CryoHub

Developing Cryogenic Energy Storage at Refrigerated Warehouses as an Interactive Hub to Integrate Renewable Energy in Industrial Food Refrigeration and to Enhance Power Grid Sustainability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691761

Deliverable D10.4

Updated report on policy

Analysis of national policies relevant to the CryoHub concept

Deliverable Information

Dissemination : Public
Nature : Report
Contractual Delivery Date : 31/12/2020
Actual Delivery Date : 31/12/2020

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Document Information

Project	: CryoHub
Document	: D10.4 – Updated report on policy
Filename	: D10.4 Updated Report on policy S1.docx
Last saved on	: 30/12/2020 by Jonathan Radcliffe (UoB)

Authorship and Review

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Release Details

Release	Date	Comments
Draft 01	17/12/20	First draft
Release 01	31/12/20	First release for approval by Coordinator
Submitted	31/12/20	Submitted to the Commission

Distribution List

- On the project Portal
- On the CryoHub Intranet (http://cryohub.psutec.com/)

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INTRODUCTION

This report is prepared as a part of CryoHub project deliverable D10.4 associated with WP10.2 'Policy assessment' (UB, CDR, EUREC).

We have assessed the policy and regulatory barriers that could prevent the energy storage technology from being deployed (at EU and national level) from desk-based research and interviews with industry and policymakers, also drawing on the work of WP8. We have also considered how the technology, if deployed at scale, could impact other energy/food industry stakeholder decisions. Whilst the technology offers the possibility of reducing costs and emissions for the user and the wider system, it is not clear that this value will be accessible such that a viable business case could be constructed.

Section 1 first introduces an approach to assessing energy storage policies according to their general function. The energy policies and status of energy storage in six countries have been analysed in sections 2 – 7, covering Germany, the UK, the USA (focused on California, New York, and Hawaii), Japan, South Korea and Australia. The approaches each country has taken, the deployment of energy storage and enabling policy intervention, have been analysed. In section 8, the typology of energy storage policies and emerging trends has been examined. This section will help us understand the approaches different countries have taken regarding energy and energy storage policy. The key trends and successful policy approaches have been identified.

Section 9 of this report helps us identify the key market and policy barriers, and opportunities for the development of new energy technologies. Working with Carbon Data Resources Ltd, stakeholders have been interviewed, though due to the COVID 19 pandemic it has not been possible to interview many stakeholders as much as anticipated on the timescale we had set out. However, we have interviewed a number of stakeholders from both refrigeration and energy sector specialists.

Finally, section 10 draws conclusions from both the policy analysis and stakeholder engagement.

1 TYPOLOGY OF ENERGY STORAGE POLICY

The energy policies and status of energy storage in six countries have been analysed in detail in sections 2 - 7: Germany, the UK, the USA (focused on California, New York, and Hawaii), Japan, South Korea and Australia. The countries discussed in the sections below have adopted different approaches and policy instruments regarding different energy storage technologies. It is difficult to find a definitive approach to 'energy storage policy' analysis because the energy storage domain is in most cases impacted by a mix of various energy policy domains. For example, Australia's Grid Reliability Fund [132] is a policy instrument that has enabled large-scale Li-ion battery storage facilities however the policy is mainly focused on Australia's Energy Policy Framework's goal of delivering a reliable energy system and equally encourages other energy systems such as coal fired plants. Similarly, California Solar initiative (CSI) is aimed at solar PV installations, but small-scale storage systems could be installed as part of the solar installation [78, 79]. In other cases, energy storage goals are implemented through a mix of different policy interventions. For example, to promote the energy storage technology in the UK a number of interventions around licensing, planning, connections and charging for storage have been put in place [53, 1].

To define these policy scenarios [2] have proposed two archetypical approaches, namely 'top-down' and 'bottom-up' approaches. The top-down approach picks up the notion that a policy mix pursues an overarching strategic intent (such as climate change mitigation) that is implemented through a mix of policy instruments. And the bottom-up approach picks up the notion that a given impact domain (such as energy storage) is affected by mix of policy instruments that pursue one common or different strategies. [3] have discussed energy policies of different states of the USA where the author has used a table outlining strengths, weaknesses, and mechanisms for improvement to summarize various policy instruments. In analysing the renewable energy policy other articles focus on one policy domain. For example, [4] explores the wind energy industry from the point of view of the wind energy policies in selected countries, [5] focused on the different solar energy policies implemented in different countries and [6] have discussed the typology of policy instruments for the early-commercialization phase of green steel in the EU.

The following typology of energy storage policy is developed from literatures focused on different policies [2, 3] and literatures focused on one policy domain only [4, 5, 6]. The typology listed below will be used to develop a table summarizing the energy storage policies in the countries discussed in next sections.

1. **Information:** Informational document or briefing paper to promote or highlight the features of a (new) government policy, a solution, product, or service. For example, the Energy White Paper by the UK government
2. **Public Procurement:** Process or system by which the public organizations (i.e., government) procure or purchase products e.g., energy) in the form of goods, services, or sometimes the combination of goods and services. For example, the UK government's Capacity Market programme.

3. **Regulation:** Statutory policy formulated by governments to impose controls and restrictions and/ or to promote certain specific activities such as building new energy storage (ES) facilities. For example, the UK's Energy Act 2008.
4. **Research & Development:** Financial support to improve current electricity storage technologies, and to develop novel ways of using other resources in a sustainable way
5. **Subsidy:** Discount, grants or benefit given to an individual, business, or institution, usually by the government.
6. **Tax:** Levy imposed (on businesses) as means to raise revenue for public expenditure, to correct market prices, to take account of environmental externalities, or to impose charges for otherwise free environmental goods.
7. **Voluntary:** Non-Statutory promotional programme, usually formulated by governments to promote certain activities or technology such as new energy storage technology

Based on the types of energy policies identified above, the following table of typology has been developed.

Table 1:Typology of energy storage policies

Heading	Subheadings
Policy Type	• Information • Public Procurement • Regulation • Research and Development • Subsidy • Tax
Point of intervention	• Supply • Demand
Direct or indirect	• Direct • Indirect
Policy goal	• Description of support / policy goal
Targeted Energy Storage System	• Targeted ESS
Policy instrument	• Policy instrument
Country name	• Australia • Germany • Japan • South Korea • UK • USA
Government level	• Central/Federal • State • Local

2 GERMANY

2.1 ENERGY SUPPLY AND CARBON EMISSIONS TARGET

Over the last few decades Germany has been a frontrunner in developing and deploying renewable energy technologies and developed a feed-in tariff scheme which many countries have based their own schemes on [7]. Despite this relatively long term support for renewable energy the German energy system's transition to a renewable energy dominated system, known as the 'Energiewende' is generally accepted to have started in 2010 when the German government announced as part of their energy concept a series of progressive targets for greenhouse gas reduction and renewable energy consumption; resulting in targets for reducing GHG's by 80% from 1990 levels, and for renewable energy to meet 60% of gross energy consumption and 80% of electricity consumption by 2050 [8] [9].

Following the nuclear accident at Fukushima in 2011, further emphasis on the need for the adoption of renewable technologies was provided when the German government then announced that all nuclear power, which supplied 22.5% of Germany's power in 2011, would be phased out by 2022 [10]. The 13th Act amending the Atomic Energy Act (Atomgesetz, AtG) sets out the plan to end the use of nuclear energy for the commercial generation of electricity in an orderly manner and to ensure orderly operation until the time of termination. The act entered into force on 6 August 2011 [11].

This has led to steady increase in the contribution renewable generation makes to Germany's energy supply. In 2018 the share of renewables in electricity consumption in Germany was 38%, overachieving the 35% target for 2020 [12]. This increase in renewable electricity production is largely due to the increase in solar PV and wind generation which from 2010 to 2018 rose from 1.9% (11,700 GWh) to 8% (45,784 GWh) and 6% (37,790GWh) to 18% (109,951GWh) respectively [13]. The high penetration of wind and solar has led to stability issues, and increasing difficulty in balancing supply and demand, which has driven the installation of additional energy storage to mitigate these issues.

Counting both operational and planned projects, Germany currently has 13.43GW of installed energy storage capacity, including 12.43 GW of Pumped Hydro System (PHS), 409.8 MW of Li-ion battery storage, 321 MW of Compressed air energy storage (CAES) and 250 MW of hydrogen [14]. Lignite, hard coal, and natural gas are still significant sources of energy in Germany; in 2017 they contributed 22.5%, 14.1% and 13.2% of gross electricity generation, respectively. The nuclear energy has dropped sharply to 11.7% of the generation [12]. According to the BP Statistical Review of World Energy 2020 oil, natural gas and coal accounted for 36%, 24% and 18% of the total primary energy consumed in Germany in 2019. Nuclear still accounted for 5% while renewable energy's share was 16% of the total primary energy [119].

2.2 Energy Policy and Programmes

Shifting from fossil fuels to renewables and phasing out nuclear energy are two key policy objectives of German energy policy. As discussed above Germany is overall successful in both renewable expansion and nuclear phase out. Renewable Energy Sources Act 2000 is the key energy policy in Germany; the successful expansion of renewable energy is credited to the Renewable Energy Sources Act, which has since been revised several times including in 2014 and in 2017 [12, 13]. The act originally aimed to facilitate market access for new technologies like wind energy and photovoltaics by guaranteeing their purchase at fixed rates.

The 2014 revision of the Renewable Energy Sources Act required a binding expansion corridor, sharply reduced the costs of renewable electricity via a concentration on the cheap technologies of wind power and photovoltaics and halted the rapid rise in electricity prices. This helped level the playing field for renewable energy to sell electricity to energy-intensive industries while maintaining the competitiveness of those industries [12].

2017 Renewable Energy Sources Act has shifted the approach, allowing the market to play a bigger role. The remuneration rates for renewable electricity are no longer being set by the government but determined by auctions on the market. To protect the small-scale photovoltaics, PV installations with a capacity of up to 750 kW are exempt from the auction, therefore, remuneration rates are fixed by the government. The 2017 revision has opened up the auctions for funding for renewable energy to other countries. It allows 5% of new renewables capacity to be installed each year to be opened up to installations in other European Member States [12].

2.3 Energy Storage

Due to the effects of Germany’s Energiewende project the battery storage capacity has grown rapidly in recent years. The uptake of small-scale, home battery systems combined with the PV has grown massively and the trend is projected to continue in the coming years [15].

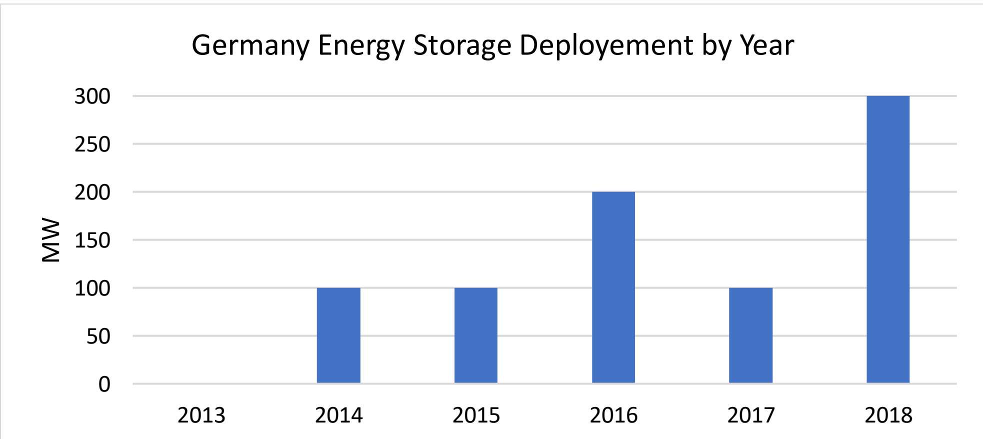

Figure 1: Germany Energy Storage Deployment by Year. Source: IEA

Figure 1 shows the annual capacity of combined utility-scale and behind-the-meter storage deployment in Germany. It can be seen that the deployment of energy storage started to grow from 2014.

Table 2 below shows the installed energy storage capacity of Germany by September 2020. Like other countries, pumped-hydro storage (PHS) is the dominant energy storage technology in Germany.

Table 2: Operational energy storage capacity of Germany in 2020. Source: [16]

Technology	Installed capacity (MW)
Electrochemical	**406.16 (5%)**
Lead acid	1.6
Li-ion	329.8
Li-ion/NaS	12.5
Unknown	62.26
Mechanical	**7024.2 (95%)**
CAES	321
PHS	6703.2
Thermal	**1.5**
Thermal	1.5
Grand Total	**7431.86**

Germany has focused on harnessing wind and solar energy and expanding the large supra-regional transmission grids and local distribution grids to support the decentralised energy generation from wind and solar. The country's energy transition is guided by the principles set out in the Federal Government's Energy Concept (2010), by further decisions by the Bundestag, and by European rules and regulations. The energy transition also focuses on collaboration between all levels of government, businesses, and civil society. The Economic Affairs Ministry has established permanent high-level energy transition platforms to facilitate such collaboration through dialogue and continuous coordination [17].

To export the modern German energy technologies in the international energy market the German federal government has launched the Energy Export Initiative / German Energy Solutions Initiative. The initiatives are mainly intended for small and medium-sized enterprises (SMEs) offering energy solutions in the fields of renewable energy, energy efficiency, smart grids, and storage technologies [12].

2.3.1 Energy Storage targets and incentives

Although Germany currently has no specific energy storage targets the growing need for energy storage since 2010 has led to a number of measures to promote energy storage. This includes the Federal Ministry for Economic Affairs and Energy's Energy Storage initiative programme which since 2012 has provided a total of over €200 Million of research funding for around 250 energy storage projects [18]. These projects have ranged in scale from distributed household storage systems, to multi-megawatt systems for use as part of a more centralised system. Stated areas of focus for the Energy Storage Initiative include batteries for distributed storage networks and thermal storage systems [18].

In addition to research funding, the German Government has also provided a number of measures and incentives to promote the uptake of energy storage systems. These include the updating of the energy act to allow electrical energy storage systems to participate in reserve markets and the exemption of electrical storage systems from a number of fees and charges including renewable energy levies and grid tariffs [19]. It also includes a number of subsidy schemes to promote distributed storage systems alongside solar PV generation. Since 2013 a subsidy for battery storage systems to be used in conjunction with rooftop solar PV systems has been available, which up to 2016 provided €60 Million to approximately 19,000 projects leading to a total investment in the region of €450 Million [18]. This subsidy was initially expected to finish in 2016 but due to the success of the scheme confirmation it was extended until 2018, although in an adjusted format to allow for the falling cost of storage systems [20]. This subsidy accounts for up to 30% of the investment cost while a low-interest loan can be provided for the remainder of the cost, however systems are only eligible for the programme if they help to reduce congestion (through load-shifting) on the local distribution network by not exporting to the grid during the mid-day hours [18].

Additional support for distributed energy storage may come from Time of Use Tariffs which are offered by many German electricity suppliers; however, adoption rates are relatively low although a roll-out of smart meters, albeit only for relatively large consumers, may begin to change this [21] [22].

As with many nations, Germanys' adoption of thermal storage technologies is relatively low however Germany's heat demand makes up around 54% of their total energy consumption with most district heat networks powered by fossil-fuel CHP systems [23], so to meet decarbonisation targets much of this heat demand will have to be met by renewable sources in the future meaning there is significant potential for additional thermal energy storage. Unlike electricity networks the nature of heat networks means that any thermal storage employed by them will be distributed.

