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Electricity storage in a redesigned market

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Executive summary

Storage technologies have the potential to significantly support the EU's electricity system, bringing a number of flexibility services. There are numerous electric energy storage (EES) technologies, tackling different magnitudes in terms of quantity of energy, ramp-up time, duration of discharge, costs, and lifetime. However, legislation around storage raises a number of challenges if analysed under the current unbundling rules involving a mix of regulated operators and market-based mechanisms. This stems partially from a non-inclusive definition of storage. The study provides an alternative definition which aims to capture the perspectives of multiple stakeholders. Furthermore, we discuss the need to value EES technologies such as batteries, pumped hydropower, flywheels, power-to-X, etc. based on their ability to provide different services. This is based on a techno-economic comparison of different EES technologies, given in additional tables. Finally, the study looks at how storage fits into the current regulatory system and proposes options for future systems so that EES are not discriminated against other flexibility options. A set of policy recommendations is provided that relates to the definition of storage, broadening ownership models, avoiding double grid fees, and valuing EES' potential for supporting the EU's 2030 energy and climate targets.

The European Energy Union is designed around five inter-related priorities[1]. There is growing evidence that energy storage can play a critical role in supporting at least three of these priorities: energy supply security, a fully-integrated internal energy market, and decarbonisation of the EU's energy system.

Technological development, viable business models, and a supportive legislative framework are some of the key factors required to realise the full potential of energy storage. In this study, we discuss the current status of electric energy storage (EES) development in terms of both technological progress and legislative support. These include the need for a common definition of storage, valuing storage, ownership issues, and legislative barriers.

(Re)defining storage

Current legislative framework and market mechanisms to support EES in the EU are lagging behind technological progress and needs. Part of the reason for this is possibly the lack of a common definition – and treatment – of EES[2].

EES can provide different services to various stakeholders. Table 1 shows the services provided to stakeholders such as utilities, generators of renewable energy, and consumers. The perspectives of these multiple stakeholders need to be taken into account in order to agree on a common, inclusive definition of storage. At present, a commonly accepted definition of energy storage is[3]:

"Energy storage in the electricity system would be defined as the act of deferring an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier"

Energy can be stored under different forms (chemical, electrochemical, heat, cold, natural gas, hydrogen). Further, it can provide power intensive functions (frequency regulation, voltage support power quality), and energy intensive functions (congestion management, load following, time shifting). It is also important to consider that energy storage can be situated at different locations: on site, on grid, within e-mobility scheme, and can thus provide new energy connections between economic sectors (for e.g. resource extraction, energy

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[1] https://ec.europa.eu/priorities/energy-union-and-climate_en

[2] Blue & Green Tomorrow, "Collaboration Essential for The European Storage Opportunity", November 2016. http://blueandgreentomorrow.com/news/collaboration-essential-european-storage-opportunity/

[3] https://ec.europa.eu/energy/en/topics/technology-and-innovation/energy-storage

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transformation, chemical, agriculture, heating, and e-mobility).

The above definition of energy storage may therefore be insufficient since it emphasises the principle through which storage acts (deferral of energy consumption) but neglects the service provision aspect - such as power quality and supply security (Table 1) - that EES can provide.

A more representative definition would treat EES as both a technology and a process/service. An alternate definition may be as follows:
Electric energy storage is the provision of one or more services based on the deferral of electricity generation to enhance supply and load capabilities, facilitated by energy conversion technologies.

Table 1 - Services provided by EES to different stakeholders[4]

Utilities	Consumers	Generators of RE
Time shifting/cost savings Revenues can be increased by storing electricity at off-peak times and discharging it at peak times. The benefit is even higher if the gap in demand between peak and off-peak is large. This may allow generation output to become flatter, which leads to operating efficiency improvement and cost reduction in fuel.	**Time shifting/cost savings** Consumers may reduce their electricity costs by using EES to reduce peak power needed from the grid during the day and to buy the needed electricity at off-peak times.	**Time shifting/cost savings** Renewable energy production such as solar and wind power is dependent on weather, and any surplus power may be thrown away when not needed on the demand side. Curtailment costs can be reduced by storing surplus energy and using it when necessary; and by selling it when the price is high.
Power quality EES can provide frequency control functions by helping to adjust the output of power generators. EES located at the end of a heavily loaded line may improve voltage drops by discharging electricity and reduce voltage rises by charging electricity.	**Electric vehicles** Electric vehicles (EVs) are being promoted for CO_2 reduction. EVs batteries are also expected to be used to power in-house appliances in combination with solar power and fuel cells; other possibilities of grid connection such as “V2H” (vehicle to home) and “V2G” (vehicle to grid) are also being explored.	**Connection to grid** The output of solar and wind power generation capacities varies greatly depending on the weather and wind speeds, which can make it difficult to connect them to the grid. EES used for time shift can absorb this fluctuation more cost-effectively than other, single-purpose mitigation measures (e.g. a phase shifter).
Efficient use of network/ system flexibility Large-scale batteries installed at appropriate substations may mitigate the power congestion caused when transmission or distribution lines cannot be reinforced in time to meet increasing power demand. They thus help utilities to postpone or suspend the reinforcement of electricity networks.	**Emergency power supply** EES can power appliances needing a continuous supply (e.g. fire sprinklers and security equipment) or as a substitute for emergency generators to operate during an outage, especially in hospitals or industries such as the semiconductor and liquid crystal manufacturing sectors, which can be greatly affected even by a momentary outage.	
Isolated grids Where a utility company supplies electricity within a small, isolated power network, for example on an island, the power output from small-capacity generators such as diesel and renewable energy must match the power demand. By installing EES the utility can supply a more stable power to consumers.	**Self-consumption of RE** EES will increase self-consumption of local power generation, e.g. from roof-top PV panels. Self-consumption of RE can lower the overall costs of the energy system through load shifting particularly if storage and demand response are managed using ICT algorithms to control charging cycles and appliance usage.	

