Involvement of TSO/DSO	* Currently the TSO/DSO do not own any energy storage plants
8. Other & General	* Energy storage is not defined in the national regulatory framework.

9. Barriers	* The main support for encouraging new build in fast acting energy storage is an auction for procuring capacity under a 6 year fixed-term contract being offered by EirGrid under their DS3 program. This auction resulted in a procurement of 110 MW of battery storage which concluded in Oct 2019. It is unclear if a similar scheme would be announced for securing system services in the future. The other route to market is an ongoing tariff arrangement but the tariff rates could fall, so there is less certainty of revenue compared to the 6 year contract. The 6 year contract is sufficient to make battery projects viable but is too short for capital intensive technologies such as hydro pumped storage or compressed air energy storage. * The Capacity Market (CRM) would not be feasible for short duration energy storage plants e.g. for grid stability services but it may work for medium and long duration energy storage. * In general, there is a lack of market mechanisms for some applications of energy storage and also the lack of long-term market signals (although a small volume of 6 year contracts are available for fast acting energy storage). * Currently Energy Storage providers that are over 0.5MW are required to pay both Transmission generation use of system charges (GTuOS)and distribution use of system charges (DTuOS). In addition, plants connected at distribution level will be subject to Distribution use of system charges (DuOS) * The Use of System Charges rule places energy storage plants at competitive disadvantage to generation or distribution technologies. * EirGrid has accepted that some Grid Code derogations are required but there have been little signs of progress in addressing these in a coordinated manner * There is no market mechanism or regulatory focus – on utilization of storage devices to assist in congestion management/grid investment deferral. * There is a lack of understanding of the role of energy storage in the decarbonisation of electricity supply and consequently the lack of clear policies and rules for storage
10. Best practices	* EirGrid's DS3 program has facilitated an increase in the instantaneous System Non-Synchronous Penetration (SNSP) from 50% to 65% with a current target of 75% when battery plants are built to provide FFR. This is significantly higher than any other country. The 2030 target is likely to be 90% to accommodate the 70% renewable electricity target adopted by the Irish government. * Public service obligation levy applies only to on-site consumption for storage.

Italy

Topic	Italy - Policy description
1. Public Support	* GSE provides a net billing scheme, the Scambio sul Posto. The Italian National Energy and Climate Plan (NECP) foresees the revision of such a scheme in order to support the installation of storage facilities. GSE (the authority managing the payment of incentives) confirmed and regulated the installation of a storage system in an existing PV power plant receiving subsidies, in order to remove uncertainties. * The public R&I budget for energy storage in 2017 was 9.69 M€. * The Lombardy region provided a support mechanism to behind-the-meter storage combined with residential PV plant in 2016, renewed for the 2017-2020 period. Due to this, the large majority of the behind-the-meter storage installations in the period in Italy are in Lombardy. In 2019 also Veneto and Friuli Venezia Giulia regions provided a support mechanism as the Lombardy. * A tax credit (in 10 years) for residential storage device was implemented in 2013. In 2019 the Italian tax authority published the circular n. 13/E, removing the tax credit eligibility to PV plants which receive subsidies in Conto Energia. * The main goal within the electricity sector is to introduce new market instruments in order to channel investments towards new storage systems and generation capacity. * The 2020 Italian Budget Law 160/2019 includes tax credits for new high-tech assets, qualifying under the Industry 4.0 Plan. Credits amount to 40% for investments up to €2.5 million and 20% for investments from €2.5 to €10 million. The final 2019 NECP version refers to electricity storage * With regard to the safety and flexibility of the electricity system, the promotion of a broad participation of all available resources — including accumulations, renewables and demand — will need to be taken into account for the transformation of the system induced by the increasing role of renewables and distributed generation, testing new architectures and management modes, including with the active role of TSOs. Similarly, it is necessary to take account of the essential need for storage systems, to avoid over-generation from installations for the production of electricity from renewable sources * Support to the deployment of distributed storage systems * Bundling of generating facilities including together with storage systems, and demand units for access to services markets * It also aims to promote the deployment and use of energy storage systems, including electric vehicles, including long-term accumulation, and the integration of the electricity system with gas and water systems * Among the most stressed topics in the sections on electric RES include positions expressed in favour of self-consumption, including in a collective form by enabling multi-user configurations within energy communities; the main arguments highlighted are the promotion of demand and supply aggregators in the PPPs and the development of an enabling environment for the full development of storage technologies, especially through pumped storage and batteries, but without neglecting the new borders of power to gas * The realisation of a large storage capacity, and storage solutions involving the use of alternative energy carriers (synthetic hydrogen/methane), is concentrated in the service of the network, is also indispensable in order to mitigate some problems and have appropriate flexibility resources * A further objective relates to the important development of the storage capacity, which will be gradually but increasingly addressed to “energy intensive” solutions, in order to limit the phenomenon of overgeneration and to support the achievement of the targets for the consumption of renewable energy * For the coming years, it is also necessary to pursue a significant development of electrochemical storage * it has been estimated that in the medium term (around 2023) new storage systems for almost 1.000 MW in production are in production, between hydro and electrochemical * It is of particular interest to be the synthesis of hydrogen from excess renewable electricity to be used for the purposes of storage or entry in gas networks * The potential for thermal energy storage technologies, especially high-efficiency cogeneration systems and district heating networks, will also be considered * In summary, the objectives for the energy security of the electricity system and its quantification are : new storage systems installed for at least 6 GW by 2030 * Increasing the flexibility of the system is certainly one of the national targets for the internal energy market. It will be pursued both by making the existing thermoelectric power park more flexible and, above all, by extending market participation to new, flexible resources. These identify aggregation and demand response, the better involvement of distributed and renewable generation not programmable to services markets and the development of new storage systems

	* Development of storage systems, including thermal, electrochemical and power to gas, and their interfaces with networks, to ensure high levels of penetration of non-programmable renewables * Where self-consumed energy exceeds 40 % of output, a specific premium is provided, which can also drive the deployment of storage systems * Legislative Decree No 102/2014 introduced the possibility to create aggregates of generating installations, including together with storage systems * The sector on which Italy was relatively more active in electrical power in 2016, from an innovative perspective, is energy storage (one fifth of the total), but also photovoltaics and wind, which together attract 37 % of the innovations produced in Italy, mainly from Lombardy and Lazio.
2. Permitting	* Installation of storage systems is not allowed for those PV power plants that benefit from the first Conto Energia subsidies, have a capacity of under 20 kW and benefit from net billing (scambio sul posto). * The absence of clear timelines and procedures to follow for permitting and the lack of environmental regulation specific for storage technologies leads to permitting barriers, according to a stakheolder. * No further specific permitting provisions identified.
3. Energy Markets and Capacity Mechanisms	* The Italian energy markets do not specificy the system actors which are able to participate, thus not blocking storage. However, the Italian wholesale energy markets do not have specific linked or loop block orders to allow tailored bids by storage. * Storage is allowed to participate in the Italian CRM (with a derating factor), whose auction took place at the end of 2019. The derating factor aggregates storage in the category 'others', giving a value of 50%, regardless of the energy-to-power ratio of the storage. According to the auction results published at the end of December 2019, storage was awarded 96 MW of new capacity, equal to 2.4% of the total awarded capacity. * Most behind-the-meter storage installed in Italy (and concentrated in the Lombardy region) is for increasing self-consumption of renewables. * There is no regulatory framework for vehicle-to-grid applications.
4. Ancillary Services	* Italy is revising the regulatory framework and design of the MSD market (balancing + congestion management). In 2018 several pilots were launched to test the opening of this market to other resources than conventional and dispatchable power plants above 10MW. In the UVAM pilot, which will continue in 2020, virtual units (of distributed generation, storage including V2G, demand and other resources) with (upward and/or downward) balancing capacity of 1 MW can now be aggregated and participate in congestion management, FCR and RR provision. A stakeholder has indicated it is focused on demand response rather than storage. * After the results of this pilot project, the partipation of virtual aggregated units to MSD will be fully allowed in the regulation. * Terna will verify in 2020 the possibility to allow the virtual units to participate in other services, especially FRR provision. * The UVAS project is to be launched in 2020 for the provision of rapid FCR (under 1 s) by non-conventional resources. The size of each UVAS must be over 5 MW. * The UPI project has been launched at the end of 2018 by the TSO Terna. UPI aims at the procurement of primary frequency regulation services from power plants above 10 MW with storage systems. It was sized at 30 MW, and this capacity fully allocated by 2020.
5. Grid Aspects	* ARERA regulation 574/2014/R/eel updated the connection and access rules to include energy storage. Tariff discounts for withdrawal from pumped hydro are extended to all electricity storage technologies, as long as energy is not intended for final consumption. This means that hybrid configurations of storage system combining also consumption assets are not eligible for the discount. Hybrid generation + storage assets are classified as generation, and energy offtakes by these hybrid assets are differentiated between withdrawals intended for powering storage (treated as negative energy input) and withdrawal intended for powerering the auxiliary generation (treated as withdrawals). In either case, consumption by hybrid generation + storage assets for ultimately providing system services is exempt from grid charges. * ARERA issued consultation 345/2019/R/EEL which closed on September 2019 on the extension of the exemption on transmission and distribution grid charges to complex configurations such as the combination of consumption and storage. The ARERA orientation is that: all electricity drawn from the grid and intended to power the storage systems for subsequent re-injection in the network and / or the auxiliary generation services should be treated as negative electricity input for determining tariffs. This would apply also to cases such as aggregated assets or vehicle-to-grid. * According to art. 38-ter of the connection network code (TICA), when storage has the same economic conditions and procedures as for high efficiency combined-heat-and-power plants, it still has to pay the connection charge.
6. Taxes & Levies	* The Italian tax authority confirms the installation of a storage system with residential PV does allow deducting the appropriate costs for tax purposes, irrespective of whether the storage system was installed together or after the PV system (Circular Letter No. 7/E of 2018). In addition, in the 2019 the italian tax authority published the circular n.

