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# V2GO: A V2G demonstrator designed to develop business cases for fleets

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## Summary

Using one battery for two applications, V2G (Vehicle-To-Grid) systems "kill 2 birds with one stone" and have the potential to be an econmical way to provide electricity storage and reduce the average total cost of ownership for fleet managers. Indeed, the development of V2G depends both on the value of the flexibility market and the scale of the electric vehicle (EV) market. Due to the uncertainty regarding these markets in the near term it is challenging to accurately determine the value of V2G and the likely successful business models without further market analaysis of the technology, service provsiions and customer acceptance under real-world conditions. To achieve this market analysis and target the right customers, there is a need to:

- Understand the customers segmentation to identify the different user profiles, vehicle applications and fleet operation strategies that co-exist in the market. This will allow us to find the right customers and the business case behind the product.
- Identify the range of services (and their associated financial value) that could be technically and practically provided (Demand shifting, discharge to the grid) depending of the V2G uses previously identified.

The ambition of the Innovate UK V2G real-world demonstrators (projects part-funded by the UK government) is precisely, among others, to provide answers to some of those questions and therefore accelerate the route-to-market for V2G products. In particular, V2GO (Vehicle-To-Grid Oxford) will develop, trial and evaluate potential business models, products and services by engaging with UK fleet operators. The project was launched in May 2018 and first business cases are currently in definition. They will be refined all along the trial that will run from Autumn 2018 to April 2021 (data loggers will be installed in 300 vehicles from different sized fleets including key local).

This paper focus and attempt to provide clarity on the quantification of the potential revenue that could be made from V2G/V1G.

*Keywords: Business Model, Demonstration, EV, Load Management, V2G, Smart Charging*

# 1 Introduction and context

## 1.1 General context

The UK government is commited to becoming a world leader in shaping the future of mobility and in the design and development of the clean technologies of the future. To help to deliver on this ambition, the government decided, among others things, to fund 21 Vehicle-To-Grid projects (V2G), paying for research, design and development, with the aim of exploring both the technologies and commercial opportunities [1].

V2GO (Vehicle-To-Grid Oxford) is one of the selected projects;it will develop, trial and evaluate potential business models, products and services by engaging with UK fleet operators. Fleet vehicles account for 56% of new registrations and are quickly (i.e <3 years) turned over into the private market. A better understanding of fleet operators' attitudes and valuations of different V2G technologies, products and services could therefore create additional pathways for increasing the uptake of Ultra Low Emission Vehicles (ULEVs). The energy storage capacity of electric vehicles (EVs), present new opportunities and value propositions for V2G power system services (e.g., potentially alleviate the need for generation and transmission investments; increasing network efficiency and energy security) [1]. Given the size and use patterns of fleets, they could generate economies of scale that will help realise V2G opportunities and maximise their values [2] .

V2GO brings together an interdisciplinary consortium of 7 partners from industry and research with expertise in energy and power markets and systems, fleet operation value chains and electric mobility (The Virtual Forge, Arrival, EO Charging, Upside Energy, University of Oxford, Oxfordshire County Council, EDF Energy R&D UK). The project addresses different objectives among which the one to demonstrate the technical and commercial potential for ULEVs through the powergrid and vehicle-to-building to directly and indirectly support the electricity system. This objective will be met through a real-world demonstrator trial, a portfolio of research, development of V2G business models, products and services and exploitation.

## 1.2 V1G / V2G: Where are we exactly?

V2G (Vehicle-to-Grid) isn't a new concept (references are found from the early 1990's), and the following definition is considered as standard [3]: "A system whereby Plug-in electric vehicles, when connected to electric vehicle supply equipment (EVSE) can provide bi-directional flow of energy". Therefore, the batteries are used to provide services to the Power Network or allowing customers sites to reduce their consumption during peak hour. If the concept isn't new, the technology is still considered as an emerging one as most V2G enabled vehicles currently in circulation are part of a demonstation project.

The concept is also often confused with V1G, also called "smart charging", where electricity flows in only one direction, from the grid to the vehicle's battery throught the charger. In this case the charger can manage the charge of the car, by reducing (power transfer rate) or delaying it. V1G could be seen as a form of demand response as it acts to reduce demand on the grid at certain times, and therefore can be used to provide energy sercices (this is detailed in the next section). V1G enable chargers are already market ready.

Obviously, most of the charger currently installed are non controlled ones meaning that the charge will start as soon as the vehicle is plugged. In this paper, this charging strategy will be reffered as NC-charging.

The main barriers to V2G are [3]:

- **V2G enabled vehicles**: This point has already been discussed previously. Very few V2G enabled vehicles are commercialy available (Nissan EVs, Mitshubishi Outlander PHEV), even if other OEMs have prototypes or made announcements.
- **Hardware:** Different configurations are possible depending of where the export inverter is fitted (vehicle or charge point), meaning that a V2G enabled vehicle will not be necessarly compliant with all the V2G enabled charge point. The range of commercially availaible V2G chargers is currently limited.

