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On the Role of Regulatory Policy on the Business Case for Energy Storage in Both EU and UK Energy Systems: Barriers and Enablers

Ahmed Gailani *, Tracey Crosbie, Maher Al-Greer, Michael Short and Nashwan Dawood

School of Computing, Engineering and Digital Technologies, Teesside University, Middleborough TS1 3BX, UK; T.Crosbie@tees.ac.uk (T.C.); M.Al-Greer@tees.ac.uk (M.A.-G.); M.Short@tees.ac.uk (M.S.); N.Dawood@tees.ac.uk (N.D.)

* Correspondence: a.fakhri@tees.ac.uk; Tel.: +44-(0)-16-4221-8121 (ext. 3660)

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Abstract: This paper presents a SWOT analysis of the impact of recent EU regulatory changes on the business case for energy storage (ES) using the UK as a case study. ES technologies (such as batteries) are key enablers for increasing the share of renewable energy generation and hence decarbonising the electricity system. As such, recent regulatory changes seek to improve the business case for ES technologies on national networks. These changes include removing double network charging for ES, defining and classifying ES in relevant legislations, and clarifying ES ownership along with facilitating its grid access. However, most of the current regulations treat storage in a similar way to bulk generators without paying attention to the different sizes and types of ES. As a result, storage with higher capacity receives significantly higher payment in the capacity market and can be exempt from paying renewable energy promotion taxes. Despite the recent regulatory changes, ES is defined as a generation device, which is a barrier to a wide range of revenue streams from demand side services. Also, regulators avoid disrupting the current energy market structure by creating an independent asset class for ES. Instead, they are encouraging changes that co-exist with the current market and regulatory structure. Therefore, although some of the reviewed market and regulatory changes for ES in this paper are positive, it can be concluded that these changes are not likely to allow a level playing field for ES that encourage its increase on energy networks.

Keywords: energy storage; regulatory barriers; storage policy; market regulations; SWOT analysis

1. Introduction

Climate change concerns are encouraging the international community to adopt policies to decarbonise the energy system by increasing the reliance on renewable energy sources (RES) such as wind and solar [1]. EU policies, for example, aim to increase the total consumed energy provided by RES to 20% in 2020 and 50% in 2050 [2,3]. Reflecting this, the total installed wind and solar energy capacity in the EU-28 countries increased by 104.1 GW and 100.4 GW in the last 10 years respectively [4]. By 2030, it is expected that the total wind and solar installed capacity in the EU will reach 327 GW and 270 GW respectively [5]. This increased penetration of RES in the electricity system poses network balance challenges to grid operators due to the intermittent nature of many clean energy sources such as PV and Wind turbines [6–8]. Also, it leads to increased reserve capacity [9], increased electricity system costs [10] and reduced system adequacy [11]. To ensure power system stability while allowing a high share of RES, several methods have been utilised such as demand side management [12], the introduction of capacity markets [13], and smart grid initiatives [14].

Energy storage (ES) is widely recognised as a key to resolve RES's intermittency by enabling electrical energy to be stored at the off-peak times and released during peak demand periods [15].

It is expected that the total global ES capacity needs to be tripled to reach 15.72 TWh if the share of RES is to be doubled in the energy system by 2030 [16]. Many studies evaluated the technical, economic and environmental performance for ES systems to identify their suitability to various grid applications [17–20].

Amongst the different types of ES systems, battery energy storage system (BESS) is interesting because of its suitability to many applications in grid-connected electricity networks such as peak shaving [21], energy arbitrage [22], reserve capacity [23], and frequency regulation [24] amongst many others. Furthermore, battery materials are constantly improving over the years to account for degradation [25], and its capital cost is expected to decrease over the next years. Bloomberg predicts that the price of battery energy storage system (BESS) for grid applications will be $70/kWh by 2030 in line with market growth for ES represented by a $620bn investment by 2040 [26]. As such, this work is concerned with BESS in particular when analyzing market and regulatory changes, and the different types of ES are beyond the scope of this paper.

BESS has the opportunity to provide different services across the electrical network if these services are technologically and operationally compatible [27]. However, despite these benefits, large-scale deployment of BESS on EU energy networks is hindered due to regulatory and market barriers that prevent storage from stacking multiple services across different markets [28,29]. Recent research [30] analysed the business model of two different BESSs and concluded that the current legislation in Europe hinders their value proposition in energy markets. Other researchers argued that the current regulatory framework forces storage developers to choose certain business models that may not be economically feasible [31]. The argument being that a reduction in capital cost of BESS technologies alone will not lead to an increase in their applications on energy networks [16]. As such, there is a need to mitigate market and regulatory barriers to make BESS commercially viable in different markets.

Energy regulators recognise the necessity of ES in modern energy networks and are exploring ways to enhance its business case. The European Commission (EC) recognises ES as a key component to accelerate clean energy transformation and is proposing a number of regulatory changes in [32]. Some of which have been adopted by UK's energy regulator (OFGEM) including: (i) defining 'Electricity Storage' in the main legislation; (ii) removing the double network and balancing charges for storage; (iii) co-locating storage with renewable generation sites that are supported through consumption levies policies; (iv) limiting storage operation by network owners; (v) facilitating ES planning permission and (vi) employing de-rating factors for storage in the capacity market (CM) [33].

The research presented here reviews the current proposals to amend the regulations governing ES and explores how these changes impact on business models for BESS taking the UK's regulator changes as a case study. This study applies the 'SWOT' analysis to examine the strengths (S), weaknesses (W), opportunities (O), and threats (T) of the future regulatory framework of ES in the UK and, by extension, in the EU since the regulatory changes are similar. Qualitative data from the EC, the UK government, energy regulators, journal articles, and reports are utilised to examine the internal (S/W) and external (O/T) factors concerning the proposed regulatory changes. Such analysis is vital to provide ES with a clearer insight into the regulatory framework surrounding future business cases for ES.