	13/E which forbids the detaxation for residential storage device if PV plant receives subsidies in the Conto Energia. * The 2020 Italian Budget Law 160/2019 includes tax credits for new high-tech assets, qualifying under the Industry 4.0 Plan. Credits amount to 40% for investments up to €2.5 million and 20% for investments from €2.5 to €10 million. * Self-consumed stored energy is exempt from taxes. No other specific mention of electricity storage identified in the legislation, thus other storage is treated as consumption for the electricity consumption tax and other levy purposes.
7. Involvement of TSO/DSO	* TSOs and DSOs may develop and operate battery storage facilities (Legislative Decree no. 93 of 01 June 2011). Regulation foresees that DSOs must submit a proposal providing a cost-benefit analysis to the regulator that justifies such investments if it is to be recovered through tariffs. * In 2012-2013 the storage pilot projects were regulated, and the TSO pilots were included in the NDP and approved by the government (Resolution 288/2012/R/eel / Ruling no. 08/2012 of NRA). * The NECPs indicates that, to satisfy the need for storage in the case of a lack of market interest, upon authorisation by the regulator and on the basis of guidelines from the Ministry of Economic Development, the TSO may implement and operate storage systems directly connected to the national transmission network in only two cases: - Storage integrated to the transmission network required for the safety of the electricity system. This storage cannot operate on wholesale markets in competition with operators; - Storage capable of providing ancillary services, where competitive procedures are employed by the market operator for procurement of these services. * Currently there is no DSO procurement of local flexibility services.
8. Other & General	* Regulatory decision 574/2014/R/eel: A storage system is a set of devices able to absorb and release electric energy, foreseen to work continuously in parallel to the grid or able to modify the energy exchange with the electricity grid. The storage system may or may not be integrated with a generating plant. Systems that enter into function only in emergency conditions like during a black out are not considered to be a storage system.
9. Barriers	* The absence of adequate long term price signals that differ from the Capacity Market is a main barrier to the development of storage facilities. A stakeholder indicates the services provided by the storage are still treated singularly and independently from each other, with no integration among them. As such, the regulatory framework is still lacking, or insufficiently attractive, to fully maximize value from storage technologies. * The net billing scheme 'scambio sul posto' is still active, and furthermore does not considers storage. It thus disincentives behind-the-meter storage, within and outside of the scheme. * In the Italian CRM the derating factor of the 'others' group is applied to storage, giving an extreme value of 50% and disadvantaging storage compared to other technologies. * While pilots are ongoing to allow the participation of (aggregated) storage in ancillary service markets, there is a need for a consistent and comprehensive opening of these markets for (aggregated) storage and loads. * Further information is needed on ancillary services are needed to develop a storage business plan based not only on the energy market.
10. Best practices	* The Italian tax authority clarified tax rules, confirming the installation of a storage system with residential PV does allow deducting the appropriate costs for tax purposes, if the residential PV plant does not receive subsidies in Conto Energia. * GSE (the authority managing the payment of incentives) confirmed and regulated the installation of a storage system in an existing PV power plant receiving subsidies, in order to remove uncertainties. * The UVAM pilot will increase the participation of storage in the procurement of various ancillary services. * The UVAS pilot will increase the participation of storage by developing a fast response frequency regulation service.

Latvia

Topic	Latvia - Policy description
1. Public Support	* The Energy Development Guidelines for 2016-2020 from 2016 indicate improving the safety of energy supply and sustainable energy are the key development targets in Latvian energy policy. However, the guidelines do not mention storage except when briefly discussing its capacity to support RES development. The draft NECP 2018 refers to electricity storage * The NECP indicates the Latvian Innovation Fund should cover a wide range of projects beginning in 2020, including innovative renewable energy and energy storage technology projects.
2. Permitting	* There are no specific requirements for permitting of storage facilities in national policies. Access permits are issued by the Ministry of Economics, while access to the grid is subject to technical regulations issued by TSOs or DSOs. Requirements in regulations are the same as for other infrastructure.
3. Energy Markets and Capacity Mechanisms	* In 2013 the Nord Pool power exchange started operations in Latvia. Nord Pool day ahead and intraday markets are open to storage. The day ahead products include hourly and block orders, while the intraday market offers 15-minute, 30-minute, hourly and block products. * Storage for consumer energy management (e.g. peak shaving) and from electric vehicle integration is not developed in Latvia. * Planned heat storage within Riga CHP-2 plant will increase flexibility provision significantly.
4. Ancillary Services	* The Latvian Regulatory Authority recently approved amendments to the National Network Code in line with EU Regulation 2017/2195, stating that energy storage companies may participate in the provision of a balancing service. * In January 2018 the Baltic common balancing market came in operation, covering mFRR. Storage is allowed to provide mFRR services. For mFRR the product duration is 15 min, the minimum bid size is 1MW. The ENTSO-E ancillary systems survey of 2018 however indicates only generators may participate in the Latvian mFRR. * Currently only FRR is used in the Baltic balancing market. The Russian Unified Power System (UPS) provides FCR and FRRa, while Baltic TSOs provide also RR.
5. Grid Aspects	* Net metering for renewable energy installations with a small-scale connection (under 3*16A amperage) was instituted in 2017 in the Electricity Market Law. * There are no specific rules for energy storage facilities to connect and access electricity grid. Storage facilities are considered as generators when supplying power to the grid and as consumers when consuming power from the grid. * In order to decrease monthly fixed grid connection costs for all system users, the Latvian NRA has proposed that the distribution-level generators should also have to pay the connection grid charge according to their connection capacity (in public consultation process in September 2019).
6. Taxes & Levies	* No specific mention of electricity storage identified in the legislation, assumption is that charging is treated as consumption for the electricity consumption tax and levy purposes.
7. Involvement of TSO/DSO	* Regulation does not address ownership and/or operation of storage by network operators. In accordance with Directive (EU) 2019/944 DSOs or TSOs are allowed to own storage plants only on specific conditions (Articles 36 and 54)
8. Other & General	* Energy storage is not defined in the national regulatory framework.
9. Barriers	* There is no regulatory framework for storage in Latvia. * Grid and taxation aspects (double charging of network tariffs, net metering for renewable energy producers with small connections) limit the business case for storage, front- and behind-the-meter.
10. Best practices	* The Baltic states implemented the Baltic common balancing market, with storage being able to provide the first product, mFRR.

Lithuania

Topic	Lithuania - Policy description
1. Public Support	The Lithuanian Energy Strategy includes the following: * A strategic direction for 2020 the development of the fifth unit of the Kruonis Pumped Storage Power Plant following a cost-benefit analysis. * A strategic direction for 2050 the 'development of effective and non-polluting energy production, supply, storage/accumulation, and consumption technologies'. * An R&I priorities for 'the development of new energy production and storage technologies with low GHG and air pollutant emissions and resilience to climate change'. The final 2019 NECP version refers to electricity storage: * Lithuania plans to reach by 2030 45 %.RES target in final energy consumption. Therefore, investments in smart energy systems, including transmission, distribution and storage infrastructure, and in increasing the required balancing capacity are envisaged in order to successfully integrate larger volumes of renewable energy and a large number of electricity-generating customers * In addition, Lithuania’s 2021-2027 operational programme for investments from the European Union funds is directly linked to the implementation of the Commission’s recommendations, with a view to allocating EU funds investments to such tasks, such as : developing smart energy systems and grids, as well as local energy storage solutions * The planned capacity mechanism will be technologically neutral, as it will be open not only to electricity generation but also to existing and future electricity installations to be installed (built) by the participants in the capacity auction before the start of the capacity delivery period, but also to installations managed by storage and independent electricity demand aggregators. * Objectives set out in the National Energy Independence Strategy**,** with, among the priority axes for energy research and experimental development : Development and integration into the grid of new technologies for low greenhouse gas emissions and ambient air pollutants that are resilient to climate change changes in energy production and storage; and integration into the EU’s strategic value chains * Promote the production of electricity storage technologies by attracting investment in the production of these technologies in Lithuania * Financing the deployment and storage of RES energy generation solutions * The generating customer shall be given the opportunity to ‘store’ the electricity produced by him and not consumed by him for his own use in the electricity networks between 1 April of the current year and 31 March of the following year. The producer shall pay a network access charge for the amount of electricity that he has ‘stored’ and recovered from the electricity networks.159The amount of electricity supplied to the electricity grid in excess of the electricity consumed by the customer during the storage period shall not be carried forward to the next storage period * It is envisaged that the ‘prosumer’ scheme will continue until April 2040 by granting the right to “storage” electricity produced and not consumed by the economy in the electricity networks * *In addition to the smart meter, it is also planned to introduce a smart metering system for meter management; reliable data collection, storage and analysis* * Financing of energy security projects (with CEF): Field and infrastructure studies for the Kruonis pumped storage plant (Kruoni HAE) * Litgrid is currently carrying out a pilot battery project to check the availability of battery storage systems under realistic operating conditions of the Lithuanian electricity system. Battery storage systems can contribute to maintaining the required level of inertia (synthetic inertia function) and to ensuring very rapid reserves of regulatory powers, which would contribute to improving system adequacy in preparation for synchronous work with continental European networks * *Promote the integration of electricity storage facilities and services into the electricity market* * Consumers will be able to consume, store and sell self-generated electricity to the market and participate in all electricity markets and contribute to increasing the flexibility of the electricity system through energy storage. * The Action Plan for the implementation of the National Energy Independence Strategy includes policy measures in the research, innovation and competitiveness sector up to 2030: Develop and implement a common data storage and exchange platform * The funds allocated to Lithuania in the Modernisation Fund would be used for the modernisation of energy systems, the deployment of energy storage solutions in both

159 https://www.vert.lt/atsinaujinantys-istekliai/Puslapiai/elektros-energija-gaminanciu-vartotoju-naudojimosi-elektros-tinklais- Service-prices.aspx

	district heating and electricity transmission and distribution networks in order to integrate the planned ambitious RES levels * *Planned policy measures for RES in the electricity sector up to 2030:* AEI8. Financing of RES energy deployment and storage solutions, including prosumers, RES Communities (EU support) ; AEI19. Promote the use of RES for CHP heat generation by assessing the potential of solar technologies, heat pumps and heat storage in CHP systems ; * *Planned market integration policies up to 2030:* ERC26. Promote market integration of energy storage facilities and services ; ERC28. Kruoni pump-storage plants (KHAE) implementation of the construction project for Unit 5 * The Ministry of energy actions on 'improvement of power generation infrastructure, energy distribution networks and energy storage' forecast as a cross-cutting adaptation policy for 2021-2030 with EU funds, but no budget is indicated.
2. Permitting	* No specific measures or requirements for permitting of storage facilities identified in national legislation.
3. Energy Markets and Capacity Mechanisms	* In 2012-2013 the Nord Pool power exchange started operations in Lithuania. Nord Pool day ahead and intraday markets are open to storage. The day ahead products include hourly and block orders, while the intraday market offers 15-minute, 30-minute, hourly and block products. * The 2017 Law on Necessary Measures against the Threats Posed by Unsafe Nuclear Power Plants in Third Countries stipulates that the Lithuanian electricity storage facilities (Kruonis Pumped Storage Hydroelectric Plant) cannot be used for storing electricity generated by unsafe nuclear power plants in third countries. * The Lithuanian CRM is technology-neutral and thus allows for the participation of storage and DSM. A consultation was closed in February 2019 and the first auction is forecasted to take place by March 2020. * The Kruonis pumped hydro plant is the only storage facility to have been identified with a significant role in the Lithuanian energy markets.
4. Ancillary Services	* In January 2018 the Baltic common balancing market came in operation, covering mFRR. Storage is allowed to provide mFRR services. For mFRR the product duration is 15 min , the minimum bid size is 1MW. The ENTSO-E ancillary systems survey of 2018 however indicates only pumped hydro is eligible to provide FRRm to TSOs, while batteries are not yet eligible to provide AS. * Currently only FRR is used in the Baltic balancing market. The Russian Unified Power System (UPS) provides FCR and FRRa, while Baltic TSOs provide also RR. * Within the context of the Baltic synchronization project the Lithuanian TSO LITGRID launched a pilot project for a 1 MW battery in Vilnius (to be procured), to study battery systems under real operational conditions, identify applications and defined requirements for the different services. The battery will be tested for FCR, FRR and RR provision.
5. Grid Aspects	* Baltic synchronization project * The political roadmap on the synchronization of the Baltic States to the Continental Europe electricity network is from 2019. Studies performed by the Baltic and Polish TSOs decide on how to provide regulating power from HVDC links, where battery systems were identified as a viable alternative to frequency regulation by HVDC systems. Final investment decisions are not due in the next years while the technical capabilities of large battery systems are not proven, but preparatory steps are being taken. * The Connection Agreement foresees additional studies with battery system suppliers regarding several technical and economic analysis on such a battery system. * There are no indications of exemptions from grid charges for storage in Lithuania.
6. Taxes & Levies	* No specific mention of electricity storage identified in the legislation, assumption is that charging is treated as consumption for the electricity consumption tax and levy purposes.
7. Involvement of TSO/DSO	* The 2000 Law on Electricity unbundling provisions do not refer to storage, requiring unbundling only of generation, transmission, distribution and supply.
8. Other & General	* Energy storage is not defined in the Law on Electricity or other legislation.
9. Barriers	* Except for pumped hydro in FRRm, there is no participation of storage for the provision of ancillary services.
10. Best practices	* The Baltic states implemented the Baltic common balancing market, with storage being able to provide the first product, mFRR. * LITGRID has started a 1 MW battery system pilot project as part of the forecasted increased penetration by 2025.