- **Regulatory landscape**: It also has to be investigated as a wide range of standard will apply (in particular for the component involved in the diferent communications of the system (EV to charge point, charge point to charge point operator, charge point operator to DNO etc.). Even if those standards are quite well developed, they don't necesarly consider all the V2G specificities (in particular for AC V2G), and some clarification would be required.
- **The lack of information regarding the potential revenue that could be generated from V2G** is also a barrier for the development of V2G. It's now crucial to assess the value for specific use cases to be able to identify the right customers for this service.

This paper will focus and attempt to provide clarity on the last point: the quantification of the potential revenue that could be made from V1G/V2G.

# 2 Quantification of the potential revenue

## 2.1 Main Challenges

To be able to assess V2G revenue, the main challenge that has to be faced is that V2G is at the intersection of both the transport and flexibility sectors which implies additional complexities in the value stream mapping. Therefore, two separate works has to be led:

- **Identification and understanding of  the range of services that could be technically and practically provided throught V1G/V2G** (Demand shifting, discharge to the grid), i.e. the different flexibility market schemes and their financial values.
- **Assessment of the V1G/V2G opportunities**, i.e. the time EVs are or could be plugged into a charging point. Obviously, the longer is this time and the shorter is the charging requirement, the greater will be the opportunities. It should also be noted that the time of which EVs are plugged will also have an influence on the services that could be provided, and thus on the value of the potential opportunies. **Consequently, the opportunity will be higly dependent of the vehicule use which means that there is a crucial need to understand the different fleets applications and operation strategies. This will be done thanks to the demonstrator.**

## 2.2 V2GO: A V2G demonstrator designed to bring answers for fleet

### 2.2.1 The project

Throught its demonstrator, V2GO will be a full-scale V2G facility designed to develop business case, and assess business model to accelerate V2G deployment.This will be based primarily on existing fleet operating activities/practices but with scope to explore with fleet managers opportunities to change the timing or nature of existing activities/practices to coincide with peak demand and supply.

The V2GO project started in June 2018, will run for 36 months in total and will involve three different trial phases in order to understand the potential for EVs and V2G (figure 1). Customers are actually recruited (with different vehicle fleets, operation strategies, and uses) and, data loggers will be installed from Autumn 2018.

The University of Oxford  did a fleet segmentation works to provide the consortium a better understanding of the market and of the different operating strategies used by fleet managers. This work and the first results that will come from the installed data loggers will feed our business cases and business models.

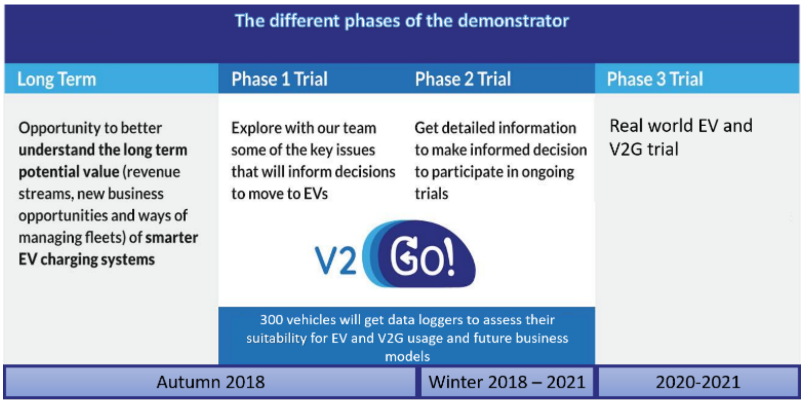


Figure 1: Different phases of the project

### 2.2.2 Overview of the model designed to identify V2G/V1G revenue

To assess both V1G and V2G potential benefits that could be made for different customers, and enable us to target the right ones, a tool was developed in two parts:

1. **Identification of potential V1G/V2G availability period**, i.e. the time EVs are or could be plugged into a charging point.
2. **Assessment of the potential revenue:** i.e. the calculation of the potential revenue that could be made trought the flexibility market and market arbitrage.

#### 2.2.2.1 Identification of potential V1G/V2G availability period

Based on real EV data (GPS data and speed), the model first determines the usage profile of the EV: driving periods and associated consumptions, assessment of the battery SOC at any time. The mobility needs are also considered to ensure that they will be achievable.

These outputs are used to identify when the vehicle could be plugged and then be available for V1G/V2G. The value of V2G is then determined based on the availability periods.

The figure 2 is just presented as an example of the results we could obtain for a specific vehicle use over a week (Nissan Leaf, 40 kWh of battery, average of 8 km/day). The availability periods for V2G are represented in blue. When the EV is not driven, the battery is used to do pure market arbitrage in this case: it charges when the market prices are low and discharges either to the site or the grid when prices are high.