It should be noted that although we analyse the impact of the recent market and regulatory changes on the business case of BESS in particular, energy regulators are taking a neutral approach. Thus, the recent regulatory changes designed to support an increased use of ES on energy networks are equal for all types of ES including BESS.

The remainder of the paper is structured as follows: Section 2 provides an overview for ES classification; Section 3 reviews the main market/regulatory aspects that affect the business case of BESS and the regulators' proposed solutions; Section 4 presents SWOT analysis as a method; Section 5 presents and discusses SWOT analysis results; Section 6 provides a summary of the paper's findings and discusses the 'Brexit' issue; and Section 7 provides concluding remarks.

2. Energy Storage Classification

ES devices can convert electrical energy into several forms that can be stored and converted back to electrical energy again. The main types of ES systems can be categorised based on their storage form, storage size, and discharge time along with their applications. These are illustrated in Figure 1. The main types of ES depending on the stored energy are mechanical, thermal, electrochemical, hydrogen, and electrical. Depending on the application needed, the amount of energy/power required and the application suitable for discharge/charge time, a suitable storage type can be chosen. For instance, Pumped Hydro Storage (PHS) provides bulk power management normally associated with the electricity generation plants.

It can also be seen from Figure 1 that BESS represented by the different types of batteries can provide services across all the electricity network whether it is for short duration power supply, transmission/distribution or bulk power management. Recently, Lithium ion batteries have been used also to provide 100 MW bulk power management for the electricity grid in South Australia [34]. Many network operators use BESS to support grid reliability and initiate services to help BESS quantify its value. For example, a number of distribution network operators (DNOs) in the UK have successfully piloted several BESS technologies for different grid applications, such as peak shaving, voltage support, and renewable constraint management [35]. Therefore, the market and regulatory changes needed to increase the share of ES on energy networks should consider the different types, applications, and capability of ES.

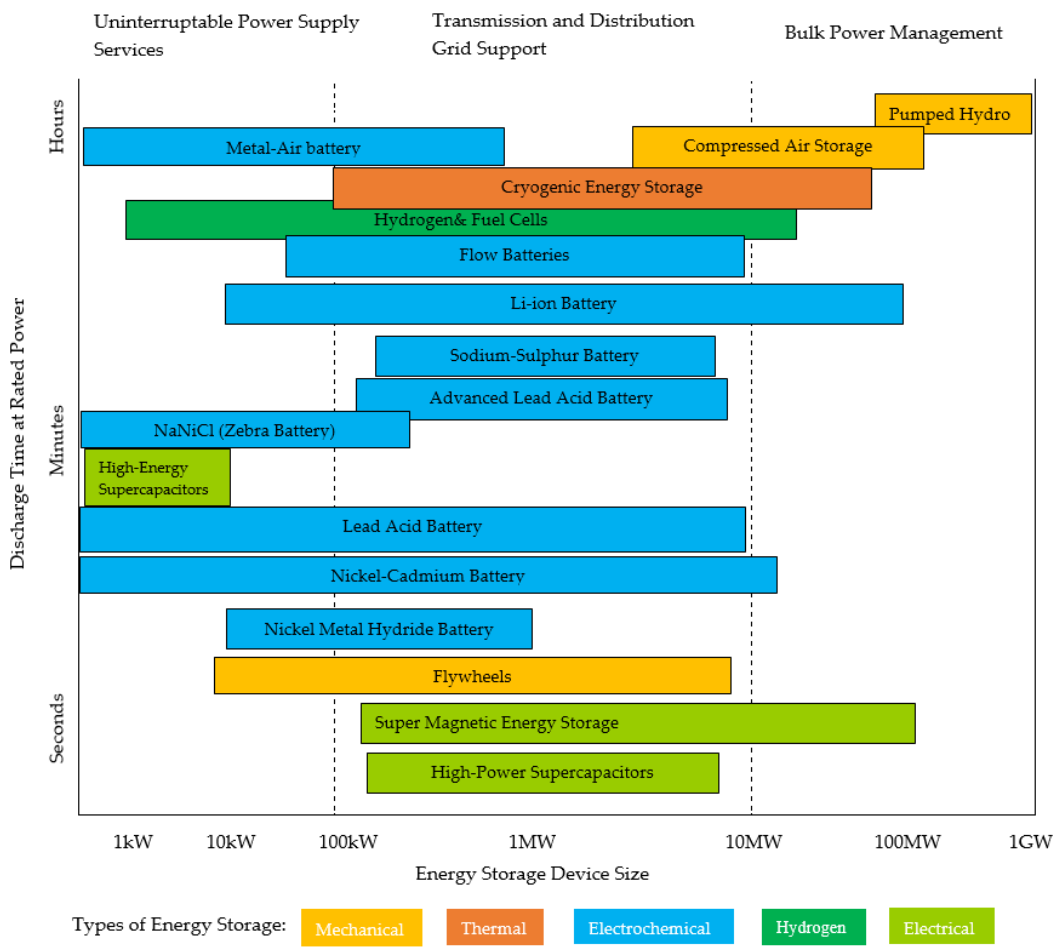

Figure 1. Classification of energy storage systems by the form of stored energy along with their power capacity, discharge time, and applications, adopted from [36].

3. Market and Regulatory Changes for Energy Storage

Market and regulatory barriers for ES in the EU and UK level are summarised in Table 1 as reported in earlier research. The following subsections analyse recent EU and UK regulatory changes that are being considered and/or implemented to mitigate some of these barriers.