Luxembourg

Topic	Luxembourg - Policy description
1. Public Support	* There is currently no dedicated national strategies, nor policies exist with regard to the promotion of energy storage solutions and their operations. * There is currently no dedicated support mechanism for energy storage. * Energy consumption of storage devices is exempt from the electricity tax. * The law on the organization of the electricity market is currently being revised to include among others the principles of self-consumption and energy communities. These new modes of production and consumption render explicit the right of every user to own and operate energy storage devices within certain technical limits. * These provisions are part of the transposition of the Clean Energy Package on storage into national law. Additional revisions/adaptations may follow. * Luxembourg's NECP lists decentralised storage and flexibility options as cornerstone for future developments.
2. Permitting	* There are currently no specific permitting rules applied to storage devices. The draft revision of the law on the organisation of the electricity market authorises all end users to own and operate energy storage devices within certain technical limits.
3. Energy Markets and Capacity Mechanisms	* The "Vianden Pumped Storage Plant", one of the largest in its kind in Europe, is located in the Grand-Duchy of Luxembourg with a capacity of 1,3 GW and approx. 5.000 MWh. Owned and operated by the Société Electrique de l'Our S.A., it contributes significantly to the flexibility and reliability of the electricity system in the greater region. * There is currently no public information on the "behind-the-meter" small-scale storage capacities. * Heat storage capacities used for the operation e.g. district heating systems do not play an important role in Luxembourg and none of those contributes to the flexibility needs in the electricity sector.
4. Ancillary Services	* Ancillary services for the Luxembourg grid area are procured by the German TSO Amprion on behalf of the Luxembourg TSO Creos due to the fact that they are in the same LFC area. Conditions are settled in a service contract. Mechanisms are currently being developed to fully enable assets in Luxembourg to participate in these procurement processes. * For the time being, the role of energy storage in consumer energy management is negligible. The new legal provisions on self-consumption and energy communities might lead to an accelerated development.
5. Grid Aspects	* There are no specific provisions that apply to the grid connection and access rules of energy storage facilities. * Consumption of self-produced electricity from renewable energies involving storage devices is exempt from the variable grid tariff, however, a fixed capacity fee is still due
6. Taxes & Levies	* According to the legislative framework, 'the energy consumption used for storage purposes' and 'the energy consumption used to produce electricity or used to maintain the capacity to produce electricity' is exempt of the electricity consumption tax. * Self-consumption - with or without storage devices - is exempt from the renewable levies
7. Involvement of TSO/DSO	* Network operators are not prevented from providing services in the context of demand management, distributed generation and others, including the storage of energy
8. Other & General	* Energy storage is not defined in the national regulatory framework.
9. Barriers	* Full market access of assets to all ancillary service procurements, also see 4. * Economic barriers remain due to the lack of business cases * Application of real-time pricing schemes
10. Best practices	* Independent of whether it comes from generation or storage, injected electricity is not subject to grid tariffs in Luxembourg

Malta

Topic	Malta - Policy description
1. Public Support	* Storage is part of the energy R&I areas and thus may receive funding, as in the case of the FLASC project for offshore renewable energy storage. * In October 2019, the government announced a scheme in its budget for 2020, whereby a grant of 25% on the purchase of battery storage shall be introduced. This grant, capped at €1 000, is available to individuals who have already installed solar panels and who are no longer benefiting from the feed-in tariff scheme. Further support schemes at the moment do not cover the combination of renewable energy production with storage, in the same site or virtually. * There are ongoing studies by Enemalta regarding the deployment of cost-effective electricity storage units to support integration of small scale renewables in system. The final 2019 NECP version refers to electricity storage: * key policies and measures regarding Energy Security in the context of the long-term objective of decarbonisation of the energy system and increased deployment of RES, will address Energy storage solutions and demand management * The importance of utility battery storage systems for security of supply reasons was also raised during the public consultation process * Ensuring system stability will either require significant spinning capacity, utility scale battery storage or flexible balancing services over the electricity interconnector with Sicily. However, the latter is limited to 200MW (the capacity of the interconnector) and would in practice be lower if already meeting part of the load * Currently, Malta has no utility scale battery storage facilities, and keeping large spinning capacity is highly inefficient and may not be technically viable at all times * Increasing the flexibility of the national energy system, including through the roll-out of cost-effective, innovative solutions such as storage * The Government will continue to assess innovative, viable and cost-effective solutions tailored to the specificities of Malta's energy system, such as the deployment of energy storage solutions, which would incorporate aspects related to increased RES generation * RES electricity in Malta is almost exclusively generated from photovoltaic systems with no storage capability and significant intermittency caused by highly variable and localized cloud cover. * Support for additional PV capacity shall also be aligned with the exigencies of a stable grid and shall consider options which facilitate the integration of battery storage. This promises to provide several benefits, including mitigation of overvoltage on the LV network, peak shaving, increased self-consumption and demand management. However, this depends significantly on the availability of storage solutions at an appropriate price point, such that any Government intervention can yield the desired results. * Battery storage. As of 2020, a pilot scheme supporting the integration of battery storage with PV systems will be launched. Early adopters of solar PVs whose feed-in-tariff has expired will be eligible to receive a 25% grant (capped at €1,000) against the purchase of a battery system for the storage of renewable energy and therefore increase the share of self-consumption. A preliminary study was conducted in 2019 to assess the feasibility of such a measure; the pilot project will feed into this continuing assessment. It is likely that a large-scale roll-out of battery storage systems for households, PV-integrated or stand-alone, would require a significantly higher level of support or lower cost of storage than at present. In this regards Malta shall be seeking EU funds (including Cohesion funds) to bridge the gap * The Government is closely monitoring the development of the energy storage market considered essential for further deployment of photovoltaic capacity and for optimization of the power system by providing for demand management and peak demand shaving * It's important to note that the range of storage solutions which could be successfully implemented in Malta is also limited. For instance, the predominant large-scale energy storage solutions, such as pumped-storage hydropower are not available in the Maltese context * Enemalta is required to apply economic dispatch which would also include aggregation, demand response and storage subject to technical requirements * Utility scale battery storage is being studied not only for security of supply reasons, but also with respect to grid stability considerations, which is currently one of the barriers limiting Malta's renewable energy potential post-2020. Investments in storage infrastructure will facilitate further deployment of renewable energy * Enemalta will monitor the development of the energy storage market.
2. Permitting	* There are no specific permitting requirements for storage nor clarity on whether it would be considered as generation. This was one of the reasons for a project not to connect to the grid while testing.
3. Energy Markets and	* There is no liquid wholesale market in Malta.

Capacity Mechanisms	
4. Ancillary Services	* Balancing in Malta is conducted by Enemalta in coordination with the Italian TSO. Independent power producers connected to the distribution system do not have balancing responsibilities.
5. Grid Aspects	* Since 2010 there is no net metering scheme in Malta, as it was substituted by a feed-in tariff. * There are no specific provisions for storage tariff discounts in Malta, and thus double charging of network tariffs applies.
6. Taxes & Levies	* No specific mention of electricity storage identified in the legislation, and thus charging is treated as consumption for the electricity consumption tax and levy purposes.
7. Involvement of TSO/DSO	* There is no TSO in Malta. * Malta is exempt from the TSO and DSO unbundling requirements of the 2009 and the 2019 Electricity Directives. However, the new storage unbundling requirement for DSOs of the new Electricity Directive applies to Malta.
8. Other & General	* Energy storage is not defined in the national regulatory framework.
9. Barriers	* There is currently no regulatory framework for electricity storage in Malta, which overall represents an important barrier and requires a case-by-case approach, resulting in significant uncertainty. The absence of a liquid wholesale market in Malta generally forecloses the participation of storage in energy markets. * Grid-connected energy storage in Malta is still incipient, with further experience necessary.
10. Best practices	* R&I policies already address energy storage projects/technologies. * The government has proposed a support scheme for domestic battery systems coupled with existing PV arrays.