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[4] IEC, ‘Electric Energy Storage’, White Paper, 2011. http://www.iec.ch/whitepaper/pdf/iecWP-energystorage-LR-en.pdf

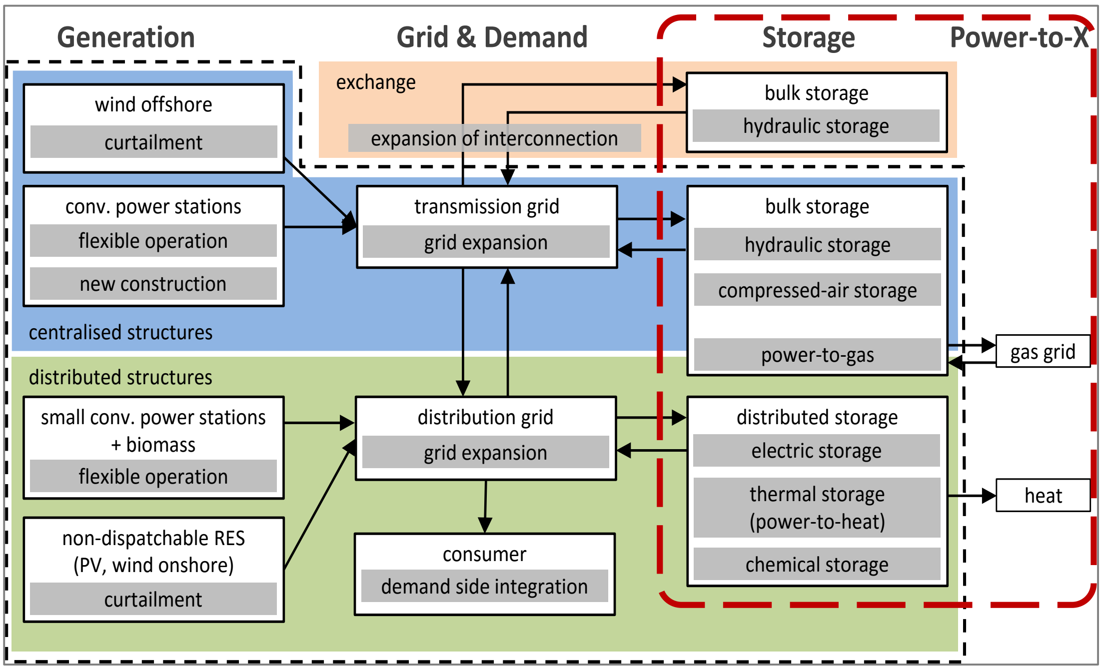

Figure 1 - Flexibility options in the electricity market[5]

Valuing storage

Current trends and policies are targeting an increased share of electricity from renewable sources in the EU electricity system, in particular from intermittent sources such as wind and photovoltaics. Further, the share of electricity in total energy consumption is likely to increase in the coming years. Together, this results in potentially large and sometimes fast variation of both electricity production and consumption - as well as the need to match them - calling for an enhanced flexibility in the electricity system in terms of both power and time. Figure 1[5] gives a schematic overview of the available options to meet the growing need for flexibility in the electricity market; they cover the categories of supply, demand, storage, and the transmission/distribution system.

EES derives its value from the myriad of services that it can provide to traditional electricity generation systems (as shown in Table 1). Nevertheless, EES technologies cannot all effectively provide all services mentioned before. For instance, it is not economically viable to use fast-acting flywheels or super capacitors for energy arbitrage or multi-hour peaking applications since remuneration is currently based on the quantity of power delivered and not the response time.

Any meaningful evaluation of EES must underline its links to multiple value streams. However, legal access to storage asset construction and operation by system operators in unbundled electricity markets in Europe is currently difficult. Though it may be possible as we will see in further sections (e.g. in Italy), a precise and complete valuation of the full range of storage services is not possible for the moment in European unbundled markets, thus hampering the potential economic viability of storage[27].