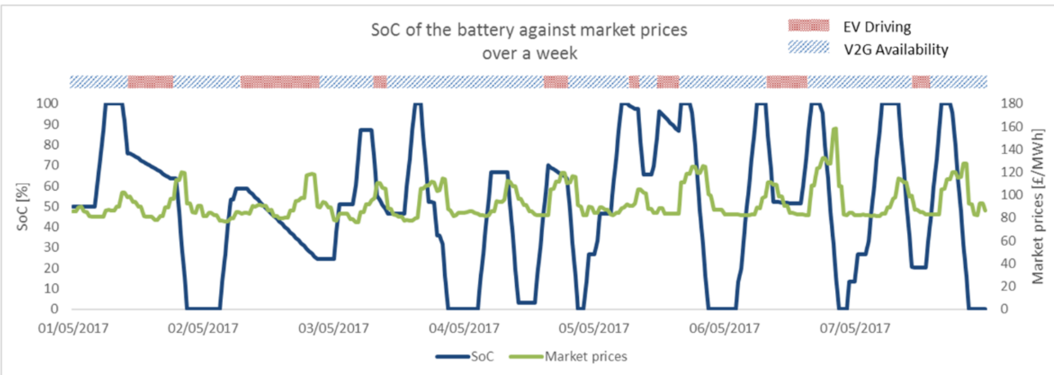


Figure 2: Example of a model output

#### 2.2.2.2 Assessment of the potential revenue:

The first step is to identify the range of services that could be technically and practically provided through V2G. There is a lot of variation between the different existing services, both in terms of requirements and value, and we need to select the ones suitable with electric vehicle's battery packs specificities. The following parameters are key.

- **Response time**: The response time is key for most of the services, both in terms of availability of vehicles following a request of service and in terms of dynamic response during the service. For some services, a longer response time could allow the car to return to depot and connect to an EVSE from the request, whereas Balancing Services like Frequency Response request a response time of a few second. In this case, the reactivity of the whole communication chain (car to EVSE to aggregator to market) is key.
- **Duration of response:** Most of the services require to hold the service for a minimum period of time. The capacity to hold the service will depend on the charger and the capacity of the vehicle's battery. This will be constrained by the SOC needed at the end of the dwell time and depends on the pattern of the use of the vehicle. In the following simulations, it is assumed that the vehicle is plugged during all the dwell time (one charger per vehicle).
- **Symmetrical response patterns and limited depth of discharge (DOD)** : Some services will require to feed and take energy on the grid in an equal and symmetrical balance, which leads to a limited depth of discharge (typically Frequency Services), This will be preferred to limit battery degradation . Academic studies are ongoing to assess if battery degradation is accelerated by V2G or not.

The table 1 identify the services that could be technically and practically delivered thought V1G/V2G in the UK, along with an EDF Energy R&D UK Centre expert opinion. Looking at the requirements of the different schemes, most of the publications available in the literature are considereing that frequency services and behind-the-meter services are the best suited for V1G/V2G.

If the EV is aggregated, revenues from Static Frequency Response (SFFR) can be considered. In the current market, SFFR prices are low at ~2-3 £/MW/hour, making market arbitrage more profitable. EVs are not able to access the Dynamic Frequency Response (DFFR) market, where prices are higher, as charge points standards currently impose 6 seconds to switch from charge to discharge (and opposite) and DFFR requires a response time of 1 second. Additionaly, there is a risk of not securing an SFFR contract due to the cannibalisation of the market and a risk of facing penalties if the EV is not available when called to provide SFFR. However, the battery would not be called often, reducing the cycling of the battery: 377 cycles/year when only in market arbitrage against 325 cycles/year when providing SFFR + market arbitrage. Battery degradation is also considered in the model.

In the UK, TRIAD refers to the three half-hour settlement periods with highest system demand between November and February. In the current market regulation, TRIAD represents an important share of the revenue as the price is high and the incentive to reduce the consumption is strong. Ofgem is currently reviewing this scheme under the TCR (Targeted Charging Review).Finally , the services retained for the following simulations are:

⇨ **Peak avoidance services** (Triad Management and NEC avoidance), even if we have to point out that triads could disappear in the next years.
⇨ **Frequency services**, knowing that their value could decrease in the near future (number of providers able to deliver the requirements of the service and cannibalisation effect)

| Market | Services | Typical response time | Typical duration of service | Revenue | EDF Expert opinion (could be technically and practically provided through V2G in UK) |
|---|---|---|---|---|---|
| **Power Supplier – Agreements between customers and suppliers** | | | | | |
| **Arbitrage - Behind The Meter (BTM)*:**<br>*Evs could also be distribution connected: In this case, it would be arbitrage only between export revenue and import costs | **Peak Avoidance services** to reduce consumption during period of high demand to avoid paying high Non-Energy Costs (NEC) charge and TRIAD | N/A | 15 mins – 2 hours | £££ | ⇨ The triad could disappear in the next years, under the TCR (Targeting Charging Review) by Ofgem<br>⇨ The discharges applied could have impact on battery degradation (deep discharge) |
| | **Utilisation of on-site generation assets, storage assets or both** | | | | ⇨ The combination of EVs battery and on-site generation assets should allow value creation in the next years |
| ⇨National Grid – Procured through tenders, auctions or bilateral agreements | | | | | |
| **Capacity Markets**<br>⇨ Has to be contracted through the TSO | **Extra positive capacity in case of stress event** | Up to 4 hours | Until the battery is discharged | £££ | ⇨ It was announced that this market is suspended (Friday 16th of November 2018)<br>⇨ The obligation to answer within 4 hours will be a barrier so will be the typical duration of the service as with EVs the priority will always be given to the driving use.<br>⇨ The discharges applied could have impact on battery degradation (deep discharge)<br>⇨ The derating could apply (instead of receiving 100% of the value, you could receive less depending of the duration of your battery) |
| **Balancing services** | Reserve services:<br>⇨ **Positive and negative reserve capacity** | 5-240 mins | 30 min to 4 hours | ££ | ⇨ The discharges applied could have impact on battery degradation (deep discharge) |
| | Balancing Mechanisms | 0-10 seconds | Duration contracted | | ⇨ Market not yet available for distribution connected and behind the meter EVs<br>⇨ Bid and offer submission -Pay as bid market |
| | Frequency services:<br>⇨ **To help balancing the grid including:**<br>- **Frequency regulation**<br>- **Restoration**<br>- **Containment** | 0-10 seconds | 30 seconds-30 mins | £££££ | ⇨ The value of those services is currently due to the low number of providers able to deliver the requirements of the service. This number may increase in the coming years.<br>⇨ In the future, many assets will be used to deliver this service (such EVs), this could saturate the market and the value of this service will reduce (cannibalisation effect). |