Netherlands

Topic	Netherlands - Policy description
1. Public Support	* The National Climate Agreement contains agreements with various sectors (electricity, industry, built environment, traffic and transport, and agriculture) on contributions to the climate goals. A chapter in the Agreement is exclusively dedicated to systems integration and cross-sector elements of the energy system. * Electricity storage is eligible for the Energy and Climate Innovation Demonstration (DEI+) subsidy, which has a total budget of 33.6 M EUR for the electricity system flexibility window in 2019, and 29 M EUR in 2020. Only storage pilot projects (and not demonstration) limited to 15 million € of support are eligible, due to restrictions to the energy system flexibility project category arising from the EU State Aid Guidelines. * As part of the National Climate Agreement, the policy framework for energy innovations is changing towards mission-oriented innovation programmes. The integral knowledge and innovation agenda (IKIA) of 2019 specifies five missions that contribute to decarbonisation of the economy. The knowledge and innovation needs for attaining these targets have been formulated in 13 innovation programmes. Integration in the energy system and energy storage as a way to facilitate this is referred to in multiple programmes. These eventually serve as the basis for energy innovation policy instruments in the Netherlands. * The Dutch government supports lead industries through the Top Sectors mechanism, including Topsector Energy and Topsector High Tech Systems and Materials. In 2019 the government has defined, together with stakeholders, 25 missions for the top sectors, including for electricity storage. Top Sector Energy missions explicitly mention storage as a key facilitator for addressing cross-cutting system integration challenges. * Storage is eligible for the renewable energy regulation subsidy scheme (HER-regeling) which provides subsidies for projects in TRL 6-8. To be eligible, projects need to lower the costs of producing renewable electricity and/or combine production and storage in smart grids. These projects need to lead to additional renewable energy production which would not be possible without the innovation that is developed in the project. * The public R&I budget for energy storage in 2018 was 5.59M€. * Around 70 subsidised projects were active in early 2020 in the Netherlands on flexibility, and electricity, heat and gases storage R&I. These projects covered among others energy management for houses, buildings and the agriculture/horticulture sector. * The National Climate Agreement resulted in a process were local government (e.g. municipalities and provinces) need to create a Regional Energy Strategy (RES). In this strategy also attention needs to be given to energy infrastructure (and thus storage) aspects. Therefore, also DSOs are actively involved in these Strategies to study the grid impact of renewables and possible mitigation measures for congestion and developing flexibility resources. * The Dutch government has commissioned specific studies on energy storage (subsurface and above-ground), including evaluations of the potential for development, the emerging for need for storage from system perspective, and strategies for energy system integration. The final 2019 NECP version provides insights about the order of mangnitude of needed controllable capacity, an estimated 15-17 GW in 2030 and 17-27TWh a year. It furthermore refers to electricity storage as follows: * Typical issues that may arise at regional or local level include, for example, the spatial integration of renewable energy options, as well as the storage and infrastructure of heat and electricity * The Netherlands already has a lot of flexibility to deal with the loss of supply or demand in line with market conditions. The Netherlands does not have separate targets for increasing the flexibility in the system. Flexibility in the form of demand response, storage or controllability is interconnected in the electricity market and is traded through the different markets without the precise identifiable element of flexibility * The growth of the number of smart meters will also enable consumers, if they so wish, to react to real time prices, with or without aggregators. In addition, any barriers to storage will be removed. The transition to electric driving can contribute to this. * New opportunities such as the deployment of flexibility, energy storage, demand and orientation and congestion management will also look at how to maximise the available space on the grid with the lowest social costs * Flexibility is further unlocked by [further] introducing dynamic tariffs in the retail market. There is a great deal of flexibility in the system, such as large scale users, which are flexible and responsive to real time prices by switching up, up- or down, and parties with storage assets dealing with different markets. Where necessary, barriers to storage will be removed * In general, the Dutch authorities pursue electricity market frameworks that promote fair competition between market players and therefore do not discriminate against any

	party. These include those providing renewable energy, demand response and storage, including aggregation. No separate national targets have been set for this purpose * Energy tax and energy bill: There are a number of changes in energy taxation and in the Sustainable Energy Storage (ODE) with an impact on energy bills. The gas tax is increased. Additional funds raised in this way will be refunded by a higher tax reduction and a lower taxation of electricity * The Netherlands has great potential for producing renewable electricity. An important part of energy security for the Netherlands is the potential for large-scale and long-term storage of renewable electricity. The development of power to gas is crucial to continue to supply a large part of its own energy needs and the storage of renewable electricity in the form of a gas entails flexibility for the electricity tourism system and a renewable energy carrier for the sustainability of transport and mobility, the industry and the built environment the Netherlands do not do so * Dynamic tariffs are also more and more entering the retail market. There is a great deal of flexibility in the system, such as large scale users, which are flexible and responsive to real time prices by ramping ups, up- or downstream storage, and parties with storage assets dealing with the different markets. In the area of Energy (TSE), systems integration and flexibility are becoming increasingly common and financial support for research (innovation).In addition, the TSO also runs several pilots with pooled/aggregated storage of small-scale storage devices such as home and electric cars
2. Permitting	* No specific permitting rules are defined, and storage characteristics are not suited for the current permitting regulations. This gives municipalities autonomy to determine their own requirements, which increases the permitting complexity. * For aquifer thermal energy storage (ATES) specifically, multiple legislation addresses the use of underground resources, environmental protection, permitting and monitoring, as well as accompanying manuals and other tools. * Businesses indicate the lack of standards (regarding storage safety such as prevention of fire and heat dissipation) is a reason to be reluctant to invest on a large scale in lines for products and services based on storage, and that it will be necessary especially for underground energy storage to obtain social acceptance.
3. Energy Markets and Capacity Mechanisms	* The National Energy and Climate Plan indicates obstacles to storage participation in the electricity market (including storage used by small consumers) will be removed * The National Energy and Climate Plan indicates dynamic retail rates will be further expanded, beyond current practices. Several electricity suppliers already provide dynamic (hourly) retail prices. * In 2018 the EPEX energy exchange introduced loop block orders, where two block orders are executed or rejected together, representing for example the storage cycle. * There is limited availability to data of the (local) energy networks to improve the provision of localized services. * There are little locational and temporal incentives for energy storage by distributed energy producers or for end-users. * There is no Dutch capacity mechanism. * There are over 2500 aquifer thermal energy storage systems in the Netherlands, with a total capacity above 1 GW and reducing both total and peak energy demand. Strong growth is forecasted to 2020. In August 2018 the total battery capacity of EVs was 2532 MW.
4. Ancillary Services	* In 2018 batteries could provide FCR/FRRa services, while load could provide FCR/FRR services. There is no pumped hydro in the Netherlands. * The Dutch system service procurement is market-oriented and accessible. Storage balance service providers in the FCR market are considered generation, but there is a differentiation made between energy-limited sources (e.g. batteries) and unconstrained sources (large gas or coal-fired production units). It is also possible to pool various storage assets under a single balancing service provider (BSP), facilitating the satisfy the FCR market requirements. * The draft National Energy and Climate Plan indicates several pilot projects offering on flexible markets resources from bundled/aggregate storage, and small-scale storage equipment (including home batteries and electric cars) * TenneT will conduct an upcoming aFRR pilot project focused on aggregators and decentralized energy assets.
5. Grid Aspects	* Access tariffs in the Netherlands are mostly capacity-based, thus avoiding double charging of access tariffs for storage. * Storage systems providing ancillary services do not benefit from grid tariff exemptions. * There are no temporal signals for network tariffs. Experiments and discussions are ongoing for more dynamic network tariffs. * The net metering will be phased out, starting in 2023. It is expected that with this phase out it will make it increasingly attractive to develop storage. * TenneT identifies the need to further develop the market model and processes for congestion management in cooperation between TSO and DSOs. The GOPACS platform is launched were grid operators, both TSO and DSOs, can prevent congestion by redispatching generation/consumption to areas outside the possible congested area.

	* Currently, it is not possible to share the connection costs between multiple companies (e.g. a wind farm and a storage facility). However, a policy change / legal possibility (AMvB) is being developed to create exemptions to connect solar PV and windturbines from various nearby projects to the network via one shared connection (cable pooling).
6. Taxes & Levies	* There is a tax ruling to avoid electricity consumption taxation for storage supplying energy directly to end consumers, but it does not cover the case of intermediary suppliers who supply energy which was previously stored. Storage systems providing ancillary services do not benefit from this taxation exemption. * The government has announced plans to end this double taxation of storage in 2021. A follow up from the National Climate Agreement is an analysis by the involved stakeholders about double taxation for storage, in certain cases. As a result it has been decided to incorporate this issue in the already outlined evaluation of the national energy taxation policy. The energy taxation policy will be extensively evaluated in 2020 by the Dutch Ministry of Finance. It's aimed to have changes in the energy taxation, when needed, for the specific situation of battery storage, take effect from 2021 on. * A tax advantage can be obtained by companies that invest in storage systems. The Energy Investment Allowance (EIA) fiscal scheme provides fiscal advantages by allowing deduction of up to 45% of the investment costs from the taxable profit.
7. Involvement of TSO/DSO	* DSOs are forbidden from exercising market activities, and may only purchase storage services.
8. Other & General	* Energy storage is not defined in the national regulatory framework. * TenneT and Vandebron are working on blockchain-based projects to sources flexibility services from EVs to the TSO.
9. Barriers	* There is no common definition of energy storage in the regulatory framework * The lack of guidelines on permitting of storage leaves the responsibility for municipalities to determine the requirements. This can lead to incoherent requirements in the Netherlands. A stakeholder indicates guidelines are necessary to orient municipalities in the permitting of storage. * There is a lack of data on (local) energy system hinders the development of storage business models for local and ancillary service markets. The mass roll-out of smart meters currently underway should mitigate this. * End-users and (small) producers have little information on how to access energy and ancillary service markets. * The lack of temporal signals in network tariffs reduces the incentives for load management by users. * The lack of tax exemptions for storage performing ancillary services or selling energy to a supplier creates undue taxation. * Taxation of gas and electricity are not conducted on the basis of the energy content, impacting the level playing field provided for both and for conversion.
10. Best practices	* There is advanced participation of storage and aggregators in balancing markets, recognized by studies. * TenneT is developing aFRR pilot projects focused on aggregators and decentralized energy assets. * Capacity-based access tariffs eliminate the possibility of double charging of access fees to storage. * Local governments (e.g. municipalities and provinces) need to create a Regional Energy Strategy (RES) as defined in the National Climate Agreement, with attention also to energy infrastructure (and thus storage) aspects. * A policy instrument facilitates experiments allowing a specified exemption under the Electricity Act, for example for experimentation with energy storage. Within 4 years the government evaluates the outcome and lessons learned, to see whether a legislative change is warranted. * During the last years a number of (de facto, international) standards have been developed with the input form Dutch parties, such as USEF (Universal Smart Energy Framework, USEF foundation) for flexibility on the market place, the OCPP protocol for flexibility from electric vehicles (Open Charge Alliance) and the protocol EFI to connect flexibility devices virtually to a market place (Foundation Flexiblepower Alliance Network, FAN). Other projects worked on a basis for a standard for smart distribution stations and the employment of direct current (DC).