2.3.2 Hydrogen

Germany has published The National Hydrogen Strategy in June 2020 [24]. The ambitious strategy plans to put Germany in leading position internationally with various collaborative action plans, especially between North Sea region and Southern European states. Between 2020 and 2023, Germany plans to provide various Hydrogen stimulus packages including 310 million euros under the Energy and Climate Fund for practice oriented basic research on green hydrogen, 200 million euros to strengthen research on hydrogen technology and 600 million euros to foster the 'Regulatory Sandboxes for the Energy Transition'. On top of that Germany has made available 7 billion euros for speeding up the market rollout of hydrogen technology in Germany and another 2 billion euros for fostering international partnerships. The strategy is focused on the production of hydrogen with renewable power and hydrogen as a collaborative European project. It is expected that around 90 to 110 TWh of hydrogen will be needed by 2030. In order to cover part of this demand, Germany plans to establish up to 5 GW of generation capacity including offshore and onshore energy generation facilities.

Although Germany is promoting energy storage across all scales and applications there is a slight preference towards distributed, residential scale storage [19]. This makes it a useful case study for those trying to promote energy storage in other nations. Whilst Germany's Energiwende has seen a rapid and large adoption of renewable technologies and the subsequent adoption of energy storage systems it has, in the most literal sense, come at a cost with German energy consumers having some of the highest bills in Europe [9]. This has been deemed by successive German Governments (and their voters) to be an acceptable cost to achieve decarbonisation, but it is questionable as to whether this would be the case for many nations.

3 UK

3.1 Energy Supply and Carbon Emissions Target

In 2019 the share of renewable electricity generation reached 37.1% in the UK [25]. In the same year, the contribution of renewables to primary fuels supply was 16% where wind, solar and hydro accounted for 5% and bioenergy and waste accounted for 11%. In 2019 coal, petroleum, natural gas, and nuclear energy accounted for 1%, 44%, 29% and 10% of the total primary fuels respectively [26]. The data suggests that the share of fossil fuel is still high while renewable electricity generation has increased significantly.

The UK Government has a nationally legislated target to reduce greenhouse-gas emissions by 80% by 2050 compared to 1990 levels, and from the EU for renewables to meet 15% of total energy demand by 2020 (which translates into approximately 30% of electricity from renewable sources) [27] [28]. Latest figures show that in 2019, 12.3% of UK energy consumption was from renewable sources, with 37% of electricity generated from renewables [25]. In December 2020, the UK government has set a new plan for at least 68% reduction in greenhouse gas emissions by the end of 2030, compared to 1990 levels [29].

The devolved governments of the UK home nations have different emissions reduction targets. The Climate Change (Emissions Reduction Targets) (Scotland) Bill 2018 aims to achieve 90% reduction in emissions of all greenhouse gases by 2050 in Scotland [30]. Wales has an 80% carbon reduction target which is in line with the UK target. And Northern Ireland currently does not have a separate target but has operated a single wholesale electricity market called the Single Electricity Market (SEM) with the Republic of Ireland therefore, their national targets are affected by the Irish targets [31].

3.2 Energy Policy and Programmes

The Climate Change Act 2008 is the key policy which sets in legislation the UK's approach to tackling and responding to climate change [32]. The Energy Act 2013 is the primary legislation that enables Electricity Market Reform, including the implementation of the Capacity Market. Building on the Energy Act 2013, the Electricity Capacity Regulations (2014) together with the Capacity Market Rules, are the more detailed secondary legislation which establishes a Capacity Market. The Regulations were amended in 2014, 2015, 2016 and in 2019. To support the delivery of its objectives, while minimising the cost to the consumer, the UK government has implemented Electricity Market Reform (EMR) [33]. Two key mechanisms introduced as a result of EMR are the Capacity Market and Contracts for Difference. In November 2020, the UK government published an information paper titled 'Ten Point Plan for a Green Industrial Revolution' which lists plans to produce 40GW of offshore wind by 2030, develop 5GW of low carbon hydrogen by 2030, shifts to electric vehicles and ban the sale of new petrol and diesel cars and vans from 2030, Green Homes Grant for energy efficiency improvement of buildings and £100 million for Energy Storage and Flexibility innovation challenges [34].

3.2.1 Capacity Market

The Capacity Market was implemented in 2014 and is designed to maintain security and reliability of supply and offers electricity capacity providers (including new and existing power plants, and electricity storage systems) a steady payment to ensure enough capacity is in place to meet demand. Capacity providers face penalties if they fail to deliver energy when needed [35]. To 'avoid the unintended consequences' of increasing carbon emissions the capacity providers are required to comply with carbon emission limits enshrined in other policies and regulations, such as the EU Emissions Trading Scheme (EU-ETS) and the Emissions Performance Standard (EPS) [35]. The capacity market is accessed by bidding in competitive auctions for a fixed level of capacity; it is hoped that this competitive process will keep costs as low as possible. Capacity auctions take place four years in advance, the first taking place in December 2014, for delivery obligations that began in October 2018 [35].

Changes to the Capacity Market in 2020 include reducing the Minimum Capacity Threshold (MCT) from 2MW to 1MW and introduction of carbon emissions limit for new build and unproven Demand side response (DSR) Capacity Market Units (CMUs) which contain a fossil-fuel component [36]. The reduction of MCT will help remove barriers for DSR and energy storage making it easier for renewable technologies to compete in auctions. It is hoped that the introduction of carbon limit will 'help push out some of the highest carbon-emitting plants and redirect funding to cleaner means of ensuring the security of supply' [37].

3.2.2 Contracts for Difference (CfD)

Contracts for Difference (CfD) is an incentive for low-carbon generators where a strike price is agreed per unit of electricity generated, and if the market price for electricity is less than this strike price then the difference is made up by the UK Government. It is designed to subsidise low-carbon generators but also protect energy consumers from paying high subsidies when the cost of electricity is already high [38]. The CfD Allocation Round 3 excluded onshore wind and solar PV, but amendments to the scheme in 2020 ahead of round 4 will reintroduce onshore wind and solar PV [39]. Energy storage can be co-located in conjunction with low-carbon generators although the storage was not considered the part of CfD and the rules for doing so were clarified in a Government response to a CfD consultation in 2017 [40]. The government intends to amend the definition of Rolling Negative Price Period in the CfD to extend the existing negative pricing rule so that difference payments are not paid to CfD generators when the Intermittent Market Reference Price is negative. By increasing the market exposure of CfD generators during negative pricing periods, this proposal aims to strengthen the incentives for generators to be responsive and flexible such as by using storage [39].

3.2.3 Feed-in Tariffs

The Feed-in Tariffs (FIT) scheme was introduced in 2010 by the UK government to promote the uptake of renewable and low-carbon electricity generation technologies[41]. The scheme requires participating licensed electricity suppliers to make payments on both generation and export from eligible installations. The solar photovoltaic (solar PV), wind, micro combined heat, and power (CHP), Hydro and anaerobic digestion (AD) were listed as eligible technologies. Small domestic installations were administered by the FIT licensees and large installations were administered by the UK energy regulator Ofgem. The scheme has encouraged some participants to install energy storage and use the excess energy when there is not enough generation.

3.2.4 Domestic energy efficiency

The UK government has also introduced a number of energy policies for reducing greenhouse-gas emissions from heat, including the Renewable Heat Incentive, the Green Deal, The Energy Company Obligation (ECO) and other energy efficiency, microgeneration, and bioenergy strategies. The Renewable Heat Incentive provides subsidies for the production of heat from a number of renewable technologies [42], whilst the Green Deal, which closed in 2015 (although private sector equivalents now exist) provided loans for energy-saving household improvements such as solid wall insulation and double glazing [43]. However, the success of these interventions has been variable with the Green Deal in particular being found to be overcomplicated [44, 45].

3.2.5 Electric Vehicles

For electric vehicles, the UK government compensate up to 35% of the cost of an electric car, up to a maximum of £4,500 depending on the model, and 20% of the cost of a van, up to a maximum of £8,000 [46]. There are also grants available towards the cost of electric vehicle charge-points both at home and at the workplace as well as for local authorities [47]. The government has announced the banning of selling petrol and diesel vehicles from 2030, 500 million of investment to drive the electrification of UK automotive sector and 1.3 billion to accelerate the roll out of charging infrastructure [34]. EV has a huge potential to become a mass energy storage device. Although the UK government has funded a number of projects including EDF Energy's V2GO scheme there are number of regulatory, infrastructure and market barriers [48].

3.3 Energy Storage

Table 3 shows the operational energy storage capacity in the UK by technology type:

Table 3: Operational energy storage capacity of UK in 2020. Source: [16]

ESS Technologies	Installed Capacity (MW)
Electrochemical	**569.8 (14%)**
Li-ion	92.5
Unknown	477.3
Mechanical	**3566.4 (86%)**
Flywheels	400
LAES	5
PHS	3161.4
Grand Total	**4136.2**

Including both operational and planned facilities, as of December 2020, 12.8 GW of energy storage capacity has been identified, of which 6.7 GW are PHS, 1.3 GW other mechanical (CAES, LAES and Flywheel) and 4.8 GW are electrochemical battery storage [16].

The BEIS renewable energy planning data [49] shows that deployment of the energy storage projects has been rapidly growing from 2018. The data includes the projects that are operational, under construction and planning permission granted. It also includes 0.8GW PHS in 2019 and 0.53 GW PHS in 2020. In particular, the battery storage deployment in the country has grown from just 0.855 MW in 2016 to 5391 MW in 2020.

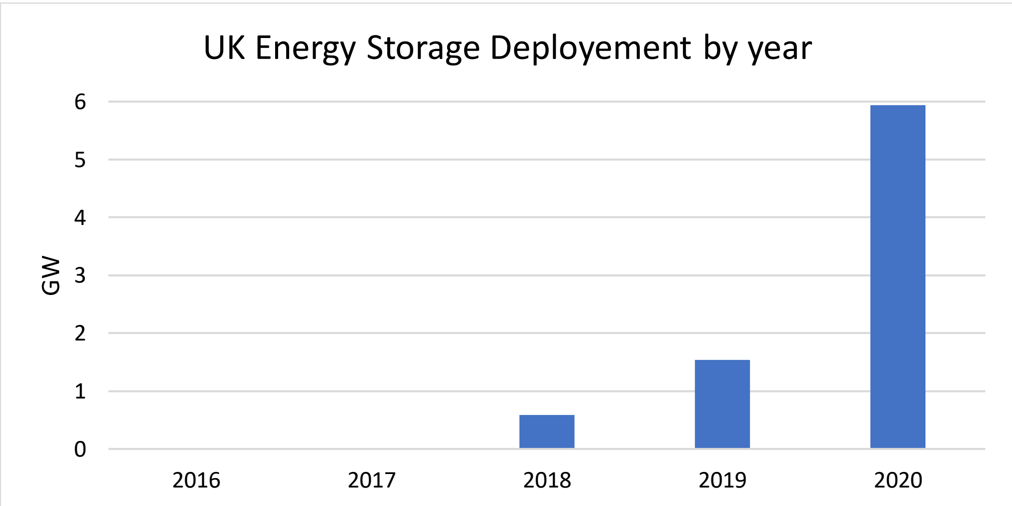

Figure 2: UK Energy Storage Deployment by year. Source: BEIS 2020

In addition to broader changes to energy policy discussed in section 2.2 the UK has also made a number of policy interventions targeted specifically at promoting energy storage. In the 2017 Smart Systems and Flexibility Plan the UK Government (and OFGEM) set out various plans to support the transition to a smarter and more flexible system, including removing barriers to electricity storage. The plan was updated in 2018 and both these plans committed to a number of interventions around licensing, planning, connections and charging for storage, to remove regulatory and policy barriers to allow energy storage technologies to 'compete on a level playing field' [50]. These include:

3.3.1 A revision to the charges placed on storage facilities

Consumers and generators are charged for using both the transmission and distribution networks through Use of System and Balancing Services Use of System charges. However, because energy storage technologies consume and generate, they are effectively double charged. This does not consider the benefits of storage to the network in providing a balancing service rather than contributing to the congestion of the network; therefore, through OFGEM's Targeted Charging Review these charges have been revised so that energy storage facilities only pay the generation charges [51].

3.3.2 A regulatory definition of energy storage

Following on from above the UK Government intends to amend the Electricity Act to include a specific definition of energy storage as a subset of the generation asset class. Providing a regulatory definition of energy storage will not only confirm that it should be treated as a generating asset but will also help to cement energy storage as an integral part of the electricity system [52].

3.3.3 A clarification of the rules around co-locating energy storage with renewable energy

It can be beneficial to co-locate energy storage with renewable energy, however many renewable energy schemes receive subsidies either from Feed-in Tariffs, CfD's or their predecessor Renewables Obligations. The Government and OFGEM have subsequently published guidelines around co-location to clarify the process and ensure that only renewable generation is rewarded by the subsidy schemes [40, 53].

In July 2020, the UK government passed the 'Infrastructure Planning (Electricity Storage Facilities) Order 2020' bringing relaxation in planning rules. The order removes electricity storage, except pumped hydro, from the NSIP (nationally significant infrastructure planning) regime, both onshore and offshore, in England and Wales. This means that the primary consenting route for electricity storage (except pumped hydro) in England is now under the Town and Country Planning Act 1990 (TCPA) [1]. The move is expected to remove unnecessary red tape saving developers time and money and encourage more ambitious energy storage projects.

The policy interventions made by the Government are bringing forward deployment of energy storage technologies, however there are limitations to these interventions. The UK's focus has been on the electricity system with a lack of policy around the integration of electricity heat and transport systems. Furthermore, many countries are developing energy storage markets at a much quicker rate and so there are lessons for the UK to learn. This includes options to support/subsidise energy storage deployment including direct subsidies, competitive auctions (such as the EFR), and co-subsidies for renewables with energy storage. An additional option, although not tested anywhere in the world, would be some form of firm power auction as suggested in the 'Cost of Energy Independent Review' this would promote storage to allow variable renewable generation to provide firm power [54].

3.3.4 Hydrogen

Unlike peer countries such as Germany and Australia, the UK does not have a national Hydrogen Strategy, though this has been planned for publication in 2021 [34]. There are calls from various forums including a campaign called 'Hydrogen Strategy Now', which a large number of private energy providers such as EDF, developers and campaign groups are part of [55].

In the recently published 'Ten-point plan' the UK government has set a target of 5GW of low carbon hydrogen production capacity by the end of 2030. The government has committed £240 million to the Net Zero Hydrogen Fund. There are plans by the energy regulator Ofgem to fund a demonstration project to provide hydrogen to 300 homes [34].

4 USA

4.1 Energy Supply and Carbon Emissions Target

The United States is one of the largest energy producers in the world. In 2017, the country accounted for 13% of total world production of crude oil and 20% of natural gas [56]. Since 2017 the US export of crude oil has almost tripled from 2.42 Quadrillion Btu to 6.20 Quadrillion Btu in 2019 [57]. In 2020 the USA exported more energy than it imported [63].

