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The reuse of electrified vehicle batteries as a means of integrating renewable energy into the European electricity grid: A policy and market analysis

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ABSTRACT

The financial sense of reused automotive battery systems providing stationary energy storage is investigated in the paper. A comprehensive review of existing used batteries projects is presented, followed by an evaluation of individual European countries regulations and electricity market conditions. The authors performed detailed simulations of the Net Present Value of four battery system investments: residential solar panel + battery or battery-only, commercial/industrial level solar panel + battery and primary reserve battery investment. The combination of electricity prices and Feed in Tariff schemes can either act as an enabler or a barrier to the economics of battery investment. At the moment, the investment in used batteries makes sense mostly in Germany but countries such as UK and Italy or Spain could be future candidates. In terms of energy policy adjustments, appropriate financial incentives are necessary to encourage the investment in such systems. Most importantly, energy policy in EU should incentivise the use of 2nd hand automotive batteries for stationary applications.

1. Introduction

This study presents one of the first EU-wide economic investigations of the business case of using 2nd hand automotive batteries for stationary storage. A country-by-country approach is imperative, given the diverse electricity price and feed-in-tariff (FiT) landscapes across Europe. The purpose of this work is to highlight the differences among EU countries when it comes to 2nd life battery investment and then to identify the reasons behind these differences and propose solutions. This is done by examining the business feasibility of used batteries in conjunction with renewables for three different application levels: residential, commercial and utility scale. In addition, the 2nd life battery cost and lifetime are taken into account as part of a sensitivity analysis.

The motivation for this study stems from the anticipation that in the coming years, large numbers of used automotive batteries will be available as a result of the increasing numbers of Hybrid (HV), Plug-in-Hybrid (PHEV) and Battery Electric Vehicles (BEV). Automotive batteries have been proven to retain around 70–80% (EPRI, 2000) of their initial capacity which by itself renders them suitable for reuse. The concept of reusing rechargeable batteries is not new (Schneider et al., 2009, 2014).

One prevailing option for used automotive batteries is that they could be diverted to the stationary energy storage market. An early report (Cready et al., 2002) identified four energy storage applications as viable options for used EV/HV batteries. These were transmission support, light commercial load following, residential load following and distributed nodes communication support. Furthermore, the use of such batteries to support the integration of renewable energy such as wind and solar has also been indicated as one of the main applications (Gohla-Neudecker et al., 2015).

Electricity prices and fiscal incentives appear to have a major impact on the viability of the 2nd life battery investment. A recent study (Heymans et al., 2014) that compared the load shifting situation for a household in Ontario with repurposed battery storage to a household without storage, under various energy prices, concluded that repurposed EV batteries have minor economic feasibility without a support from government. The authors consider these findings very relevant with the present study as they highlight the significance of a favourable regulatory and support framework. Similarly, Knowles and Morris (2014) derived a representative daily household energy demand based on data collected from 15 houses from UK house-installed solar panels. The benefit for the consumer was estimated at ~ £250/kWh over 10 years of operation. However, the economic benefit was found to be highly sensitive to the size of the storage system with a direct link to

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the variation of energy consumption patterns of the residential customer. In the same direction, Saez-de-Ibarra et al. (2015), investigated the economic sense of 2nd life batteries meant for reducing the energy bill of residential customers already equipped with solar panels (PV). In a simulation considering real PV data and household energy consumption from the Spanish market, positive economical results were obtained. Based on this observation, the authors of the present study investigated the case of PV plus battery and battery-only (PV assumed to pre-exist) investment. The purpose has been to evaluate which of the two investment strategies provides a more meaningful option for the customer.

When looking into large scale applications, the business case seems to be more straightforward. Wolfs (2010) investigated the potential return on investment (ROI) when considering a large number of retired traction battery packs (with 80% remaining capacity) into a 6.5 MWh level stationary storage for electricity grid support in the Australian daily energy market. The net present value was found to reach \$459/kWh for 20 years' grid support. This revenue could be further increased by using the same battery for providing multiple storage services (Neubauer et al., 2012; Faria et al., 2014).

Beyond existing case studies and theoretical analyses, in recent years, there have been several projects led by car OEMs and power/electricity players, in which the reuse of retired electric vehicle batteries included off-grid and on-grid storage units but also fast green charging to promote further the deployment of electric vehicles. A summary of them can be seen in Table 1.