Poland

Topic	Poland - Policy description
1. Public Support	* Storage is eligible for grants of the National Fund for Environmental Protection and Water Management ('NFOŚiGW') , which however covers only the R&I phase, and not market deployment. Depending on the project scale, grants could require State aid approval. * The public R&I budget for energy storage in 2018 was 2.05 M€ Thefinal 2019 NECP version refers to electricity storage: * it is important to develop technologies for energy storage, the roll-out of smart grids, the development of electromobility, the introduction of energy-efficient and highly efficient technologies * Technological progress will have a significant impact on the scale of RES use, both in terms of the current generation of energy and in radically new technologies, but also in energy storage technologies * The small elasticity of the Polish energy market (on the supply side and the supply side) is mainly due to the fact that there are practically no regulatory sources (except for pumped storage) which would be in a state * Investments in gas generation and transmission infrastructure are a key element in ensuring the flexibility of the system in view of the increasing role of RES.The participation of active audiences and aggregators, also through the deployment of smart grids, will be able to respond to situations of scarcity. In the long term, the development of demand side management (DSR), energy storage, as well as energy clusters, which should have the potential to be self-balanced can also be taken into account in the long term * The existing potential for the offshore wind sector (offshore sector) in the Baltic, in view of the need to ensure adequate storage capacity and the transmission of such energy generated after 2025, offers opportunities for the development and use of this technology beyond * In the context of R & D & I, it will be important to support the area of innovation in infrastructure (including technologies) for generation, storage and use of hydrogen, … * The development of storage technologies is a prerequisite for the development of RES and for the development of storage technologies * The capacity market is technologically neutral, thereby creating a level playing field for all electricity, electricity storage and DSR (Demand Side Response) technologies of, taking into account the degree to which individual technologies contribute to security of supply and provided that the requirements of the Power *Market Act of 8 December 2017* are met * Particular attention should be paid to the capacity market that allows DSR auctions and energy storage facilities. In the auctions held in 2018 and 2019, strong contracts were awarded to close to 3 200 MW of DSR units and to energy storage facilities * Measures will be taken to increase the flexibility of the energy system in relation to the generation of energy from renewable sources, e.g. smart grids, aggregation, DSR, storage, distributed generation, mechanisms control, re-dispatching and curtailment as well as real-time price signals, including the introduction of intraday coupling * Energy storage facilities, including cells and batteries for electric vehicles: the development of electromobility is in line with the EU's strategic direction * Another way is production based on hydrogen (P2L), which can be CO2 neutral and can contribute to a significant reduction in greenhouse gas emissions while maintaining the liquid form. The maintenance of a liquid form is greatly facilitated by the transport and storage of energy * In 2018 the Operational Programme on Infrastructure and the Environment 2014–2020 supported Tauron Dystrybucja for a demonstration project for a stationary energy storage system as a smart grid element.
2. Permitting	* No specific measures or requirements for permitting of storage facilities identified in national legislation.
3. Energy Markets and Capacity Mechanisms	* The capacity market design in the Capacity Market Act of 2017 prioritizes low-emission technologies, including storage, with the minimum required provision period being shortened to 4 hours.
4. Ancillary Services	* Storage is not allowed to participate in any balancing market according to the ENTSO-E ancillary services survey. Load may provide RR energy. * Aggregation may not provide balancing services in Poland. * Electric vehicles may not feed-in electricity to the network in Poland.
5. Grid Aspects	* There is a net metering scheme in Poland since 2016. * There is uncertainty regarding whether double charging of storage applies in Poland, which is thus assumed to apply.

6. Taxes & Levies	* There is no exemption to other surcharges such as for RES or cogeneration support. * There is no exemption for the electricity consumption tax in Poland.
7. Involvement of TSO/DSO	* Regulation does not address ownership and/or operation of storage by network operators. * Due to uncertainty existing projects are mostly for R&I and have the participation of network operators.
8. Other & General	* The 2015 Act on Renewable Energy Sources (the RES Act) defines an energy storage facility (Art. 2 point 17) as a dedicated facility or group of facilities where electric energy generated as a result of technological or chemical processes is stored in a different form. The RES Act also specifies that an electricity storage facility should be considered a part of a renewable energy source installation. This restricts storage to supporting intermittent RES. * The consolidated Energy Law of 1997 now defines energy storage: installation for storing energy, connected to networks having the ability to supply electricity to the network. * Definitions and references to 'energy storage' or 'electricity storage' differ from each other in the RES Act, Act on the Power Market, and Act on Electromobility. * In 2018, the Minister of Energy published a draft amendment of the Energy Law pertaining to the development of energy storage and smart metering. In this document, the Minister sets forth the framework for storage activities, define basic terms in this respect, provide clear rules for connecting the stores to the grid. The draft amendment in the beginning of 2019 was still in the process of public consultations, thus, the final form and rules are still to be determined (from TLR, 2019).
9. Barriers	* There is uncertainty and conflicts on the legal definitions of energy and electricity storage. * Storage may not provide ancillary services, aggregated or not. * Storage is subject to double charging of network tariffs as well as payment of the electricity consumption tax and other surcharges. * Lack of clarity regarding network operator ownership and operation of storage impacts non-regulated storage projects.
10. Best practices	* The capacity market design in the Capacity Market Act of 2017 prioritizes low-emission technologies, including storage, with the minimum required provision period being shortened to 4 hours.

Portugal

Topic	Portugal - Policy description
1. Public Support	* The government is considering conducting an auction for storage in 2020 with a total capacity of 50-100 MW. * The public R&I budget for electrical storage in 2015 was 0.02 M. The final 2019 NECP version refers to electricity storage. It forecasts an increase in storage capacity, first through pumped hydro and, closer to 2030, with a more relevant contribution of hydrogen and batteries. A large part of this capacity should be related with solar and wind renewable generation, and the remaining with stand-alone storage. The NECP also considers that, to increase the role of demand response in the electricity sector and incentives to behind-the-meter storage in buildings and industry will be very relevant, along with the increase of smart charging in EVs. * Smart grids, management support systems, producer and/or consumer aggregators, smart meters, storage systems, local energy generation, active consumers, flexibility of offer/demand, electric vehicle, among others, are the variables to be taken into account in constructing the grid model of the future * The development of new technologies and the improvement of existing low carbon technologies requires a significant effort in research and innovation that will be achieved through the adoption of an ambitious and comprehensive agenda covering all stages of the technological development until their commercialisation. This will greatly contribute to national support frameworks that will be oriented towards research and technological development in line with the country's priorities, such as hydrogen, storage, smart grids, advanced biofuels, deep geothermal, concentration thermal, energy from the oceans, energy integration, energy conversion and storage, low carbon processes, circular economy, precision farming, among others * For the electricity sector, a strong impulse is given to the electrification of the consumption associated with the decarbonisation of production by enhancing the exploitation of the renewable energy potential with a particular focus on onshore/offshore wind and solar technologies, in parallel with the promotion of distributed generation, promotion of storage, strengthening and optimisation of the transmission and distribution networks and by promoting pilot projects * Pilot projects based on Concentrated Solar Thermal Technologies will be promoted as a technology enabling energy storage * 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 * A significant part of the new storage capacity should be directly linked to the renewable electricity generating centres * By 2030, storage capacity is expected to increase, mainly via reversible pumping hydro, and at a later stage of the decade a contribution of batteries and hydrogen technologies. A significant part of this capacity should be linked to the production sites themselves via wind and solar technologies, with the remaining dedicated storage * In the electricity sector, industrial installations and storage incentives behind-the-meter in the building and industry sectors, so as to make changes in the daily load profile in the public service electricity grid less marked, as well as the generalisation of "smart" charging strategies on electric vehicles * new hydroelectric plants with storage and reversibility (pumping operation) that are expected to be placed in service until 2026 (reversibility, Daivões and Alto Tâmega) ensure an important contribution to increasing the flexibility of the system * Hydrogen has a huge potential as an energy carrier, which could serve as energy storage or fuel for the various sectors of the economy * Ensuring security of supply should be ensured by adopting appropriate measures addressing an imbalance between supply and demand, including those related to the overall technical management of the system, which encourage the diversification of supply sources and which contribute to the planning, construction and maintenance of the necessary infrastructure. The increase in interconnection capacity, storage systems (key in an essentially renewable energy system), the adoption of new network planning mechanisms, the dissemination of smart grids, etc * To promote storage systems, the following action measures are envisaged : 1/ Create the legal framework for the implementation of storage systems ; 2/ Promote a roadmap for storage in Portugal ; 3/ Promote the implementation of storage projects associated with renewable electricity generation centres ; 4/ Promote storage on islands. * The demand aggregator will aim to bring together different actors/entities, such as final consumers, small producers, storage, recharging points for electric vehicles, or any combination of them, and act as a single entity and participate in the electricity market and provide system services.

	* The development of activities associated with renewable energy, storage, hydrogen, advanced biofuels and other 100 % renewable fuels will require the provision of specialised training needs covering various levels of training * The Innovation Fund is one of the largest funding programmes for low-carbon innovative technology demonstration projects and focuses on, among others, energy storage. * *InnovFin Energy Demo Projects :* This financing arrangement consists of loans, loan guarantees or financing of property type, normally between EUR 7,5 and EUR 75 million for innovative energy system transformation projects, including but not limited to: renewable energy technologies, smart energy systems, energy storage, carbon capture and storage or carbon capture and use. This financing mechanism is complemented by the European Investment Bank * The challenge of the adequacy of network infrastructure enabling an effective energy transition arises in particular to the Low Voltage Network (LV) that will no longer be a passive network to integrate a whole set of new concepts, from network intelligence, management support systems, smart meters, storage, energy management, local production, energy communities, electric vehicles, among others, are variable to be taken into account in the construction of the future network
2. Permitting	* Legislation indicates the generation and storage license shall include the conditions for storage (not impacting storage for self-production). * Autonomous storage units require a license, but rules are yet to be set in complementary legislation (Decree-Law 76/2019). Until this occurs, there are no further specific permitting requirements for standalone storage.
3. Energy Markets and Capacity Mechanisms	* A new system operations manual is in development but is not public, to gauge the participation of storage in energy markets.
4. Ancillary Services	* Except for pumped hydro, storage may not participate in ancillary service markets, aggregated or not. The TSO proposal on terms and conditions for balancing service providers and balancing responsible parties states that it should be possible that loads, energy storage and generation be aggregated. * The regulator (ERSE) promoted in 2019 a pilot project for demand with an available capacity of 1MW to participate in the RR market. There are no explicit restrictions on a demand unit that can optimize its flexibility management of energy use through storage, but there were barriers on the possibility of aggregation, according to a stakeholder. * The revision of the RES self-production and energy communities framework in the Decree-Law 162/2019 requires storage units to have a meter it those are directly conected to the public grid as an electric facility apart from the consumption and generation units. EVs are considered storage only if they have bidireccional chargers. * Only conventional generators provide (mandatory and non-remunerated) voltage control in Portugal. * Black-start is not mandatory. A CCGT and a hydro plant provide the service in Portugal.
5. Grid Aspects	* Decree-Law n.º 68-A/2015 indicates without practical impact: Network tariffs and regulation should not impede ancillary services for decentralized generation in electricity organized markets, including storage * Self-consumers and small producers (including with storage) must pay the connection costs to the grid. In what concerns self-consumed energy, they only pay for grid charges concerning the connection voltage level (and not for the costs of higher voltage networks). When there is reverse flows to higher voltage levels, the exemption is partial following a methodology set by the national regulator. * There are no indications of discounts on network tariffs for storage.
6. Taxes & Levies	* There is no exemption for storage from the electricity consumption tax set by the Law-Decree n.º 73/2010. * No other indications of tax & levy exemptions for storage in Portugal.
7. Involvement of TSO/DSO	* The Portuguese TSO REN is fully unbundled from other activities including storage.
8. Other & General	* Energy storage is not defined in the primary national regulatory framework, only in the renewables self-consumption and energy communities framework. * The regulatory framework for the electric mobility is defined in Decree-Law no. 39/2010, as amended by Decree-Law no. 90/2014.
9. Barriers	* The requirements for permitting autonomous storage units are not yet defined, and there is no expected date on legislation. * For pumped hydro and batteries demonstrating the licensing compliance is a complex process. * The prohibition for renewable energy generators with storage from withdrawing energy impedes the use of the storage assets for multiple applications.

