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Overcoming barriers to electrical energy storage: Comparing California and Europe

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Francisco Castellano Ruz and Michael G. Pollitt

Abstract

Multiple market drivers suggest that electrical energy storage (EES) systems are going to be essential for future power systems within the next decade. However, the deployment of the technology is proceeding at very different rates around the world. Whereas the sector is progressing quickly in California, it is not gaining much traction, so far, in Europe. This research aims to clarify why the prospects for energy storage in Europe are not as good as they are in California. The market and regulatory framework in California and Europe are analysed critically, and changes to overcome the main barriers are recommended.
The research shows that the main barriers are: inadequate definition and classification of EES in legislation; lack of markets for some ancillary services; inadequate market design that benefits traditional technologies; and the lack of need for EES in some jurisdictions.
The prospects are better in California because regulation is more advanced and favourable for the technology, and regulators are collaborating with developers and utilities to analyse barriers and solutions for the technology. In Europe, there is a need to clarify the definition of EES, create new markets for ancillary services, design technology-neutral market rules and study more deeply the necessity of EES.

Keywords electrical energy storage, battery, market design

JEL Classification L98

Contact m.pollitt@jbs.cam.ac.uk
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Overcoming barriers to electrical energy storage: Comparing California and Europe

Francisco Castellano Ruz

fcastellano90@gmail.com

Energy Policy Research Group

University of Cambridge

United Kingdom

and

Michael G. Pollitt[1]

m.pollitt@jbs.cam.ac.uk

Energy Policy Research Group

Judge Business School

University of Cambridge

United Kingdom

1. Introduction

The pursuit of a low carbon energy mix is leading to a rise in variable renewable energy sources, most notably wind and solar. The unpredictability of these sources will cause energy flow fluctuations in the network inducing a greater stress for the grid and, therefore, increasing the need for flexibility.

[1] Corresponding Author.

Electrical energy storage (EES) is a technically feasible technology as proved in multiple grid applications. EES can increase the reliability and resilience of the network and deliver energy more efficiently. However, its high capital costs and various market and regulatory barriers are hindering the required deployment of the technology.

Whereas the EES sector is progressing quickly in California, in Europe it is stuck at this moment. This paper aims to clarify why the prospects for energy storage in Europe are not as good as they are in California. The UK, Germany and Spain are the countries chosen as generally representative of the European situation. The market and regulatory framework in California and Europe are analysed critically, and changes to overcome the main barriers are recommended.

There are currently[2] 1311 energy storage projects under operation, in construction or announced in the world. Regarding GWs installed, pumped hydro storage (PHS) accounts for more than 96% of the power installed worldwide. PHS is a mature technology, historically coupled with large baseload power plants that can be sized up to 4GW (EPRI, 2010).

This article is focused on distributed storage at level of the distribution grid. We focus on electrochemical batteries (i.e. Lead-acid, Li-ion, NaS and flow batteries) because these are able to perform most of the required grid services (DOE, 2013, p. 29). By

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[2] The total power installed is around 186GW. Electrochemical batteries account for more than half of the projects, followed by Pumped Hydro Storage (PHS). The USA (525 projects) is leading the deployment of energy storage, followed by China (96) and Japan (89). In Europe, Germany (67) and Spain (65) are the countries with the highest number of installations. The source of all data presented below is the database developed by the Department of Energy of the USA (DOE) which provides up-to-date information about grid-connected EES projects worldwide. (http://www.energystorageexchange.org/). Data provided updated and accessed in October 2015.

contrast bulk storage systems such as PHS and compressed air storage (CAES) produce a narrower range of system benefits.

Electrochemical batteries will most likely dominate the grid EES market during the next decade since:

- they can provide multiple services and therefore potentially access to several revenue sources,
- they have reached a sufficient level of maturity to be commercially operated (SBC, 2013), and,
- a strong decrease in the costs of these installations is expected (Rocky Mountain Institute, 2015b).

There are currently (end of October 2015) 706 electrochemical battery projects around the world operating or announced. The following table shows the number of electrochemical battery projects in each of the jurisdictions analysed:

[Insert Table 1 here]

Our methodology is based on a literature review and interviews with industrial stakeholders. Firstly, the main barriers were identified by analysing several reports published by different industrial stakeholders (regulators, utilities, developers and consultancy firms). Interviews with people inside the EES sector were conducted to find out directly the major problems they are facing. The main companies contacted were: UKPN in the UK, Younicos in Germany, Abengoa in Spain or Energy

Strategies Group in the USA. Based on the published documentation and our interviews we propose a number of recommendations and actions.

Section 2 looks at the market drivers for EES. Section 3 examines sources of revenue for EES and section 4 outlines the value of EES to the system. Section 5 goes on to discuss the market and regulatory barriers to further deployment of EES. Section 6 asks why the prospects for EES are generally better in California than in Europe, and section 7 concludes with what might be done to improve the prospects for EES in Europe.

2. Market drivers for electrical energy storage

The key drivers that, according to Lyons (2015), indicate that EES will be an essential technology for the future power system are:

Increasing need for flexibility: Large-scale integration of VRES induces uncertainty in the planning and operation of the electricity system. The unpredictability of these sources will produce energy flow fluctuations that have to be mitigated. System operators must match supply and demand. Traditionally, this has been done with controllable power plant units to regulate real and reactive power up and down. Nowadays, with the penetration of renewable energies, there are higher levels of non-controllable (or expensive to control) generation resources.[3] As such generation sources increase, more regulation and operating reserves, frequency control and start-up services will be required. For instance, the California Independent System Operator (CAISO) has identified a need for additional ramping capacity to allow the proper integration of increasing amounts of renewables into the grid. Under the scenario of 33% of renewable energies by 2020 legislated in California, a need for 4.6GW of flexible capacity to integrate new VRES is forecast (Casey, 2011).