Table 1. The main regulatory and market barriers for Energy Storage deployment in the EU/UK.

The Barrier to Energy Storage Deployment	References
The absence of ES definition and classification	[29,37–47]
Storage ownership by network operators	[37,38,40,41,43,45,46,48,49]
Payment of double network fees	[29,37,38,41,44,46,50,51]
Payment of final consumption levies (FCLs)	[37,38,43,46]
Lack of ancillary services remuneration	[29,37–41,43,52]
Reserve market requirements	[29,38,39,45]
Fixed electricity pricing	[37,43,53]
Absence of direct subsides	[29,38]

3.1. Definiation and Classification of Energy Storage

ES is not explicitly defined in most electricity markets as an activity or an asset. Therefore, it differs from other activities in the electricity market such as generation, transmission, distribution and supply. Historically, PHS is classified as a generation asset. This has resulted in all types of ES being classified as generation assets. According to EU Directive 2009/72/EC, ES is an "asset that produces electricity". Similarly, the UK Electricity Act 1989 provides a broad definition of the process of electricity generation as "generating at a relevant place". While this definition and classification may be adequate for large-scale ES such as PHS it poses investment risks for BESS because it limits the applications that ES can provide to those relating to generation.

BESS have a shorter lifecycle and lower energy capacity than PHS [54], making them suitable to help network operators effectively manage distribution and transmission networks in line with integrating distributed generators. Therefore, some network operators suggest creating an independent asset class to ES that identifies storage as a solution to integrate RES rather than competing with traditional generations [55]. Other network operators have proposed many solutions to the storage definition barrier for BESS by suggesting [56]:

- Defining storage as a discrete activity or asset class to ensure investment certainty.
- Introduce storage provisions within the distribution license so network operators can be free from some generation license rules.

EC proposed a definition for ES states that "Energy storage in the electricity system means the deferring of an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier" [32]. Similarly, OFGEM's proposed definition states that "Electricity Storage in the electricity system is the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy in a controllable manner" [57]. Both OFGEM and EC believe that storage should continue to be captured by the generation license in order not to distort competition.

3.2. The Interaction of Storage with Final Consumption Levies

The competitiveness of ES technologies are affected by policies that encourage RES deployment. For example, in Germany, there is no incentive for wind farm operators to store the energy generated because they are paid 95–100% of the relevant wind Feed in Tariff (FiT) for the curtailment of that energy [46,58]. In the UK, FiT, Renewables Obligation (RO), Contract for Difference (CfD), and Climate Change levy (CCL) are examples of FCLs policies introduced to encourage the deployment of RES. Consumers and storage are charged these levies for storage when importing electricity. However, it is argued that ES is not the final consumer of energy and should be exempted from such levies that increase the operational cost for storage owners [33]. It is found that the cost of RO and FiT levies accounts for 80% of all non-energy-related supply costs when charging a commercial grid-scale battery [59]. OFGEM recently proposed that any storage owner with the newly modified generation license (that define ES and its characteristics) could be exempted from paying those FCLs, if the main purpose of storage is to export electricity to the grid only (not for a self-consumption) [57]. If, however, an owner is exempt from obtaining a generation license, the payment of FCLs is still required (A generator and by extension a storage device could be exempt from applying for a license if it is generating at a rate below 100 MW in England and Wales).

3.2.1. Energy Storage Treatment in FiT/RO Sites

FiT is a scheme used to encourage customers and businesses to generate their own electricity from RES and be paid if there is energy surplus. RO works alongside FIT where electricity suppliers are obliged to buy certain amounts of electricity generated by large renewable generation plants. In both FiT and RO schemes, the technology type used, its installation, and capacity play a role in deciding the tariff rate, eligibility criteria and consequently the payment received by the owner [60,61]. Since the storage is essential for some technologies such as solar PV, it is the case of putting the accreditation at risk if storage is installed on FiT/RO sites. For example, if a battery is integrated with a PV solar site and a metering arrangement is installed in a way that leads the owner to receive payments from the electricity exported from the grid to the storage.

OFGEM'S recent regulations state that storage installation in FiT/RO sites should be permitted if the purpose of storage is to store electricity generated by renewable sources only and if the total contracted capacity is not changed [62,63]. To comply with these conditions, certain electricity meter arrangements need to be in place to distinguish between the imported and exported electricity.

3.2.2. Energy Storage Treatment under CfD

The basis of a CfD contract is to receive payment on the (clean) electricity generated by the CfD facility. Hence, if storage is defined within that CfD facility, there is a possibility for electricity to be imported from the grid, which cannot be necessarily generated by RES, and poured into it at another time (export time), which compromises the contract.

Two proposed options were introduced to mitigate this problem by the UK government [64]. First, any storage device in a CfD facility needs to be registered in a separate metering unit to ensure storage independency of the CfD facility. Second, storage can be registered in the same metering unit of a CfD facility only if certain metering arrangements are in place that prevent storing electricity other than that generated by the CfD facility generation equipment.

3.2.3. Energy Storage Interaction with the CCL

A climate change levy exempt certificate (LEC) can be issued if the electricity is generated by RES. Therefore, if the ES device imports electricity (from non-LEC generator), then a CCL is applicable. The worst scenario is if ES imports electricity (from non-LEC generator) and then exports that electricity to an industrial user, resulting in a double CCL being incurred by the end-user.

There is no regulatory clarification from the UK government about the above issue. However, based on the aforementioned regulatory changes, it is expected that storage will not pay the CCL when importing electricity but still pays the CCL as a generator.