	* The new systems operation manual in development is confidential, impeding the evaluation of the proposed measures concerning energy storage. The uncertain evolution of the new BRP/BSP terms and conditions increases the lack of clarity. * Storage charging is subject to the electricity tax. * There is no definition of energy storage in the primary legislation. * There are no clear rules to allow for DSO procurement for flexibility services in the market (and under which rules), which may include storage.
10. Best practices	* Regulation on permitting requirements for autonomous storage forecasted in legislation. * Permitting of batteries in generation facilities are considered retrofitting and went well in the past.

Romania

Topic	Romania - Policy description
1. Public Support	* The government ordinance no. 28/2014 defines specific measures for fostering pumped hydro plants with an installed capacity exceeding 15 MW. The ordinance encourages investments in new plants, which are considered public utility works. * The Romanian energy strategy 2007 –2020 aims to develop the 1000 MW Tarniţa-Lăpuşteşti pumped hydro plant. However, the new Romanian Energy Strategy 2016-2030 indicates that investments in a large pumped hydro plant before 2030 are unlikely, but a pre-feasibility study for small plants could be useful. * The Romanian Energy Strategy 2016-2030 has multiple 'avenues for development related to storage': turning Romania in a manufacturing centred (including household-size batteries), promotion of electric and hybrid vehicles, and develop smart grids and buildings. The draft NECP 2018 refers to electricity storage * The government plans to integrate over 400 MW of battery storage capacity to flatten the load curve and provide balancing reserves. * The development of small storage capacities to foster the integration of RES is one of the main policies of the operational objective 'Ensure energy storage and backup systems capacities'. This comprises the development of pumped hydro, including the construction of the Tarnita-Lapustesti station. * Hybrid technologies for the storage of energy is a main research direction of the National Hydrogen and Fuel Cell Centre, in the form of the Lithium-Ion program. * The possibilities for storage and aggregated production of multiple consumers/producers should be considered.
2. Permitting	* There are no specific permitting rules for storage in Romania * For small scale, the active consumer permitting rules will be applied. * Permitting duration is long (2-5 years for greenfield storage projects) , but is not seen as a central barrier.
3. Energy Markets and Capacity Mechanisms	* As of 2016 demand response was already allowed in the Romanian electricity wholesale market, but was not active. The legal framework is well-established, but due to a number of key barriers, is has not taken off the ground due to the lack of secondary legislation, the lack of smart meters and the electricity system is supply-driven.
4. Ancillary Services	* There is no framework for the participation of storage in the provision of ancillary services in Romania. Only generators are allowed to participate in any of the balancing markets.
5. Grid Aspects	* Law 121/2014 on energy efficiency lists energy storage services as one of the criteria for assessing energy efficiency for network operators. * There are no specific electricity grid connection and access rules for energy storage facilities, so double charging is applied for storage. Some of the distribution-connected pumped hydroelectric storages facilities are fully exempted from transmission-related injection charges in Romania. * Net metering for renewable energy installations of up to 100 kW was introduced in 2018 through an amendment to Law 220/2008. * A feed-in support scheme for renewables is in place where the price is set to the last year's average from the day-ahead market. The price that the consumer is buying energy from the grid is almost double due to fees (distribution fee, transmission fee, extraction fee).
6. Taxes & Levies	* No specific mention of electricity storage identified in the legislation, assumption is that charging is treated as consumption for the electricity consumption tax and levy purposes.
7. Involvement of TSO/DSO	* Storage plants in Romania can be owned and operated by DSOs or TSOs.
8. Other & General	* There is no specific legal or regulatory framework for storage in Romania. The Romanian Energy Regulatory Authority ("ANRE") indicated it could include energy storage in a future legislative package.
9. Barriers	* There is no regulatory framework for storage in Romania. * The high hydropower installed capacity in Romania (6.4 GW) including pumped hydro (200 MW) may act as a disincentive to further development of energy storage and related policies * In practice demand response is not active in the Romanian electricity and balancing markets.
10. Best practices	* The NECP provides a target to integrate over 400 MW of battery storage capacity * EDPR has inaugurated in 2018 a 1MW battery system in its Cobadin wind farm * Research laboratories specialising in the development of energy storage technologies are forecasted.

Slovakia

Topic	Slovakia - Policy description
1. Public Support	* Currently, there are only few projects in the area of storage. Slovakia is using mostly hydro pump storage or underground gas storage facilities for large scale energy storage. Commercial battery storage is very limited due to high investment costs into the overall system and long payback. * There is no direct support for electricity storage * Indirect support are: the program smart city; incentives to create new EV charging stations; the electromobility development strategy; incentives focused in energy efficiency measures and RES; preparing integration in Horizon 2020, and Important Projects of Common European Interest (IPCEIs) * Slovak company Nafta a.s. announced a domestic R&I project called "Large-scale energy storage". In cooperation with Institute of Earth Sciences of the Slovak Academy of Sciences (SAV), Institute of Inorganic Chemistry, Institute of Geotechnics and Slovak Technical University, the project partners will investigate the interaction of hydrogen with underground structures and its utilization for energy storage The final 2019 NECP version refers to electricity storage * the deployment of intelligent energy systems and electricity storage systems is particularly important. * in line with the overarching European legislation, to create conditions for the provision of support services allowing the **aggregation** of demand facilities, energy storage facilities and power generation facilities for the purpose of offering balancing services * The development of energy storage will ensure the integration of variable RES into the grid * The integration of the local storage of energy in storage appliances, energy storage devices and electric vehicles or in the gas distribution network with their storage capacities is therefore an important element of the smart grid. * the maintenance and support of the existing capacity and operation of pumped storage power plants and, where appropriate, to assess the potential increase in storage capacity by building a new pumped-storage hydroelectric power plant * State R&I programme (SRDP) Energy Security includes storage * Conditions for the provision of support services from among others storage, including balancing services should be created * Indicates support to shortening of the currently used trading intervals on daily, intraday and balancing markets.
2. Permitting	* Energy storage units go through the standard permitting process (environmental, construction, connections, location, others), and there are no specific rules for energy storage. * Large scale energy storage (pumped hydro) has to fulfill standard technical specification of TSO/ DSO for connection. There are currently no specific permitting rules for other types of energy storage (batteries), therefore existing framework should be adapted.
3. Energy Markets and Capacity Mechanisms	* Due to competitiveness the typical utilization of storage is limited to back-up power supply, provision of ancillary services (pumped hydro) or peak shaving. * Small installations are used in households combined with PV generation. In small business for 'peak shaving', to a limited extent. * There are some applications of CHP systems storing heat to provide electricity system products to the markets but mainly services to the TSO. * CZT allows for the provision of support services in electricity systems and the storage of energy in the form of heat.
4. Ancillary Services	* Under the Slovak rules, pumped hydro will be eligible to provide specific products (Tertiary 3 min+/-) and also standard products of mFRR+/- services * Batteries are eligible to provide ancillary service - primary control (FCR).
5. Grid Aspects	* No specific requirements to storage compared to other connection points, technical and commercial conditions needs to be fulfilled as in any other case * There is no specific regulation with regard to storage at the moment. The DSO in Slovakia (VSD) treats storage the same way as generation and consumption * Energy storage is considered as "buyer of electricity", paying for full reserved capacity like any other buyer (determined on the basis of the maximum consumption) and is considered as "generator of electricity", subject to G-charge at the level of 30 % of the reserved capacity (determined on the basis of installed capacity) when connected to DSO. The final payment is the higher from both. Hydro pumped storage does not pay G-charge and reserved capacity (as a supplier of Ancillary services). All electricity generators connected to TSO network pay to the TSO a payment for access calculated based on reserved capacity, special coefficient of capacity involvement and the value of the tariff for reserved capacity.

	* Connection fee to the Distribution System are payed twice, as "buyer of electricity" and as "generator of electricity" (there are some exemptions, for PHS as example).
6. Taxes & Levies	* charging for storage is treated as consumption for the electricity consumption tax and levy purposes (that also constrains the potential of usage of energy storage).
7. Involvement of TSO/DSO	* DSO and TSO are not allowed to offer other services than those related to their core business (distribution and transmission)
8. Other & General	* There is no definition of energy storage in the regulation. An holistic approach for energy storage would support and ease its development
9. Barriers	Main existing barriers: • National legislation (policy) does not contain definition of energy storage or energy storage for elektricity (only for natural gas). • The investments costs of storage are very high and it may not pay back its usage in area of peak shaving or deviation/ imbalance management. • Regulatory: Energy storage (except hydro pumps) is burdened by capacity and injection fee that overcharges its usage.
10. Best practices	* National R&I programme includes storage in the energy security category

Slovenia

Topic	Slovenia - Policy description
1. Public Support	* The Energy Act refers to the facilitation of inclusion of advanced technologies for the provision of ancillary services. * The Eco-fund subsidizes companies and private owners to purchase vehicles battery electric vehicles. * No subsidies are envisaged by the current legal framework, but are mentioned within the Action Plan for Energy Efficiency within the period of 2014 – 2020 as enhancing the efficiency of distribution systems for which subsidies are envisaged in the future until 2020. The draft NECP 2018 refers to electricity storage * Technological development and commercial breakthrough of storage technologies is listed as a key challenge for Slovenia. * Slovenia's Smart Specialisation Strategy (S4) includes a pillar on mobility including related energy storage systems.
2. Permitting	* Depending on the technology (for example pumped storage) storage of electricity might be considered as production, so construction of such projects of more than 1 MW connected to public grid requires a permission issued by the Minister for Infrastructure.
3. Energy Markets and Capacity Mechanisms	* Behind-the-meter storage is already allowed. Besides larger projects, there have been some smaller projects including the vanadium-flow batteries installed at a restaurant in the Slovenian Alps.
4. Ancillary Services	* In 2018 pumped hydro could provide FRRa services, while loads could provide FRRm services. * The Slovenian regulator has launched in July 2019 a public consultation regarding the establishment of a flexibility market in Slovenia, that deals with the role of storage as well. It explores the possible roles of storage in providing flexibility services and seeks input from stakeholders regarding dynamic tariffs and possible flexibility products. It identifies several barriers on market design, measurement, validation, support systems and technical solutions. * There is also a reference in the Energy Act regarding facilitating the inclusion of advanced technologies for the provision of ancillary services.
5. Grid Aspects	* Storage facilities are exempt from the network charges under certain conditions as defined by the 'Act determining the methodology for setting the network charge, the criteria for establishing eligible costs for electricity networks, and the methodology for charging for the network charge' adopted every 3 years by the regulator. * In Slovenia, specific incentives for smart grid investments exist: If the network operator realizes investments in smart grids that meet the requirements set out in the methodology, a one-off incentive is acknowledged amounting to 3% of the current value of the asset in the year in which the asset was put into service. Yet, these incentives were considered to be too low and will be increased in the next regulatory period. Nevertheless, a PCI smart grid project, SINCRO.GRID, is already being carried out in Slovenia and Croatia (from EC, 2019). * The TSO National Development Plan should define the provision of storage facilities among other aspects (from EC, 2019) * To access the network, storage facilities must contract with the TSO (ELES) or the DSO SODO and/or the sub-contracted distribution companies * Slovenia applies net metering for small consumers
6. Taxes & Levies	* No specific mention of electricity storage identified in the legislation, assumption is that charging is treated as consumption for the electricity consumption tax and levy purposes.
7. Involvement of TSO/DSO	* The role of the Slovenian TSO excludes storage systems.
8. Other & General	* There is no definition of storage in the national regulatory framework, although it is addressed in secondary legislation. Especially the network charge methodology is set by the 'Act determining the methodology for setting the network charge, the criteria for establishing eligible costs for electricity networks, and the methodology for charging for the network charge' adopted every 3 years by the regulator.
9. Barriers	* According to some stakeholders, the scope of the TSO's role is a barrier, as it does not involve new technologies, such as storage (from EC, 2019). * Storage has access only to FRR balancing markets * Electricity consumption tax is applied to storage * Given the lack of special status of energy storage and the lack of subsidies, there are pending regulatory burdens and potential disadvantages for investors interested in this particular field
10. Best practices	* Slovenia and Croatia have established the SINCRO.GRID project which plans to install two 5 MW battery systems. In 2014, the transmission system operators (HOPS and ELES) and distribution system operators (HEP ODS and SODO) of Croatia and Slovenia