*Table 1: Overview of the services taht could be technically and practically provided throught V2G (in grey, the ones that could also be provided throught V1G)*

### 2.2.3 Valuation of V1G/V2G and identification of key drivers of the V2G/V1G revenue

In this section, V1G/V2G revenue will be first assessed for a base case that reflect a realistic scenario. Then, sensitivity analysis will be realised to identify key value drivers.

#### 2.2.3.1 Base Case

The base case scenario considers an EV of a delivery fleet (e.g. Royal Mail, Amazon, …), driven for 31.5 km [5] from 9am to 5pm during weekdays and is plugged the rest of the time (week-ends and five weeks of holiday) based on the fleet schedule. The charge point is installed behind-the-meter on the delivery company site and allows 7kW on charge and discharge. The site load is high enough so the overall site is always net import.

The EV is a Renault Kangoo ZE with a battery capacity of 33 kWh, with an assumed average autonomy of 160 km (Range announced by the manufacturer: 270 km (NEDC) – 120-200 km (real conditions) [6]). The usable energy capacity is 70% of the total capacity of the battery in the base case. As the EV is driven 30 km/day, the daily consumption is 6.5 kWh over 8 hours. For the analysis, all the charging stratagies (NC-charging, V1G and V2G) will be compared. The costs associated to NC-charging in this specific case is £235/year. Revenues are calculated under 2017 market conditions.

The cost of having an equivalent ICE (Kangoo, same usage, with an average consumption of 6.5 l/100km and a fuel price of 1.361 £/l [7]) is also provided

The table 2 and figure 3 present the energy procurement costs (negative values) and revenues (positive values) for the considered vehicle

- The EV is plugged and charged during the evening peak in the NC-charging strategy, increasing the value of V1G by avoiding peak prices, with almost 50% savings on energy and non-energy costs.
- TRIAD savings are achieved by not charging during the TRIAD event in V1G,and by discharging to the load during the TRIAD event in V2G.
- As the energy discharged for NC-charging and V1G is the same, NC-Charging and V1G have the same impact on the EV battery.
- Two V2G case are presented: EV Aggregated (V2G A) with the possibility of targeting SFFR revenue at night and EV Non Aggregated (V2G NA) not able to capture SFFR revenue and capturing arbitrage revenue.

| | | ICE | EV | | | |
|---|---|---|---|---|---|---|
| | | | NC-Charging | V1G | V2G NA | V2G A |
| **Peak Avoidance** | Energy trading | -£685 | -£95 | -£54 | £101 | £20 |
| | Non-Energy costs Avoidance | | -£140 | -£67 | £77 | £87 |
| **TRIAD** | | - | -£393 | £0 | £393 | £393 |
| **SFFR [1;1.8;2.5 £/MWh] between 11pm and 7am** | | - | £0 | £0 | £0 | £[20;37;51] |
| **TOTAL** | | **-£685** | **-£628** | **-£121** | **£576** | **£[520;537;551]** |

*Table 2: Costs/Revenues [£] per year obtained for the base case*

- The cost found for the vehicle doing V1G is reduced by 82% compared to the one of the ICE
- The revenue coming from V2G allows a saving between £640-700 for the base case vehicle

Those numbers do not include CAPEX costs (vehicles, chargers, installation, etc.) and are only valid for the use considered in the base case. Also, these revenues will have to be shared between the stakeholders (car manufacturer, charge point operator, agrregator and supplier).