[3] There are examples of operational problems as a consequence of large variations of VRES. In 2008, an unexpected 1.4GW drop in wind-power generation coincided with an unexpected load increase and the loss of a conventional generator in Texas. This forced the Electric Reliability Council of Texas to take emergency steps and cut 1.1GW firm load to restore the system frequency (Du and Lu, 2015, p.3).

Declining cost and increasing use of solar PV: The sharp decrease in the cost of PV installations – the cost of PV modules has decreased by one order of magnitude from 2008 (Lyons, 2015) – will accentuate the need for flexibility and make solar-plus-battery systems more attractive. The combination of both technologies can maximise the value obtained from them by optimising the operation of the whole system. These systems reduce the interactions with the grid, allowing reduced import from the grid for final users and reduced exposure for stand-alone generators to export curtailment when the grid is congested. The global market for solar-plus-batteries could reach US$ 2.8 billion by 2018, which will be a boon for the EES sector (Lux Research, 2013).

Decreasing cost of EES installations: The use of storage technologies in other industries, such as Li-ion in electric vehicles and electronic portable devices, is one of the main drivers for the declining cost of the technology. California's mandate for the installation of 1.325GW of energy storage systems is a further boost for the industry. Although this is a location specific policy, this will reduce the cost of the technology, which will affect every market. The price of Li-ion batteries has halved every 2.5 years since 2009 and several reports forecast that the price of EES installations will continue going down (e.g. Rocky Mountain Institute, 2015b).

Although the cost of battery cells may continue at the same rate of decrease, the complete system cost is not likely to come down as fast. Non-battery costs – related to grid connection, inverter, management system and contingency – account for around 60% of the total cost at a storage facility (Rocky Mountain Institute, 2015a).

Increased security and reliability concerns due to natural disasters: Hurricane Sandy resulted in 8.5 million people being without power in 21 states and caused US $65bn in damage, and took the lives of 117 people in the USA. Nick Chaset (2013), California Governor's Special Advisor for Distributed Generation, Energy Storage and Combined Heat and Power, proposed distributed generation combined with energy storage as a way to enhance the future resiliency of the grid.

The way in which the traditional centralised system failed after the hurricane increased the interest in microgrids as a way of increasing the reliability of the system after facing natural disasters. Energy storage can be represented as an investment in microgrid enabling technology options (Lyons, 2015).

Increased risk of fossil fuel-based investments: Ceres (2012) has evaluated the risk of new generation resources. The outcome of the study shows a lower risk in practically every category of risk they identify (including exposure to fuel costs, new regulation, carbon pricing, water shortages) for VRES compared to alternative technologies such as nuclear, biomass or thermal energy with carbon capture and sequestration technology. This implies a larger investment in VRES in the medium and long term. Such a general trend implies a favourable background for VRES enabling EES investments.

3. Main sources of revenue of EES and additional benefits to the grid

EES systems can provide multiple services at different stages of the electricity system – generation, transmission, distribution and final consumer. The primary applications and main sources of revenue for EES installations are[4,5]:

[4] A description of all applications can be found in the electricity storage handbook by the DOE and EPRI (2013).

[5] The names of the applications can vary from one location to another. We use those terms common in the USA.

Load following: EES systems can vary their output to balance generation and load within a specific region. Electricity is stored when demand is low and discharged during periods of peak demand. This can be done over various timescales – from minutes to whole days.

Price arbitrage: EES systems can take advantage of price variations on the wholesale market over the day. Price arbitrage consists in charging (i.e. buying or not exporting energy) the battery when the electricity price is low and then discharging (selling) it when the price is high. This application complements load following as low and high price periods coincide with low and peak demand periods respectively.

Supply capacity: This involves using the storage facility to provide reserve capacity to the grid at peak times. This involves having the facility ready to discharge at those times, in a similar way to conventional back-up fossil fuel generation.

Transmission and distribution (T&D) investment deferral: EES systems can be installed to defer the installation or upgrade of T&D lines or substations where grid capacity is being reached.

Ancillary services: Fast-response energy storage can inject or withdraw energy from the grid within a few seconds to maintain the frequency and the voltage within the technical limits to avoid instability and blackouts. The most common ancillary services are: frequency regulation, voltage control, spinning reserve and black start.

Renewable integration: Renewable resources are unpredictable and do not align with typical peak load patterns. Having a storage device will allow the storage and discharge of renewable generation, facilitating increased shares of renewable energy in the total energy mix, in line with renewable energy and carbon reduction targets.

Apart from the capability to provide these services, EES gives other advantages to the whole power system compared to traditional flexibility providers:

Situation of the plant: EES systems can be sited closer to the loads. They face fewer site constraints as they are silent, scalable and do not produce any emissions. Gas-fired peaker plants usually work at partial load, which increases their unit CO_2, NO_x, and CO emissions. Therefore, they easily violate air quality minimum requirements to be installed in urban areas (Lyons, 2014). Hence, a gas-fired peaker plant must be sited away from demand centres which means further from the loads. This increases line losses. Therefore, using EES instead of gas-fired peaker plants reduces losses in the lines and, at the same time, improves air quality substantially.

Planning: Siting, permitting and installation is much faster in the case of EES. Modularity makes batteries easy to install. An EES system can complete the whole process and be commissioned in 1.5 years. However, in the case of a combustion gas turbine, this time can be up to 5 years. This reduces the riskiness of the investment and increases the flexibility of the technology (Lin, 2014).