3.3. Network Charges for Energy Storage

Generators, suppliers and consumers of electricity are required to pay network and balancing charges to cover the ongoing network costs. With the absence of clear EU legislation regarding the charging arrangement of ES, some countries (the UK, France, Germany, The Netherlands) impose double network charges for ES, once when charging and the other when discharging [65].

In the UK, if the storage capacity is above 100 MW (large-scale), two sets of Transmission Network Use of System (TNUoS) and Balancing Services Use of System (BSUoS) charges are incurred by the storage if it is connected on the transmission network. If the storage capacity is below 100 MW (small-scale) and connected on the distribution network, only Distribution Use of Services (DUoS) charges will be paid either based on the Common Distribution Charging Methodology (CDCM) or Extra High Voltage Distribution Charging Methodology (EDCM) rates. However, the current distribution charging methodology seems inconsistent. For instance, the CDCM charge for a recent storage project over 8 months was £54,149, while the EDCM charges over the same period were £10,668 [56]. Therefore, connecting storage to extra voltage lines is more cost-effective than high voltage lines.

OFGEM presented several solutions for the charges discusses above to support a level playing field for ES as equal to other generation technologies [66,67]. These changes are listed below and presented in Figure 2.

- Removing the TNUoS demand and generation residual charges;
- Removing DUoS demand residual charges;
- Removing BSUoS demand charges;
- Introducing new fixed charges to cover the increased implementation of 'behind the meter' storage.

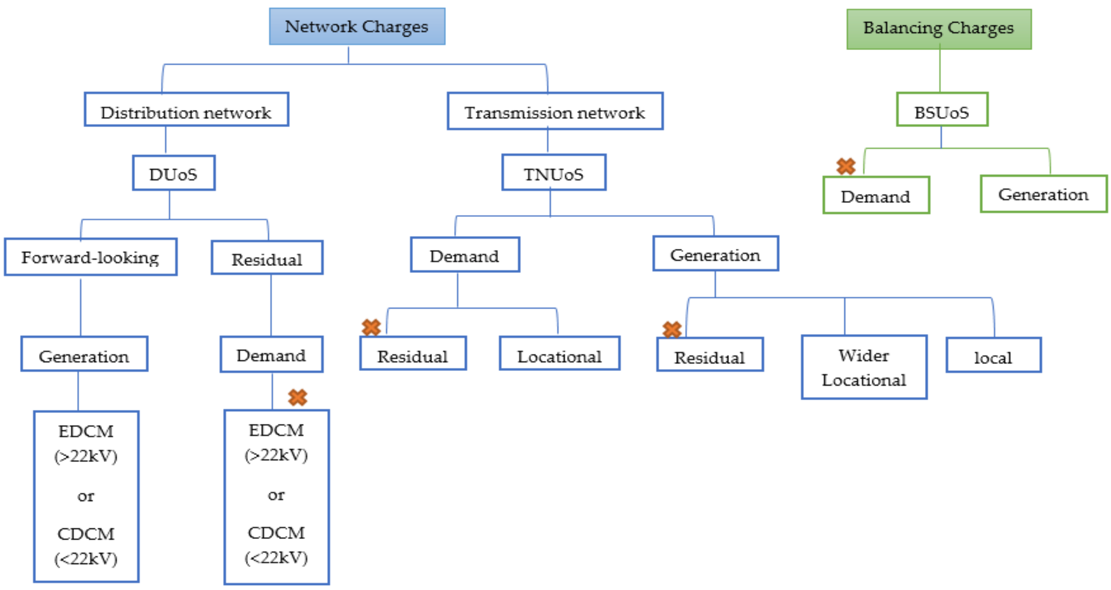

Figure 2. Network and Balancing system charges in the UK's electricity system, adopted from [68]. (x) means removed for ES per new legislations.

3.4. The Treatment of Energy Storage in the Capacity Market

The participation of ES in the CM is important to its business case [69]. Yet, the ability of ES to provide the necessary energy adequacy has been questioned due to its limited discharge capacity. As such, ES participation in this market is limited in some EU markets (for example, Ireland, Italy, Germany, France, Denmark, and the UK) [45]. For instance, ES was secured at a total of 3.2 GW in the UK's CM Tier-4 auction in 2016 in which 0.5 GW came from BESS [70]. In 2017, a study by the system operator found that a stress event could last for 2 h in the UK while the maximum duration of the current storage response is 30 min. This leads to linking the de-rating factor to the maximum discharge duration of storage [71], which means that maximum payment that a 0.5-h duration storage can receive is only 21.34% compared to 96.11% payment for a 4 h+ duration storage.

3.5. Energy Storage Ownership

The typical liberalised electricity market structure is illustrated in Figure 3. In this structure, transmission and distribution network operators (DNO, TNO) are legally required to separate network and non-network activities so as not to distort competition, which is referred to as 'Unbundling'. As storage is defined as a generation asset, this means that network owners cannot own, develop, manage, or operate storage assets for grid balancing or reinforcement under the EU rules, other than in the case of a few exceptions [72]. However, there is a lack of clarity regarding these exceptional circumstances leading to this rule being implemented differently in different EU's member states. For example, In the UK, if ES capacity is less than 100 MW, network operators can apply for a generation license exemption, thus owning storage [31]. Also, the Italian system operator (Terna) is granted permission to own and implement several ES projects to relieve the transmission network congestion [73]. This unclear ownership and operation status of ES creates uncertain investment environments, particularly for network operators.