A key aspect of this is the importance of valuing network reliability services provided by EES. Even though grid storage is expected to be beneficial from an integrated, system-wide perspective, it is not likely that the deployment of storage at an efficient scale would be reached if it only captures the value of grid services. Deploying storage assets at specific locations on the transmission and distribution (T&D) system is indeed important for capturing the value associated with each location through, for instance, T&D investment deferrals. A significant challenge for most T&D investments is that while they must be sized based on peak loads, much of their capacity is unutilised for a majority of the time. Energy storage can provide a cost-effective alternative to expensive T&D investments by supporting peak load capacity in locations where they are most needed. However, in many cases, this may not be enough for covering the

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[5] Hufendiek, K., 'Elements of a new target model for European electricity markets', Towards a Sustainable Division of Labour between Regulation and Market

Coordination, 8-9 July 2015. A Cost Effective Mix of Flexibility Options for Integrating a High Share of Variable Renewables, Paris, 2015

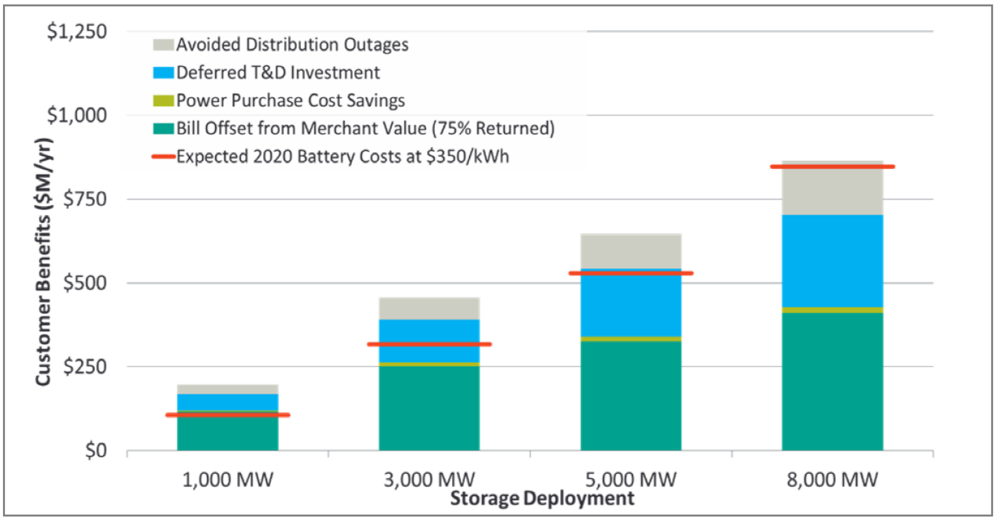

Figure 2 - Example of customer benefits and storage costs for a transmission and distribution system[7]

costs of the asset. As compared to conventional alternatives for congestion relief applications, e.g. new transmission & distribution equipment, storage can provide additional services: mainly improvement of network reliability, but also other unregulated services (e.g. arbitrage[6], frequency regulation). The values of these services will vary depending on the case considered but are usually critical to ensure storage economic viability. This situation is illustrated in Figure 2[7]. In addition, considering that storage used for T&D deferral is often needed for just a few tens of hours to 200 hours per year, storage can be used for other services for the most part of the year.

Ownership

Ownerships models for electricity grid storage are closely linked to the regulation locally enforced regarding assets for energy generation and transmission. In order to assess the actual potential of ownership models, a global legal review has to be performed. It should also be kept in mind that the legal framework for storage assets is not clearly established in the EU and will need to rapidly evolve due to growing development of requirements such as grid support.

Current ownership models

In the EU, transmission network operators can have three different statuses:

- Independent System Operator (ISO): a fully unbundled system operator who does not own the grid assets that belong to an integrated company. This system is used in Ireland and in Latvia but is not recommended by the European Union as asset owners do not have proper incentives to develop the grid, maintain it and to treat congestions. This regulatory system is a hindrance for the development of storage assets as it does not encourage new investments. On the other hand, it abolishes a major regulatory difficulty present in unbundled systems where TSO own grid assets (and hence cannot own generation or storage assets).
- Ownership Unbundling (OU): it is the most popular model in the EU, which states that the TSO must be unbundled from any integrated company. The TSO owns the grid assets and is paid by energy suppliers to use the grid. Under current European regulation, they are not allowed to own any producing assets, including storage assets.
- Independent Transmission Operators (ITO): quite similar to a TSO respecting the OU principle. The main difference is that the TSO is an independent subsidiary of an integrated company. This independence is guaranteed by specific mechanisms enforced by the regulator. Eight countries in the EU have ITOs (Austria, Bulgaria, France, Germany, Greece, Luxembourg, Latvia and the Slovak Republic)

The unbundling principle, present in the EU and some other countries (Australia, etc.), hinders the acquisition of storage assets by system operators. Mitigating this prohibition Terna, for example, has

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[6] Buying electricity at off-peak prices and selling at peak prices.