Amount of flexibility provided: Unlike gas turbines, electrochemical batteries do not have a minimum output and, moreover, they can work also as a load. The minimum power output of a gas turbine that meets environmental requirements is around 50%. Below that level, the temperature of the combustion goes down, which means less conversion of CO to CO2 (Wartsila, n.d.). Thus, if we compare a gas turbine with a battery with the same nameplate capacity, the flexibility that the battery can provide will be between three and four times larger. Comparing a 100MW gas-fired peaker plant with a 100MW battery, a battery could offer 200MW (100MW as generator and 100 MW as load) of flexibility whereas the gas turbine could only provide around 50MW.

Utilization of the plant: If gas-fired peaker plants are only used for flexibility purposes and start-ups and shutdowns account for around 20% of their operation hours (Lin, 2014), their load factor is rarely above 10% (Lyons, 2014). On the other hand, EES systems can be operating 95% of the hours due to their fast ramp capabilities and the possibility of providing multiple services while their peaking capacity is not needed.

Performance: EES systems respond much faster and more accurately to signals from the system operator when it comes to providing flexibility services. For instance, the ramp rate of an EES system can be up to 600 times faster than a gas-fired peaker plant. A battery is able to provide its maximum power in less than one second, whereas for a gas turbine this could take up to 10 minutes from minimum output (Lin, 2014).

Overall system benefits: Due to all the benefits explained above, the installation of EES systems as flexibility providers increases the technical and economic efficiency and sustainability of the system.

As EES systems can respond faster and more accurately as the need for flexible capacity increases. For instance, if the California system operator (CAISO) dispatched fast-response EES resources, its frequency regulation procurement costs could be reduced by 40% (Du and Lu, 2015, p. 100).

Using EES allows better optimization of the operation of the available generation fleet, which means less ramping and part-loaded generation and, therefore, less fuel wasted and less air pollution. The reduction in emissions could be significant. In the case of California, relative to using Pacific Gas and Electric's base load electric mix as the off-peak source of electricity, EES could reduce CO2 emissions per MWh by more than half (with even more significant reductions in nitrous oxides and carbon monoxide), according to Lin (2011).

With EES, the system would avoid having costly gas-fired peak plants that are not producing any power during 90% of the year. For example, 20% of New York State's generation capacity runs for less 3% of the year (Lyons, 2014). However, an EES system can be working 95% of the year providing multiple services.

The consumption of water, another scarce natural resource in many parts of the world, would also be reduced. A 100MW gas-fired peak plant would consume 30000 litres/hour whereas an EES has little or no water usage (Lin, 2014).

4. The value of electrical energy storage

Calculating the value of EES is a complicated task, as the systems can access multiple revenue streams and the potential benefits from them depend on several factors such as the ownership of the asset or its location.

The main issue when it comes to calculating the value of energy storage is that EES costs are typically larger than benefits from any individual grid application. Only in certain areas of the USA, after the implementation of Order 755 issued by FERC in the USA, can EES be profitable by providing only frequency regulation.

Although EES can provide multiple services, their benefits cannot just be added together as each of them requires part of the operational availability of the asset. Assuming that there are no regulatory and market constraints, the technical potential of EES is obtained after optimizing the operation of the asset and the time allocated for each service. However, the technical potential cannot be monetized entirely since, in reality, market and regulatory barriers do exist. Depending on the market situation and the ownership of the asset, potential benefits will shrink or could even disappear. Moreover, there is competition to provide services as the penetration of EES increases. Thus the potential value of the n^{th} unit will be lower than the value of the first unit.

As mentioned previously, one of the advantages of EES is the additional benefits provided to the whole electricity system and the society. The problem is that, currently, there is no method to evaluate these benefits and, therefore, to compensate EES systems for providing them.

There are several studies that confirm this. EPRI (2013) studied the cost-effectiveness of EES in California at the transmission and distribution level. They calculated the technical potential value of energy storage and compared it to the costs of the installation over its lifetime. The results demonstrate the points mentioned above. An EES can be cost-effective provided it provides multiple services and there are no regulatory and market constraints, with the exception of installations providing frequency regulation after the application of Order 755. The report also shows that the highest benefits are obtained from frequency regulation – also before the application of Order 755, T&D deferral and capacity supply.

In the case of the UK, SBC (2013) published a comparison of the annual benefit of storage applications compared to the annualized cost of the installation. Again, individual applications do not cover the costs of the installation but a bundle of applications can. This is applicable to the other European countries. However, an equivalent measure to Order 755 has not been applied in Europe yet. Therefore, the possibility of providing only frequency regulation cost-effectively in Europe does not exist.

Market and regulatory barriers are, together with the high cost of EES technologies, the main factor hindering the deployment of the technology.

5. Market and regulatory barriers for EES in California and Europe

The following sections analyse and compare the market and regulatory barriers existent in California and Europe. Three countries have been chosen as representative of the European situation: the UK, Germany and Spain.

5.1. Inadequate definition and classification of EES

EU legislation provides a definition for the conventional activities within the electricity system – generation, transmission, distribution and supply. However, electrical energy storage is currently not defined as a separate activity or as an asset class.

Energy storage has been traditionally treated in the same way as generation. This originates from large scale PHS technology that competes with generators in the provision of bulk energy and balancing services. While this treatment works for large scale EES systems, it is not convenient for smaller scale assets which can provide other services.