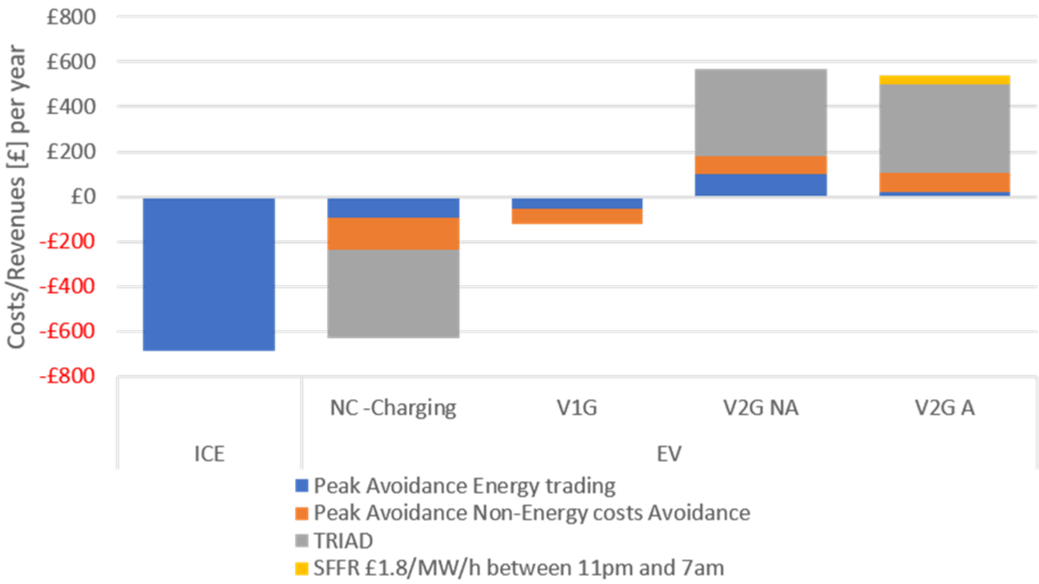


*Figure 3: Costs/Revenues [£] per year obtained for the base case*

#### 2.2.3.2 Sensitivity on the system parameters for V2G: Charge point power, System Efficiency and Usable energy capacity

Three different sensitivities have been identified to understand how each parameters would impact the value of V2G, considering the base case when the EV is not aggregated (pure market arbitrage):

- **Charge point (CP) injection power**: The higher the power of the charge point is, the shorter the duration of charge/discharge of the battery will be. A 22 kW CP could increase the savings on the costs of procuring electricity by 46% compared to a 7 kW CP. In addition, as TRIAD is a revenue based on the kW discharged, TRIAD savings would increase by 200% the TRIAD revenue, assuming the battery is discharging at full power during the three TRIAD events.
- **System Round-Trip Efficieny:** In the analysis, the round-trip efficiency is the efficiency of the overall system when charging and discharging, including the charge point efficiency. Increasing the efficiency of the system "battery + charger" from 84% to 95% would increase the market arbitrage revenues by 60%.
- **Usable energy capacity**: Some car manufacturers currently limit the usable energy capacity of the battery to limit the effect of degradation that are higher at extreme state-of-charges. Therefore, the value of V2G is lower as there is less energy tradable on the market.

The respective impacts of those parameters are presented in Figure 4. The parameter that seems to have the most impact is the speed of charge, but it has to be noticed that the sensitivity observed is mainly explained by the revenue from the TRIAD which could disappear in the next years.

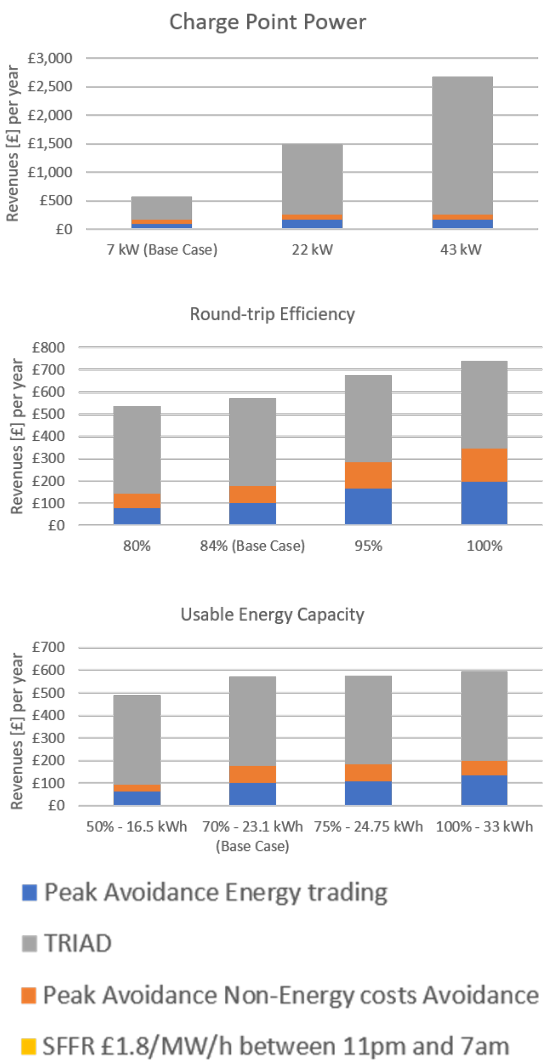


*Figure 4: Sensitivity on the system parameters*

#### 2.2.3.3 Degradation

As mentioned above, some car manufacturers limit the usable energy capacity to prevent the degradation of the battery, explaining why the analysis is considering a battery with 70% usable energy capacity as a base case.