[7] The Brattle Group. (2014). *The Value of Distributed Electricity Storage in Texas - Proposed Policy for Enabling Grid-Integrated Storage Investments.*

deployed 40.9 megawatts (MW) of battery storage since 2013 for grid stability[2]. This attests to the fact that no clear legal statement exists for storage ownership and operation by TSO respecting the unbundled principle. One way to remedy this precarious regulatory situation is to contract third parties to install, own and run storage assets and to access, as an energy producer, to additional revenue streams on unregulated markets.

Potential business models

Depending on the above-mentioned ownership models, three main business models can be outlined. An overview of the three business models is provided in Table 2.

Model 1: System operator owns the storage asset and captures network value only
In this model, the investment is made by the transmission or distribution network operator to provide network services only. The energy storage asset is integrated in its regulated assets base (RAB), and is eligible for cost recovery through regulated revenues. Preferably, the transmission or distribution network operator keeps the whole control of the system, and is itself in charge of the dispatch in case of congestion or reliability events. The operation of the system by a third party is also an option (e.g. stakeholders with specific skills for optimizing and managing energy storage devices).

Model 2: System operator owns the storage asset and captures both network and market values
In this model, the investment is made by the transmission or distribution network operator to provide network services first. The transmission or distribution network operator is also seeking for unregulated revenues from market services (arbitrage, frequency regulation). The storage system should then be considered as a "shared asset" by the regulator in unbundled markets. In this case, the distributor has then a partial control of the system, at least for the dispatch in case of congestion or reliability events. In unbundled markets, one or several third parties are likely to take responsibilities for the market dispatch.

Model 3: A third party owns the asset and captures network and market value
In this model, the storage asset is owned by an independent party, who can be registered as a generator and/or a customer on the market. The transmission or distribution network operator has a contractual agreement with the energy storage system owner to benefit from network services. Expenses of the transmission or distribution network operator for using storage capacities then qualify as OPEX and can be recovered through the fee charged for using the network. The third party keeps the control of the storage system and can optimize the use of the system according to its own interest (market operations, etc.) as well as the requirements of the distributor.

In addition to the above-mentioned models, mixed models may also emerge. For instance, UK Power Networks (UKPN) plans to gain indirect access to the market through a supplier with specific expertise in renewables trading called Smartest Energy[8]. UKPN and Smartest Energy will collaboratively develop the new arrangements needed to provide access to the wholesale market and facilitate access to the products and services necessary under this category. With this approach, UKPN does not need to hold a 'supply licence' to operate an energy storage facility for the duration of the project. With Smartest Energy providing the route to market for imported or exported electricity, a 6 MW battery storage facility will be interacting directly and visibly with the wholesale market and its contribution can be explicitly measured to deliver learning outcomes. It is also in line with the prohibition for DSO's to hold a generation license.

Legislative framework

As shown in previous parts of this report, energy storage supports specific functions of energy systems. One important function of energy storage is its participation in energy only markets for energy arbitrage (i.e. price arbitrage of peak to base load price differential)[9]. Energy storage may also participate in ancillary services' markets (frequency control, reserve settlement), whereby system operators procure critical services related to the physical balancing and security of the grid. In these cases, additional forms of revenue, although still low in relative terms[10], can complement energy arbitrage[11,12].

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[8] Smarter Network Storage - UK Power Networks, http://www.smartestenergy.com/power-purchase/ukpn/

[9] Energy storage can also participate in capacity markets for adequacy remuneration.

[10] "Les stations de transfert d'énergie par pompage (STEP)", Toulouse School of Economics, November 2014

[11] Dena Ancillary Services Study 2030, "Security and reliability of a power supply with a high percentage of renewable energy"

[12] Energy Storage Association, Public comments to FERC: "Electric Storage Participation in Regions with Organized Wholesale Electric Markets", June 2016

Table 2 - Comparison of potential business models and their main features

Business model	Ease of implementation	Revenue base for TSO/DSO
Model 1	Easier to implement and less subject to regulatory constraints as shown by the example of Terna in Italy (see above), since only regulated revenues are captured (investment deferral, network reliability); does not threaten the unbundling principle.	Limited to regulated revenues only, which could hamper its economic viability.
Model 2	More complex to implement and subject to regulatory constraints; Requires third parties to be involved in order to capture unregulated services. Uncertainties about the legal feasibility of this model, but it is being investigated by some T&D operators, such as ONCOR in Texas who proposed to "auction off" to independent third parties the wholesale market dispatch.	Larger than for the previous model since both regulated and unregulated revenues are captured
Model 3	More complex to implement due to different contractual agreements and revenue streams. The legal feasibility of this model is not clear.	Larger than for the first model

Energy storage assets connected to the grid cannot be classified as Renewable Energy Source (RES) as the energy drawn from the electricity grid entails a carbon footprint of some 200 gCO_2/kWh[13] in the EU. However, as energy storage is part of decarbonisation policy options, a specific framework should be put in place to favor these technologies.