This is the situation in California and in Europe: EES is not clearly classified within the electricity system and it is usually treated as generation. This prevents utilities or developers from obtaining revenue by providing services under multiple classifications (SANDIA, 2013). The different stakeholders involved in the industry state recognise this as a significant issue (CAISO et al., 2014).

EES can work as generation, load and as a T&D asset. Therefore, the treatment of EES as generation does not cover all its possible applications and this has consequences regarding the operation and the ownership of the asset

5.2. Unbundling requirements

The first consequence of considering EES as a generation asset is the effect of the unbundling requirements arising from the electricity market liberalisation process. In the European Union, Directive 2009/72/EC establishes the requirements for unbundling. These requirements were designed to prevent discrimination between network users by integrated network owners and may effect the ability of network owners to capture all of the benefits of owning and operating EES[6].

This affects Transmission and Distribution System Operators (TSOs and DSOs). TSOs have three possible models (UKPN, 2014b):

- **Ownership unbundling (OU):** This involves separate ownership of transmission assets from both generation and retail.
- **Independent System Operator (ISO):** This involves a wholly independent system operator, who has no interest in the ownership of transmission, distribution, generation or retail assets. This allows vertical integration of transmission assets with generation and/or retail assets to continue.
- **Independent Transmission Operator (ITO):** This specifies that transmission assets must be operated in a wholly separate business (with strict ring-fencing), if it continues to be owned by a vertically integrated company.

The following table shows the models adopted within the countries analysed:

[Insert Table 2 here]

As EES is treated as generation, TSOs under the OU model cannot own EES systems. Under the ITO model, EES could be owned by it must be operated independently from the grid.

The requirements for DSOs are for full legal unbundling from other parts of the electricity system, including generation and supply. Therefore, European transmission and distribution system operator licence holders cannot obtain value from assets that require a generation licence, such as EES.

[6] Paragraph 9 of Directive 2009/72/EC.

There are some cases that exempt owners from holding a generation license. For instance, in the UK there is an exemption if the project is considered a “small generator”. An EES will be considered a “small generator” if the electricity that it provides is[7]:

- under 10MW or,
- 50MW as long as the declared net capacity is less than 100MW.

In the case of Spain it is not necessary to apply for authorization if the generator output is less than 50MW[8]. Therefore, TSOs/DSOs could own batteries that meet this requirement.

In California, since the California Public Utilities Commission (CPUC) issued Decision 13-10-040 and Decision 14-10-045, investor-owned utilities are allowed to own energy storage resources and, besides, they can provide generation, transmission and distribution services. However where they participate in more than one market at the same time, the cost recovery procedure still has to be clarified.

As the CPUC admits, the existing regulatory framework does not consider storage as a generation asset and a transmission asset. There is a regulatory and decision making gap between the Federal Energy Regulatory Commission (FERC), CPUC, and the California Independent System Operator (CAISO)’s transmission planning processes. Storage that could provide both transmission and generation functions is not able to take advantage of both benefits in comparison to other alternatives (CPUC, 2013). For instance, being a transmission asset rewarded through regulated

[7] Electricity (Class Exemptions from the Requirement for a Licence) Order 2001.

[8] Article 53 Ley 24/2013.

charges while also participating in energy markets is not allowed by FERC (CAISO et al., 2014).

5.3. Obligation for TSOs and DSOs not to distort competition in the electricity markets

Although European TSOs/DSOs are allowed to own EES systems that meet the requirements for a “small generator”, they have the obligation not to distort competition in the electricity market, as this is not their core business. These entities would need to buy and sell energy to charge and discharge the batteries but this requirement is blocking the possibility of trading in the wholesale market. This means that they will require a third party with a licence to participate in the wholesale market on behalf of the DNO/TSO able to operate the battery. This party could be part of the DNO/TSO, but only if it is ring-fenced appropriately (UKPN, 2014b). Adding a third party to the business case brings complexity (transaction costs) and requires that each party must make a return from the operation to make the arrangement worthwhile.

This barrier, together with the unbundling requirements, only allows DSOs/TSOs to obtain value from deferring an investment in the system. They are not allowed to trade in electricity markets so they cannot obtain benefits from the other potential revenue streams. They need to add third parties through complicated contractual agreements that decrease the attractiveness of the investment as the benefits have to be split between the parties.

Case study: UKPN Smart Network Storage Project

To illustrate these problems the case study of UKPN Smart Network Storage (SNS) Project is explained. The SNS project involves a 6MW/10MWh Lithium-ion battery installed at the Leighton Buzzard primary substation. It is intended to defer the investment needed to reinforce the grid. The project is trialling the commercial arrangements needed to exploit the value of the services produced by EES.

UKPN holds a distribution licence. It owns, operates and manages three electricity distribution networks in the UK and it has more than eight million customers connected to its lines. Peak demand at Leighton Buzzard has exceeded "firm capacity"[9] several times since 2007. Furthermore, peak demand is forecast to continue to grow which means that a reinforcement of the network will be needed. As a distribution company, UKPN is responsible for this reinforcement. The conventional reinforcement option would be adding a 33kV additional circuit and a third 38MVA transformer (UKPN, 2013).

Instead, UKPN installed a battery with the purpose of deferring the needed upgrade at Leighton Buzzard. Moreover, this battery can give them access to additional revenues. The issue is that UKPN, to avoid distorting competition, is not allowed to take part in wholesale energy markets to charge/discharge the battery and operate the asset commercially to supply services such as frequency response. This requires the inclusion of two partners – Smartest Energy (SE) and Kiwi Power (KP) – in the business case.

