1. Background

The world is now at the crucial moment due to the shortage of fossil fuel, climate change and increasingly problematic pollution, which pressurize us to find sustainable alternatives to ensure our acquired wealth and further growth. Modern technologies have already provided us with substitutes such as wind turbines, photovoltaic cells and biomass, which also come with some inevitable flaws, inconsistent production (or sometimes referred to intermittency) [1]. The alternative sourced electricity is limitedly sensitive to the system demands, hence, more flexibility is needed to deal with unpredictability and variability of generation by the evolution of smart technologies such as energy storage.

Rapid urbanization has strongly boosted economic growth and significantly reduced overall levels of poverty [2]. Meanwhile, it also causes transport congestion, environmental degradation and huge demand of energy, which is expected to continue growing in foreseeable future [3]. People are working on turning cities more sustainable and smart, which should be able to provide a good quality of life to current residents without any opportunities reduction for future residents. To achieve the aim, energy storage is considered as an applicable method to balance the system and provide an alternative to traditional network reinforcement.

Therefore, the role of energy storage has risen to unprecedented heights. Serval countries have introduced policies related to supporting and developing energy storage technology markets. Most legislative bills tended to 1) establish financial incentives for both utility-scale and distributed storage facilities; 2) initiate technical potential analysis and possible policy pathways and 3) use specific energy storage procurement standards or adding multipliers to existing renewable portfolio standard policies to encourage storage adoption. [4]

However, apart from pump hydro storage, UK seems to have very limited storage options at present, due to the enormous financial cost for potential alternatives and traditional reliance on large scale conventional generation assets. Furthermore, at the present stage, energy storage deployment is further hindered due to insufficient government support to investors, lack of access to finance and market education and information, and lack of unified definition for energy storage and technical standards.[5]

2. Aims and Methodology

The primary objective for the mini project is to identify the current main barriers and incentives of energy storage. The relationship between technical solutions and legislative and economic parameters will be explained in the report. Ultimately, a recommendation regarding UK’s energy storage development will be given.

The first part of report will be based on the findings of peer researchers, mainly focusing on identification of hinder on three different perspectives including market, legislation and risks. Then a case study of California energy storage development over last ten few years will be undertaken. The related factors will be collected involving with changes in related policies issued by either California government or Federal government, procurement target capacity roadmap and technology development. The relationship between different parameters will be connected in a certain order. All data and legislation framework are from government website and trustworthy energy consultancies and institutions.
3. Current Energy Storage Deployment Barriers and Initiatives

The global electricity market encounter a number of remarkable and potentially conflicting challenges, including changing profile of demands, decarbonization, security of supply, upgrading of energy networks and aging infrastructure. The most key issues relate to the ‘energy trilemma’, which is to balance the energy supply security and rising cost while minimizing accompanied environmental influences. In other words, the ultimate goal is to ensure the energy is secure, sustainable and affordable [6].

Electricity can be considered as a commodity that is typically bought and sold multiple times in a wholesale market before consumed by customers. However, electricity itself cannot be stored unless being converted into other types of energy, such as chemical battery energy storage and mechanical flywheel energy storage. Furthermore, electricity is difficult to move around due to its specific transmission frequency requirement. In general, most countries and UK use 50 Hz as standard frequency while that of north America is 60 Hz. The electricity frequency stability is heavily reliant on the consumer demand and electricity supply, of which the balance has to be monitored and maintained at all times by ineffectively ramping fossil-fuel generators up and down to meet the electricity fluctuation.

With the increasing integration of renewable energy such as wind and solar, it requires higher level of service to manage more complicated generation variability and uncertainty. In addition, it also highlight the needs of a more stable system with ancillary services. The ancillary service is defined as services to support the transmission of capacity and energy from resources to loads while maintaining reliable operation. It includes operating reserves, reactive power and black start, which can be delivered by energy storage [7]. Hence, it creates a potential market incentives for energy storage that is identified as one of the eight key technologies by UK government in order to become a global leader and optimize the ability of the UK’s generation capacity to meet the national demands.