This section discusses some of the necessary adaptations of the electricity legislative landscape resulting from the integration of energy storage. It focuses on electricity grid regulation supporting grid access charges, and discusses potential policy incentives for enhancing energy storage. Recommendations are being elaborated to alleviate the main existing regulatory barriers[14], and to propose fair principles in recognition of the benefits of the different energy storage technologies.

Energy storage and electricity regulation

The fast response brought by energy storage capabilities compared to 'traditional' energy supply capacities should theoretically allow economic benefits to the energy system. However, economic conditions and regulatory environments are major considerations to gain a comprehensive understanding of the role of storage in redesigned energy markets. This section focuses on the influences of energy storage ownership, the potential changes that it implies to the main regulatory boundaries of the sector, in terms of grid fees and incentive systems.

Grid fee charging in the European Union

In the European Union, the justification of grid fees based on energy volumes coming into/outside of energy storage is drawn from the assessment made by National Regulatory Authorities (NRAs) and grid system operators of energy storage, which aims at:

- renewable energy sources' integration,
- energy system efficiency (ex: energy generation curtailment[15], grid congestions) and security.

Most European countries apply grid fees to both charging and discharging of energy storage i.e. when energy is both withdrawn from the grid, and injected into the grid. Given the nature of energy storage - storage leads to a high number of sequences[16] of charging and discharging modes -, grid charges lower the total amount of revenues that storage can generate over its lifecycle, and are therefore considered as an entry barrier for energy storage technologies into energy markets.

Challenges to existing boundaries of electricity regulation(s)

The main principles of the existing energy grid regulations are founded on the assumption that the electricity (and natural gas) grids enjoy a monopoly situation. In the electricity sector, a market organization (market design) supervises the regulated sphere of the grid; with the latter acting as

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[13] Eurelectric, Power Statistics and Trends, 2013

[14] INSIGHT_E, B. Normark, A. Faure, Policy Report: "How can batteries support the EU electricity network", November 2014

[15] "Curtailment refers to a reduction in the output of a generator from what it could otherwise produce given available resources", National Renewable Energy Laboratory, US Government

[16] Up to 500,000 cycles over lifetime for supercapacitors.

mutual socialization of both spatial and temporal benefits/costs for the main players[17].

For the high voltage transmission, the Third Package legislation (Directive 2009/72/EC) foresees unbundling between generation/supply and transmission players based on different legal, functional and accounting degrees[18]. Access to gas storage is provided through European regulation on natural gas storage[19], and through energy efficiency legislation on combined heat and power generation units[20]. By default, access to other forms of energy storage is left to system management entity. This is the case for the use of energy storage in system balancing, which has been increasing over the last years. In Germany for example, the installed battery capacity for primary control provision has increased from about 1 MW in 2012 to 27 MW in 2015[21].

Still, most large scale energy storage technologies available in energy systems are designed to act as generators in the intraday market, by providing market arbitrage. They are therefore subject to double grid fees, being often considered as a load type to the grid. Some observers consider that energy storage shall not provide a "generation function", as its operation does not increase the net volume of energy on the system[22], but simply displaces it over time. In reality, the generation and the demand characteristics of energy storage facilities are restricted to specific moments in times. This makes the implementation of these characteristics into the traditional policy framework (unbundling separation between generation/supply and transmission) difficult to assess. Restricting energy to a regulated type of asset may also have important consequences for the assessed profitability of storage technologies, as energy storage would rely on lower average investment rates of returns. This shall necessitate a stable policy framework, together with a wider assessment of the European energy storage supply chain and industry.

In the case of distribution grid fees, the Energy Efficiency Directive (Directive 2012/27/EC - Article 15) and the Renewables Energy Directive (Directive 2009/28/EC - Article 16 - Access to and operation to the grid) require that network tariffs aim at supporting an increased overall system efficiency (including energy efficiency), demand response and integration of renewables. Article 16 also requires Member States to undertake appropriate grid and market-related operational measures to minimize the curtailment of electricity produced from renewable energy sources

In the European and national legislation, grid access tariffs should be founded on the principles of non-discrimination, transparency and network cost reflectiveness (Directive 2009/72/EC). As electricity grid fees are supported by non-regulated actors (generators, aggregators, supply entities, consumers), outside of the regulatory scope, they are an important element of market competitiveness and should therefore also be subject to transparency and non-discriminatory rules (partly due to unbundling rules[23]).

Overview of grid exemptions' cases to energy storage

Within the European Union, the existing levels and structures of grid fees are summarized in the European Network Transmission System Operator for Electricity (ENTSO-e) overview of transmission tariffs[24]. Despite a common unbundling model, grid access tariffs remain fragmented throughout the geographical regions covered by the ENTSO-e. This situation partly stems from different types of charges included in grid methodology calculation: load or generation based charges, system services, or other regulatory components (renewable surcharge, public interest etc. See Annex 2: Main principles for grid fee calculation).Except in the case of Power to Heat and Power to Gas, most European countries apply a double grid fee to energy storage. In the majority of cases, it is interpreted that energy storage acts as load[25]. In this context, Germany, Austria and Ireland provide exemptions to double grid fee charging.