According to the battery degradation specifications provided by the manufacturer, usable energy capacity of the battery would be 55% after 4,800 cycles. Considering the base case scenario for a V2G doing pure market arbitrage, the battery would do 377 cycles per year, in which 82% associated to market arbitrage activities. The battery degraded capacity would reach 70% after 3,500 cycles or almost 10 years assuming that the EV battery operation remains unchanged. After year 10, the usable energy capacity would be decrease over cycling and revenue would decrease.

In the valuation of V2G and definition of business models, the manufacturer warranty should be considered instead of the battery specifications.

#### 2.2.3.4 Sensitivity on market parameters for V2G: price volatility and non-energy costs region

- **Wholesale price volatility**

The wholesale price volatility, defined as the standard deviation, creates more or less opportunities for the battery to generate value by charging and discharging. To evaluate the impact of the volatility, three wholesale price scenarios are evaluated: historical prices from 2017 and Aurora (consultancy) price projections for 2020 and 2040, who projects that volatility will increase in the future. As there is no view for non-energy costs value for 2020 and 2040, the comparison is not considering non-energy costs in the overall energy costs.

As shown in Table 1, Aurora sees the volatility more than doubling, increasing the energy revenues by more than 100%. Although projections show an increasing volatility, the future of market prices remains uncertain and regulations and non-energy costs will also play a role in the future of EVs.

| Scenario | Volatility | Energy trading |
|---|---|---|
| Historical 2017 | £13/MWh | £122 |
| Aurora 2020 | £19/MWh | £182 |
| Aurora 2040 | £38/MWh | £291 |

*Table 1:Sensitivity on Wholesale price volatility*

- **Non-Energy costs region**

In the UK, non-energy costs, DUoS in particular, and TRIAD are specific to each DNO region (see for example simulations done for a given vehicle with a specific use figure 5 – The energy costs considered are the ones of the year 2017) :

- For each region, DUoS structure and value are different. Peak avoidance value in V2G is highly correlated to DUoS charges. Peak avoidance revenues can vary between £2/year in West Midlands to £192/year in East England.
- TRIAD price can vary between £11/kW in North Scotland to £40/kW in London.

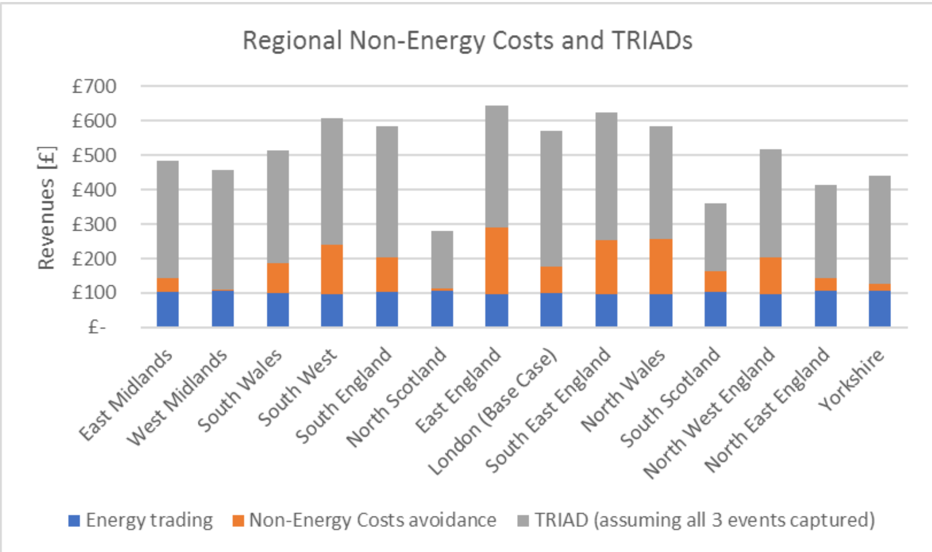


*Figure 5: Dependency of the results on the region where the fleet is based*

#### 2.2.3.5 Sensitivity on the usage for V2G

- **TRIAD Revenue**

As for now, forecasted TRIAD alerts are given on two consecutive half-hour periods with a medium or high probability. In 2017, TRIAD alerts occurred between 4:30pm and 6pm. TRIAD events are only on one half-hour. TRIAD revenue are highly depending on the following aspects:

- Accurate forecast of TRIAD events
- If an event were to happen between 4:30pm and 5pm, in this case, the EV wouldn't be able to capture the TRIAD value as the EV would still be used for driving purposes. Similarly, if the EV were to be plugged later, it could miss a TRIAD event.
- Available amount of energy during the alerts. The value could be lower if the power discharged during the event was not at maximum.

If the EV "misses" one TRIAD event, it would loose 1/3 of the TRIAD value and reducing the yearly value of V2G by 33% as TRIAD is the major revenue stream.