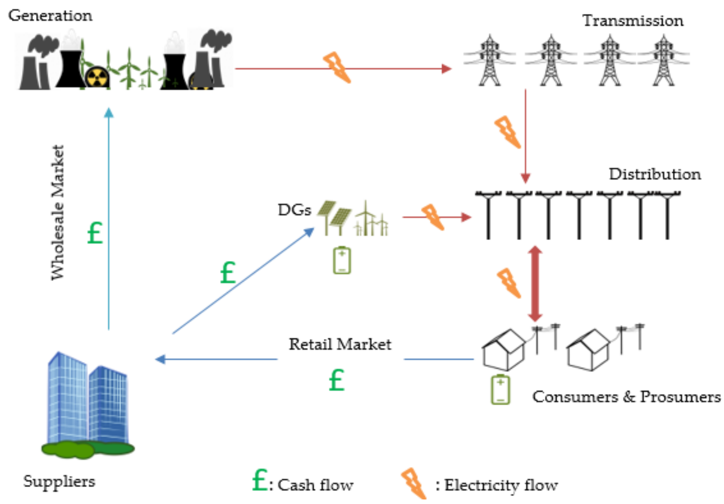

Figure 3. Example of a liberalised electricity market structure.

OFGEM aims, in line with the EC proposals, to strengthen the unbundling requirement by requiring separation of operation for storage assets owned by network operators even if it is below 100 MW (license exempted), while considering preventing DNO's ownership to storage in the near future [32,74]. Consequently, for now, storage can exceptionally be owned by network operators to provide services but not for trading in the electricity markets or provide balancing services.

3.6. Energy Storage Planning System

When network operators identify ES as a key solution to provide services to the network or prevents costly network expansions, ensuring access to infrastructure with appropriate time scale by the planning regimes is important. The EC is clear that storage should be granted access to grid infrastructure in a non-discriminatory way. Large-scale ES projects that are above 225 MW are included in the EU's cross-border infrastructure projects that link the energy system in at least two EU countries [75]. However, it remains unclear how small-scale ES such as BESS is to be treated in the planning system.

At the UK level, the government published a consultation to clarify the planning regimes for energy storage (small and large-scale) as follows [76]:

- If ES capacity is below 50 MW, the storage developer obtains planning consent from the local council.
- If ES capacity is above 50 MW, it is regarded as a nationally significant infrastructure project, and thus, storage owners obtain consent from the government.

- If storage is included in a composite project with other forms of generation, and the capacity of each of this installation is below 50 MW, this falls under the local planning regime.

4. SWOT Analysis Method

Earlier research published in [38] categorised 16 investment barriers that can be linked to four main regulatory and public attitudes barriers for ES. Since then, energy regulators in the EU and UK have acted to mitigate some of these barriers as detailed in the previous section. However, for the previous discussions, it is evident that the future of ES in national networks is not clear due to complex and interlinked market and regulatory changes. In an attempt to add further clarity to this issue, this study presents a SWOT analysis to highlight the future business potential of BESS in the future considering the recent market and regulatory changes.

A SWOT analysis, although criticised [77], is a widely used strategic planning tool that supports business to evaluate the strengths, weaknesses, threats, and opportunities of a proposed project [78]. Research into energy networks has been used to assess energy technologies [79], evaluate national policies [80] and assess international policies [81].

The SWOT analysis examines helpful and harmful aspects of the recent regulatory changes. The internal factors (Strengths/Weaknesses) are the direct regulatory and market changes proposed by energy regulators that affect storage's business avenue. External factors (Opportunities/Threats) are those affecting storage's business potential because of the indirect aspects beyond the stated market and regulatory changes. It should be noted, however, that SWOT analysis may provide incomplete qualitative examination such that the assessment may be subjective. As such, in this paper, all the SWOT analysis assessments will be supported by earlier research or quantitative reports.

5. Results

Table 2 provides the results and the general structure of SWOT analysis while more details and discussions of the results are provided below.

Table 2. SWOT analysis of the market/regulatory changes for ES in the UK.

Factors	Helpful to Storage Business Case	Harmful to Storage Business Case
	Strengths	Weaknesses
Internal	• Removing double network charges • ES co-location with FCLs sites • Facilitating grid access for ES	• ES definition and classification • Strengthen the unbundling requirements • Payment of FCLs for small-scale ES (<100 MW) • Employing de-rating factors in the capacity market • Introducing fixed charges for behind the meter ES
	Opportunities	Threats
External	• Encouraging private parties' investment in ES • Ancillary services aggregation	• High capital cost • Cannibalisation of revenue streams available for ES

5.1. Strengths

5.1.1. Removing Double Network Charges

The network and balancing system charges need to be included and paid by ES owners as part of operational costs for importing/exporting electricity to the grid. For example, the total cost of DUoS charges for one ES project owned by a DNO was found to be between £64,900 to £80,500 per annum, which is not cost-reflective [82]. Moreover, the TNUoS demand and generation residual charges represent approximately 80% of the total transmission network charges [68]. As such, removing these charges is a step forward towards reducing the operational cost for ES.

5.1.2. Energy Storage Co-Location with Final Consumption Levies Sites

Policies that support the deployment of low carbon technologies such as FiT and RO have significantly increased the uptake of RES across EU countries [83]. This makes ES co-location with RES essential to match the electricity supply and demand [84]. The new OFGEM regulations allowed ES to be co-located with FCLs sites without compromising the accreditation of these schemes. This triggered many positive responses from the industry and trade associations, because this means, for example, that home PV owners can install ES without the fear of compromising FiT payment scheme [85].