In these countries, pumped hydro system operators (also referred as Pumped Hydro Storage – PHS) are being exempted from double grid fee payment,

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[17] "At the Speed of Light? - Electricity Interconnections for Europe", Note Ifri, Susanne Nies, 2009.

[18] Independent Transmission Operator, Independent System Operator, Ownership Unbundling. The Independent Transmission Operator model, including the ownership of the transmission asset, prevails in the European Union.

[19] "EU strategy for liquefied natural gas and gas storage", SWD (2016) 23 Final

[20] See Article 14 of Directive 2012/27/EU - Repealing CHP Directive

[21] Germany Trade & Invest projections

[22] Amy L. Stein, "Reconsidering regulatory uncertainty: making case for energy storage", Florida State University Law Review

[23] Exemption from unbundling rules can be granted to TSOs in the case of interconnectors, which are under certain circumstances considered outside of a strict monopoly situation (duopoly situation).

[24] ENTSOE, Overview of transmission tariffs, June 2016, https://www.entsoe.eu/Documents/MC%20documents/ENTSO-E_Transmission%20Tariffs%20Overview_Synthesis2016_Final.pdf

[25] Think – Topic 8 - Electricity Storage: How to Facilitate its Deployment and Operation in the EU

under specific conditions. In Germany, the exemption is granted for 10 years, as long as the volume of energy storage grows by 5% per annum. In Italy, energy withdrawals for generation plants ancillary services, and for pumped hydro storage plants are exempted, under specific conditions, from transmission and distribution fees[26].

A wider system and customer perspective is also considered for supporting grid exemption rules, including the assessment of pricing zone definition and pricing system formation (zonal pricing vs nodal pricing)[27].

Policy actions towards an increased energy storage contribution in the energy system

This section provides a number of policy actions that aim to clarify uncertainties perceived as market barriers, including energy storage definition. Reducing these uncertainties will support the uptake of new business models for the integration of energy storage.

Alleviating market barriers
Policy action is required for further streamlining the European Union network code for ancillary services[28]. These network code including requirements for generators shall ensure that energy storage is not considered as load, but, as a mitigation device, that shall not be disconnected in case of emergency or frequency restoration[29]. Over time, energy storage technically reacts to both generation and load. From a definition perspective, it shall consequently be differentiated from distributed generation and demand response.

Under system operator supervision, energy storage used to answer ancillary services needs like fast response or congestion[30] need to be expanded further to specific critical places of the system (e.g. critical physical grid congestions). This expansion may be coordinated by system operators (TSO-DSO coordination[31]) and NRAs.

Interpretation of energy storage ownership
Ownership rules should be defined considering the above-mentioned considerations. Energy storage shall be recognised as a system component reacting both to generation and load types. These technical characteristics allow it to improve the energy efficiency of the overall system.

The role of national regulatory authorities (NRAs) shall be reinforced in light of the forecasted rise of energy storage at the distribution level. NRAs[32] shall assess the evolutions of the regulated perimeters at DSO level, and supervise regulatory adaptations[33]. They shall ensure efficient and transparent exchange of data at the distribution level to the benefit of new entrants.

A policy evolution towards the recognition of an independent storage operator may be considered (see section on business models).

Throughout this process, new forms of contracts, remuneration schemes (auctions, tenders[34], contracts for differences) will need to be evaluated in order to support the effective development of energy storage outside of the regulated framework.

Innovation in new modes of grid regulation
Traditional grid regulation mechanisms (also known as cost-plus, or rate of return regulation) foresee grid cost recovery by aligning the return of the grid operator to its cost structure. Under more innovative mechanisms (performance based incentive regulation), NRAs delegate certain operational decisions to the grid operator, from which it can benefit from costs' reductions. All regulatory approaches face the problem of asymmetric information, such as the difficulty in determining the 'right' (optimal) rate of return pathway for investments. Innovations in grid regulation to support distributed generation shall also be applied to energy storage[35].