In 2019, 37% of US electricity was generated from natural gas, followed by coal (24%), renewables (19%) and nuclear (19%) and, among renewables solar and wind electricity share was 15% and 38% respectively [63]. The share of solar electricity is predicted to rise to 46% in 2050, subject to the funding and natural gas prices. In the same year fossil fuel contributed to 81% while nuclear energy contributed 8% and renewable energy contributed 11% of the total primary energy mix of the country. Among the renewables the solar, wind and biomass contributed 1.04%, 2.73% and 5.16% respectively [57]. The figures from U.S. Energy Information Administration show that contribution of fossil fuel in national energy mix has increased steadily after 2017. While total renewable contribution did not see significant increase in the total energy mix, the contribution of solar has increased form 0.77% in 2017 to 1.04% in 2019. The primary drivers of the increased solar energy are the availability of renewable energy tax credits and the continued decline in the capital cost of solar photovoltaic.

The United States committed to a target to reduce GHG emissions by 26-28% below 2005 levels by 2025 under the Paris Agreement in 2015 [58]. However, on 1 June 2017, the Trump administration announced its intention to withdraw the United States from the Paris Agreement. On 4 November 2019 United States formally began the process to withdraw from the Paris Agreement [59], making USA the biggest carbon emitter in the world that does not have a carbon-neutral target. However, it is important to note that although the USA has withdrawn from the Paris Agreement, many US states have committed to the agreement. After the US presidential election in November 2020, the president-elect Joe Biden has announced that he will re-join the Paris Agreement [60].

4.2 Energy Policy and Programmes

The current US energy policy is shaped by 'energy dominance' strategy, which aims to maximise energy production, play a larger role in energy exports and be a global leader in energy technologies [61, 56]. To achieve these aims the US government has taken unprecedented steps including withdrawing from the Paris Agreement, rescind the previous administration's Clean Power Plan, accelerate the process to build the Keystone XL Pipeline, giving permission to oil drilling in Artic wildlife reserves [62] etc. The continued growth in petroleum and natural gas production and exports has resulted in the United States becoming a net energy exporter in 2020, for the first time since 1953 [63]. Although the domestic consumption has decreased due to the COVID 19 pandemic, EIA report predicts that the production of U.S. crude oil and natural gas plant liquids will continue to grow through 2025 [63].

According to IEA, the Federal Power Act, Clean Air Act, National Environmental Policy Act, Natural Gas Act, Energy Policy and Conservation Act and, American Recovery and Reinvestment Act are the key regulations that direct the US energy policies. There are various regulatory regimes in different states to oversee the energy policy and programmes. On the federal level US Department of the Interior holds auctions for drilling for oil and gas or mining for coal and, oversees all offshore energy resource development that falls beyond states' purview [56]. Regulation of natural gas pipeline, storage, liquefied natural gas facility construction, interstate transportation and, rates and practices of oil pipeline companies engaged in interstate transportation are regulated by Federal Energy Regulatory Commission (FERC). Approval of rates for wholesale sales of electricity and transmission in interstate commerce for jurisdictional utilities, power marketers, power pools, power exchanges, and independent system operators are regulated by FERC in the US [64].

4.3 Energy Storage

Figure 3 below shows the annual capacity of combined utility-scale and behind-the-meter storage deployment in the United States. It can be seen that the deployment of energy storage has grown in 2018 however, the deployment was low between 2015 – 2017 compared to other countries such as South Korea.

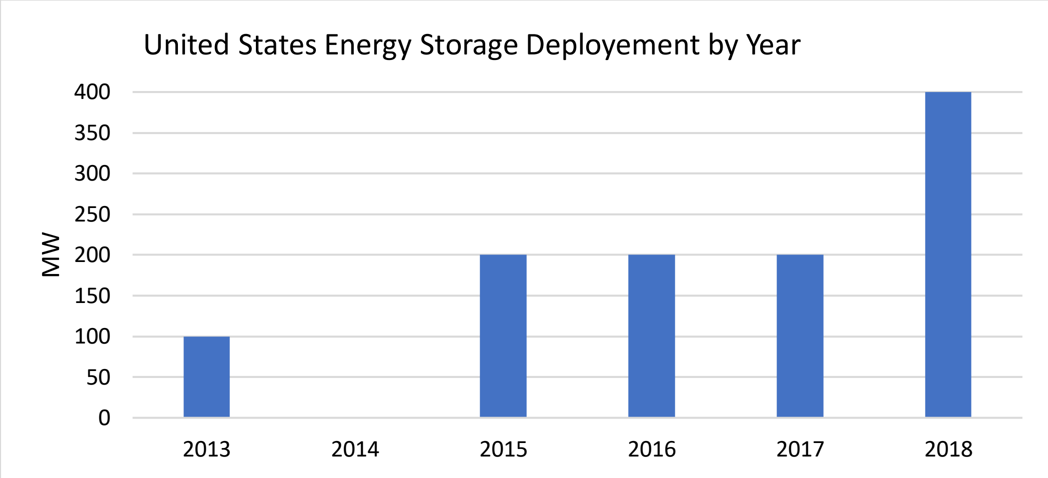

Figure 3: United States Energy Storage Deployment by Year. Source: IEA

The USA has one of the largest numbers of large-scale /grid-connected battery storage projects in the world with a total installed capacity of 869 MW operational by the end of 2018 [65] and is one of the leading innovators in energy storage policy [21]. The federal government have enacted a number of policies aimed at supporting the deployment of energy storage including:

4.3.1 Energy Independence and Security Act 2007

Aimed to increase the USA's energy security by increasing the generation of renewable energy. Regarding energy storage, through the United States Energy Storage Competitiveness Act of 2007 it called for the founding of energy storage research labs, a new national committee to draft a five-year plan on energy storage and demonstration programmes for a number of storage technologies [21, 66].

4.3.2 American Recovery and Reinvestment Act 2009

Provided financial stimulus through grants and loan guarantees for a variety of technologies including approximately $185million for energy storage projects [21, 67].

4.3.3 Federal Energy Regulatory Commission (FERC) Orders

Over the last decade the FERC (the federal transmission and wholesale electricity regulator) has passed a number of orders to remove the barriers to energy storage including

- **Order 890 (2007)** which allowed non-generation sources including energy storage and demand response to be considered for ancillary services [67, 68].
- **Order 719 (2008)** updated regulations to improve the operation of the wholesale electricity market, particularly around areas of demand response and market pricing during periods of low operating reserve. Also changed the way utilities calculate the minimum value of ancillary services (five-minute calculations), benefiting energy storage technologies with quick response times [21, 68].
- **Order 755 (2011)** aimed to ensure a level playing field for energy storage technologies by requiring network operators to pay for capacity and performance when acquiring frequency response services [21, 68].

- **Order 784 (2013)** allowed energy storage owners to provide ancillary services at competitive market-based rates to public utilities [21, 68].
- **Order 841 (2018)** Remove barriers to the participation of electric storage resources in the capacity, energy, and ancillary service markets operated by Regional Transmission Organizations (RTO) and Independent System Operators (ISO) (RTO/ISO markets)
- **Order 2222 (2020)** Empowers new technologies to come online and participate on a level playing field enabling distributed energy resource (DER) aggregators such as EV, solar PV, home batteries etc to supply in all regional organized wholesale electric markets

4.3.4 Clean Power Plan 2015

Aims to set targets for carbon reduction by power generation and promote renewable energy. Although not specifically a storage policy the promotion of renewable energy technologies would in turn drive the need for energy storage [66]. However, the policy was rescinded by the Trump administration.

As well as these federal energy storage policies there are a number of state-level initiatives that are driving energy storage. The remainder of this section will focus on three particular states California, New York, and Hawaii.

4.4 California

The latest available figures (as of September 2020) from the US DOE Global Energy Storage Database suggest that around 23% of the battery storage and 18% of the pumped hydro storage of the total operational US energy storage facilities are in California [74]. This clearly suggests that California has the largest energy storage market in the US and is a leader in environmental and energy policies.

In 2011 the California Renewable Portfolio Standard (RPS) set a target requiring 33% of California's electricity to be generated from renewable sources by 2020 [69] and in 2018 Senate Bill (SB) 100 was passed by the legislature which requires that renewable energy and zero-carbon resources will supply 100% of electric retail sales to end-use customers by 2045. Following that California has committed to 50 percent of the state's electricity from renewable resources by 2030 [70][71].

In 2013 it initiated its CO2 cap and trade scheme aimed at lowering power producers' emissions and increasing the value of clean energy sources [72]. The subsequent increase in intermittent renewable electricity has driven the need for energy storage and California has become something of a posterchild for energy storage policy with an ambitious target of 1.3GW of non-pumped hydro energy storage by 2020 to be procured by the three largest utilities [67, 73]. It currently has 4.3GW of grid connected energy storage, although 3.9GW of this is large-scale (>50MW) PHS [74].

4.4.1 California's energy storage targets

Table 4 shows California's energy storage targets to 2020 broken down by utility and the level of connection (transmission, distribution, or customer), with over 47% of the total targeted energy storage coming from the distribution or customer level. It is important to note that although the utilities have to procure these levels of storage, they are restricted to owning no more than 50% of the storage assets themselves, this subsequently opens the market up to non-utilities [21]. As of early August 2018, California's three largest 'Investor Owned Utilities' (IOUs) have procured or are seeking approval to procure almost 1,500 megawatts (MW) of energy storage [75].

Table 4: California Energy Storage Targets (cumulative, MW) [76]

Utility and level of connection	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal	90	120	160	210	580
Pacific Gas & Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal	90	120	160	210	580
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal	20	30	45	70	165
Total	200	270	365	490	1,325

4.4.2 Energy storage policies

In addition to the targets there has been a number of policy measures put in place at the state level to help ensure these targets are met. The main subsidy scheme available to energy storage providers in California is the Self Generation Incentive Program (SGIP). The SGIP has been in place since 2009 [77], and offers a subsidy for advanced energy storage technologies, which decrease with capacity up to 6MWh [78]. The storage technologies can be either stand-alone or paired with a generating system but must be capable of discharging fully at least once a day [78]. With the relatively small cap on storage capacity and the decreasing nature of the subsidy the SGIP is of greater benefit to small/medium size energy storage projects at the distribution level or lower and so is effectively promoting more decentralised forms of energy storage [21].

The California Solar initiative (CSI) provided funding for small-scale solar (solar PV and solar thermal) projects for domestic and commercial customers with an aim (which was met) of installing 1,940MW of solar capacity from 2007 to 2016 [79, 80]. Whilst not strictly a storage subsidy, small-scale storage systems could be installed as part of the solar installation [21].

With increased renewable generation there can be increased strain on electricity networks as periods of high and low demand do not always correspond with periods of high and low generation. To counter this the California Public Utilities Commission in conjunction with the three utilities in California have implemented a Permanent Load Shifting Program (PLSP) [81, 82]. The PLSP incentivises utility customers to install storage systems to be used for load shifting by paying up to $875/kW of installed load shifted capacity [81, 82]. Thermal energy storage (TES) systems such as ice and chilled water are particularly encouraged as the demand for cooling is usually during times of high demand and so allows for useful load shifting to take place [81, 83]. To be eligible for the PLSP a storage owner must be on a Time Of Use (TOU) tariff which are offered by all three utilities [21], this provides an additional monetary benefit for the installed storage asset as the electricity used for cooling can be bought during periods of low demand when prices are lower. Additionally, TOU tariffs can be used by storage systems, independent of the PLSP and provide an income through arbitrage.

Despite California's success in promoting energy storage there have been several suggestions for improvement. These include an even greater focus from the SGIP on non-transmission level storage as it has more value at the household level where load variability is likely to be greater. [19] has warned that as the SGIP is particularly generous compared to other countries the funding organisations should ensure that the uptake of subsidies does not exceed the funding available so as to avoid a boom-and-bust cycle.

4.5 New York

New York's Climate Leadership and Community Protection Act (CLCPA) legislates the state's goal of 70% renewable energy by 2030 and 100% clean power by 2040 while also cutting greenhouse gas emissions 85% by 2050 [84]. To help meet the balancing need this creates, New York currently has 1.44GW of grid connected energy storage. The vast majority of this is PHS, although there is increasing energy storage capacity from battery and thermal storage systems [74]. The state has placed itself a target of 1,500 MW of energy storage by 2025 and 3,000 megawatts of energy storage by 2030 [84]. The DOE Global Energy Storage database suggests that New York is already in course of meeting its 2025 target with latest (as of September 2020) total operational energy storage capacity of 1446MW. Like California most of New York's energy storage is PHS [74].

New York is traditionally an innovator in energy efficient buildings and has clear policy instruments in place, for example NYC Climate Mobilization Act (2019) requires buildings over 25,000 square feet to cut climate emissions 40% by 2030 and requires strict coordination between the State and local government [84]. New York is also leader in demand-side management and its implementation of energy storage reflects this [21]; since 2009 New York has put in place a number of measures to promote energy storage.

NYISO, the system operator for New York was, in 2009 the first system operator to allow energy storage technologies to provide frequency regulation services [21, 85, 86, 87]. Subsequently a 20MW flywheel system was commissioned in 2011 in Stephentown to provide frequency regulation to NYISO [88]. Energy storage technologies also have access to a day ahead and real-time wholesale markets and so have access to a revenue stream through arbitrage [89]. In 2010 the New York Battery and Energy Storage consortium (NY-BEST) was created with seed funding from the New York State Energy Research and Development Authority with a mission 'to catalyse and grow the energy storage industry and establish New York State as a global leader' [90].

In 2014 the Governor of New York announced plans to modernise New York's electricity industry, known as the 'Reforming the Energy Vision' (REV). The REV calls for a market for distributed energy, known as the Distributed System Platform (DSP) to be created [19]. In 2016 New York's main electricity supplier, Consolidated Edison produced Implementations plan for the DSP. The plan was wide-ranging but included a five-year roadmap for integrating approximately 800MW of distributed energy resources by 2020 with distributed battery storage planned to provide 4MW of load reduction capacity by 2020 [91].

As in California, the state's main electricity supplier (Consolidated Edison) offered a demand reduction program which incentivised electricity consumers to shift their load to help lower peak grid demand. The program was open to a range of load-shifting technologies which could shift a minimum load of 50kW including TES and battery storage. For 2018 the program paid up to $1500/kW of installed load shifted capacity, Table 5 shows the eligible technologies and the maximum incentive they could receive for 2018 and 2019.

Table 5: Consolidated Edison Demand Reduction Program Technologies and Incentive Levels 2018 & 2019 [92]

Technology Type	**2018 Maximum Incentive Level ($/kW)**	**2019 Maximum Incentive Level ($/kW)**
Thermal Storage	1,500	1,700
Battery Storage	1,500	1,350
High Efficiency Electric Chiller/HVAC/BMS/Controls	1,000	1,000
DR Enablement Controls	650	1,000
DR Enablement (for CHP, covers only incremental kWs that can be generated above base load level)	650	5,00
Steam Turbine Chiller, Double Stage Absorption Chiller, Gas Driven Chiller	1,000	1,000
Single Stage Absorption Chiller	600	600

Steam Turbine Chiller Control Panel for Improved Efficiency	500	500

TOU tariffs are offered by Consolidated Edison allowing additional savings to be provided by these storage assets [93]. TOU tariffs can also be used by storage systems (including residential systems) to provide an income through arbitrage. Additionally, as in California, Consolidated Edison provide a TOU specifically for Electric Vehicles.