What can be noted is that OEMs have been active in the entire range of battery scales going from residential to commercial and then utility scale level. The main focus has been integration of renewables into various contexts. However, with few exceptions (e.g. Nissan/Eaton X-storage) most such projects have served as demonstration or PR activities rather than commercial propositions. The reasons for that are the relatively low number of reused batteries existing at the moment, but most importantly the challenging business case and economics of such ventures and the lack of favourable regulatory framework.

More specifically, there is no uniform policy in Europe covering this matter. In addition, there is large variation of electricity prices and support schemes. The details of FiTs and electricity prices per country can be seen in Table 2. Probably the most favourable regulatory landscape for energy storage is found in Germany where there is a clear will to encourage residential energy storage. From 2013 to 2015, the 'KfW 275 Kredit' initiative subsidised residential PV plus storage systems with a 30% of the initial investment as well as low interest loans (1.1%) resulting in 19,000 battery systems being installed. This represents about 50% of all the residential battery systems in the country. After the success of 'KfW 275 Kredit', in March 2016, a new KfW incentive was introduced for households looking to install a battery system alongside their rooftop PV (Hildebrandt, 2016). In addition to this, the German electricity prices are among the highest in Europe (~ 30 cts €/kWh). This fact alone, encourages households with PVs to be self-sufficient and to invest in batteries. Furthermore, the FiT (Feed in Tariff) for solar PV of less than 10 kW is low (~ 13 cts €/kWh in June 2015) compared to few years ago and these numbers are expected to decrease further. In parallel, the ancillary services prices are high enough to almost render storage a meaningful option. This justifies the high number of grid storage projects offering ancillary services to the grid. Very recently, similar to Germany, Sweden announced a government subsidy to support installation of residential energy storage systems. The subsidy applies to the battery system and installation costs and covers 60% of the system cost up to a maximum of ~ €5100 (Hanley, 2016).

After having summarised previous studies and projects as well as the regulatory framework in separate EU countries our analysis is presented in the following structure: In Section 2, the methodology is presented together with the case by case assumptions and considerations. In Section 3, the results for each case are presented. In Section 4, concluding remarks are made followed by discussion and policy recommendations in Section 5.

2. Methodology

2.1. Overview

This work seeks to evaluate the economic sense of retired batteries used as stationary storage in various European countries. To address this question, the authors computed the Net Present Value (NPV) of representative projects for such batteries. The calculation was performed for three different levels of storage size and grid integration. For these levels of storage size, the following systems were considered:

1. Residential customer load levelling with a roof-top solar (PV) energy generation.
2. Commercial/Industrial load levelling with on-site solar (PV) energy generation.
3. Primary Reserve for frequency control at utility level.

In general, the equation that represents the profitability of a projected investment for these systems (Eq. (1)) is fairly simple and includes a fixed capital cost and the cost-revenue balance over the entire system lifetime or a predefined time horizon defined as the investment horizon.

$$NPV = C_{fixed} + \sum_{1}^{n} (C_{in} - C_{out})\bullet(1 + i)^{-n} \tag{1}$$

In Eq. (1), C_{fixed} represents the up-front capital cost, C_{in} is the annual cash flow in (revenue) and C_{out} is the annual cash flow out (cost). n indicates the number of years the investment is done for and i is the discount rate.

2.2. Assumptions

2.2.1. Sizing and lifetime

The authors chose assumptions as representative of the market as possible, using a wide range of literature data and personal communications with consulting agencies and battery vendors. Li-ion batteries were used as the example but also as the benchmark technology in terms of performance and price. Other batteries could be assumed to follow the same kind of analysis. In addition, it has been considered that the degradation rate of both used and new batteries in the 2nd hand application does not vary significantly, hence the new/used battery degradation behaviour would be very similar. The used batteries, though, have endured a small capacity loss due to the in-car application. Then, for a residential storage system, the battery capacity was assumed to match that of the PV (e.g. 5 kWh battery to match a 5 kW PV installation).

2.2.2. Investment time and discount rate

The investment time is related to the remaining lifetime of used batteries. Usually, 5–10 years have been considered in the literature (Neubauer et al., 2012). In this study, a lifetime of 10 years was chosen as a representative investment time for all the applications. A 15 years' service time was also investigated for residential and commercial/industrial energy storage system. In terms of discount rate, the authors consider a rather low value of 1%, based on the KfW scheme in Germany (KfW, 2017), in which the interest rates for such investments are at 1.1%. The sensitivity of the NPV value to the discount rate was evaluated here by considering also a 10% rate as the extreme case.

The fact that the irradiation will be different in each country and that the energy produced would vary as a result, was not taken into account here.