Illustrations have recently been provided by national regulatory authorities in Italy, Spain and the United Kingdom, in particular in relations to ancillary services management and balancing. According to

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[26] Ibid - ENTSOe
[27] INSIGHT_E, Abhishek Shivakumar (KTH); Paul Deane (University College Cork); Bo Normark (KIC InnoEnergy); Aurélie Faure (Ifri), Policy Report, "Business Models for Flexible Production", December 2015
[28] Regulation (EC) N°714/2009 – ENTSO-e Ancillary Services Stakeholder
[29] Operating reserve used to restore frequency to the nominal value and power balance to the scheduled value after sudden system imbalance occurrence.
[30] RTE frequency response contract
[31] Faure A, Ifri, 'The EU Electricity Policy Outlook for the Smart grid roll out', June 2015
[32] NRA approval has to make sure that energy storage does not create price interferences in the energy market.
[33] F. Geth, Battery Energy Storage Systems and Distribution Grid Supports, Ku Leuven, September 2014
[34] Competitive tender auctions for new builds - Article 8 of Directive 2009/72/EC
[35] DG Grid Project Results," Regulatory Improvements for Effective Integration of Distributed Generation into Electricity Distribution Networks", November 2007, https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/dg-grid_summary_of_the_dg_grid_project_results.pdf

Italian decree law 93/11 (Art 36, Paragraph 4), Italian system operators (Terna and distribution operator ENEL Distribuzione) are in the process of installing batteries for transmission congestion relief, frequency regulation and voltage support (with battery projects of above 1 MW connected to the high voltage grid). Regulatory amendments have also been added in the Italian distribution regulation framework, to enhance the development of energy saving technologies (i.e. heat pump)[36].

In the United Kingdom, 40% of the balancing costs between 2013-2014 arose from the necessity for generators to adjust their production profile to local constraints[37].

The Spanish Ministry is elaborating a legal framework supporting the use of grid batteries, if they are supplied with a renewable based electricity source[38].

Building on the United Kingdom case, storage operators providing balancing services could be offered a fee exemption on system charges[39,40,41]. However, such a measure can only be effective if implemented together with a wider energy storage policy, and should consider broader policy actions as presented in this section.

Large scale energy storage and energy security

A new system security policy shall also be developed to further refine the role of large scale energy storage[42] technologies from the existing potentials of hydro storage, pumped hydro storage, natural gas storage and heat storage. A system adequacy analysis of the EU should be performed to better assess how large scale energy storage can complement intermittent renewables in different Member States[43]. This will include a review of generation mixes (of dispatchable and non-dispatchable sources) and the existing potential of large scale demand response. In the longer term, additional research needs to be performed in assessing the development of energy storage at a decentralised level.

Consequences for grid fees and decentralised storage

The principles of grid access tariffs based on "non-discrimination; transparency and network cost reflectiveness" (Directive 2009/72/EC) shall be maintained. The evaluation of grid fees shall be performed over the life-cycle of the energy storage facility, in assessing the adequacy of storage with system needs over its duration. A methodology could be developed using a fair differentiation of services that one single technology could be providing to the grid (using the technical specifications provided earlier in the report). Under these principles, grid fee exemptions may be granted by system operators to energy storage facilities owners.

End-uses storage schemes are being developed in Belgium[44], Germany, the Netherlands and Italy. In Germany, eligibility for exemption is provided for certain types of battery technologies like lithium-polymer, lithium titanate, lead-acid and lead acid gel batteries[45]. This rapid development at the decentralized level results from the fact that grid cost parity is achieved at an early stage, as electricity prices drawn from the grid are higher than wholesale generation prices. In Germany, electricity generation costs currently account for 22% of total residential price for electricity[46].

At the distribution level, integration of energy storage technologies (batteries in residential premises, heat pumps in district heating) together with electric mobility, implies technical challenges requiring the system operator to deal with bi-directional flows below the sub-station, thus necessitating a reinforced cooperation between TSOs-DSOs.

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[36] AEEGSI, http://www.medreg-regulators.org/Portals/45/capacitybuilding/1st/1st_MEDREG_Capacity_building-AEEGSI-Lanza.pdf

[37] Electricity Balancing Services, National Audit Office, 2014, https://www.nao.org.uk/wp-content/uploads/2014/05/Electricity-Balancing-Services.pdf

[38] "Solar energy policy in the EU and the Member States, from the perspective of the petitions received", Study for the PETI Committee, 2016

[39] ICE, January 2016, https://www.ice.org.uk/getattachment/media-and-policy/policy/ice-submission-on-electricity-interconnection/ICE-submission-to-NIC-call-for-evidence-Electricity-Interconnection-and-Storage.pdf.aspx

[40] Smarter Network Storage Low Carbon Network Fund Electricity storage in GB:
SNS4.13 – Interim Report on the Regulatory and Legal

[41] EWEA, "Balancing Responsibility and Costs of wind power plants", February 2016.

[42] Large scale energy storage can be defined as energy storage connected to the high voltage network. It encompasses pumped hydro storage, natural gas, hydrogen, compressed air systems, redox flows batteries.