[9] Firm capacity of a substation is the available capacity for that substation, given the transformer with the highest MVA rating having been switched out. The expected substation loads should not exceed the substation's firm capacity.

Smartest Energy is the entity chosen to access the wholesale market to charge/discharge the battery. UKPN and SE have an energy supply and tolling agreement. Thus, SE buys and sells the energy that UKPN needs. The benefit that SE gets from this is a fee, which UKPN has to pay.

The tolling agreement works in the following way: SE can take over control of the asset to use for buying and selling energy and get a certain outcome (pure arbitrage or reduction of imbalance risk) after pre-payment of a toll to UKPN. It is similar to a lease of the asset for a fixed (low-risk) fee. Thus, each week SE will issue a price together with an import/export profile which reflects when it would be profitable for them to schedule the use of the asset (i.e. determine its use). UKPN will compare this option with the other possible uses of the asset (selling ancillary services or providing security of supply) and, if this is the most beneficial, they will accept the offer from SE (UKPN, 2014a).

Regarding the other contract, UKPN has an aggregator services agreement with KP. KP aggregates small distributed energy resources to be sold in the Short Term Operating Reserve (STOR), Firm Frequency Response and Fast Reserve markets, run by the National Grid.

KP undertakes research and pricing information about the services provided. UKPN will notify KP about the availability of the asset and will dispatch the energy under KP instructions. UKPN receives a monthly report on sources of aggregation revenue from KP. KP charges a percentage of the revenue for its services (see UKPN, 2014a)[10].

[10] This is a simplified version of the complex arrangements between the different parties. More information can be found in the report published by UKPN (2014a).

This is a good example of the problems stated previously. Due to the unbundling requirements and the obligation not to distort competition, two more parties have to be included in the business case in order access to the multiple revenue streams that the battery can offer. Obviously, the project must be cost-effective for the three parties. Furthermore, these contracts have significant transaction costs. This decreases the value that UKPN could potentially obtain from its ownership of the asset.

An alternative business model studied by UKPN would be opening a tender process for third parties that would finance, own, build and operate the asset. The third party would have to provide security of supply when agreed with UKPN and, the rest of the time, they could use the asset to access additional revenue streams. The advantage for UKPN is that this would reduce significantly its construction, operational and commercial risks in the project. However, UKPN will lose the control over the asset, which could lead to an overuse of it to maximise profits at the expense of meeting its basic requirement to manage network peak capacity in the local area. Such an arrangement would directly compete with conventional grid upgrades that would be normally supplied by the UKPN.

While the unbundling requirements and the obligation not to distort competition affect mainly TSOs and DSOs, the barriers introduced in the following sections affect all entities.

5.4. Lack of markets or inadequate market design

Some of the services that EES can provide are not rewarded properly and, in some cases, they are not even remunerated at all.

Lack of data about ancillary services: Traditionally a lot of ancillary services have been procured under bilateral contracts. This makes it difficult for new storage facilities (and their investors) to value the services that they produce, or to get access to the market (THINK, 2012).

Non-remunerated services: Some ancillary services have to be provided for free by generators as a condition to connect to the grid, e.g. voltage control and black start in Germany and Spain. Only if additional voltage control is needed (enhanced voltage control) can providers be remunerated. Primary frequency regulation in Spain is not remunerated either. EES systems are capable of providing these services but, since there is no market for them, so they cannot obtain value.

Inadequate compensation methods: Secondly, existing compensation methods do not value the quality of the service provided[11]. In most cases, ancillary services are paid based on the availability of the asset to provide the service and the actual utilization of the asset. The faster and more accurate performance of EES systems providing flexibility services is not rewarded. Therefore, the current market design is more convenient for traditional flexibility providers.

The following table shows the different procurement and remuneration methods for ancillary services in the European countries analysed:

[11] By quality of the service, we mean, for example, the speed of the frequency response, hence the new enhanced frequency response product in the UK. This product requires response within 1 second (rather than the 5 seconds it might take a pumped storage facility to respond).

[Insert Table 3 here]

California presents similar problems. The markets for ancillary services are designed for traditional generators. They reflect the (often low) opportunity cost of withholding capacity from the wholesale energy market in order to provide other electricity products. A storage device, on the other hand, is designed to provide ancillary services and will, likely, not be adequately remunerated by existing payment regimes.

There are no enablers that allow operators to leverage unique characteristics of storage for some ancillary services (CESA, 2014). Therefore, not all potential benefits can be fully monetized.

Despite the implementation of Order 755, which only affects frequency regulation, the other ancillary services' compensation methods do not take into account speed and accuracy. This is a sign of a non-technology-neutral market that benefits traditional providers.

For instance, black start (recovery after an outage) is often not remunerated at all. Black start might be required at anytime, though perhaps not in at all (SCE, 2011). Similarly, in the case of voltage control, there is no remuneration while voltage remains within its normal range (FERC, 2012). Such non-explicit remuneration might be ok for an existing conventional generator, however it is not an adequate revenue stream for an EES facility.

Californian regulators admit that such distribution grid services are not well enough defined and open to competition in ways that EES could reasonably be expected to participate (CAISO et al, 2014).

Another issue affecting both Europe and California is that contracts are usually of a short-term nature, so they do not offer financial certainty about what the revenues from this source are going to be. The California Energy Storage Alliance (CESA, 2014) confirms that the lack of long-term contracts is another hurdle for developers, as it makes financing projects difficult.