5.1.3. Facilitating Grid Access for Energy Storage

One of the factors affecting the investment decision in ES is the infrastructure access for the device and consequently the planning application. As discussed earlier, OFGEM has recently facilitated the planning regimes for ES technologies with a capacity below 50 MW by allowing ES developers to obtain planning permission from the local council. This is positive legislation for two reasons. First, the average capacity of the current and planned ES technologies projects is 27 MW, which is significantly below 50 MW [86]. Second, the composite projects that have total capacity above 50 MW (for example a generation unit with 40 MW and ES with 40 MW) are also applying for planning permission from the local council. This reduces the additional consent time (1–2 years) as well as the cost of application when compared to the application set at the national level [76].

5.2. Weaknesses

5.2.1. Energy Storage Definition and Classification

A unified and explicit definition for ES in the related legislations is a basic step to create certain investment environment. This clarifies the ownership and operation issues for ES. It also allows ES owners to have a clearer view over the available revenue streams during ES lifetime. However, ES definition proposed by both the EC and OFGEM limits its services related to generation. For instance, if a battery is used to curtail a wind turbine's surplus energy, it is exporting rather than generating electricity, which is a service to balance the system. The word 'generated' in the EU definition (see Section 3.1) implies that ES is a generation asset and therefore does not recognise other potential services and applications (please see Figure 1).

Classifying BESS as a generation asset puts it in direct competition with traditional bulk generators. This undermines its business case because BESS cannot trade in a large wholesale market as a generation asset due to its low capacity and low technical maturity [40]. Moreover, a unified ES definition is absent at the EU level due to national differences that prevent a fully integrated EU market design [37].

The current EU and UK ES definitions and classifications fall short behind California state legislation of ES services. The Assembly Bill No 2514 provides the following list of conditions applicable to ES that allow it to provide multiple services across the electricity network [87]:

- The ES system can be centralised or distributed.
- The ES system may be owned by a load serving entity, a customer, a third party, or local publicly-owned electric utility.
- The ES system can provide generation, transmission and distribution services.

5.2.2. Strengthen the Unbundling Requirements

If network operators are prevented from owning ES of any size, all ES devices connected to the distributing or transmission network will have to be operated by a legally separate party from the network operators. However, many DNOs have already installed ES devices in parts of their networks to defer conventional network upgrades and provide ancillary services. The latter have been shown to reduce the energy costs for customers and enhance network efficiency [35]. Some of the ES projects in the UK including their capacity, locations, ES type, and the type of the business model used are summarised in Table 3 [88–94]. Based on Table 3, two weaknesses can be noticed to this regulatory change. First, most DNOs are using smaller-size BESSs to increase network efficiency based on the 'DNO merchant' business model (this business model allows the DNO to procure and fully operate the storage device, and thus, use the storage services on its network and needs), which will not be legally valid if strengthening the unbundling requirements comes into force. Second, even though DNOs used 'DNO contracted' (the DNO procures, owns and operate the storage asset and use it in certain times only while a third party can have a contractual agreement with the DNO to commercially use the asset) and 'contracted services' (a third party procures, owns and operate the storage asset then sell the services to the DNO) business models for larger size BESS, they needed to enter into a complex contractual agreement with third parties to make revenue streams in the market because each party involved with the DNO needs to make a profit, which reduces the overall revenue.

Table 3. Some of BESS projects in the UK including their capacity, locations, type, DNO name, and the type of the business model.

Project Name	Capacity and Locations	ES	DNO	Type of BM
CLNR	RiseCarr: 5 MWh, H.Ngate: 0.2 MWh WoolerRamsay: 0.2 MWh Maltby: 0.1 MWh, Wooler St. Mary: 0.1 MWh Harrowgate Hill: 0.1 MWh	Li-ion	NPG	DNO Merchant
Short-Term Energy Storage	Hemsby: 200 kWh/200 kW	Li-ion	UKPN	DNO Merchant
SNS	Leighton Buzzard: 6 MW/10 MWh	Li-ion	UKPN	DNO Contracted
FALCON	Milton Keynes: 100 kWh	$NaNiCl_2$	WPD	DNO Merchant
Orkney Park	Kirkwall: 500 kWh, 2 MW	Li-ion	SSEPD	Contracted Services
NINES	Shetland Iceland 3 MWH, 1 MW	Lead-Acid	SSEPD	DNO Merchant
Low Voltage Connected Energy Storage	Chalvey, Berkshire 2 kWh, 25 kW	Li-ion	SSEPD	DNO Merchant

5.2.3. Payment of FCLs for Small-Scale ES

Large-scale ES are exempted from paying FCLs, which is seen as positive in determining its commercial availability [95]. However, this is not in favor of BESS given that the power is 50 MW for the largest battery energy storage project in Europe [96], and the average capacity of the current and planned ES technologies projects is 27 MW [86]. It has been demonstrated that the payment of these FCLs by ES can cost up to £20k–£50k per annum for the SNS project in Table 3 and makes the project's business model unprofitable outside the peak demand months [89].

5.2.4. Employing De-Rating Factors in the Capacity Market

Before introducing the de-rating factors to ES in this market, its participation was not penalised according to its discharge capacity, which meant that all storage devices received full payment of the clearing price. However, due to de-rating factor changes, discussed in Section 3.4, BESS participation in this market has decreased. For instance, in the T-4 auction of 2018, only 158 MW of BESS have secured a contract compared to 500 MW in the previous auction [97]. As depicted in Figure 4, the number of 0.5 h and 1 h duration batteries decreased from 40 and 91 in T-1 2018 auction to 17 and 32 in the T-1 2019 auction respectively. Moreover, the number of 1.5 h duration batteries increased from 8 in the T-4 2021 to 18 in the T-4 2022. This is in line with first time appearance of 11 and 2 batteries providing 3 h and 4 h discharge duration, respectively. The decline in the shorter duration storage (0.5 h and 1 h) and the increase in longer duration storage (1.5 h, 3 h, 4 h) may be a result of other services commitments. However, it is an indication of a regulatory change that encourages the battery industry to increase its energy and power density by introducing higher payment for longer duration storage.