New York clearly has ambitions to deploy significant levels of energy storage, however barriers to it realising these ambitions exist. These include uncertainty around the programs for supporting the uptake of energy storage and as in California a warning that the incentives under the demand reduction program may lead to a boom-and-bust cycle [19].

4.6 HAWAII

The majority of Hawaii's energy needs are currently met by expensive, imported, oil-fired generation resulting in electricity prices which are over twice that of the other US states [21, 19]. In 2018 oil and coal contributed to 61.3% and 11.9% of Hawaii's electricity generation respectively while solar and wind accounted for 11.2% and 4.9% electricity generation [94]. High energy price from oil-fired generation alongside the high renewable resource potential of the state and isolated nature of the individual islands' electricity grids which are not connected to each other, has led to the state actively pursuing the adoption of renewable energy technologies.

Indeed, Hawaii's RPS is one of the most ambitious, with a target of 40% of electricity sales coming from renewable sources by 2030, and 100% by 2045 [95], good progress is being made in achieving these targets with the Hawaiian Electric companies (who provide electricity to 95% of Hawaii's population) supplying 28.4% of their electricity from renewable sources in 2019 [96, 97]. There has also been a drive for distributed solar PV generation which at the end of 2016 made up 33.5% of all renewable generation [98]. Along with the renewable generation targets, Hawaii also has demand reductions target. Hawaii's Energy Efficiency Portfolio Standard aims to achieve a reduction of electricity consumption by 4,300 GWh by 2030 [94].

The increase in renewable generation has led to an increased need for balancing measures, including both centralised and decentralised energy storage, with Oahu (the island with the greatest population and electricity demand) experiencing issues with regulating voltage and frequency as well as the inefficient use of thermal generation to provide spinning reserve [19]. Hawaii currently has 44MW of grid-connected energy storage, with battery storage making up almost 93% of this capacity [74].

4.6.1 Energy storage policies and incentives

Hawaii's Smart Export Programme (2017) provides the option for customers to install a rooftop PV system plus a battery energy storage system. Under Smart Export Programme customers can export energy to the grid during evening, overnight, and early morning and receive a monthly bill credit for energy exported to the grid, however energy exported during the daylight hours (9am – 4pm) is not compensated. The export credit rates are fixed for five years until October 22, 2022 [94].

Hawaii's other incentives indirectly contribute to the energy storage market. Customer Grid-Supply program (CGS), Customer Grid-Supply Plus and the Customer Self-Supply program (CSS) support the growth of decentralised rooftop solar generation systems, which may include a storage system. The CGS is the successor to the net energy metering program and allows any excess power generated by a PV system to be exported to the grid; the customer is then given credits (ranging from 15c/kWh to 28c/kWh depending on the island) of their electricity bills for each unit of power exported to the grid. The CSS allows for an expedited review and approval of applications for solar PV systems which are only expected to provide generation to the host property or to a storage system for use by the property later, as such any power exported to the grid is not compensated for. Due to the lack of export compensation the CSS is particularly likely to promote storage systems.

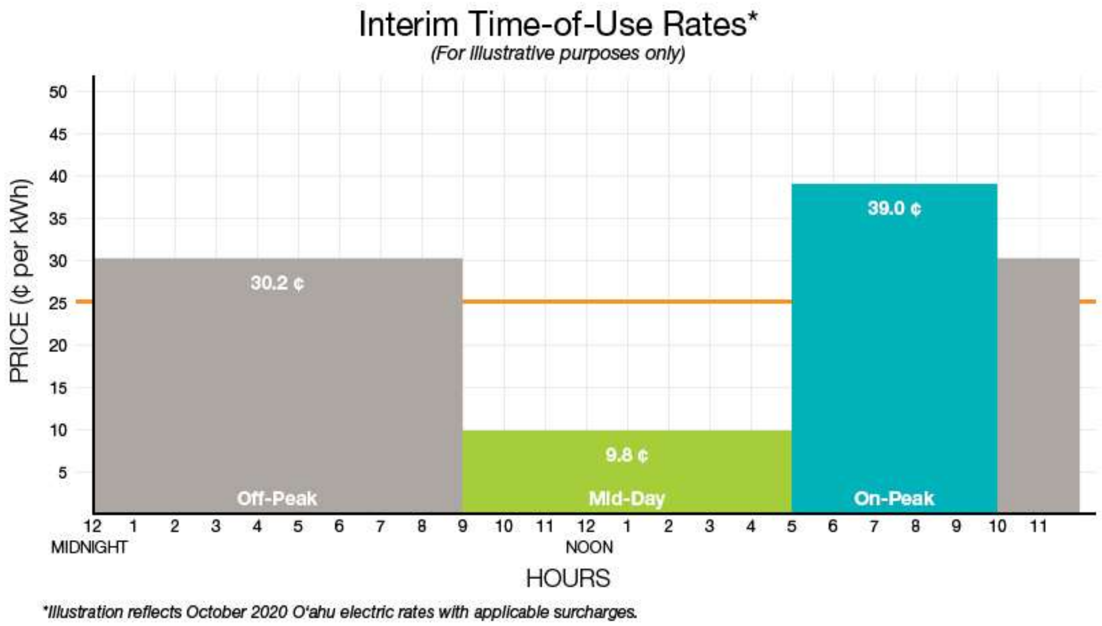

Figure 4: Hawaiian Electric Companies TOU Tariff Rates October 2020. Source: Hawaiian Electric [99]

In addition to these measures the Hawaiian electric companies are currently piloting a TOU tariff. TOU tariff rates are shown in figure 4, unlike many tariffs the lowest price is in the middle of the day (when solar generation is at its greatest) rather than during the night. This provides an incentive to shift electrical consumption away from the on peak times by storing it during the low-rate times for use at a later time.

The inherently decentralised nature of Hawaii's electricity networks alongside the relatively large proportion of distributed solar PV generation makes it an important case study for those trying to promote decentralised energy storage in the UK. However, an important difference is that the high electricity price in Hawaii makes renewable energy and subsequently energy storage more financially viable than in many places in the world, including the UK.

5 JAPAN

5.1 ENERGY SUPPLY AND CARBON EMISSIONS TARGET

Japan imports almost all of its fossil fuel (oil, coal, LNG) and is heavily dependent on imported fossil fuel to meet its energy demand. Japan is the world's largest liquefied natural gas importer and ranks in the top four countries for the highest coal imports, net imports of petroleum and other liquids, and consumption of crude oil and petroleum products [100]. Following the Fukushima Daiichi nuclear disaster of 2011 Japan’s reliance on fossil fuel increased to 87% in 2017 from 81% of primary energy supply in 2010. Among the total primary energy supply oil, coal and LNG contributed to 39%, 25.1% and 23.4% respectively while nuclear energy contributed to just 1.4% in 2017. In the same year renewable energy contributed to 11.1%, of which 3.5% was hydroelectricity [101]. The country was the world’s 6th largest energy consumer in 2019, according to estimates from the BP Statistical Review of World Energy June 2020 [119].

Japan aims to achieve a 26% reduction of its greenhouse gas emissions by 2030 in comparison to 2013 level (18% in comparison to 1990 level) [101]. The amount of carbon emissions increased sharply after the Fukushima Daiichi nuclear plant in 2011 and reached the highest recorded (1417 Million-tCO2) in 2013. Japan has since managed to decrease its carbon emissions below the 2010 level (year before nuclear disaster); in 2017 the country’s carbon emissions were 1292 million -tCO2 [101][119]. In October 2020 Japan’s new government has pledged to be carbon neutral by 2050 [102].

5.2 ENERGY POLICY AND PROGRAMMES

Before the accident at the Fukushima Daiichi nuclear plant in 2011 Japan was the third largest producer of nuclear power with its nuclear power fleet providing 26% of the country’s electricity supply [19]. Following Fukushima all 54 nuclear reactors were shut down, although 10 of these reactors are now operating or expecting to begin operating soon nuclear generation is no longer expected to make the contribution that it once did [103 104]. This in addition to Japan’s high dependence on imported fossil fuel reserves [105], had led to the Japanese Government aiming in successive strategic energy plans to expand its level of renewable generation to replace much of its nuclear generation and meet decarbonisation targets [106, 107]. A number of measures were put in place to drive the installation of renewable energy including a FiT with a particularly high rate for solar PV [68, 108]. This has led to an increase in the contribution renewable generation makes to Japan’s energy supply from 4% in 2010 to 11.1% in 2017 of total primary energy supply [101][109]. This increase in renewable generation is largely down to the growth of solar PV generation which went from providing 0.33% of the electricity demand in 2010, to 7.4% in 2019 [109].

5.2.1 Energy Basic Plan

Japan's "Fifth Energy Basic Plan" published in 2018 sets latest carbon emissions reduction and energy ambitions including 80% reduction in greenhouse gas emissions by 2050. The Fifth Energy Basic Plan is guided by the so called 3E + S (economic efficiency, energy security, environmental protection, and safety) objectives. The plan outlines the aim of "steady conversion of renewable energy into a major power source" and "creation of new technologies such as the world's most advanced floating offshore wind power systems and large-scale storage batteries" [110]. Japan plans to address the grid constraints (for distributed and variable renewable energy generation) by "utilizing Virtual Power Plants (VPPs) and Vehicle-to-Grid (V2G) technology that controls the reverse power flow from storage batteries in EVs, stationary-type of storage batteries and, in the long term, hydrogen" [110].

Other key energy policies include the Act on the Rational Use of Energy 2018, Japan Solar PV Auctions 2017, Building Energy Efficiency Act 2016, Act on Sophisticated Methods of Energy Supply Structures.

5.3 Energy Storage

The rapid increase in solar PV generation has led to a pressing need to increase the flexibility of the energy system which has begun to drive the need for centralised and distributed energy storage [111]. In addition to this push for renewable generation, Japan's energy suppliers offer residential TOU tariffs with relatively large price differentials, which can help to drive the uptake of distributed energy storage.

Due to its nuclear generation legacy, Japan has high levels of pumped hydro storage capacity (28.25GW) [74]. The remainder of Japan's grid-connected storage is made up exclusively of electrochemical batteries, much of it relatively new but some of it such as around 100MW of sodium sulphur batteries developed for assisting with balancing the baseload nuclear generation [74, 19]. Although the large PHS capacity is used to store the additional solar PV generation produced during the day, the increased flexibility needed is driving new policy measures to develop additional energy storage capacity.

5.3.1 Batteries

The focus for this additional storage capacity is on batteries with the fourth strategic energy plan (2014) setting Japanese companies the target of capturing a 50% share of the global battery storage market by 2020 [112, 113]. Since 2012, the Japanese Government through the Ministry of Economy, Trade, and Industry and the Ministry of Environment has launched a number of battery subsidy schemes which provide payment for up to 2/3's of the cost of a battery system (predominantly focused on lithium-ion) and target a range of systems and scales from decentralised and residential to large-scale and utility [112, 114]. These subsidies encouraged over 100MWh of household battery storage installations by the end of 2013 alone [115].

In conjunction with these subsidies innovative business models are also being used to drive the uptake of distributed energy storage, for example One Energy Corporation, a collaboration between three large Japanese corporate institutions (ORIX Corporation, NEC Corporation and EPCO Incorporated), offers residential owners of PV systems the opportunity to lease domestic scale battery systems for a monthly fee rather than having to pay a large upfront cost for a battery system [116].

5.3.2 Hydrogen

Japan has published its ‘Strategy for Developing Hydrogen and Fuel-Cell Technologies’ which aims for the introduction of 5.3 million units of household fuel cells (Ene-farm) by 2030 and ‘achieving the self-reliance market by around 2020’ [117][91]. The country has an ambitious plan for the fuel cell vehicles (FCVs) and hydrogen stations and aims to “install hydrogen stations at 320 locations by 2025 and make the hydrogen station business self-reliant by the second half of the 2020s”. Similarly, aims to increase the number of FCVs in the country to 200,000 units by 2025 and to 800,000 units by 2030. These targets are more ambitious than that of South Korea which is also putting forward ambitious plans for FCV. There were plans to showcase Japan’s hydrogen superiority in the 2020 Tokyo Olympics which has now been cancelled due to COVID 19 pandemic [91]. The strategy strives for technological development, innovation, cost reduction, and full-fledged commercialization of hydrogen technology both in domestic and overseas (mainly European) market in near future.

As already discussed, due to its once high levels of nuclear generation, Japan has a history of promoting energy storage (PHS and Sodium-sulphur batteries). However, the events at Fukushima have given Japan a unique driver for rapidly installing additional renewable generation which in turn is driving the need for energy storage. Although Japan has provided a range of support measures for energy storage they are almost entirely focused on Lithium-ion batteries; focusing on one technology allows Japan to become a world leader in that technology and is similar to the UK approach to offshore wind. However, energy storage is a rapidly developing sector and this approach may be seen as a high-risk strategy as it provides a level of technology lock-in which may be undesirable if Lithium-ion batteries are superseded by a superior, but significantly different storage technology. However,as wells as Lithium-ion batteries, Japan has recently been pushing for Hydrogen technology with ambitious targets and investments.

6 South Korea

6.1 Energy Supply and Carbon Emissions Target

South Korea is one of the world’s leading energy importers as it relies on imports to meet about 98% of its fossil fuel consumption [118]. The country was the world’s tenth-largest energy consumer in 2019, according to estimates from the BP Statistical Review of World Energy, June 2020 [119]. Oil, coal, and natural gas accounted for 43%, 28% and 16% of the primary energy consumed in the country in 2019. In the same year nuclear energy accounted for 11% while renewables accounted for 3% of the total primary energy [119].

In the 2016 Paris Climate Change Agreement, South Korea committed to a 37% carbon emissions reduction target by 2030 [120]. Following the commitment, the Ministry of Trade Industry and Energy (MOTIE) announced the Renewable Energy 3020 Implementation Plan (RE3020) which sets a goal to produce 20% of its energy from renewable sources by 2030 [121].

6.2 Energy Policy and Programmes

The RE3020 plan introduced Korean Feed in Tariff System targeting the small-scale solar PV (<1000 kW), provided long-term and low-interest loans for PV installation and planning permission and operator selection by local government for the PV and wind generation. The plan also aimed at fostering distributed power industry by creating new markets for aggregating small-scale distributed power and expanding renewable energy and energy storage system integration [121].

South Korea announced the 8th Basic Plan for Long-Term Electricity Supply and Demand (called 8th BPE for simplicity) in January 2018, which stated plans for nuclear phase-out and the acceleration of renewable distribution, particularly solar and wind. Since the Moon administration is encouraging the installation of more solar energy, the share of solar generation is expected to be up to 84% of all renewable generation by the 2030 target date. The highest share of renewable electricity supply is expected to be 16% of the total supply, while 18% is expected only in spring season. In the short term, the gap from the shut-down of nuclear plants is fulfilled by LNG and in the medium to long term renewable energy will replace nuclear. But renewables have a number of technical limitations, especially the high fluctuation in production that must be overcome to become a stable electricity provider [122]. Following 8th BPE, in 2019, Korea unveiled its draft version of the 3rd Energy Basic Plan. According to the draft plan Korea aims to increase its renewable energy to 35% in its power mix by 2040 [123].

6.3 Energy Storage

Figure 5 below shows the annual capacity of combined utility-scale and behind-the-meter storage deployment in South Korea. It can be seen that the deployment of energy storage has been rapidly growing from 2016.