Minimum technical requirements: As these markets were designed for traditional providers, minimum requirements for participating in them are a hurdle for EES systems. For instance, in Germany the minimum power requirement to provide secondary frequency regulation and spinning reserve is 5MW. In the UK, the minimum power is 3MW for STOR with a minimum duration of 2 hours (50MW and 15 minutes in the case of Fast Reserve). In Spain, at least 10MW has to be offered to provide secondary frequency regulation and spinning reserve (National Grid, 2015; regelleistung.net, and Ministerio de Industria, 2009). Thus, EES systems with less power capacity or duration cannot participate in these markets unless they are combined with other providers through aggregation.

The German Federal Ministry for Economic Affairs and Energy (BMWi, 2015, p.57) admits this problem in its white paper about the electricity market and states that the balancing market will be opened to new participants.

There are no such minimum requirements in California.

5.5. Lack of need for EES

The necessity of deployment of EES is not the same in the countries analysed. While in the UK and California the need for EES as a source of flexibility seems clear, in the case of Germany and Spain it is not so evident.

As Germany is in the centre of Europe, the German electricity market is closely linked to its neighbouring countries. It has an interconnection capacity of 20GW and this substantially reduces its need to manage supply and demand for electricity services within its own borders (BMWi, 2015).

Germany has managed the integration of VRES (so far) with modest changes to its power system. This is because it started with strong grid capacity, flexible coal plants and nuclear plants and a lot of interconnection with other countries with plenty of flexible generation themselves. According to Martinot (2015), the expectation among potential investors is that there is little requirement for EES in Germany until renewables provide more than 40% of electrical energy (Martinot, 2015). Agora (2014) also states that there will be no need for EES at the transmission level in the medium term. However, EES could have an important role at the distribution level as expensive expansions of the system could be avoided.[12]

Regarding Spain, it has an oversized power system. The peak demand in 2014 was 39GW and the power installed is over 100GW (REE, 2014). This has several consequences. First, there are many plants that are not operating, which decreases energy prices and makes it difficult to obtain any return from them. This results in

[12] Neither Martinot (2015) nor Agora (2014) takes into account the additional benefits of EES, such as reduction of GHG emissions or the increase of the efficiency of the system. This suggests a need for EES to be studied more in depth, taking into account all the additional effects of their deployment.

more risk for investments in new installations. Second, all this unutilized capacity can cover the flexibility needs of the Spanish systems. The average load factor of combined cycle gas turbines (CCGT) in 2014 was 51.2% (REE, 2014). This makes them perfect candidates to provide flexibility to the system.

Moreover, a significant increase in the share of VRES is not expected. Unlike the UK or Germany, Spain does not have a target to reduce its GHG emissions beyond the EU requirement. Furthermore, in 2013, subsidies for renewable energies were removed, which reduces the attractiveness of installing new plants[13]. This suggests EES is unlikely to be needed in the next decade.

The case of the UK is different. Its interconnection capacity is currently only 4GW – compared to the 20GW of Germany. At the end of 2014, the capacity installed in the UK was 85GW and the maximum load was 54GW (DUKES, 2015). The capacity margin is not as large as the one in Spain. Moreover, as a consequence of the Large Combustion Plant Directive[14] and the nuclear policy, 14 power plants that account for 16.9GW are expected to shut down (EnergyUK, n.d.). Therefore, new capacity will be needed to cover some of these closures.

This new capacity will consist mainly in VRES (and possibly nuclear plants) as the UK has to meet its target of 80% GHG emissions reductions by 2050 relative to 1990[15]. Therefore, the need for flexibility in the UK power system is expected to increase. There would be system savings arising from the installation of 2GW EES by 2020 (Strbac et al, 2014). National Grid is currently running (April 2016) an

[13] Real Decreto 2/2013.

[14] European Directive 2001/80/EC.

[15] Climate Change Act, 2008.

auction for a new enhanced frequency response product, which explicitly rewards the sort of very fast response that EES can provide.[16] The UK one of the most attractive markets for EES in Europe.[17]

Regarding California, significant changes are underway already. The state has ambitious targets for its share of electricity from renewables and it plans to retire (and/or repowering) 16 GW of aging gas-fired power plants (CPUC, 2013a). Against this background the regulator has identified the need for 4.6 GW of new flexible capacity, some of which could be EES.

6. Why are the prospects for EES better in California than in Europe?

As explained in the previous section, there are similar market and regulatory barriers in Europe and California. However, the deployment of the technology is much larger in California. As mentioned in the first section, there are currently 145 battery projects operating or announced in California, more than double the total number in the three EU countries analysed. The main reason is the significant progress in terms of regulation for EES at the national (federal) and state level in California. The following are the main regulatory changes that are boosting EES in California.

6.1. FERC Order 755: Pay for Performance

This Order, issued by the national Federal Energy Regulatory Commission (FERC) in October 2011, addresses the compensation method for frequency regulation with the purpose of having a non-discriminatory technology-neutral market. FERC requires market operators – such as the California Independent System Operator

[16] See http://www2.nationalgrid.com/Enhanced-Frequency-Response.aspx

[17] There are also significant developments in Ireland, where the regulator is currently designing 7 new ancillary services product markets which could provide sources of revenue for EES facilities (see DotEcon, 2015, for a discussion).

(CAISO) – to reflect in their compensation methods a capacity payment and a performance payment. The performance payment should reflect how fast and accurate is the response to the signal from the system operator. Tariff modifications proposed by CAISO were approved by FERC in November 2014.

This benefits fast-response assets like energy storage as, prior to this Order, they were paid the same as slow-ramp generators. EPRI (2013) estimated the effect that this Order would have in the cost-effectiveness of EES. The benefit/cost ratio would increase 18% at the transmission level and 13% at the distribution level. Besides, in the same report, they confirm that an installation providing only frequency regulation would be cost-effective.