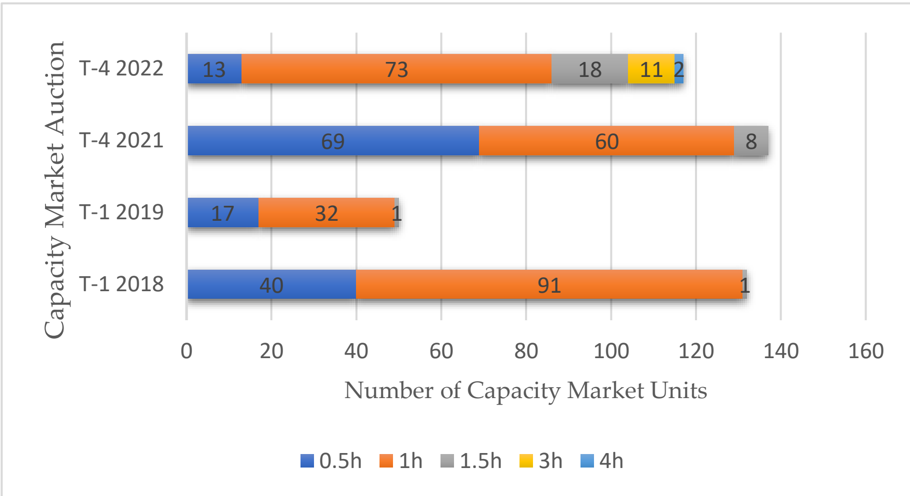

Figure 4. The number of batteries participating in the UK's capacity market from T-1 2018 to T-4 2022 as reported in the CM register (adopted from [98]).

A basic rule of the CM requires participants to remain ready in case of a system stress event. This means that storage must be fully charged at all-times, thus increasing its rate of degradation. This is one of the main barriers to BESS in the CM [38]. However, the degradation economic losses are neither remunerated nor studied in the de-rating factor study by the system operator [71].

5.2.5. Introducing Fixed Charges for behind the Meter Energy Storage

Behind-the-meter storage is normally used to reduce the electricity bill for commercial users. They are normally charged based on their consumption during the peak demand periods. However, because more users and businesses are able to predict these periods, they reduce their exposure to these charges when reducing their consumption due to using ES or demand side management techniques. Thus, OFGEM introduced fixed consumption charges although users can reduce the network charges for themselves; other electricity users need to compensate and cover the network fixed cost. This would seem to suggest that storage is regarded by energy regulators as a disruptive technology that can displace the existing energy regime [99].

5.3. Opportunities

5.3.1. Encouraging Private Parties' Investment in Energy Storage

Energy regulators in most liberalised countries are seeking to encourage competition between energy sector entities and regulate the revenue for market monopolies. The ES applications that can be provided by each electricity market entity are summarised in Table 4. It can be seen that private operators under the current market arrangements can provide all ES applications compared to other actors. As discussed in Section 3.5, energy regulators are considering strict unbundling requirements. Therefore, TSOs and DNOs will need to procure these services from the private sector that is increasingly interested in investing in ES [99].

Table 4. ES applications mapped to electricity industry actors [35].

Application	DNO	TSO	Energy Supplier	Generators	Private Operators
Energy Arbitrage	x	x	√	√	√
Peak shaving	√	x	x	x	√
Voltage support	√	√	x	x	√
Constraint management	√	x	x	√	√
System balancing	x	x	√	√	√
Portfolio balancing services	x	x	√	√	√

5.3.2. Ancillary Services Aggregation

The act of aggregation refers to the grouping of several units (consumers, or prosumers) in the power system to act as a single entity when trading in the electricity market [100]. Several studies identified the role of aggregators for ES in providing different services in the energy markets. However, the business case for aggregators is seen as hampered by the regulatory frameworks that prevent wider market access [41,101,102]. In 2016, the EC required member states to facilitate direct market access to the retail market [103]. Similarly, OFGEM identified some of the barriers to service aggregation and acted to amend some of the balancing market codes to allow aggregators to stack multiple revenue streams from different services [104].

5.4. Threats

5.4.1. High Capital Cost

Although the capital cost of BESS continues to fall, a recent study found that a cumulative investment of US$175–510 billion is needed in order for the capital cost of battery packs to reach US$175 ± 25/kWh, which is expected between 2027–2040 [105]. In another study, battery technology experts found that even with the recent advances in battery pack manufacturing capabilities and chemistry changes, the battery pack cost will not significantly decrease by 2020 [106]. As a result, a capital cost barrier is still a threat to the potential market growth of many BESSs.

5.4.2. Cannibalisation of Revenue Streams Available for Energy Storage

With the increased deployment of ES technologies combined with the necessity for a sustainable business case, there is a risk of revenue streams cannibalisation as a result of market competition. This risk is considered in the UK's system operator studies when the forecast of ES deployment falls from 18.3 GW by 2040 to 10.7 GW by 2050 [107].

6. Summary and Brexit Discussion

This section offers a summary to the obtained results in Table 2. It also discusses the 'Brexit' issue on the policy implication for both the EU and UK with regard to ES. Table 2 shows that the current ES policy has both strengths and weaknesses. Also, it shows an indirect implication to this policy represented by some threats and opportunities.