<table>
<thead>
<tr>
<th>Ancillary Services</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency regulation</td>
<td>Balancing of electricity supply and demand to keep frequency within operational bounds. Includes services for responding to both increases and decreases in system frequency.</td>
</tr>
<tr>
<td>Spinning reserve</td>
<td>Generation capacity that is connected to the power system but not generating electricity until needed, with the ability to respond immediately, within 10 minutes.</td>
</tr>
<tr>
<td>Non-spinning reserve</td>
<td>Generation capacity that is not connected to the system but can be brought online after a brief delay.</td>
</tr>
<tr>
<td>Voltage control</td>
<td>Similar to frequency regulation but using reactive power to maintain proper transmission system voltage.</td>
</tr>
<tr>
<td>Black start</td>
<td>Ability to restore power to part of the grid after failure occurs.</td>
</tr>
</tbody>
</table>

Table 1: Ancillary Services [7]

However, energy storage adoption is still very slow due to various reasons that either hinder deployment of storage technologies or prevent deployment. There are many other decisive parameters to the technical storage solutions although it is predominantly determined by the capital cost in the current stage.

3.1. Market and Economic Barriers

It has been highlighted for so many times that the main barrier of deploying energy storage is the multiple value provided to the grid cannot be accurately captured and quantified [8]. Valuation of storage usually involves with the ability of storage to provide basic services: base load and load leveling, regardless of ancillary services. The neglected evaluation is caused by both drawbacks of capacity-expansion software used by suppliers. The restructured markets and introduction of
ancillary services with acceptable tariff managed to emerge some fast-response services fit for certain energy storage technologies. There is a more severe flaw remain in the market valuation attribute to the low efficiency of price signals and lack of transparency of prices to end users [8].

Most projects related to distribution network or end users barely have any risks of market exposure, because the customer-aimed storage value is predominantly determined by utility rate structures that is unable to capture the varying cost of electricity at different time of the day. For this reason, it elevates the importance of widely introducing smart grid that is able to adjust in real time and control devices under provisional standards. Hence, it can further encourage more market participants to invest into the market and bring more technical and economic benefits of distribution and customer-sited storage. The energy storage at end-user side can save some unnecessary energy lost during T&D, making it more flexible for storage device placement. It is easier and more convenient to have fewer large-scale T&D networks than thousands of customer-sited assets from the perspective of construction difficulty, but customer-sited storage devices can contribute to considerable benefits by inter temporally shifting transmission and distribution level loads [9].

Another thing worthy being mentioned is that electricity suppliers cannot simulate at distribution level and hence the effects brought by new policy introduction and latest technology cannot be obtained. In this way, it is not worthwhile to install energy storage services in local user end where can potentially maximize the benefits, especially for those load-sited storage such as thermal energy storage, but still need some efforts to develop a new business model to simulate those utility-owned customer-sited facilities. It provides an intriguing opportunity to mature the market by introducing a third party participant acting as a mediator between utilities and customers [10]. However, some utility-developed models were developed based on historical local marginal prices data, which might possibly lead to ineffective investment regardless of the fact that restructured market can relive flaws in T&D [11][12]. The lack of complicated compensation mechanism further worsen the deployment of energy storage, because current service providers cannot receive compensation in accordance with their performance, only based on their capacity reserved and net energy provide.

Currently existing market cannot fully capture the benefits of energy storage due to various reasons. Those markets heavily reliant on utilities are still lacking of a comprehensive understanding of energy storage technologies and the important role it will play in the future. The potential revenue generated by energy storage struggles to be accurately estimated with current limited ability based on uncertain schedule and operation, especially for those with dynamic ancillary services. The lack of markets makes it difficult and sometimes even impossible for service provider to make a business case for deployment.

3.2. Regulatory Barriers

Recent years have witnessed a significant change in the electricity industry that shifts from a conventional vertically integrated utility to restructured markets. Both markets will still play an important role in future US electricity market that brings a huge challenge to the storage investors. The electricity market in US will show a hybrid profile that the system is running under both cost-of-service regulation and complete reliance on markets due to the fact that the electricity is provided from either monopoly markets or competitive markets. The hybrid characteristic leads to the fact that storage assets are considered as with generation, transmission or distribution devices. The way recovering cost either through the market or rate base is mainly dependent on the its category and hence result a controversial situation.