6.1.1. FERC Order 784: Third party provision

This order, issued in July 2013, intends to promote competition in ancillary service markets. FERC Order 784 takes Order 755 requires public utility transmission providers to account properly for speed and accuracy in ancillary services. For example, if storage is determined to be three times more effective than a slower-responding fossil-based generator, then a utility that is self-providing with a slower generator must reserve three times the nominal capacity rating of storage (Lyons, 2013).

6.1.2. FERC Order 1000: Transmission Planning and Cost Allocation

With the application of Order 1000, non-transmission alternatives (NTA) – including energy storage – have to be taken into account in regional transmission planning processes. Under FERC Order 1000, NTA projects can now compete directly with new transmission lines, and the costs to develop NTA-type projects are now fully recoverable from the rate base (Lyons, 2013). According to Lyons, FERC Order

1000 may create a larger market potential for EES through T&D deferral/substitution than Order 755 and Order 784 have created for frequency regulation.

6.1.3. Assembly Bill 2514

In September 2010, the AB2514 was approved by Governor Arnold Schwarzenegger. The bill required the CPUC to adopt energy storage system procurement targets (by the end of 2015 and again by the end of 2020).

In October 2013, the CPUC issued Decision 13-10-040 with its procurement target. It requires the three largest Investor Owned Utilities (IOU) – Pacific Gas and Electric (PG&E), Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) – to procure 1325 MW of EES systems by 2020. The quantity to be procured is specified for each utility at different points of interconnection (transmission, distribution and customer) for 2014, 2016, 2018 and 2020 (CPUC, 2013b).

The EES systems installed must be cost-effective. The cost-effectiveness assessment has to be done on a project-specific basis and utilities can propose their own cost-benefit methodology.

This is the largest boost to EES globally so far and its effect will be seen not only in California but also internationally. The results to date are positive:

- In November 2014, SCE awarded more than 250MW of EES systems under the Local Capacity Requirement procurement, which has to be added to the requirement to procure 90MW under the AB 2514 (SCE, 2014).
- PG&E issued a Request for Offer (RFO) for 74MW of EES (PG&E, 2014). They have received more than 5000MW worth of applications which proves

the huge number of developers that want to participate in the Californian market (St. John, 2015).

- SDG&E issued a RFO for a minimum of 25MW of EES systems but allows for a maximum of 800MW of EES to be procured. So, similarly to SCE, it could end up with far more energy storage than the minimum required by CPUC (SDG&E, 2014).

California Energy Storage Roadmap (CESR)

The CESR was developed during 2014 by CAISO, CPUC and California Energy Commission (CEC). The roadmap, issued in December 2014, identifies five areas where challenges exist: planning, procurement, rate treatment, interconnection and market participation. Through stakeholder engagement, barriers and possible solutions are proposed. The document finally presents the actions that would need to be taken and their priority.

Workshops and conferences with industrial stakeholders were organised to gather comments from all the parties involved in the sector (including CESA, PG&E, SCE, SDG&E, NREL, developers, etc.).

7. Conclusion and Policy Implications

So, what needs to be done to improve the prospects for EES in Europe?

Definition and classification of EES: EES definition and the services that the systems can provide must be clarified by legislation. Otherwise, ownership and operational problems will not allow owners monetize all the potential value of EES and investors will not have clear sight of the revenues across the lifetime of the asset. The fact that EES is not defined in the European legislation gives responsibility to national regulators to decide what the role of EES can be as long as they demonstrate that the unbundling requirements are met.[18]

To reduce the uncertainty, EES must be defined in relevant European Directives. This requires extensive stakeholder consultation to be done effectively. The CESR carried out in California can be taken as an example. The final outcome should not compromise the fair functioning of the markets and should facilitate the selection of the most cost-effective solution for providing grid services.

[18] There are two examples in Europe where EES is treated differently when it comes to TSO/DSOs ownership and operation (UKPN, 2014b). In **Italy,** TSOs and DSOs are allowed to build and operate batteries[18]. They can do this where they can demonstrate that EES is the most efficient way to solve the problem they are addressing. In **Belgium**, TSOs and DSOs are allowed to have some level of control over EES facilities as long as market fairness and transparency is not put at risk.

Further study of the need for EES and the benefits from its deployment: The US and, particularly, California began to study EES early, and this has allowed them to make more progress with deployment of EES.[19] The European Commission and each country's government should study what the role of EES in their power systems could be, taking into account future developments related to renewable energy and grid upgrades. EES must be compared to traditional generation options, interconnectors and demand side response.

Additional benefits for society such as the improvement of air quality, reduction of GHG emissions, and the improvement in the overall efficiency of the power system must be included and valued properly in these analyses. This may be relevant in the case of Germany, as current research, e.g. Agora (2014) and Martinot (2015), is not clear about the necessity for EES in the country but does not take into account the factors mentioned above.

At this moment the UK, compared to Germany and Spain, is the country where public institutions are taking EES more into consideration, which may be a reflection of the actual need of the country for EES which is not so clear in the other two cases.

[19] Knowing if EES is actually needed and the benefits from its deployment compared to other alternatives is essential. EES started to be considered as an asset suitable for grid applications in the late 1990s/early 2000s in the USA. Since then, multiple studies on the topic have been undertaken. Some examples are as follows. A handbook of the different T&D applications of EES was published by the Electric Power Research Institute (EPRI) and the US Department of Energy (DOE) in 2003 and has been updated in 2013. In 2012, DNV-KEMA together with SANDIA developed the ES-Select™ tool, which aims to allow comparison of the value of different storage technologies. In 2012, CPUC approached EPRI to study the cost-effectiveness of EES in California in connection with AB2514. The DOE has a substantial EES program.