[43] Daniel Huertas Hernando, System Planning Advisor, ENTSO-E - Security Adequacy Methodology, http://ec.europa.eu/competition/sectors/energy/capacity_mechanisms_working_group_3.pdf, January 2015

[44] Battery Energy Storage Systems and Distribution Grid Support

[45] IRENA, "Battery storage for renewables: market status and technology outlook", January 2015

[46] BDEW-Strompreisanalyse November 2016 (Haushalte und Industrie) https://www.bdew.de/internet.nsf/res/17C4483BB515C7F4C125807A0035E077/$file/161124_BDEW_Strompreisanalyse_November2016.pdf

Grid optimized charging of energy storage modules, associated to distributed generation (PV), allows a reduction in distributed generation peaks (Schott et al. 2014). Such grid optimized charge modes can help improve local power quality and provide an upgraded transmission and distribution grid deferral in case of high local distributed generation penetration.

On the regulatory side, the "use of system charges", whereby charges are segmented between different times, is considered as a solution for giving location signal and facilitating decentralised generation and the deployment of decentralised storage systems[47]. At the retail level, grid fees exemptions may be implemented together with renewables surcharge exemptions, VAT exemptions and other forms of tax exemptions.

Conclusions

The separation of interests between generation / supply and networks as foreseen in unbundling rules prevailing within the EU should be adapted to the mid-voltage to low voltage levels, whereby energy storage and renewables are likely to be further deployed in the future[48]. New grid controls equipment and procedures, including energy storage, have to be evaluated in light of new grid flows patterns. This requires an adaptation of the existing network codes to the identified energy storage functionalities.

However, energy storage should not be restricted to any specific asset class (generation, transmission and distribution), as its technical characteristics allows many interactions between these different segments and the corresponding markets, where it can operate/serve. Energy storage can be defined as a device reacting to events occurring both in generation (supply) and load (demand). Although its technical capabilities (fast response, long duration) compared to energy supply 'traditional' technologies should theoretically allow economic benefits for the energy system, regulatory reforms are required to unlock its potential. To that extent, incentives (feed in tariffs; feed in premium) for energy storage could be envisaged if they can help overcome technological barriers (non-maturity of some storage technologies). They shall nevertheless not impact the basis schemes for operation/remuneration of energy storage, that shall remain predominantly based on market conditions (energy-only market, capacity market, ancillary services, auctions).

A reform of the existing grid fees is necessary, and a general framework for grid fee exemptions should be assessed. Fees exemption shall also be envisaged, upon NRAs approval and under the principles of transparency, cost reflectiveness, and non-discrimination to facilitate market opening to new type of actors and possible storage owners/users (aggregators, virtual power plants).

As such, energy storage will be able to both enhance existing competition and support flexibility (generation curtailments, load modulation, peak load shaving, peak load shifting[49]) in energy markets.

In the framework of European Union's innovation policy, additional research would need to be performed in relation to the contribution of energy storage to the large scale system's security.

For further reading or information, please visit www.insightenergy.org

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[47] International Energy Agency - PVPS, "Review and analysis of PV self-consumption policies", 2016

[48] "Policy Framework Conditions for Provision of Ancillary Services in a Distribution Network by Distributed RES Generation", Gubina A.F., Tuerk A., Pucker J., Taljan G., IEEE PowerTech 2015, June 2015

[49] "Regulatory recommendations for the deployment of flexibility", EG3 report, Smart Grid Task Force, January 2015

Annex 1: Definition of ancillary services

Ancillary services consist in measures that are performed by system operators (transmission system operators and distribution system operators) to ensure integrity and stability of the grid, i.e. to ensure that grid frequency and voltage remain under specific tolerance boundaries and that the system is able to restart after a fault.

Some of these rules are embedded into European and national grid codes[50]. These services are procured by system operators[51] from third parties, through bilateral agreements or market mechanisms for specific situations/events like voltage support (in the event of voltage circuit or drop outside of permitting range), 'black start' or islanding at times of emergency and restoration. The contractual form for providing these services is different from one country to another and from one service to another[52]. For instance, 'black start' and voltage control are highly dependent on the location of the required failure[53]. More information is provided on the US Government initiative: "Greening the grid" project[54].

Annex 2: Main principles for grid fee calculation

The associated grid fee system is constituted from the following elements:

A grid fee or grid access fee is collected by the electricity grid operator, covering the financial costs (operating expenditures and capital expenditures) related to the operation, maintenance and development of its grid regulated activities. It should allow the operator to generate an annual return on investment above its cost of capital.

Grid investments are planned, based on the adequacy of installed capacity with peak power demand and assumed growth rate of electricity volumes.

For both transmission and distribution, grid fees (including both volume and capacity charges) are determined according to the amount of revenues collected by the system operator and divided by the volume of electricity (generation or load) being transmitted on the grid.

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[50] INSIGHT_E, Policy Report 3, B. Normark, A. Faure, 'How can batteries support the EU electricity network', November 2014

[51] Dena Ancillary Services Study 2030. "Security and reliability of a power supply with a high percentage of renewable energy, July 2014

[52] Kapetanovic et al., 2008; KU Leuven and Tractebel, 2009

[53] 'Topic 8 - Electricity Storage: How to Facilitate its Deployment and Operation in the EU', Think Project, July 2012

[54] http://greeningthegrid.org/integration-in-depth/ancillary-services