Applied Energy 212 (2018) 881–894

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

A social cost benefit analysis of grid-scale electrical energy storage projects: A case study

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HIGHLIGHTS

- A Monte Carlo simulation is paired with the social cost benefit analysis.
- Battery lifespans may be shorter than the lifespan of a conventional upgrades.
- Only a subset of locational and system-wide benefits is captured simultaneously.
- Future cost decline drives the social welfare of grid-scale storage investments.

ARTICLE INFO

JEL classification:
L94
L98
Q48
D61

Keywords:
Electrical energy storage
Battery
Social cost benefit analysis

ABSTRACT

This study explores and quantifies the social costs and benefits of grid-scale electrical energy storage (EES) projects in Great Britain. The case study for this paper is the Smarter Network Storage project, a 6 MW/10 MWh lithium battery placed at the Leighton Buzzard Primary substation to meet growing local peak demand requirements. This study analyses both the locational and system-wide benefits to grid-scale EES, determines the realistic combination of those social benefits, and juxtaposes them against the social costs across the useful lifecycle of the battery to determine the techno-economic performance. Risk and uncertainty from the benefit streams, cost elements, battery lifespan, and discount rate are incorporated into a Monte Carlo simulation. Using this framework, society can be guided to cost-effectively invest in EES as a grid modernization asset to facilitate the transition to a reliable, affordable, and clean power system.

1. Introduction

Electrical energy storage (EES) can support the transition toward a low-carbon economy (decarbonisation) by helping to integrate higher levels of variable renewable resources, by allowing for a more resilient, reliable, and flexible electricity grid and promoting greater production of energy where it is consumed, among others [1]. In addition to decarbonisation, EES promotes lower generation costs by increasing the utilisation of installed resources and encouraging greater penetration rates of lower cost, carbon-free resources [2]. EES plays an important role supporting distributed generation and distribution planning processes for future power systems. Different jurisdictions are evaluating the value of EES (and other Distributed Energy Resources) for planning purposes related to the next generation of electric distribution utilities [3–5].

The global electrical energy storage market is expanding rapidly with over 50 GW expected by 2026 of utility-connected energy storage and distributed energy storage systems.[1] In the United States alone, deployment is expected to be over 35 GW by 2025 [6]. This upward trend is mainly explained by favourable policy environments and the declining cost of EES, especially batteries [7]. Market structures that support its deployment are also observed (i.e. California Public Utility Commission – CPUC and the goal is to install 1.3 GW of EES by 2020) [8]. The declining costs of EES combined with cost optimisation models show an increase in the number of applications and use-cases of storage technologies [9,10]. There are different types of EES technologies with specific technical characteristics (i.e. response time, number of cycles, discharge time, storage duration), that make them more or less suitable for a different range of EES applications (i.e. peak shaving, voltage control, frequency regulation) [11,12]. Depending on the market, EES technologies and their applications can be subject to different regulatory context and policies [13–15]. Even though there are a large

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[1] See: https://www.navigantresearch.com/newsroom/global-annual-power-capacity-additions-for-utility-scale-and-distributed-energy-storage-to-exceed-50-gw-by-2026.

https://doi.org/10.1016/j.apenergy.2017.12.085
Received 4 October 2017; Received in revised form 7 December 2017; Accepted 24 December 2017

number of EES technologies, not all of them are exposed to the same level of development. This reflects the different size of capital and/or operational costs among them. In fact many of them are still in a research or development stage. While pumped hydro storage is among the most mature and cheapest storage technologies for short-term and long-term storage [16], battery storage is the one with the most commercial interest and growth potential [17].

EES can be used for multiple applications and can therefore generate different revenues streams whose value depends on the type of technology[2] [18] and the place where the EES facility is located, at generation sites, on the transmission or distribution grid or behind the end consumer's meter [19]. Different studies have evaluated the cost and benefits of EES however few of them take into account the multi-product nature in agreement with the diverse EES revenues streams and the uncertainty component. Idlbi et al. [20], estimate the net benefits of battery storage systems – BSS (connected at medium voltages (MV)) in the provision of reactive power versus other options such as conventional reinforcement. They suggest that BBS for voltage compliance is more economically viable than the grid reinforcement option but less viable than power curtailment. However this viability can increase if we take into account the multi-product nature of BSS, which is not limited to reactive power support only, and the fact that battery costs show a downward trend, which is making EES more competitive. Gunter and Marinopoulus [21], estimate and evaluate the contribution of grid connected EES to frequency regulation and peak limiting (for demand charge reduction) in the eastern United States (PJM served area) and California (CAISO served area). Results from their cost benefit analysis (CBA) and sensitivity analysis suggest that EES deployment is economically viable even with market structures less beneficial than the current ones. However, the large profitability of EES in California may be explained by the subsidies applied to the development of EES (i.e. Self-Generation Incentive Program – SGIP[3]). Shcherbakova et al. [23] evaluate the economics of two different battery energy storage technologies (Sodium-Sulfur and Lithium-ion) for energy arbitrage in the South Korean electricity market. They find that none of these storage technology is economically viable based on the current market conditions. They also recognise that the inclusion of other potential financial benefits in ancillary services (e.g. frequency regulation) and other applications may reverse this result. Wade et al. [24] evaluate benefits of battery storage (focused on a specific trial operated by EDF Energy Networks in Great Britain) connected to the distribution network. The benefits of the storage system are evaluated based on the response of multiple events requiring voltage control and power flow management. The authors find that the introduction of EES embedded in the distribution network has a positive impact on the tasks associated to these two variables.