- **Variation of the driving window by one hour**

As described above, the variation of the usage and driving window of the EV would have a major impact on the TRIAD revenue. Non-Energy costs avoidance are also highly impacted if the profile is different, as the EV may not be plugged during the evening price peak to discharge. Two sensitivities have been assessed and results are presented in Table 2 using the same usage profile but only shifting the driving period:

- The EV is driven between 8am and 4pm: non-energy costs avoidance are higher because the EV is plugged earlier to benefit from peak prices. TRIAD value is not affected as the EV is still connected during all events.
- The EV is driven between 10am and 6pm: Non-energy costs avoidance value is becoming a cost as the EV is not available during the evening peak to discharge and there is no TRIAD revenue as the EV is not plugged to respond to the alerts.

| Driven Scenario: same duration | Energy trading | Non-Energy costs avoidance | TRIAD |
|---|---|---|---|
| 9am to 5pm | £101 | £77 | £393 |
| 8am to 4pm | £101 | £90 | £393 |
| 10am to 6pm | £96 | -£3 | £0 |

*Table 2: Sensitivity on the driving window*

These results show the variability of the V2G from one usage to an other. Value of V2G must be assessed for each fleet to reflect their usage profile.

- **Discussion around the difference between planned and actual, and potential market penalties?**

The value of V2G is highly correlated to the usage profile and mobility needs and the additional risk created by the difference between the planned profile and the actual profile has to be considered and evaluated. Suppliers or aggregators will contract energy on the market based on the planned driving profile and consumption.

The risks of not being able to deliver the market contracts are:

- The actual energy capacity of the battery is different. (e.g. the EV has consumed more than planned during its driving period and is not able to discharge fully as planned)
- The actual EV availability. (e.g. the EV is plugged later than planned)

If not delivering the contracts, the supplier/aggregator will be penalised at cashout prices, which can be high depending on the current market conditions.

#### 2.2.3.6 Key drivers analysis

The sensitivity analysis demonstrates that many parameters impact the revenue calculation:

- **System parameters**: The more sensitive parameter will be the speed of charge, but, this sensitivity observed is mainly explained by the revenue from the TRIAD which could disappear in the next years.
- **Market parameters:** Wholesale price volatility could have a substantial impact on the revenue and there is an uncertainty on how the market will evolve Also, NEC are specific to the regions in the UK, creating income disparity.
- **Usage**: The usage of each fleet is driving the revenue and creates some very low value if the EV is driven during the peak, decreasing value for Non-Energy costs avoidance and missing the TRIAD value.

# 3 Assessment of various Business cases

As discussed, the opportunity will be highly dependent of the fleet applications and operation strategies. In this section, our model is used to assess the potential revenues coming from different fleets. The table 3 below present the tested uses and the potential revenue obtained for each:

- **Taxis:** Value for V2G for taxis is linked to the period of the driver shift. There is no value between 1pm and 9pm. Outside of this window, price spreads are not high enough to generate revenues. TRIAD value is created as 2 events happened on Monday and during the holiday period, when the EV is plugged. In any case, value is not as important as the base case because of the more intensive use of the EV.

- **Commercial fleet**: There are no value for TRIAD as the car is unavailable before 5:30pm during TRIAD events. For the 100km/day scenario, value from market arbitrage is negative as the EV needs to charge at full capacity for mobility purposes and the charger is 7kW, leaving no “space” for V2G.

- **Company vehicle**: Revenues are limited by the fact that the EV is plugged only 8 hours during working days and needs to have enough energy before unplugging during the evening peak.

This analysis confirmed that the results depends on both:

- **The intensity of the use of the vehicle** (number of km done per day): The longer is the daily driving distance, the longer is the charging requirement, and the smaller will be the opportunities.
- **The time of the opportunities (**the vehicle is plugged and available for V1G/V1G**)**: It will have an influence on the services that could be provided, and thus on the value of the potential opportunities.
- **The speed of charge/discharge:** The higher is this power, the higher will be the revenue as the vehicle will be faster charged/discharged.

| Fleet application | | Delivery vehicle | Taxi | | | Commercial fleet vehicle | | Company vehicle |
|---|---|---|---|---|---|---|---|---|
| **Vehicle** | Type | Kangoo ZE equivalent | Nissan Leaf equivalent | | | Kangoo ZE equivalent | | Nissan Leaf equivalent |
| | Battery capacity | 33kWh | 40kWh | | | 33kWh | | 40kWh |
| | Usable battery capacity | 70% | 70% | | | 70% | | 70% |
| | Range considered | 160 km | 270 km | | | 160 km | | 270 km |
| **Use description** | Distance driven | 31,5 km/ day | • 240 km per shift<br>• One shift per day from Tuesday to Saturday | | | • 30-100 km/ day<br>• No use during weekend | | • Home<> Work journeys = 20 Km<br>• Vehicle not used during the week-end |
| | Start/ End of the shift | from 9am to 5pm | **3 scenarios** depending of the shift (5am-1pm/1pm-9pm/9pm-5am) | | | from 9:30 am to 5:30 pm | | from 8:30 am to 9:00 am and 6:00 to 6:30 pm |
| **Charge strategy** | Charger | 7kW Plugged when not in use | 20kW Plugged when not in use | | | 7kW Plugged when not in use | | 7kW<br>• Plugged when not in use excluding weekends (work place) |
| | Charge place | In depot | In depot | | | In depot | | Work place |
| | Time of charge | Plugged when not in use | Plugged when not in use | | | Plugged when not in use | | Plugged when not in use excluding weekends |
| **Revenues** | Scenario | | 5am-1pm | 1pm-9pm | 9pm-5am | 30km/ day | 100km /day | |
| | Energy tradind | £101 | £16 | -£92 | -£80 | £99 | -£108 | -£53 |
| | Non-Energy Costs Avoidance | £77 | £32 | -£179 | £96 | £37 | -£205 | £91 |
| | TRIAD | £193 | £1,121 | £755 | £1,121 | £0 | £0 | £393 |