Meanwhile, for UK, the principal legislation regarding governing electricity (The Electricity Act 1989) fail to give any specific definition or reference to electric storage. The electricity storage is categorized as a sub-set of generation and cannot operate as a system operator under EU completion rule although it shows a great potential for economic, environmental and security of supply [13]. Additionally, other operators with government issued licenses such as Distribution Network Operators and Transmission Network Operators are restricted from operating electricity storage. For this reason, any energy storage operator encounters a problematic administrative
issue, which is unlikely to comply with the Grid Code and deliver information and account to Ofgem. The uncertain treatment of energy storage imposes a barrier for investment especially those in large scale.

Energy storage facilities are technically able to provide services related to production, transmission and distribution. However, it is the same in both countries that regulatory restrictions along with accounting practices and requirements and the lack of clarity and transparency in application and requirements, leading to the ineffectiveness of developers obtaining revenue. The service providers cannot participate in the generation wholesale market and T&D market at the same time regardless of the fact its technical ability.

3.3. Risk and Uncertainty

The future of developing energy storage remains unclear since the current regulatory framework adds countless risk and uncertainty. In addition, besides the regulatory structure, slow development of energy storage also results form the revenue and technology risks. Although the current regulated markets only need a utility proven to be prudent, there is not any changes due to the lack of intriguing incentives to introduce new technology into regulated energy markets [14]. This might be worsen by the incomprehensive market value demonstration and evaluation as discussed, which makes the storage implementation less persuasive to the developers and customers unless the proposal is able to reduce the variability of consumer cost by specific beneficial tariff plan.

For the investors, the revenue risk can be identified as following five perspectives. The first one is the regulatory treatment of storage including how the current regulatory framework proceeds and the future evolution of storage-related framework. The second concern is that there is no way to predict how the future changes in rules impact on capturing value streams. The third issue is immature market for some specific services and the effect of market entry in terms of storage or competing technologies. The fourth problem is uncertain timing of construction of storage facility and variable profile of market when finished, such as generation mix. The last issue relates to the impacts contributed by the future technology development [15]. These problematic matters are worthy being thoroughly considered by the investors to defer investment decision and wait for more future technological improvement that expected to bring more economical benefits.

Technology risks also substantially prevent the storage implementation due to the limited deployment scale and insufficient manufacturers. There are many technologies proven to be technically viable but reluctant from investors to implement, such as compressed air energy storage and liquid electrolyte flow batteries. Even mature technologies are facing risks as well. For example, bulk energy storage application like pump hydro storage tend to have very large size and enormous upfront capital investment due to long permitting and construction period of time [16]. It became less competitive due to the decreased conventional fuel price and increasing proportion of solar and wind electricity in the entire energy generation market.

3.4. Current Initiatives

The main barriers preventing energy storage deployments are discussed in previous section, which introduce the current three initiatives at state levels. First is to address revenue compensation for energy storage resources and lack of available markets into which to offer energy storage resources. The second initiative is to identify the need for an appropriate functional classification mechanism of energy storage in order to make sure that various benefits can be brought by storage resources. The last is to focus on reducing high cost of technology, deploy demonstration projects, develop more complicate simulation software and other methods enabling more people aware of the multiple advantages of energy storage resources. These initiative cannot entirely remove those obstacles facing the deployment of energy storage systems, but will be helpful to provide a framework for which other initiatives can be formed.
4. Electricity Market Regulation in US and UK

4.1. Electricity Market of US

Since 2011, there were 14 bills introduced to at least ten states to encourage energy storage [4]. However, regional differences across the United States play an important role in the electricity industries, which can be shown representatives as follows. Most states are contained with territories of an Independent System Operator (ISO) or a Regional Transmission Organization (RTO). Both ISO and RTO are predominantly operating the wholesale electricity markets. Sometimes it relates to some areas independent from ISO or RTO, which usually conducts through private bilateral agreements. Regarding electricity retail, states like New Jersey and Texas have investor-owned utilities separated their generation assets [17]. Hence, the customers can make their own decision based on needs among competitive electricity providers, but New Jersey’s incumbent electric utilities still serve customer load as default supplier while Texas does not as those utilities only act as transmission and distribution (T&D) companies. In some other states such as Colorado and Wisconsin, electricity service suppliers have strong vertically-integrated utilities, which is capable of generation, transmission and distribution, and provide retail load.