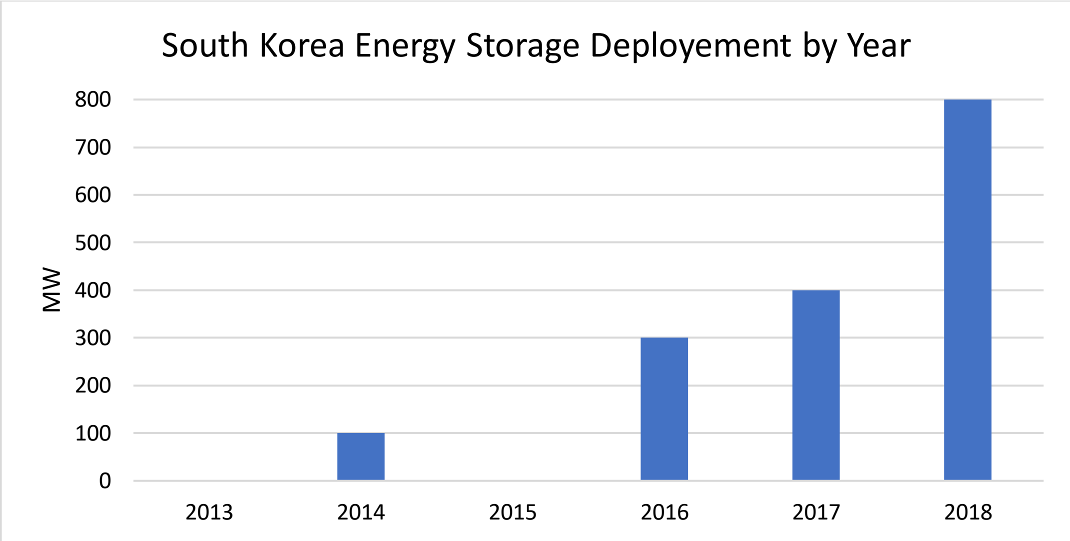

Figure 5: South Korea Energy Storage Deployment by Year. Source: IEA

6.3.1 Batteries

Energy policies mentioned in section 6.2 have led to the new policies and R&D in various energy storage system in South Korea. Among the ESS technologies practiced in Korea, electrochemical energy storage (ECES) is significantly advancing recently. Among various ECES systems, rechargeable batteries have made the greatest strides in Korea in the past decade along with the huge hike in the production and sales in industrial batteries and automotive [125].

6.3.1.1 Private sector R&D investment ECES

South Korea's private sector in particular is one of the leaders in development and production of ECES. South Korea is the home to major Lithium-ion battery (LIB) companies such as LG Chem, Samsung SDI, S.K innovations Hyosung and LS Ind. The Korean battery companies, including LG Chem, Samsung SDI and SK Innovation, signed a memorandum of understanding (MOU) in the beginning of 2019 to jointly fund USD 88.04 million to develop next-generation battery technology and support promising rechargeable battery companies [124]. The LIB research is extensive over both industry and academic levels in the country. Owing to the major role of materials for device performance, large parts of research have focused on the nanomaterials with desired nanostructures and large surface areas [125].

6.3.2 Hydrogen

Hydrogen has also been taken as one of the key components of energy storage systems in the country. On 17th of January 2019, the Korean government announced the Road Map of Hydrogen Economy with the aim to create an ecosystem of hydrogen industry including energy production, storage, transportation, safety and harnessing its use. The road map also aims to make the country the No. 1 producer of hydrogen powered cars and fuel cells globally by 2030. The government also aims to promote the manufacturing of fuel cells or power generation to reach a combined capacity of 15 gigawatts by 2040. In the end aiming to export to European market, Korean governments and private sectors are actively collaborating with European companies in the R&D of ESS [126, 127]. The Korean government has planned to create a national heat map by 2020 to include all the wasted and unused heat energy from power plants, incineration facilities, district heating facilities, fuel cells, and industrial facilities [128]. The initiative is also likely to promote and integrate the energy storage technologies in local energy system.

7 AUSTRALIA

7.1 ENERGY SUPPLY AND CARBON EMISSIONS TARGET

Most of Australia's energy relies on traditional non-renewable fossil fuels. Coal and gas account for about 79% of electricity generation. Renewable energy from sources like wind, solar and hydro provide about 21% of Australia's electricity supply [129]. The country was the world's 18th largest energy consumer in 2019, according to estimates from the BP Statistical Review of World Energy June 2020 [119]. In 2019 oil, natural gas and coal accounted for 33%, 30% and 28% of the total primary energy consumed in the country. In the same year renewables accounted for 9% of the primary energy among which hydroelectric contributed to 22% of the renewables and 2% of the total primary energy [119].

In the 2016 Paris Climate Change Agreement Australia committed to reduce emissions by 26–28% below 2005 levels by 2030. To deliver Australia's 2030 Paris climate commitments it has launched a $3.5 billion investment fund called Climate Solutions Fund. The scheme offers landholders, communities, and businesses the opportunity to run new projects that reduce or remove greenhouse gas emissions from the atmosphere. In running a Climate Solutions Fund project, the participant can earn carbon credits and sell them to the Australian Government, or to businesses and other private purchasers. Each carbon credit represents one tonne of carbon dioxide equivalent greenhouse gas emissions stored or avoided [130].

7.2 ENERGY POLICIES AND PROGRAMMES

Australia's Energy Policy Framework (2019) is the key document that outlines the country's energy priorities. Delivering an affordable and reliable energy system, putting energy consumers first and taking real and practical action to reduce emissions, and meet Australia's international commitments are 3 pillars of Australia's Energy Policy Framework [131]. In line with Australia's Energy Policy Framework's reliability goal the Grid Reliability Fund was announced on 30 October 2019.

The Grid Reliability Fund supports the Australian Government's investment in new energy generation, storage, and transmission infrastructure. The fund prioritises investments in jurisdictions where state and territory governments are working with the Australian Government towards an agreed reliability goal and to ensure sufficient reliable generation capacity is available to meet periods of high demand in the National Electricity Market. Eligible investments include energy storage projects including pumped hydro and batteries, transmission, and distribution infrastructure and, grid stabilising technologies [132]. The Regional and Remote Communities Reliability Fund (Fund) supports feasibility studies looking at microgrid technologies to replace, upgrade or supplement existing electricity supply arrangements in off-grid and fringe-of grid communities located in regional and remote areas [133].

Other energy programmes such as the Underwriting New Generation Investments (UNGI) and Supporting Reliable Energy Infrastructure program focus on lowering electricity prices, increasing reliability in the system, and securing energy affordability for commercial and industrial users. The programs are technology neutral, providing a level playing field to enable the best and lowest cost generation options to be supported [134].

7.2.1 Integrated renewable and battery storage

The Australian Government is investing in new forms of renewable energy, particularly in concentrated solar thermal and battery storage technology, to provide additional backup in times of peak demand. Since 2013, the government has committed over $220 million to support energy storage technologies. In Australia, research and development grants are provided by the Australian Renewable Energy Agency (ARENA), the Australian Research Council and the CSIRO. Financing for emerging technology is provided by the Clean Energy Innovation Fund. Projects near commercial deployment can access debt and equity finance from the Clean Energy Finance Corporation (CEFC) [135]. The CEFC invests commercially to increase the flow of funds into renewable energy, energy efficiency and low emissions technologies. The CEFC has committed $94 million as a sole debt financier for Windlab and Eurus Energy's Kennedy Energy Park in central north Queensland. The project will be Australia's first fully integrated wind, solar and battery project. The project includes 43.2 MW of wind, 15 MW (AC) of solar and 2 MW of battery storage and is expected to deliver lifetime emissions abatement of almost three million tonnes of CO2-e [135].

7.3 ENERGY STORAGE

7.3.1 Domestic Battery

Plenti Green Loan programme helps deliver the South Australian Government’s Home Battery Scheme, to give 40,000 South Australian households access to finance for the battery component of residential solar and battery installations. Plenti is Australia's first peer-to-peer green lending platform that brings together investors, borrowers, and clean energy product providers. Through the online platform, investors can nominate the amount they wish to invest, the interest rate they are prepared to accept, and their request can then be matched to approved borrowers. Borrowers can access this finance to invest in eligible clean energy assets [138].

7.3.2 Large-Scale / Grid-Scale Battery

CEFC also invests in big battery supporting grid system such as Hornsdale Power Reserve [136] which claims to be the world’s largest battery. International renewable energy developer Neoen, which owns the landmark “big battery” in South Australia, is expanding the capacity of the battery to 150MW/181.5 MWh. The expansion provides an Australian first large-scale demonstration of the potential for battery storage to provide stabilising inertia services that are critical to the future integration of renewable energy. Australia has also focused on the mining of raw materials needed for battery storage. The first stage of the Pilgangoora lithium-tantalum project [137] in Western Australia has been completed (as of August 2020) and the mine is producing high quality spodumene concentrate used in lithium battery storage [138].

7.3.3 Pumped hydro

The Australian Government is making targeted investments in large pumped hydro projects such as Snowy 2.0 [139] and Battery of the Nation [140]. The Snowy 2.0 is the plan to expand the original Snowy Mountains Hydroelectric Scheme [139] with an additional 2000MW of electricity generation capacity and 350,000MWh of energy storage. Battery of the Nation is expected to deliver up to 2500MWs of pumped hydro, more than doubling Tasmania's generation capacity, and offer major new energy storage resource [141].

7.3.4 Hydrogen

In November 2019, Australia published Australia's National Hydrogen Strategy [142] which outlined the country's 'vision for a clean, innovative, safe and competitive hydrogen industry that benefits all Australians'. It aims to position Australia's hydrogen industry as a major player by 2030 with creation of Australian hydrogen supply chains and large-scale export industry infrastructure. A key element of Australia's strategy is to create hydrogen hubs; clusters of large-scale demand which 'will provide the industry with its springboard to scale'. The objectives of such hubs are to make the development of infrastructure more cost-effective, promote efficiencies from economies of scale, foster innovation, and promote synergies from sector coupling.

Various forms and levels of collaboration can be observed in the energy programmes in Australia. For example, Australia's National Hydrogen Strategy focuses on collaboration with 57 'joint actions' identified. The joint actions are themed around national coordination, developing production capacity, supported by local demand; responsive regulation; international engagement; innovation and research and development (R&D); skills and workforce; and community confidence [142].

8 SUMMARY OF ENERGY STORAGE POLICIES OF SELECTED COUNTRIES

The following table summarises the operational energy storage capacity of the countries discussed above.

Table 6: Operational Energy Storage Capacity of the selected countries. Source: developed from DOE Global Energy Storage Database

	Energy Storage Technologies Rated Power (MW)				
Country	Electro-chemical (Battery)	Electro-mechanical (CAES and flywheel)	Pumped Hydro Storage	Thermal Storage	**Grand Total**
Australia	164	2	2542	4	**2712**

Germany*	406	321	6703	-	**7430**
Japan	242	-	27422	-	**27664**
Korea, South	155	-	4700	-	**4855**
United Kingdom*	569	400	3161	-	**4131**
United States	763	484	22561	664	**24473**

The above table is developed from combining DOE world energy storage database [74] and the Database of the European energy storage technologies [16]. The Germany and the UK data (marked *) are taken from the EU database while the data for the rest of the countries are taken from the DOE database. The table suggests that United States has the biggest battery storage capacity followed by the UK and Germany. However, it is important to note that the dataset for other countries such as Japan and South Korea may not have been as up to date as the USA, UK, and Germany.

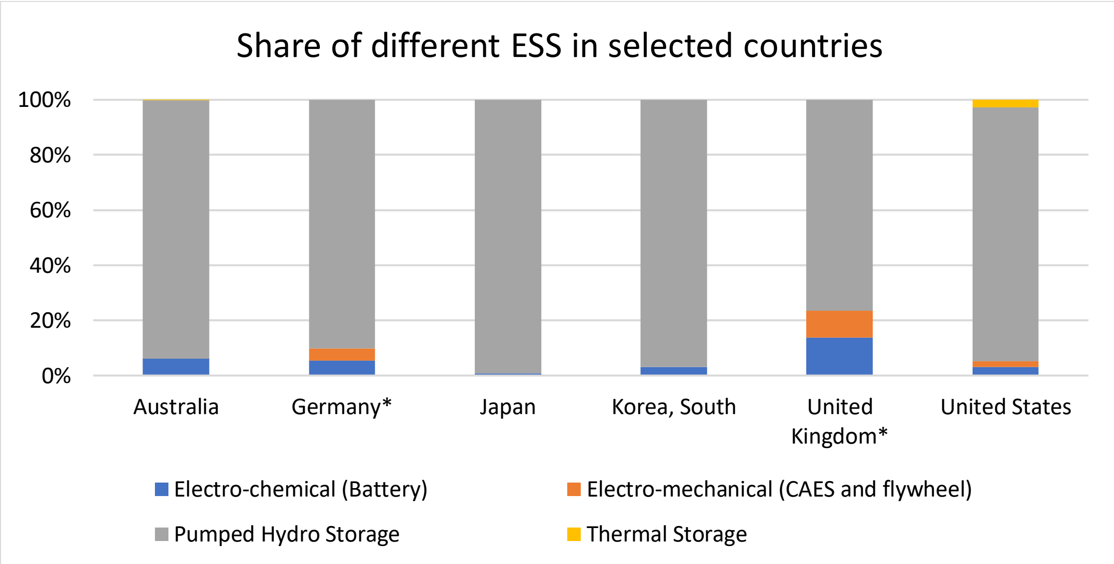

Figure 6 : Share of various ESS in selected countries. Source: Developed from DOE Global Energy Storage Database

Based on the table 6 above, figure 6 shows the share of different energy storage systems of the selected countries. It can be seen that the PHS is a dominant energy storage in all the countries. Other storage system such as battery and thermal storage account for very small percentage of the total storage capacity. Due to the rapid uptake in small and domestic batteries combined with solar PV in most of the countries studied, the share of the battery storage is going to increase significantly in the coming years.

Based on table 1 and discussion in sections 2 – 8, table 7 below summarizes the energy storage (and related) policies of the selected countries.