	began to search for joint solutions and decided for an international cooperation in setting up smart grids. The SINCRO.GRID - Phase 1 smart grid project offers an innovative integration of mature technologies that will be beneficial to the electricity systems of Slovenia and Croatia as well as to the countries in the region. The project includes the deployment of compensation devices, an advanced dynamic thermal rating system, a battery electricity storage system, as well as a virtual cross-border control centre. In 2015 the EC included the project on the PCI list. The contract 'Action n° 10.3-0022-SIHR-W-M-16 Implementation of the SINCRO.GRID PCI – Phase 1 ' on co-financing of the project by the EC was signed in 2017. * The Slovenian electricity TSO has created a department for strategic innovation. The TSO is active regarding smart grids, being the leader of the first smart grid PCI. The TSO has a 'budget under coordination' of 130 million € for innovation, within which the main focus is on R&I, demonstration projects and pilot projects which range from core-business practices to international cross-border cooperation and cross-border market projects. They are conducting a micro grid project for the city of Ljubljana and are involved in a consortium led by the French RTE working on OSMOSE, a project on storage at a cross-border level and including multiuse of storage (from EC, 2019). * Aside from major projects, there have been some smaller projects including the vanadium-flow batteries installed at a restaurant in the Slovenian Alps. * The STORY project in the network of the DSO Elektro Gorenjska foresees the installation of a energy storage system, at two different locations * NGEN has started operating in 2019 the first Tesla PowerPack in Europe, providing balancing solutions to balancing responsible parties in Slovenia.

Spain

Topic	Spain - Policy description
1. Public Support	* In the period 2014-2016 the Spanish National Program on Research, Innovation and Competitiveness has invested over 24M€ in basic research projects in the Societal Challenge 3: Sustainable Energy. Energy storage projects amount 2.6 M€, approximately 11% of the total. * In the last support auction for renewable generation in the Balearic Islands, generation facilities with batteries received extra points versus facilities without batteries. Nevertheless, the awarded projects did not get any additional remuneration. * The Ministry of Science, Innovation and Universities launched in 2019 the Cervera program financing innovation in SMEs and technology centres. Cervera includes battery components and systems as well as hybrid generation and storage technologies among the eligible ones. * The Ministry of Science, Innovation and Universities is developing Innovation Missions with a consultation in mid-2019. The missions,on which the Spanish storage association has contributed to, include 1) safe, efficient and clean energy for the 21st century and 2) sustainable and intelligent mobility for the 21st century, * The public R&I budget for energy storage in 2017 was 0.92 M€ The draft NECP 2018 refers to electricity storage * Specific auctions may be developed in the short-term for renewable generation combined with storage. Government plans seem to focus on concentrated solar power plants with thermal storage. Other technologies providing similar benefits, as wind or photovoltaic power plants with batteries, should also be allowed to participate in these auctions on equal terms. * Plan to add 6 GW of storage (3.5 GW of pumping and 2.5 GW of batteries), with a balanced presence of the different renewable technologies. Additionally, 5 million electric vehicles are expected in Spain by 2030, of which 3.5 million will be cars while the remaining 1.5 million will be motorbikes, trucks and buses.
2. Permitting	* Permitted behind-the-meter storage is explicitly allowed to consume electricity. * A case of permitting of batteries for a wind farm required the farm not to take energy from the grid for storage and to store only the generated electricity. * No other specific measures or requirements for permitting of storage facilities identified in national legislation. * A stakeholder indicates the permitting process is lengthy with different administrations involved.
3. Energy Markets and Capacity Mechanisms	* Spain's regulatory framework does not address energy storage systems, with the exception of pumped hydro, which is considered a conventional generation system, and thermal storage associated with thermal solar power plants. * There is no regulation for the electricity storage participation in the market in the resolution 15049/2019, which updated the rules for the day-ahead and intra-day markets, but mentions only producers, suppliers and consumers. Active customers are permitted when fulfilling the self-production decree requirements. * There is no capacity remuneration mechanism in Spain, central actors are studying the matter. Stakeholders indicate it may be necessary given electrification, the decommissioning of coal, nuclear and potentially CCGT capacity, and the need to provide long-term revenue certainty for the development of e.g. hydropower. * The draft National Energy and Climate Plan indicates regulation should be adapted to develop aggregated generation, response to demand and storage * The wholesale market price cap was set at 180 €/MWh with the Law 54/1997, until the implementation of the clean energy package. * There is no specific regulation adapted to allow vehicle-to-grid applications.
4. Ancillary Services	* in 2018 pumped hydro could provide FRRm services * Currently storage is not allowed to participate in ancillary service markets, either individually or aggregated (except pumped hydro in FRRm). The Spanish NRA is consulting on a regulation for the participation of aggregated resources in balancing markets, running until September 2019. The Spanish Ecological Transition Ministry is also consulting on self-production rules which touch on storage for stabilizing energy consumption. * There is no definition of aggregator and independent aggregator agents in the Spanish regulatory framework. * IDAE and the market operator OMIE are exploring local electricity market models, with possible pilots starting in the future. * The limits between national and local energy markets are not defined, nor their interaction. * Black start and voltage control services are regulated, without remuneration. * DSOs are not allowed to procure ancillary services. * There is no EV to grid experience in Spain.

5. Grid Aspects	* There is double charging of network access tariffs for storage in Spain, except pumped hydro. Pumped hydro pays for the energy injected and the energy lost in the storage cycle, resulting in 0.2€/MWh for charging and 0.5€/MWh for injection. The new CNMC (the national regulator) tariff proposal eliminates access charges for all generators, and thus for pumped hydro. * Net metering is simplified for active consumers with less than 100 kW in law-decree 15/2018. * Self-consumed energy from renewables, co-generation or waste is exempt from network tariffs and other tariffs in law-decree 15/2018. * Grid tariffs are capacity-based and have a time component, but it does not corresponded to actual grid usage. The new CNMC proposal improves the time-of-use periods.
6. Taxes & Levies	* There is no specific mention of electricity storage in the taxation legislation, thus storage discharge is subject to the electricity production tax (Impuesto sobre el valor de la producción de la energía eléctrica, IVPEE). Self-consumption installations under 100 kW are exempt. * There is no clarity on the application of consumption taxes on self-produced and stored energy.
7. Involvement of TSO/DSO	* There are no unbundling requirements for TSOs/DSOs owning storage since regulation does not address the topic (except for pumped hydro in islands). * System operators are the owner of pumping capacity in the Canary islands to secure the supply of energy, to ensure the system's safety or to integrate non-manageable renewable energy sources (act 17/2013).
8. Other & General	* Storage is not defined in the Spanish regulatory framework. However, the 2019 proposal on the Climate Change and Energy Transition law includes the definition of the: - Holder of storage installations, which acquires energy to generate it in a posterior moment according to the regulatory terms. This with no prejudice to producers, consumers or holders of transmission and distribution networks owning these types of installations without losing their condition, according to the regulatory terms; - Demand aggregator, which combines multiple loads of consumers, producers of storage installations for its sale or purchase in the organized or system service markets.
9. Barriers	* Storage is not allowed to participate in energy and ancillary service markets, with some exceptions for pumped hydro and thermal storage associated with thermal solar power plants. * The lack of a definition for (independent) aggregators increases the uncertainty for storage and impedes its participation in energy and ancillary service markets. * The lack of markets for the provision of black start and voltage control services and the impossibility for TSOs to procure ancillary services reduces the revenue streams available for storage. * Full double charging is a problem. Even for pumped hydro the exemption is inadequate and it still pays partial tariffs for the charging cycle, and full tariffs for production. * Net metering hampers the development of behind-the-meter storage. * CNMC has proposed a new methodology for allocation of connection costs which introduces barriers to hybrid projects combining generation and storage. * A stakeholder indicated DSOs should develop a tool to publish congestion information. * Double taxation for storage exists in Spain. * The 2019 proposal on the Climate Change and Energy Transition law indicates the system operator will be able to establish the pumping and generating strategy for new hydropower concessions (including pumped hydro) in order to maximize the integration of renewables. This could impact the business case of pumped hydro. * The electricity cost is disadvantaged vis-a-vis the gas cost as network access tariffs incorporate charges for subsidization of renewables, the recovery of past tariff deficits and subsidies for the electricity supply in islands. * A stakeholder indicates the planning regulation needs to assure system operators adequately weight expansion investments against procuring flexibility from markets. * Prototypes and pilot projects face the same permitting requirements as large-scale projects while having a more limited project duration. Demonstration equipment has trouble to meet conventional permitting requirements due to the lack of standards for a developing technology. Pilot and demonstration projects deserve specific and streamlined permitting processes which would accelerate and reduce the costs of the development cycle.
10. Best practices	* Indicative development of storage to 2030 in the NECP, separated between pumped hydro and batteries. * In the last support auction for renewable generation in the Balearic Islands, generation facilities with batteries received extra points versus facilities without batteries.

	* Potential inclusion of renewables combined with storage in the next support auctions, intended for thermal solar but open to all technologies due to technology-neutral approach. * 2019 proposal on the Climate Change and Energy Transition law includes the definition of holders of storage installations. * Various initiatives in Spain supporting the deployment of energy storage pilots have been gathered through the Smart Grids Technological Platform FUTURED and the Cross-platform Storage Workgroup, GIA, now part of Spanish Technological Platform for Energy Storage, BatteryPlat. BatteryPlat aims to continue this task and be the national hub for energy storage pilot and demo projects involving any energy storage technology, not only batteries.