![North American Independent System Operators and Regional Transmission Organizations (Federal Energy Regulatory Commission, 2016)](imageurl)

To a developer, the core interest of energy storage service development is the financial opportunity, which is significantly influenced by the characteristics of wholesale and retail electricity markets and related regulatory structure which the electricity providers operate and follow. ISO or RTO served areas have transparent prices for electricity and freedom of energy resource selection, either from independent power producers and power marketers. For those area outside ISO/RTO control, the price is determined by bilateral contracts, which means the electricity price is of very limited transparency. The vertically-integrated electricity supplier can use energy storage service to recover partial cost, but planning tools and methodologies still impose a huge challenge for the whole country. However, most electricity markets are not structured to allow to integrate energy storage and other small distributed energy resources [18].
4.2. Electricity Market of UK
In the early 1990s, the privatization of generation industry led to the increased number of generating companies in Great Britain. Currently, the domestic electricity is mainly generated by EDF energy, E.ON, RWE, Scottish Power, Centrica, SSE, Drax Power Limited and so on. With the increasing penetration of renewable energy application, the number and categories of companies become more diverse with new entities such as the offshore and onshore wind farm owners. The electricity transmission system is operated by National Grid Electricity Transmission (NGET) and the ownership of transmission and distribution assets is more mixed and complicated that are shown below respectively [19].

The provisions of the third energy package have been implemented into UK legislation and the main requirement for transmission system operators (TSOs) is to separate the transmission interests from generation, production and supply activities. The IME3 specifies the roles and responsibilities of transmission owners on three different perspectives including operation, maintenance and development. The IME3 requires TSOs to comply with one of the ownership unbundling models set out in the Directives [20]. It aims to avoid conflicts of interest and provide transparency, which separate the regulatory authorities from governments and industry actors.

5. California Energy Storage Case Study
The State of California has shown very strong interest in energy storage by having their energy agency and legislature committed to examine the benefits. Assembly Bill (AB) 2514 allows the California Public Utility Commission (CPUC) to set brand targets for energy storage procurement but highlight that any deployment must be consistent with technical viability and cost effectiveness. The procurement targets for each Investor Owned Utilities (IOUs) is expected to achieve 1,325 MW the end of 2020 and implemented by 2024 [21]. Additionally, the CPUC provides funding programs including Permanent Load Shifting and the Self Generation Incentive Program that provide incentives for adoption of customer-side energy storage. Energy Commission keeps funding important research to turning energy storage as a viable grid resource via Electric Program Investment Charge. At national level, Oder No 792 clarifies that electric storage devices are classified as generation facilities [22]. Furthermore, the U.S. Department of Agriculture High Energy...
Cost Grant Program and Business Energy Investment Tax Credit continues to provides support for energy storage.

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Point of Interconnection</th>
<th>2014</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Gas and Electric</td>
<td>Transmission</td>
<td>50</td>
<td>65</td>
<td>85</td>
<td>110</td>
<td>310</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
<td>50</td>
<td>40</td>
<td>50</td>
<td>65</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>Customer</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>35</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Subtotal PGE</td>
<td>90</td>
<td>120</td>
<td>16</td>
<td>21</td>
<td>580</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>Transmission</td>
<td>50</td>
<td>65</td>
<td>85</td>
<td>110</td>
<td>310</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
<td>50</td>
<td>40</td>
<td>50</td>
<td>65</td>
<td>185</td>
</tr>
<tr>
<td></td>
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<td>15</td>
<td>25</td>
<td>35</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Subtotal SCE</td>
<td>90</td>
<td>120</td>
<td>16</td>
<td>21</td>
<td>580</td>
</tr>
<tr>
<td>San Diego Gas and Electric</td>
<td>Transmission</td>
<td>10</td>
<td>15</td>
<td>22</td>
<td>33</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
<td>7</td>
<td>10</td>
<td>15</td>
<td>23</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Customer</td>
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<td>5</td>
<td>8</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Subtotal SDGE</td>
<td>20</td>
<td>30</td>
<td>45</td>
<td>70</td>
<td>165</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>270</td>
<td>365</td>
<td>490</td>
<td>1,325</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Energy Storage Procurement Targets in MW and Development of California Policies [23]

Backed by strong support, California energy market starts to embrace energy storage and also encounter various problematic issues which can be generalized into three categories: a) ability to realize the full revenue opportunities constant with the value energy storage can provide; b) reduction of cost of interconnection and ongoing operations and c) uncertainty regarding processes and time. The rule making process contains two main phases, 1) establishment of general procurement rules and procedures and 2) establishment of methodologies for evaluating and privatizing individual projects with the procurement.