Other studies concentrate on the analysis of the costs and benefits of EES and renewable energy integration (i.e. storage and renewables) using specific optimisation models. Sardi et al. [25] evaluate the cost and benefits of connecting community energy storage in the distribution system with solar PV generation. A comprehensive set of EES benefits and some specific costs were identified. The authors suggest that the proposed strategy helps to find the optimal location of the EES that maximises the total net present value (NPV). Han et al. [26], propose an optimisation model for integrating grid-connected micro-grids with solar PV and EES. A cost benefit analysis is used in order to establish a generation planning model of a micro-grid that maximises the net profits.

Among the studies that are more related to this study are Perez et al. [27], Newbery [28] and SNS [29]. These studies are also focused on the evaluation of net benefits of a particular case study (Smarter Network Storage project). However, our paper is the one that includes the most comprehensive list of EES benefits and costs. This paper in comparison with others, incorporates risks and uncertainty of net benefits, costs and battery lifespan (using Monte Carlo simulation). In addition, rather than modelling EES from a business case perspective or in a future-state of the power system dominated by renewables and distributed generation, this study uniquely evaluates a specific energy storage project from society's perspective (social welfare) in order to cost-effectively guide investment in EES projects and discuss policy implications and electricity market reforms for achieving a low carbon network. Accurately valuing EES projects helps inform system operators, distribution network operators, generators, suppliers, regulators, and policy-makers to make decisions to efficiently allocate resources to modernize the electricity grid.

This paper seeks to examine the empirical trials from the Smarter Network Storage (SNS) project through the lens of a social cost benefit analysis to evaluate publicly sanctioned investments in grid-scale EES in Great Britain. The social cost benefit analysis framework answers the fundamental question of whether or not society is better off after making the investment in grid-scale EES. The uncertain benefit and cost streams are evaluated through a Monte Carlo simulation and then arranged through a discounted cash flow to provide a net present social value of the investment. SNS represents the first commercially-deployed, multi-purpose grid-scale battery in Great Britain, and it has been selected as the case study for this research because its empirical results from years of trials are well documented.

The paper is organised in the following manner. Section two provides the background and a brief description of our case study: the Smarter Network Storage project. Section three discusses the Cost Benefit Analysis method. Section four identifies and quantifies the social costs. Section five identifies and estimates the different social benefits and related revenues streams. Section six discusses the results by combining the analysis of the costs and benefits and the implications of the net present value results. Section seven lays out the conclusion and offers insights into policy recommendations for enhancing the value of EES through electricity market reforms.

2. About the case study: Background of the Smarter Network Storage project

2.1. Smart Network Storage project background

In order to facilitate the low carbon transition of the power system, the Office of Gas and Electricity Markets Authority (OFGEM) established the Low Carbon Network Fund, a £100 million per annum (p.a.) fund – which ran for 5 years from April 2010 to March 2015 - to support clean energy demonstration projects sponsored by Distribution Network Operators (DNOs).[4] One such DNO, UK Power Networks (UKPN) established the Smarter Network Storage project in 2013 to showcase how EES could be used as an alternative to traditional network reinforcements, enable future growth of distributed energy resources, and a low carbon electricity system. The Smarter Network Storage project deployed a lithium-ion battery with 6 megawatts (MW) and 10 megawatt-hours (MWh) of power and energy, respectively, at the Leighton Buzzard Primary substation to offset the need for an additional sub-transmission line to alleviate capacity constraints.

[2] Classification based on the way how energy is stored.

[3] In the latest budget allocation (which comes from authorised revenue collection), energy storage technologies get 80% of funds and generation technologies the remaining 20%. Total authorised regulatory revenue collection to the end of 2019 amounts to circa US$ 501 million. Different incentives rates applied for energy storage (US$/Wh) depending on the type of system (large-scale storage, small residential storage) and the Step (from 1 to 5), [22].

[4] For more information: Office of Gas and Electricity Markets authority. "Low Carbon Networks Fund." Available at: https://www.ofgem.gov.uk/electricity/distribution-networks/network-innovation/low-carbon-networks-fund.