Table 7: Summary of Energy Storage Policies in Different Countries

Type of policy	Point of intervention	Direct or indirect?	Policy goal	Targeted ESS	Policy instrument	Country	Government Level
Research and Development	Demand, innovation	Direct	Funding for R&D, national and international research, collaboration, and market research	Hydrogen	Australia's National Hydrogen Strategy 2019	Australia	Central
Subsidy	Supply		Supports Australian Government investment in new energy generation, storage, and transmission infrastructure	Grid- scale battery storage and pumped hydro	Grid Reliability Fund	Australia	Central
Subsidy	Demand	Direct	Give 40,000 South Australian households access to finance for the battery component of residential solar and battery installations	Home battery storage	Home Battery Scheme (South Australian Government)	Australia	State
Information, Voluntary	Supply, innovation	Direct	Support small and medium-sized enterprises (SMEs) offering energy solutions in the fields of renewable energy, energy efficiency, smart grids, and storage technologies	All (German) storage technologies	Energy Export Initiative / German Energy Solutions Initiative	Germany	Central
Regulation	Supply	Indirect	Facilitate market access for new renewable technologies by guaranteeing their purchase at fixed rates.	-	The Renewable Energy Sources Act 2014	Germany	Central
Regulation, Public procurement	Supply	Indirect	Facilitate market access for new technologies by setting remuneration rates for renewable electricity on auctions on the market	-	Renewable Energy Sources Act 2017	Germany	Central
Research and Development	Demand, innovation	Direct	Funding for R&D, national and international research, collaboration, and market research	Hydrogen	The National Hydrogen Strategy 2020	Germany	Central
Research and Development	Supply, Innovation	Direct	Provides research funding for energy storage projects	Batteries for distributed	Energy Storage Funding Initiative	Germany	Central

Type of policy	Point of intervention	Direct or indirect?	Policy goal	Targeted ESS	Policy instrument	Country	Government Level
				storage networks and thermal storage systems			
Subsidy	Supply	Direct	Investment in battery storage units that are installed alongside PV systems and connected to the grid.	Battery storage units installed alongside PV systems and connected to the grid	Funding programme for decentralised battery storage systems (ended 2018)	Germany	Central
Information	-	Indirect	Outlines the country's latest carbon emissions reduction targets and numerous energy policies and programmes	-	Fifth Energy Basic Plan (2018)	Japan	Central
Regulation	Supply	Indirect	Auction system for awarding fixed tariff to large-scale solar PV projects. Projects selected through bidding competition receive 20-year long Power Purchase Agreement (PPA)		Japan Solar PV Auctions (2017)	Japan	Central
Regulation	Demand	Indirect	Various energy saving measures and evaluation of energy saving the efforts contributing to the equalization of electricity demand on the demand side to deal with peak demand of electricity	-	Energy Saving Act (2013 Amendment)	Japan	Central
Research and Development, Subsidy	Demand, Innovation	Direct	Plans to introduce of 5.3 million units of household fuel cells (Ene-farm) by 2030, install hydrogen stations at 320 locations by 2025, increase the number	Hydrogen	Strategy for Developing Hydrogen and Fuel-Cell Technologies	Japan	Central

Type of policy	Point of intervention	Direct or indirect?	Policy goal	Targeted ESS	Policy instrument	Country	Government Level
			of FCVs in the country to 200,000 units by 2025 and to 800,000 units by 2030. And make the hydrogen station business self-reliant by the second half of the 2020s.				
Research and Development	Demand, innovation	Direct	Funding for R&D, national and international research, collaboration, and market research	Hydrogen	Road Map of Hydrogen Economy 2019	South Korea	Central
Subsidy	Demand	Direct	Feed in Tariff and provides long-term and low-interest loans for PV installation	Small-scale solar PV (<1000 kW), wind and small-scale battery energy storage	Renewable Energy 3020 Implementation Plan (RE3020)	South Korea	Central
Regulation	Supply	Direct	Relaxation of planning permission for ES facilities by removing unnecessary red tape saving developers time and money	All ESS except pumped hydro	Infrastructure Planning (Electricity Storage Facilities) Order 2020	UK	Central
Regulation	Supply	Indirect	Obligation set by the government for licensed electricity suppliers to offer a tariff and make payment to small-scale low-carbon generators for electricity exported to the National Grid, providing certain criteria are met.	-	Smart Export Guarantee (SEG) Scheme	UK	Central
Regulation, Public Procurement	supply	indirect	A strike price is agreed per unit of renewable electricity generated, if the market price for electricity is less than this strike price then the difference is made up by the UK Government	All renewables and co-located energy storage	Contracts for Difference (CfD) (Electricity Capacity Regulations 2014), last amended in 2019	UK	Central

Type of policy	Point of intervention	Direct or indirect?	Policy goal	Targeted ESS	Policy instrument	Country	Government Level
Regulation, Public procurement	Supply	Indirect	Ensures security of electricity supply by providing a payment for reliable sources of capacity.	Energy capacity and co located energy storage	Electricity Capacity Regulations (2014), last amended in 2019	UK	Central
Regulation	Supply	Direct	Empowers new technologies to come online and participate on a level playing field enabling distributed energy resource (DER) aggregators to supply in all regional organized wholesale electric markets	Solar PV, Home Batteries, EV, thermal storage etc	Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, The Federal Energy Regulatory Commission (FERC) Order 2222	USA	Central/Federal
Regulation	Supply	Direct	Remove barriers to the participation of electric storage resources in the capacity, energy, and ancillary service markets operated by Regional Transmission Organizations (RTO) and Independent System Operators (ISO) (RTO/ISO markets)	All ESS capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid.	Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, FERC Order No. 841	USA	Central/Federal
Regulation, Subsidy	Supply, Innovation	Indirect	Provided financial stimulus through grants and loan guarantees for a variety of technologies including approximately $185million for energy storage projects	-	American Recovery and Reinvestment Act 2009	USA	Federal/Central

9 Stakeholder surveys on energy storage policy and regulation

This report contains the results from three surveys with refrigeration sector specialists from the EU countries Belgium, France, Spain, Bulgaria, Austria, Germany, and the UK. The survey responders and interviewees included representatives from large grocery supermarkets with hundreds of stores, a food storage supplier with large warehouse, a large fast-food retailer with hundreds of stores in different EU countries, energy technology specialists, energy system operators and researchers. The surveys collectively feed into the aim of the research which is to identify the policy and regulatory barriers that could prevent the energy storage technologies from being deployed (at EU and national level). Sections 9.1 and 9.2 discuss the energy storage issue, and 9.3 discusses the energy system in general.

9.1 Refrigeration Sector and Energy Storage

The first part of the survey was carried out in the form of questionnaire to understand the attitude of specialists on energy storage. This survey was conducted during an online CryoHub webinar in March 2020[1] therefore a small number of the responders were from outside the EU and the UK. Secondly, semi-structured interviews were carried out among the selected industry representatives that operate one or more large, refrigerated warehouses. The industry they represented include supermarket, fast food restaurant chain, vegetable storage warehouse and energy technology installer/contractor. The following results are a combination of questionnaire results and semi-structured interviews.

9.1.1 Attitude towards energy storage

When asked about the benefits of energy storage 96% of the responders suggested that they are aware of it. This suggests that there is a wide awareness of the potential of the energy storage.

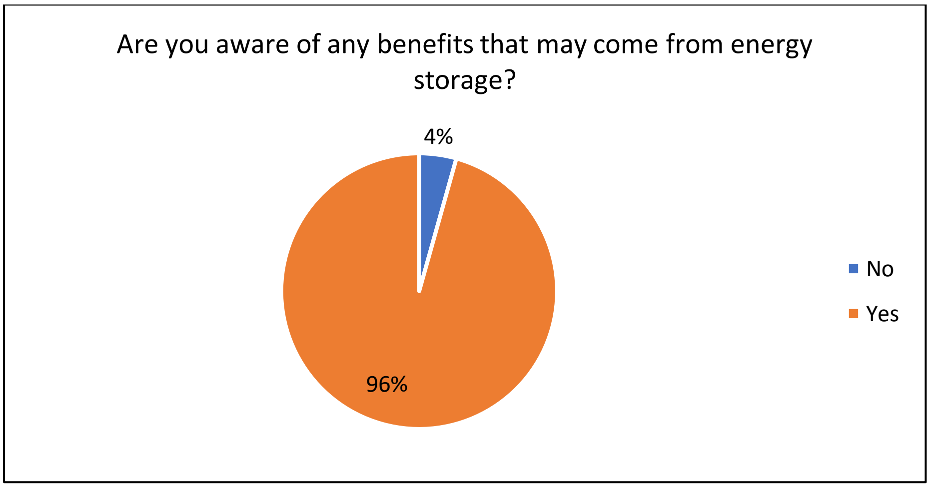

Figure 7: Stakeholder enquiry on benefits of energy storage

[1] See https://cryohub.info/en-gb/next-generation-sustainability-for-cold-stores.

The responders were asked of their attitude towards testing or demonstrating the new technologies in their business. Although 67% of the responders said they were enthusiastic and 8% said they were very enthusiastic, a significant percentage of the responders said they were either reluctant or neutral.

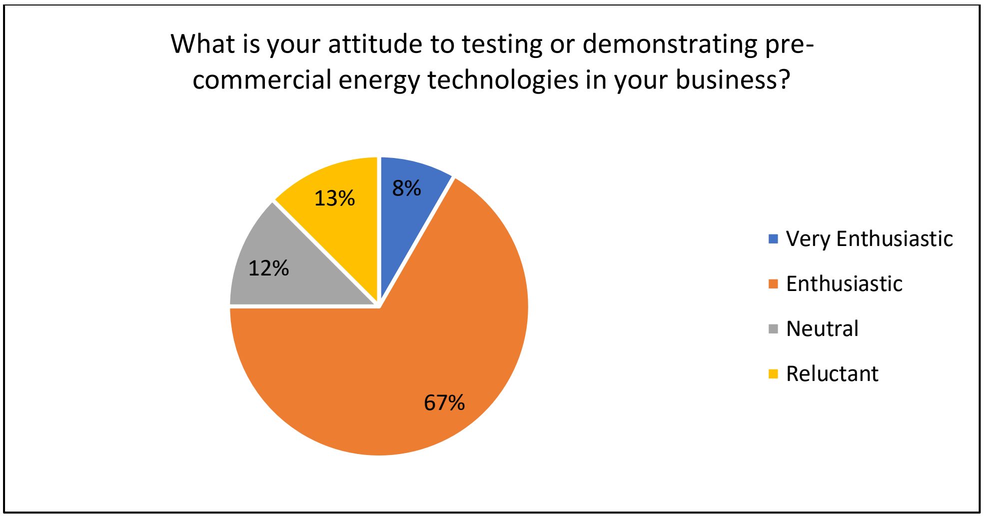

Figure 8: Stakeholder attitude on testing pre-commercial energy storage technologies

The food producer and/or storage industry were more sceptical towards testing the new technology because their energy demand is variable, depending on the quantity of agricultural production on given season, weather, and market demand. Since they are already dealing with a few uncertainties in their energy demand, they fear the new technology may add to that. During the semi structured interview one of the food storage industry representatives said he was neutral towards testing but "…depends on the situation of market".

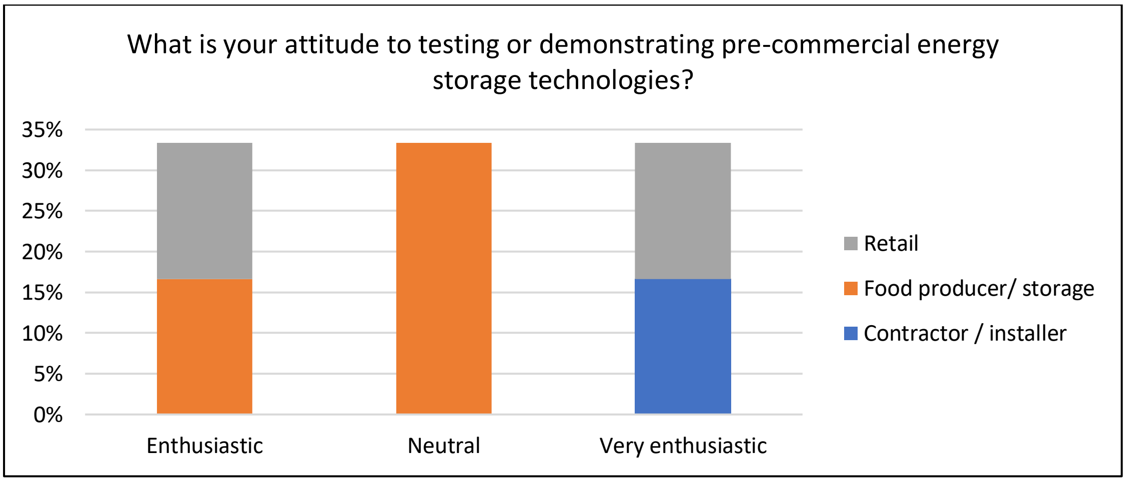

Figure 9: Industry-wise attitude on testing pre-commercial energy storage technology

On the contrary, the retail industry was very enthusiastic or enthusiastic towards the new energy technologies. They have an established supply chain and more predictable energy needs, therefore, testing new technology did not add great amount of uncertainty. However, they stressed that the new technology should be financially profitable. One retailer said he is very enthusiastic but the new technology "…. must provide return on investment (ROI) between 3-5 years of its installation".

9.1.2 Factors affecting decisions on the deployment of new energy technologies

From the review of literature, the following factors were identified as the main factors affecting the decisions on deployment of new energy technologies:

1. Capital expenditure
2. Impact on running costs
3. Integration with existing technologies/processes
4. Lack of understanding of the new technology and
5. Maturity of the technology

In the survey the responders were asked to pick the two factors they think are the most important. 47% of responders picked 1) capital expenditure and, 2) Impact on running costs as the two main factors. 13% of responders picked 1) capital expenditure and, 2) integration with existing technologies/processes as the two main factors.

In the interview the responders were asked to rate the factors very important, important, minor importance or not important.

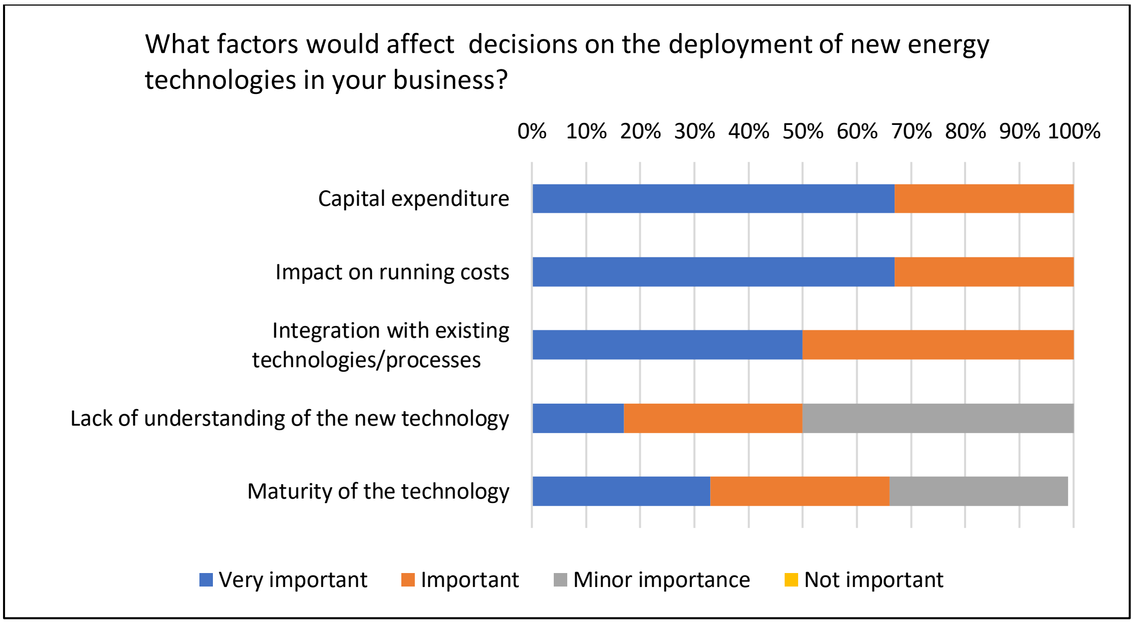

Figure 10: Factors affecting the decisions on the deployment of new energy technologies

From both the survey and interview it is clear that the following are the three most important factors affecting the decisions on the deployment of new technologies.