Energy storage application has been widely implemented in California even before the new rules. CalCharge has committed to construct 30 storage startups in the San Francisco Bay Area alone. The new rule also brought in massive investment as well. Energy storage companies raised $630.5 million just within a year since the new bill introduced within a year and grew 13 fold to represent 11% of the total state’s clean technology venture capital investment. The massive capital investment was payed off by a series of innovation, for example, there were 258 battery patent filed just between 2008 an 2010 in statewide [24]. The incorporation between storage projects and smart micro grids also increased. A pump storage plant in the Eagle Mountain was under construction, which would deliver 1300 MW of electricity after finished. For small scale applications, a 2000 KW, 4 MWh lithium ion phosphate battery was introduced into the local smart grid system in Alameda County’s Santa Rita Jail. There are more than 13 major projects in California with operational, contracted or under construction according to Sandia National Laboratories database.

6. The Energy Storage Development in UK

The UK electricity market is currently undergoing a massive transformation where energy storage is believed to play an increasingly important role in future. Electricity Market Reform aims to promote more advanced technologies such as energy storage that is included in the capacity market, which many people believe the inappropriate mechanism can restrict the role of energy storage can play. The Electricity Storage Network put efforts to persuade Government to deploy and compensate large-scale storage projects to embed...
them with more important role [25]. The House of Lords and Technology Committee recommended that it is necessary to examine if the electricity storage should be treated under the Contract for Difference regime [26].

In 2015, the Department of Energy & Climate Change conducted a report suggesting that: a) Removing regulatory barriers to storage in order to provide an appropriate framework for storage; b) Allowing network operators to recover revenue from various sources and hence making energy storage a viable alternative to network reinforcement; and c) Backing up the development of new technologies and demonstration projects with targeted funding and support [27]. Several public bodies such as DECC and Ofgem each have programmed funding electricity and heat storage development with multi-year sufficient budgets. In 2003, Research and development spent £9m on public sector energy storage and £5m on demonstration [27]. For the transport sector, several policies to support lower carbon vehicle are introduced by the government that committed to spending £500m on low-emission vehicles over 2015-2020.

For stationary electricity and heat storage, it is significantly determined by the low-carbon energy generation proportion in total generation mix. Higher levels of flexible fossil-quelled generation incorporating with carbon capture and storage will possibly contribute to lower electricity storage demand. Locally used energy storage will heavily rely on the attitude of household towards getting independence from the grid. Heat storage demand will increase due to the promotion of heat pumps. Furthermore, the future of electricity storage for transport use is of confidence with other low GHGs exhausted alternatives, but the high upfront battery cost will remain as the biggest barrier.

7. Discussion and Conclusion

The storage industry evolution is significantly encouraged by storage-friendly policies and procurement. The market is expected to play a more important role in the promotion of energy storage in the foreseeable future. Energy storage technology will remarkably contribute to further grid expansion and stability, intermittent renewables, carbon reduction and saving cost of ratepayers through advanced T&D facilities. AB 2514 and its related framework are a successful example of energy storage, which will inspire other states and countries to pursue similar changes and ultimately lead to a widespread better transformation of the world. However, the uncertainty of specific energy storage project roadmap will remains in the future, because it is still unclear to see how the technically advancement develop and impact the industry. Furthermore, increasingly vital greenhouse gases reduction plan and longterm rising price will make traditional fossil fuels less competitive, which will lead to more economically viable use of energy storage.

The UK should urgently address the requirement for all kinds of advanced energy storage technologies and remove legislative and market barriers in order to exploit the investment in UK’s energy market. It is necessary to introduce more mature compensation mechanism to bridge gap between traditional electricity and energy storage market. On the perspective of technical solutions, the priority is the reduction of storage technology price and make it more competitive on commercial terms in a not very distant future.
8. References


[21] Legislative Council of the State of California, 2010, Assembly Bill No.2514,

[22] Federal Energy Regulatory Commission Order No. 792, SI 2013/792