One of the main strength points of the UK's ES policy is the reduction of the operational cost for ES devices due to the removal of double network charges in the electricity markets. This is backed up by facilitating the planning permission for ES devices on a national and local scale. Another ES enabler factor is the co-location of ES devices with FiT and RO supporting schemes, which is a step forward in recognizing ES as a key enabler to greener electricity systems.

In terms of the weaknesses, the energy storage definition limits ES's role of generation only while this generation classification prevents a wide range of other revenue streams. Other barriers are preventing network owners from owning and operating ES from all sizes, payment of FCLs for small-scale ES introducing fixed charged for behind the meter storage, and de-rating the ES's capacity in the CM. These barriers can reduce the overall profit for ES assets.

Despite the aforementioned weaknesses, a number of opportunities have arisen. For instance, strengthening the 'unbundling' requirements for network owners can encourage private parties to invest in ES and stack multiple revenues from different services. Another opportunity is the shift towards allowing multiple smaller-scale ES assets to be aggregated together to provide vital ancillary services. Although stacking multiple revenues may be attractive for all ES assets, a threat of cannibalisation of the available revenue streams by all ES assets may occur. Another threat is the current high capital cost of ES.

The above analysed SWOT factors and their effects on ES's business case can be hugely changed due to the UK's exit from the EU (Brexit). The UK's electricity markets and the regulatory landscape are currently compliant with the EU regulation. Indeed, some studies such as in [108] analysed the implications of Brexit on the electricity sector and how the UK could lose the economic benefits of the interconnectors of some EU countries. These interconnectors usually provide valuable services to the UK's electricity network by managing intermittent RESs. In the case of a Brexit agreement that does not involve electricity market integration or interconnector share, there is a significant need for ES and other flexibility options to mitigate RESs intermittency [109]. Therefore, it seems that Brexit can raise the deployment of ES devices in the UK. A recent study also confirmed this finding by stating that the economic investment in large-scale ES to increase the UK's peaking capacity may be boosted without the EU's interconnectors sharing [110].

In case of a Brexit scenario that limits the UK's access to the EU's single market or a trade arrangement that sees tariffs imposed between the UK and the bloc, importing batteries from the EU may not be cost-effective to meet the local UK's demand. Therefore, the UK government should adopt policies to build battery gigafactories in the UK to cover the local demand whether it is for electric vehicles or the grid. The Faraday institution estimates that at least eight gigafactories are needed in the UK by 2040 [111].

7. Conclusions

ES is recognised as a key technology to mitigate the intermittency of many RES. Earlier research found many barriers to the rollout of ES in current energy networks. Since 2017, energy regulators in the EU and the UK proposed changes to enable a level playing field for ES and remove these barriers. The changes include (i) defining 'Electricity Storage' in the main legislation; (ii) removing double network and balancing charges for storage; (iii) co-locating storage with renewable generation sites that are supported through consumption levies policies; (iv) limiting the storage operation by network owners; (v) facilitating ES planning permission; and (vi) employing de-rating factors for storage in the capacity market (CM). Since the proposed regulatory changes at the UK and EU level are similar, the UK is taken as a case study considering its market design and relevant regulations.

This paper presented a SWOT analysis to explore the impact of the recent changes on the business potential of BESS and examined whether these regulatory changes have been supportive to BESS's business case in the UK.

Three main benefits of the recent regulatory changes were found. First, the removal of the double network charging for ES by eliminating the demand residual charges (when importing electricity from the grid) can reduce its operational cost. Second, ES co-location with RES sites that receive government subsidies can not only boost its business case but also recognise ES as a key player in integrating these intermittent resources. Third, facilitating ES access to the grid by allowing cost-effective infrastructure access and planning permission can positively affect investment decision in ES. The recent regulation supported faster implementation of composite projects that have a total capacity above 50 MW (for example, a generation unit with 40 MW and ES with 40 MW).

However, a number of drawbacks were found in the recent regulatory changes that may outweigh these benefits. First, the new definition for ES recognised it as a generation device, thus it has to compete with traditional generator assets in many instances, which it cannot do cost effectively. Second, the introduced regulations do not consider the different types and sizes of ES and tend to support large-scale ES with a capacity of 100 MW or above (similar to generators). However, there is a key role for smaller-scale ES in current energy systems in the form of BESS as discussed in the paper. From the perspective of the regulators, this makes sense as they do not want to disrupt the current energy market structure by creating an independent storage asset class. Instead, they are looking for a technological advance for different types of ES to increase its energy and power density to place it in the traditional generator's category. Third, only large-scale ES assets (above 100 MW) are exempt from paying FCLs, however, most of the current ES projects especially BESS are far below 100 MW. As such, in the case of BESS, this might be a longtime coming, limiting its value in current energy systems under current regulatory and market regimes. In the CM, for example, higher-duration BESS receives more payment than smaller-duration.

Despite the previous drawbacks and a high current capital cost for BESS, many opportunities have been found for private parties who are encouraged to own and operate ES devices to stack multiple revenues from different services. The recent regulation meant that private parties are in the best place to provide ES services. This is along with the suggestion that allows several ES units to be aggregated, and thus, provides services in the wholesale market.

Finally, we suggest a number of policy implications from the above SWOT analysis results. First, an independent asset class should be created for ES because the current energy markets are designed without electricity storage in mind. Second, a unique definition for ES that reflect its features is needed. For instance, the current definition for both the EU and the UK does not recognise the ES service when charging the device to help store the exceeded power from a wind farm. Third, in the CM where the capacity of the BESS asset is de-rated, the economic assessment of the degradation cost should be taken into account. This is because degradation can affect the availability of these assets, which in turn can affect the reliability and the energy security of the electricity network should the implementation of ES be increased.

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