1) Capital expenditure and
2) Impact on running costs and
3) Integration with existing technologies/processes

With regards to the 'lack of understanding of the new technology' most responders agreed that it can be learnt, or the installers can explain, therefore it is not necessarily a major barrier.

Regarding the maturity of the technology, one of the responders stated the following:

"…. there is no one who wants to try new technology".

This comment highlights that some private sector businesses can have strong reservations towards new, particularly pre-commercial technologies. Therefore, it is important to have a government policy or incentives to promote / commercialise the new technologies. There are different business priorities of different industries, therefore the incentives should be more flexible to accommodate maximum numbers of priorities.

9.1.3 Business priorities regarding the generation and use of energy

The technologies aligned with the business priorities of targeted businesses are more likely to succeed through the commercialization phase of innovation process. Therefore, it is important to understand what the business priorities of intensive energy users are regarding the new energy technologies.

In the survey, the responders were asked to pick the "two most important issues regarding the generation and use of energy for their business". In contrast to the 'factors affecting the decisions on the deployment of new technologies', the responders provided extremely varied answers and there was no single priority that stood out as the most important. The highest rated priorities were 1) Reducing environmental impact, emissions, pollution etc, and 2) improving reliability of supply, which were picked by 13% of responders.

In the interview the responders were asked to rank the business priorities as very important, important, minor importance and not important. 'Lowering energy bills' was rated as 'very important' by all of the interviewees. Similarly, 'reducing environmental impact (carbon emissions, pollution etc)' was rated as very important by 67% and as 'important' by 33% of the responders.

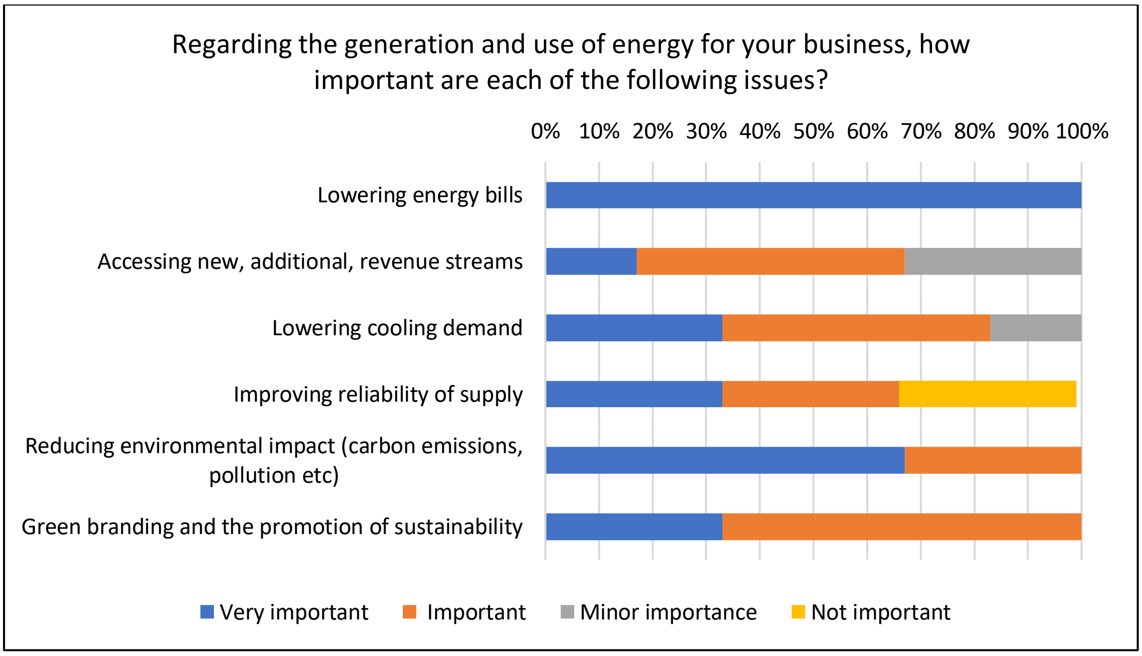

Figure 11: Factors affecting the decisions on generation and use of energy

The business priorities regarding the generation and use of energy varied depending on the geographic location of the business and type of the business. One of the responders who rated ‘improving reliability of supply’ as ‘Not important’ explained that in (their country) electricity grid is very reliable, therefore ‘improving reliability of supply’ is not an important priority. In contrast another responder said that ‘improving reliability of supply’ is ‘very important’, because energy is not reliable in (their country).

Another geographical issue was related to the energy policy and bureaucratic process; some responders suggested that ‘accessing new, additional, revenue streams’ would be ‘important’, but the bureaucratic process can take too long and end up spending more time and money than they would earn by selling the energy to the grid. Another said that it is “important, we would like that but don’t know the process”.

The type of business; whether it is directly customer facing or not dictated their rating on ‘Green branding and the promotion of sustainability’. Industry such as the food storage/producers do not usually have their own brand; they supply products to the retailers; therefore, they do not necessarily benefit from the so-called green branding directly. However, because of the consumer awareness the retailers want to promote the green branding, as an effect the producers/suppliers are also starting to also have an interest in it. One warehouse representative suggested that some of their costumers ask for kg CO_2e (per kg) figures, therefore they “value” the green branding. One of the retailers said that green branding is “important for marketing”.

9.2 Energy Sector and Energy Storage

This section of the report contains the results from interview with energy sector specialists from the EU countries Belgium, France, Spain, Bulgaria, Austria, Germany, and the UK. In the interview the questions were asked around the following three themes:

1. Flexibility
2. The role of energy storage
3. Energy storage innovation and policy

9.2.1 Flexibility

One of the key benefits of energy storage is the flexibility it can provide to energy systems, therefore it is important to capture the industry opinion on the matter. Among the responders 75% said that the need for flexibility in the energy system over the period to 2030 will ‘increase substantially’ assuming the EU maintains its current energy policy goals. There are various energy system and technology related factors that will drive the need for more flexible energy system in the coming years. The following developments were identified as the major drivers for increased energy system flexibility.

1. Increase in variable renewables (e.g., on- and off-shore wind and solar PV)
2. Increase in electric vehicles
3. Increase in electric heating (e.g., heat pumps)
4. Increase in CHP and district heating
5. Increase in space cooling

The participants were asked to rate these drivers as very important, important, minor importance, not relevant.

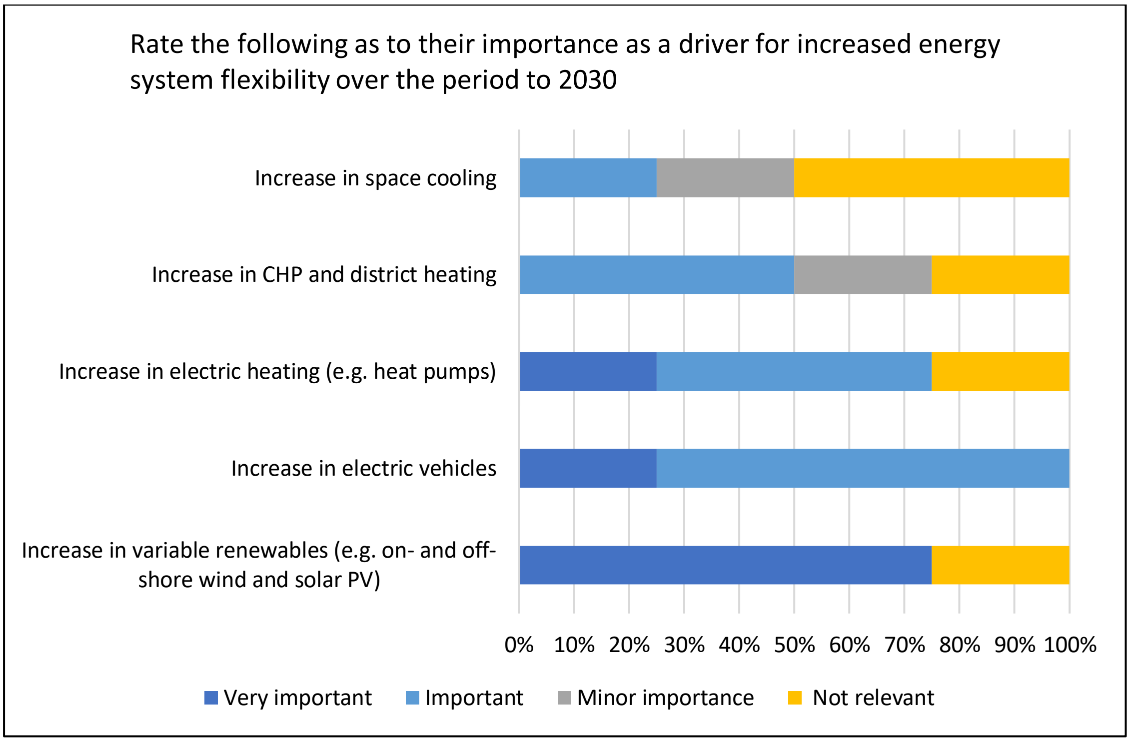

Figure 12: Drivers for the increased energy system flexibility over the period to 2030

Among the developments, 'increase in electric vehicles' was rated as 'very important' by 25% and 'important' by 75% of the responders. On the contrary 'space cooling' was rated as 'minor importance' or 'not relevant' by 25% and 50% responders, respectively. Although a strong majority of 75% responders said that 'increase in renewables' will drive the need for flexible energy system, 25% said it is not relevant. One responder representing energy system operator (ESO) who rated 'not relevant' commented as following:

"Replacing polluting resources by renewables will lead to the lack of baseload supply. While the wind generating basically from midnight to the morning and PVs during the noon, there will be surpluses during these periods that should be consumed/stored, but during the peak loads (evening) renewable energy disappear."

Another responder commented that "The main issue is with PV which is operating only few hours a day (at best!). Importance on flexibility is high …. but playing on 'negative' flexibility!"

Regarding the timeline, 75% of the responders stated that, they think, the current energy system will prove to be insufficiently flexible to cope with the developments identified above by 2025 - 2030. The response suggests that the energy industry insiders acknowledge the urgent need of energy system flexibility.

Flexibility in energy system can be achieved through various interventions at different level. Among them the following are the key options.

1. Storage
2. Demand response
3. Interconnection
4. Back-up flexible fossil capacity

All (100%) of the responders rated 'Demand response' as the 'very significant' option for providing flexibility in the energy system. Apart from demand response 50% of the responders also rated 'storage' as 'very significant' and another 50% rated it as playing 'significant' role in providing energy system flexibility by 2030.

9.2.2 The role of energy storage

The deployment of energy storage is becoming more important to increase system flexibility. The responders were asked to list the most important developments that could increase its role by 2030 and the three most important developments that could decrease the role of energy storage. From the analysis of the answers, the following list has been developed.

9.2.3 The developments that could increase the role of energy storage by 2030

1. Decrease in cost in €/MWh and increase in safety aspects (Li batteries mainly)
2. Improved use/integration of Information and Communication Technologies in energy storage
3. Decommissioning of traditional (fossil and/or nuclear) power and increased variable energy will lead to need for storage technologies to compensate fluctuation.
4. Decrease in hydrogen storage cost, such as through development of "solid" hydrogen sources (MgH2 type) at industrial level
5. Development of small Pumped Water Stations with nice environment integration
6. Improved energy storage in mobility, for example more powerful smaller storage units

9.2.4 Developments that could decrease the role of energy storage by 2030

1. Installation of large-scale energy storage capacity. For example, from second use of batteries of EV in large quantity the need for additional flexibility will be reduced.
2. Lack of legislation or wrong taxation.
3. Secure electric power available by whatever sources
4. Market dependency outside Europe
5. Trend to reduce renewable energy to the systems
6. Power to fuels and Power-to-X will play a role in decreasing the role of energy storage but will not be a threat to storage as they supply a different market.

9.2.5 Suitability of energy storage for system flexibility

There is an argument that the energy storage is not necessarily the best option for providing flexibility in all areas of the energy system. For example, in the previous section we discussed that the responders favoured more to 'demand response' than to 'storage' as an option for system flexibility. In the next question the responders were asked which timescale energy storage is best-placed to provide flexibility to the system. The result suggests that energy storage is best placed to provide system flexibility for 'hours' and 'hour-days'. 50% of the responders thought storage is unlikely to provide system flexibility for months.

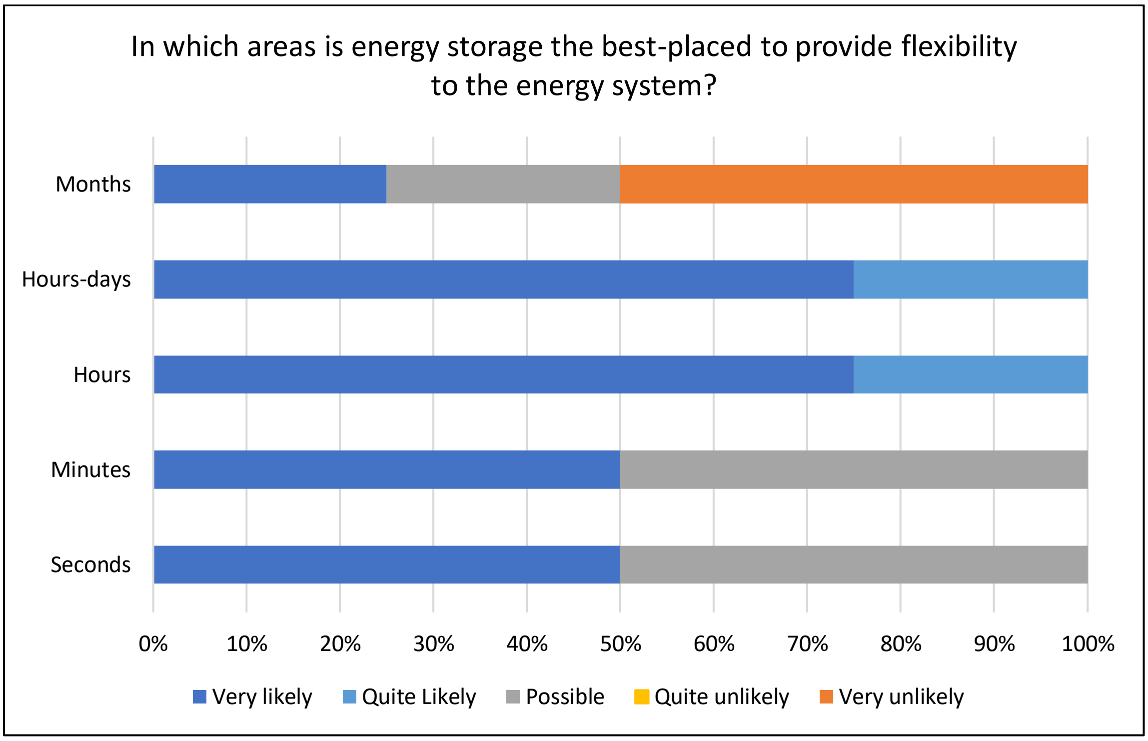

Figure 13: Suitability of energy storage for system flexibility

Another important discussion around the energy storage is regarding the governance and physical location of energy storage. There is a strong argument for the smart local energy system (SLES) suggesting that the energy storage governance and regulation should be situated in the regional or local level. In terms of the electricity system, there are also discussion around where the storage is best suited for, customer level, distribution level, transmission level or generation level. The interview result suggests that the responders thought additional energy storage should be situated at the customer level and distribution level. 50% said storage is 'very unlikely' to be situated at transmission level, similarly 25% and 25% said that storage is 'quite unlikely' and 'very unlikely' to be situated at generation level.