Creation of new markets for ancillary services: One of the main reasons why it is not possible to monetize all the potential value of EES is because there are no markets for some of the specific services that they can provide. This is currently the case for voltage control and black start in all jurisdictions analysed – except for black start in the UK. This is clearly an area where the EU can learn from the procurement processes for EES being undertaken in California. This may be changing in the EU, as the UK's national grid has recently announced a call for tenders to supply a new product to supply power within one second (known as Enhanced Frequency Response) from April 2016.[20] This is specifically defined to create a market for the sort of fast response that only EES can provide.

Some argue (THINK, 2012) that it is unlikely that voltage control and black start can be procured more efficiently given that it is a highly location-specific service and only a few units can provide the service. This could lead to abuse of market power by some participants. However, in future decentralised markets there will more potential providers such as distributed EES. Therefore, opening a market for these services should result in the most efficient option providing the service and cheaper procurement costs for the system operator. Thus, to enhance transparency and foster competition, the procurement method should be through tender process or spot market. This is important for developers to have reliable market signals in order to be able to estimate potential revenues.

It will be important however that the quantity to be procured in any new competitive process does not exceed what is necessary, and that markets are not put in place to

[20] See http://www2.nationalgrid.com/Enhanced-Frequency-Response.aspx Accessed 19 February 2016.

facilitate new technologies (such as EES) which cannot provide the required services at any lower cost than traditional providers (Rebours, 2007).

Technology-neutral market design: Both existing and new markets should be adapted to the new technologies that can access them. They must be technology-neutral. Markets have to be designed to capture all the value that each technology provides to the system. EES has the ability to provide ancillary service faster and more accurately than traditional generation units, and this is not reflected by market designs. Order 755 "Pay for Performance", implemented in the USA, ought to be taken as an example.

Currently, EES systems that do not meet the minimum requirements have to be aggregated with other assets, which reduces the monetizable value of the installation. This implies that the minimum requirements to participate in the market should be reviewed to open the market to other potential providers such as EES.

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Country/State	Li-ion batteries	Flow batteries	Lead-Acid batteries	Na-based batteries	Others	Total
California	122	9	2	7	5	145
The UK	13	1	6	2	-	22
Germany	16	5	2	2	4	29
Spain	6	1	1	-	6	14

Table 1. Electrochemical battery projects under operation or announced (DOE, 2015)

Country	System Operator	Model
UK	National Grid Electricity Transmission plc	OU
	Scottish Power Transmission Limited (SPTL)	ITO+
	Scottish Hydro Electric Transmission Limited (SHELT)	ITO+
Germany	50Hertz Transmission GmbH	OU
	TenneT TSO GmbH	OU
	TransnetBW	ITO
	Amprion GmbH	ITO
Spain	Red Electrica de España SA	OU

Table 2. TSO models in the UK, Germany and Spain (Bundesnetzagentur, 2013)

Service	The UK		Germany		Spain	
	Procurement	Remuneration	Procurement	Remuneration	Procurement	Remuneration
Primary Frequency Control	Tendering	Pay as bid	Tendering	Pay as bid	Compulsory	None
Secondary Frequency Control	-	-	Tendering	Pay as bid	Spot Market	Clearing price
Spinning Reserve	Tendering	Pay as bid	Tendering	Pay as bid	Spot Market	Clearing price
Voltage Control	Compulsory and tendering	Pay as bid	Compulsory	None	Compulsory	None
Enhanced Voltage Control	Tendering	Pay as bid	Bilateral Contracts	Pay as bid	Tendering	Regulated price
Black Start	Bilateral Contract	Pay as bid	Compulsory	None	Compulsory	None

Table 3. Procurement and remuneration methods in the UK, Germany and Spain (Ministerio de Industria, 1998, 2009, 2014; Rebours et al, 2007; National Grid; regelleistung.net; Castro, 2013)

List of acronyms

AB2514	Assembly Bill 2514
AGC	Automatic Generation Control
BMWi	Bundesministerium für Wirtschaft und Energie
CAES	Compressed air storage
CAISO	California Independent System Operator
CCGT	Combined cycle gas turbine
CEC	California Energy Commission
CESA	California Energy Storage Alliance
CESR	California Energy Storage Roadmap
CONE	Cost of New Entry
CPUC	California Public Utilities Commission
CSP	Concentrated Solar Plant
DOE	Department of Energy of the USA
DSO	Distribution System Operator
EES	Electrical energy storage
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse gases
IOU	Investor Owned Utilities
ISO	Independent system operator
ITO	Independent transmission operator
KP	Kiwi Power
NREL	National Renewable Energy Laboratory
NTA	Non-transmission alternative
OATT	Open Access Transmission Tariff
OU	Ownership unbundling
PG&E	Pacific Gas and Electric
PHS	Pumped hydro storage
PV	Photovoltaics
REE	Red Electrica de España
RFO	Request for Offer
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SE	Smartest Energy
SHELT	Scottish Hydro Electric Transmission Limited
SNS	Smart Network Storage
SO	System Operator
SPTL	Scottish Power Transmission Limited
STOR	Short Term Operating Reserve
T&D	Transmission and Distribution
TSO	Transmission System Operator
UKPN	United Kingdom Power Networks
VRES	Variable renewable energy sources
VRFB	Vanadium Redox Flow Battery