Sweden

Topic	Sweden - Policy description
1. Public Support	* In order to help increase the ability of individual customers to store their self-generated electricity, a contribution to the storage of self-generated electricity has been in place since November 2016. It allows individuals to receive financial support for the installation of storage systems[160].The grant is limited in time until 2020, if SEK 60 million per year. Grants may not exceed 60 % of the cost of the storage system, with a maximum of SEK 50 000 * Hydro storage plants provide storage capacities by storing water in reservoirs (total capacity +/-120TWh in SE and Norway). These plants cover, up to now, the Nordic grid balancing need over all time scales. The need for batteries, pumped storage hydro or other storage technologies to balance the grid is therefore very limited for the time being (but increased interst could come in a near future). Today Hydro generates 40-45 % of the nation's electrical demand, and takes care of the dominating part of the variation of demand in all time scales (year, week, day, minutes). The final 2019 NECP version refers to electricity storage * In the Government Budget Bill for 2020 (prop.2019/20: 1(21) The Government notes that a future electricity system with a higher proportion of variable wind and solar production increases the need for flexibility in programmable generation, demand response in user sectors, energy storage and system services to support and stabilise the electricity system * In the direction of the Energy Policy Bill[161], the Government considers that the network owner's role may need to be given a broader content to fully exploit the benefits of smart grids, energy storage and demand response to the electricity system * Existing subsidy provides financial support to individuals for the installation of storage systems. Förordning (2016:899) om bidrag till lagring av egenproducerad elenergi.
2. Permitting	* in Sweden, permits for water utilisation (incl hydro storage plants) are granted without a time limit under the condition that hydropower operators respect the environmental conditions stated in the original permit (compliance with the environmental quality standards and the rules on special protection areas) * Environmental obligations in original permit are more and more constraining for new hydropower installations. * In Sweden, national legislation requires that hydropower generation facilities have concessions in order to operate. Most water concessions were granted in the mid-1900s and have no time limit. National legislation does not appear to provide for competitive procedure (for new concessions and concession renewals)
3. Energy Markets and Capacity Mechanisms	* Owners of energy storage facilities are allowed to offer flexibility in energy and balancing markets. However, DSOs (and the TSO) are restricted to use storage only for grid operational purposes and not commericial trading. * The CoordiNET (2019) creates a platform for TSOs and DSOs where they can collaborate and utilize common resources to create a safe and efficient electricity system, by providnig solutions to : balancing, overload management, controlled drift and voltage regulation. Through a dedicated platform, CoordiNET aims to increase the share of renewable energy in the electricity grid and also open up more possibilities of income for users. CoordiNET prepares the system for the network code implementation, allowing storage and demand side management. CoordiNET could be scaled up at EU level (SE-NO ambition). * Heat and electricity systems are integrated in several ways, e.g. in co-generation of electricity and heat, or when DH is produced with electric boilers or heat pumps. Heat can also be stored more easily than electricity, and thermal storages are used to improve the system balancing of variable power generation. By utilising co-generation, heat pumps and thermal storages, a DH supplier can respond to price signals on the electricity market. In times of high electricity prices, DH production can be adjusted to maximise the power generation and thermal storage used to cover heat demand, and in times of excess power, DH suppliers can utilise more heat pumps.There is a number of heat storage projects ongoing based on storage on the DH systems.
4. Ancillary Services	* The Swedish TSO, Svenska Kraftnät, states that the requirements on ancillary services will generally increase and will much more clearly reflect and be adapted to the system's needs. In 2019, Svenska Kraftnät started to establish a market for FFR (Fast Frequency Reserve), where electricity storage could be an important part.
5. Grid Aspects	* An owner of a grid connected electricity storage is obliged to pay a grid tariffs and tax for electricity supplies to the storage from the grid. Storage owners are also formally obliged to pay a feed-in-tariff for electricity feed into the grid from the storage, however storage units with a capacity less than 1500 kW are excepted.

[160] Ordinance (2016: 899) on subsidies for the storage of self-generated electricity.
[161] prop.2017/18: 228 The direction of energy policy.

	* The storage owner is entitled to a compensation from the DSO for the grid value of supplies electricity from the storage. * During 2019, there was a huge media attention in Sweden regarding lack of grid and electricity production capacity in major cities such as Stockholm and Malmö. Due to this situation, the Swedish Energy regulator, Energimarknadsinspektionen was given a task to investigate means to address the capacity limitations. Flexibility and storage and markets solutions connected to those is one aspect to be investigated. The investigation will be presented in late 2020.
6. Taxes & Levies	* There is tax deduction for the excess electricity injected into electricity network from renewable energy (residential solar PV, wind etc.), equal to SEK 0.60/kWh * Recovery of energy tax on electricity after storage of batteries : as of 1 January 2019, Chapter 11, Section 13 of the Energy Tax Act (1994: 1776) provides for the possibility to apply for a refund of energy tax on electricity consumed from a network subject to a concession, stored and then fed back to the same electricity network subject to a concession. This is to avoid unintended double taxation
7. Involvement of TSO/DSO	Swedish electricity grid companies may use energy storage for operational purposes, but not for commercial services. The TSO Svenska Kraftnät is currently developing the market for flexibility services such as Frequency Restoration Reserves (FRR) and Replacement Reserves (RR).
8. Other & General	
9. Barriers	The Swedish Energy regulator conducts an annual investigation on the swedish flexibility market. The 2019 investigtion showed that there are not technical or legal barriers for flexibility measures, such as electricity storage. A general problem though is the lack of access to metering data of sufficient resolution for creating more real-time markets for flexibility and the time for the market actors to access such data. The main obstacle for electriciy storage in Sweden is the lack of economic incentives due to the lack of price volatility on the Nordic electricity market.
10. Best practices	

United Kingdom

Topic	United Kingdom - Policy description
1. Public Support	* The National Grid 2017 annual report forecasts on the future design of energy markets and indicates an increasing need for flexibility to which storage could contribute to, from 4 GW in 2016 to 6 GW in 2020 and 6-9 GW in 2030, plus up to 30 GW to accommodate renewables by 2050. * To integrate and incentivise energy storage, BEIS, Ofgem and National Grid are launching a series of framework reforms, including: * Changes to the electricity generation licence to add the definition of 'electricity storage' and 'electricity storage facility' in SLC1 (Definitions) in order to provide regulatory clarity on the treatment of electricity storage within the regulatory framework (consultation closed, awaiting decision). The modified licence will provide regulatory certainty to storage facilities, both existing and developing, encourage deployment of this new technology into the system and will ensure that a level playing field exists, so that storage can compete fairly with other sources of flexibility. * New standard licence condition (SLC E1) to require licensees operating or owning storage to make available information to their suppliers to support the correct calculation of levies and charges (consultation closed, awaiting decision) * In 2019 the government launched the 'Storage at Scale' competition to fund the demonstration of innovative large-scale energy storage. * Storage is included in the National Energy and Climate Plan (2019), with the most pressing challenges discussed and indicative solutions proposed to issues such as double charges. * 2017 Upgrading our Energy System study sets out 29 actions to remove barriers including to storage. Implementation is targeted to 2022. The 2018 progress update shows 15 of the 29 actions are implemented, and sets priorities, including 9 new actions. * The Energy Innovation Needs Assessment (EINA)will assess themes such as power generation including bioenergy, carbon capture and storage, hydrogen, demand and supply of heating and transport * Smart systems innovation funding: Up to £9 million to reduce the cost of energy storage technologies (including electricity storage, thermal storage, and power-to-gas technologies), up to £600 000 on feasibility studies for a potential first of a kind large-scale future energy storage demonstrator.
2. Permitting	
3. Energy Markets and Capacity Mechanisms	* Pumped hydro storage is active in wholesale markets. * The UK has a capacity market suitable for storage * In 2018 the EPEX energy exchange introduced loop block orders, where two block orders are executed or rejected together, representing for example the storage cycle. * One issue is the limited duration of balancing service contracts and whether duration constraints exist for non-balancing services procured by network system operators.
4. Ancillary Services	* Pumped hydro is eligible to provide FCR/FRRm/RR services, while batteries are eligible to provide FCR and FRRm services. * To meet increasing balancing needs, National Grid plans to standardise and improve the procurement and open them to market from April 2018. The services are: 1. Balancing: merger of services (mainly enhanced and fast frequency responses) into standardised auctions from April 2018, and rationalizing slow reserves; 3. Voltage Regulation: Opening of the market of new services ; 4. Black start: Opening of the market of new services * In the UK, the Piclo Flex platform – currently being trialled by several UK DNOs – provides a marketplace for DNOs to tender for and receive bids to resolve anticipated network congestion needs.
5. Grid Aspects	* Variable charges are applied on the total injections (injection-based tariffs or charges) or withdrawals (with balancing services use of system). Scottish storage (under 100MW) connected to the 132 kV transmission network receive a tariff reduction. Some of the distribution-connected storages facilities are fully exempted from transmission-related injection charges in the UK. * The profitability of pumped hydro storage is impacted by high transmission tariffs
6. Taxes & Levies	* Storage could face double charging of final consumption levies. A clarification of the regulatory framework for electricity storage is currently being processed: Statutory consultation on proposed modifications to the electricity generation licence. * The regulatory framework does not explicitly state that transmission-connected pumped hydro is considered as a producer, while in practice it is apparently the case, thus exempting taxes and surcharges for the plant
7. Involvement of TSO/DSO	* The current regulation does not address ownership and/or operation of storage by network operators.

	* Ofgem decided to introduce a new condition in the electricity distribution licence to ensure that distribution network operators cannot operate storage (consultation closed, awaiting decision). * In its RIIO-2 Sector Specific Methodology Decision (May 2019), Ofgem requires the Electricity System Operator to develop an Early Competition Plan. Early competition is 'competition run prior to the project design process to reveal the best idea to meet a system need, and could reveal non-network (and flexibility) solutions'. It aims to generate a wider range of potential solutions for the system needs identified in the network planning process, including non-network flexibility options (such as storage). * Some Distribution Network Operators are at the forefront of the creation of flexibility markets where storage can provide a solution. * National Grid was separated in 2019 into the Electricity System Operator (ESO) and the Transmission Operator (TO). The ESO is responsible for the system planning and operation, as well as coordination with distribution system operators, and is ramping up efforts to increase competition with solutions proposed by the TO.
8. Other & General	* The 2017 National Grid report proposed to amend the Electricity Act of 1989 to include a specific definition for energy storage as a distinct subset of energy generating assets
9. Barriers	* The main barriers identified and under regulation changes are: planning process; network connections; network charging; final consumption levies; regulatory clarity; * There is generally a need for markets that reward the value of storage, such as renewable curtailment avoidance and support to network stability (i.e. voltage and frequency control).
10. Best practices	* The 2017 Upgrading our Energy System study sets out 29 actions to remove barriers including to storage. * The Energy Innovation Needs Assessment (EINA) will assess various themes including storage. * To meet increasing balancing needs, National Grid plans to standardise and improve the procurement and open them to market from April 2018. The services are: 1. Balancing: merger of services (mainly enhanced and fast frequency responses) into standardised auctions from April 2018, and rationalizing slow reserves; 3. Voltage Regulation: Opening of the market of new services ; 4. Black start: Opening of the market of new services * In 2019 the government launched the 'Storage at Scale' competition to fund the demonstration of innovative large-scale energy storage. * Ofgem's RIIO-2 Sector Specific Methodology Decision (May 2019) Early Competition Plan requirements will improve the weighing of non-network flexibility solutions versus network investments. * The CRM design is positive for storage development in UK as a very limited de-rating factor impacts storage participating to CRM

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