9.2.6 Energy Storage Innovation and Policy

There are various elements of a technological innovation system. In this section the market and policy issue of energy storage innovation is discussed. The responders were asked to list the most important priorities for the innovation in energy storage technologies. From the analysis of their answers, the following energy storage innovation priorities can be summarized.

1. Decrease the cost of electrochemical batteries storage

2. More R&D should be carried out for system integration, demonstration and good programming for materials and component research
3. Improve cycle efficiency of energy storage system
4. Decrease the energy storage system size

9.2.7 Barriers to the deployment of energy storage

There are various barriers to the deployment of energy storage and the barriers are varied in different countries. From the review of the literature the following barriers were identified.

1. Technology cost and performance
2. Uncertainty in future value
3. Regulatory framework
4. Market structure
5. Lack of business models

The interviewees were asked to rate the identified barriers as very important, important, minor importance, and not a barrier.

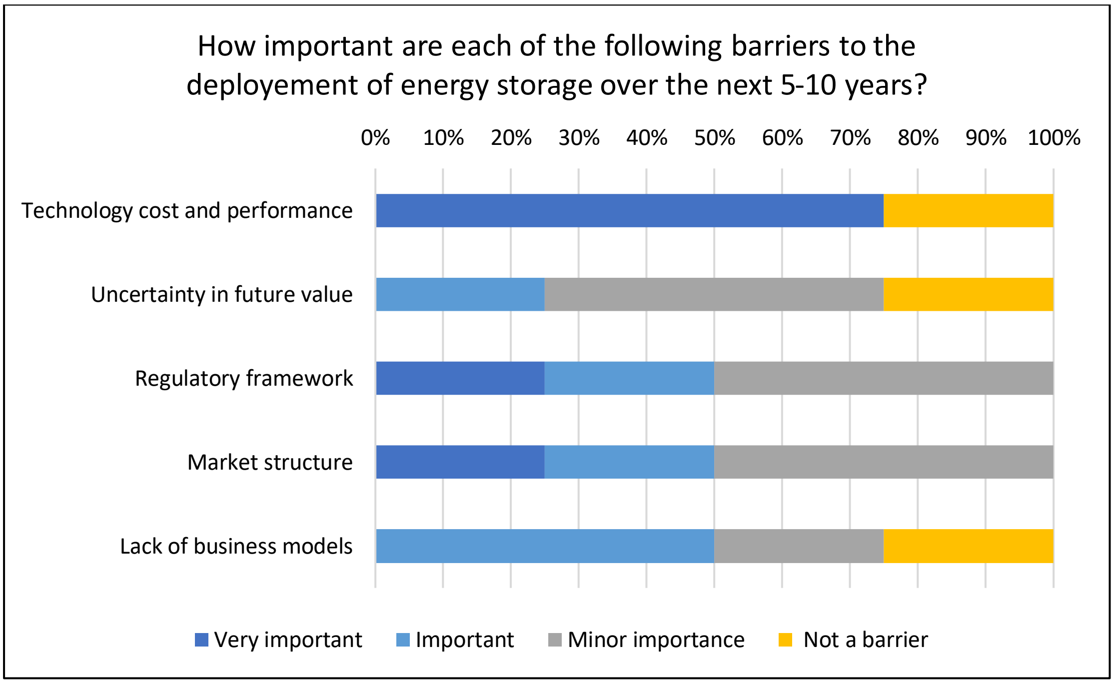

Figure 14: Barriers to the deployment of energy storage over the next 5- 10 years

75% of the responders suggested that the 'technology cost and performance' is 'very important'. They stated that the "energy storages are still expensive and new more effective future technologies can affect the risk of investments". Another responder argued that "although cost is often given as the main factor, lifetime of storage capacities is important for environmental impact of these solutions and economically viable businesses".

Regulatory framework and market structure were also rated as important or very important by 50% of the responders. On regulatory framework, double taxation of storage was raised as an issue. It was suggested that the CO2 taxation can play an important role to enable the uptake of storage. The responders stated that there is need to extend the access to electricity flexibility options to wider industrial and private sector. If more industrial and private sector have access to energy flexibility options, then the market for storage will develop and increase. Regarding the current market structure, it was raised that current electricity market and heating market is too rigid and there is not enough freedom for new business models. Another responder said that if the regulatory framework is correct the market structure 'goes along'.

Lack of business model was rated as 'important' barrier by 50% however the other 50% rated it as minor or not a barrier. Some stated that 'lack of business model is not a barrier because there are examples of different implemented business models (cooperatives, hybrid power plants etc.) that can be adopted for energy storage market.

Some suggested that the issues of business model and technology performance are co-related, for example, lifetime of storage capacities is important for environmental impact of these solutions and economic viability of the businesses model.

9.2.8 Policy interventions required to enable the energy storage

Many of the medium and large-scale energy storage technologies are at the early stage of development. In the innovation system literature various stages of energy technology have been suggested. Among them Research, Development, Demonstration, Market formation and Diffusion are commonly used stages of innovation system (Gallagher et al 2012). There are various actors and institutions involved in the process of innovation. The government's role (for example, policy intervention) is regarded as important for the success an innovation process. The participants were asked whether they agreed that governments should provide (further) explicit support for the development and/or deployment of storage over the next 5+ years as it does for a range of low carbon technologies and 100% of the participants answered that they 'strongly agree' to that.

Governments have supported different new technologies in different ways. The support can be a funding incentive, taxation to discourage certain behaviour in favour of others, strategy, information, regulation etc. In the interview the responders were asked to rate the following government support from very desirable, desirable, not needed.

1. Additional support for R&D
2. Additional support for demonstration
3. Regulatory reforms to remove barriers and create a more level playing field
4. Deployment support (e.g., mandates, capital subsidies, operational subsidies etc.)

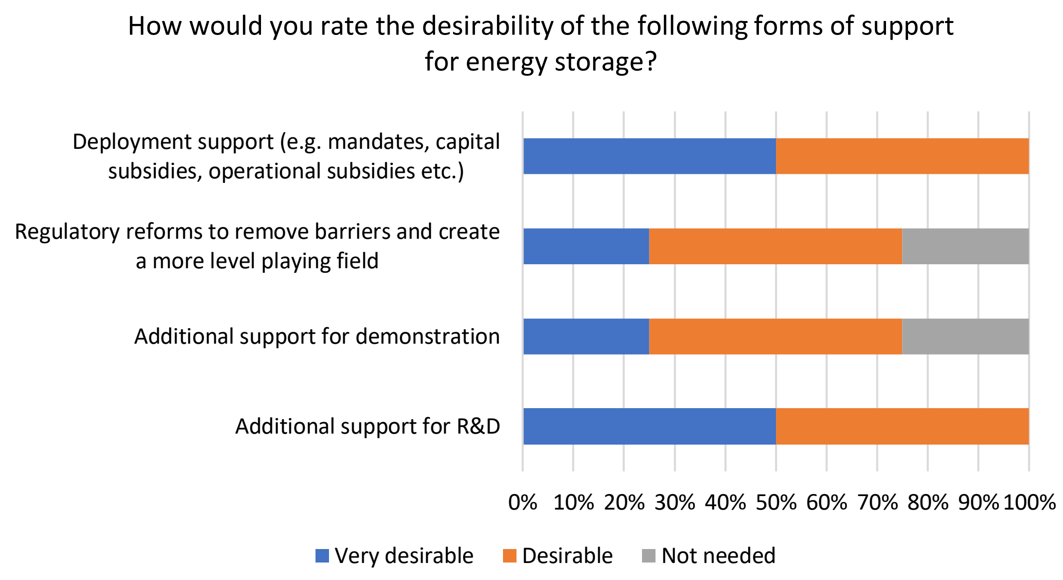

Figure 15: Desired policy intervention for energy storage technology

Some governments such as the state government of California, USA and Japan have set energy storage deployment targets. This can potentially send a positive market signal and help build the confidence of market. Among our responders 50% said that such targets are 'very meaningful' and 50% said 'meaningful'. One responder stated that it is very meaningful to have a target to implement energy storage, as it is a key component for energy transition, but therefore you need to change regulatory framework so that the business case for storage could develop. To have a deployment target itself is less meaningful, but if it comes with changes in regulatory framework (e.g., changes in laws and regulations), it will be very meaningful. Another argued that it will be very meaningful to have a target if the country has separate deployment targets for different forms of energy storage, i.e., for electrical storage, thermal storage, power to fuels and power to X.

10 Conclusions

10.1 Conclusions from Energy Policy Analyses of Selected Countries

Dina (2019) argues that the governments from countries with greater share of renewable energy invest more in energy storage technologies [143]. This argument is based on the calculation of the share of the public R&D and D expenditure on energy storage of the OECD countries which includes all of the six countries discussed in this report. The paper suggests that countries with a growing renewable energy supply from intermittent sources, such as solar and wind energy, should consider future needs for investments in energy storage technologies.

In our study Australia has the highest percentage of renewable energy followed by Germany, UK, Japan, USA, and South Korea, respectively. The USA has the largest capacity of novel non-conventional energy storage (i.e. excluding PHS) followed by UK, Germany, Japan, Australia, and South Korea.

Table 8: Share of renewable energy in the energy mix and energy storage capacity. Source: [16, 74]

Country	Share of renewable energy (%)	Energy Storage Capacity excluding PHS (MW)
United States	11	1912
United Kingdom	16	970
Germany	16	727
Japan	11	242
Australia	21	170
Korea, South	3	155

This suggests that although the share of renewable energy plays a determinant role in pushing for public R&D investment at the national level, that may not necessarily translate to the commissioning of energy storage facility. It is difficult to compare these countries just based on the public R&D investment because it excludes private sector investment and these countries have taken contrasting approaches to energy storage and renewable energy. Countries such as Korea and Japan have tradition of innovation system with a strong collaboration with the private companies from the beginning. Australia and USA (California in particular) have a few MW battery storage projects at construction phase in 2020 with majority investment coming from the private sector. Germany and UK have scaled up the renewable energy generation, in particular wind, which has created a necessity for the investment in energy storage.

From the analysis of the six countries, the following four distinct approaches can be seen:

1. Scaling up the renewable energy generation which demands the need for the public investment in energy storage technologies – Germany and the UK
2. Public investment in R&D of the new technologies – Germany and the UK
3. Providing the favourable policy environment along with abundance of natural resources for renewable generation which attract the large-scale private sector investment – Australia and California/USA
4. An innovation system that provides a level playing field for private sector actors from the early phase which in turn helps in commercialization of the new technologies – Japan and South Korea

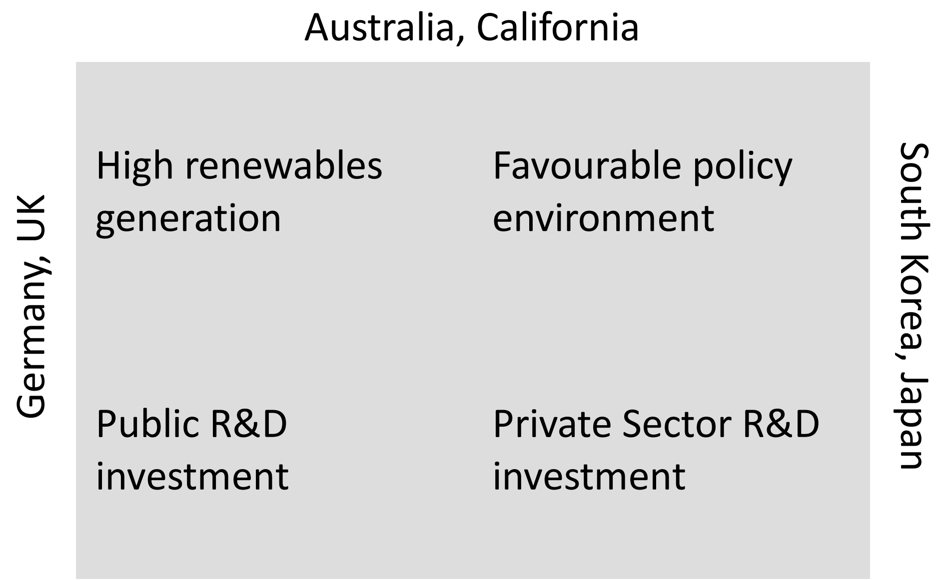

Figure 16: Energy Storage Policy Trends of selected countries

From the analysis it can be concluded that the energy storage technologies and market are highly dependent on the favourable policy environment and investment on R&D. Examples of key policy approaches enabling energy storage are listed below.

1. Consumer led deployment of energy storage in Japan [114] and California [78]
2. Demand side management in New York [84]
3. Integrated renewable and energy storage and ease of starting new business in Australia [144] [136]
4. Private sector investment in R&D of energy storage in South Korea [124]
5. Prosumerism in Germany [18], the UK [41] and Hawaii [94]
6. Target setting and sending positive signal to market in Japan [112], [113]

10.2 Conclusions from stakeholder surveys on policy and regulation

The stakeholder enquiry through the questionnaire and interview has helped us identify the key policy and market barriers of new energy storage technology such as Cryogenic Energy Storage. They are as follows.

1. **Capital expenditure/ Technology cost**: New technologies are likely to be expensive which discourages stakeholders to install such technologies. The stakeholders were cautious about the financial performance of new technology. It was suggested that the new technology should be able to demonstrate a tangible evidence that it can provide return on investment (ROI) within 3-5 years of installation
2. **Technology integration**: If the new technology can not be integrated with the existing system/ process, this can discourage the businesses to install it.

3. **Uncertainty in future value:** Energy storage technologies are still expensive and new more effective future technologies can affect the risk of investments
4. **Regulatory framework:** Existing regulatory framework was designed for centralized energy system, which can become barrier for the new, distributed energy systems. Therefore, regulatory reforms to remove barriers and create a more level playing field for niche systems such as Cryogenic Energy Storage is necessary. Some countries have double taxation of storage while others have bureaucratic processes that can take too long to get permission for installation of new technology.
5. **Market structure**: Current electricity market and heating market is too rigid and there is not enough freedom for new business models. Energy storage technologies such as batteries have market dependency outside Europe which can also be a barrier to the development of new technologies inside the EU.

The majority of industry stakeholders are aware of the benefits of energy storage and enthusiastic about the new energy storage technologies. In order to materialize their enthusiasm, the stakeholders suggested the following technology related issues that need to be addressed:

1. Decrease the **cost** of electrochemical batteries storage
2. Improve **cycle efficiency** of energy storage system
3. Decrease the energy storage **system size**
4. Clear **labelling** or demonstrating of the environmental efficacy of the technology to allow front-runner businesses to promote their 'green branding'.
5. More **R&D** should be carried out for system integration, demonstration and good programming for materials and component research

Industry stakeholders such as operators of food storage warehouses have to deal with natural uncertainty such as variable quantity of harvest, variable timing of harvest and ever-changing market demand, therefore new technology should be designed to both cope with such changes and minimize uncertainties. On the policy side, the governments should provide (further) explicit support for the development and/or deployment of storage, including Cryogenic Energy Storage, over the next 5+ years as it does for a range of low carbon technologies. The government should also provide additional support for R&D, demonstration and deployment support.

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