*Table 3:Business cases description*

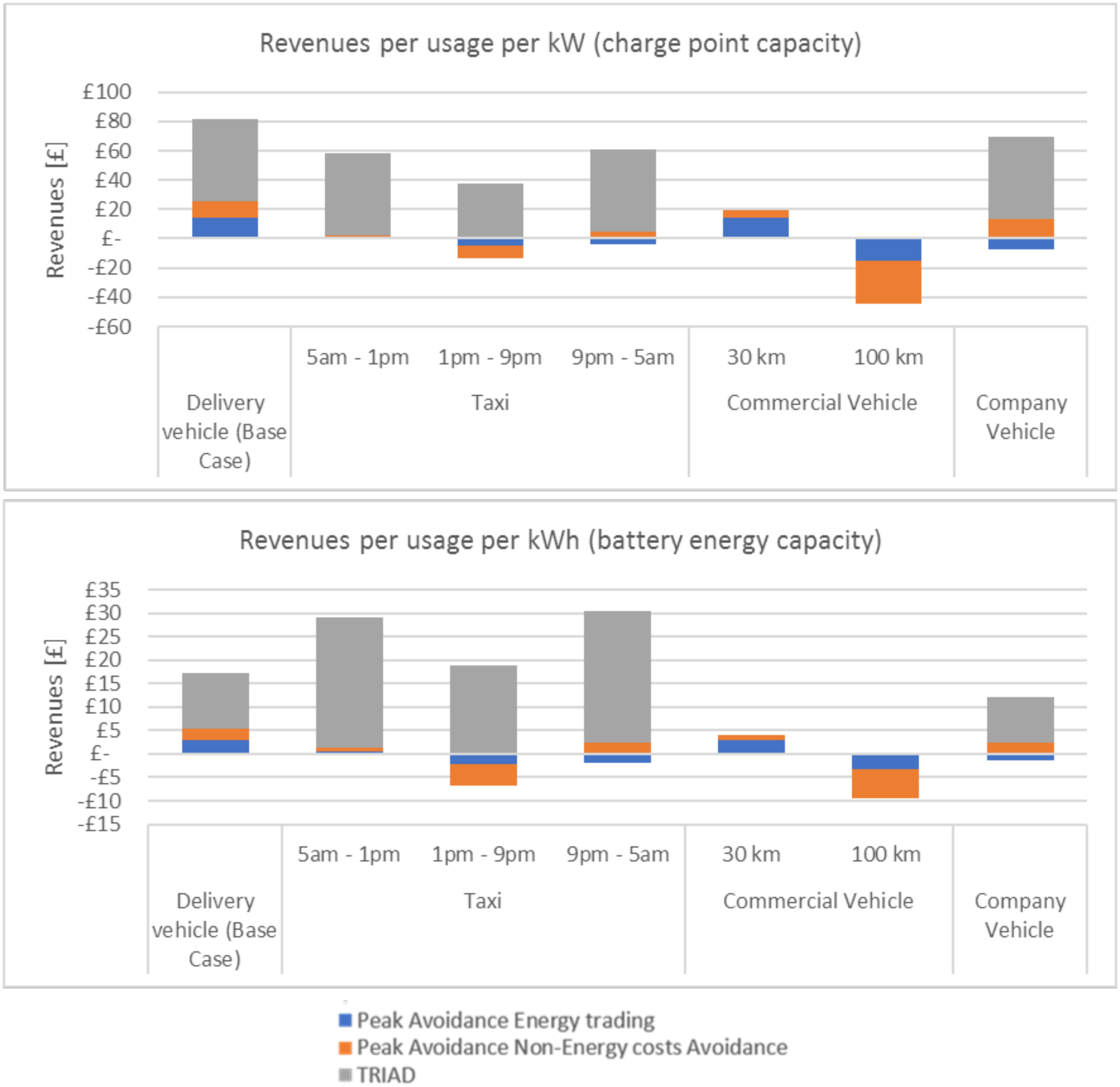


*Figure 6: Revenues streams from V2G per usage and per kW (charge point capacity) or kWh (battery energy capacity)*

# 4 Conclusion and next steps

A model was developped to quantify the revenue coming from V1G/V2G and will be used to assess the potential of V2GO's customers. This primilary work allows us to know what are the key parameters of this evaluation: use of the car, region, market price volatility and flexibility market evolution.

From Autumn 2018 (with the objective to catch the Christmas season for delivery companies), data loggers will be installed in 300 vehicles from different sized fleets including key local players). Those new data sets will feed our first business cases.

**From fleet to vehicles: the additional challenges**

Additional challenges will have to be considered when we will assess fleet instead of vehicles. For exemple, the ratio number of charger/ vehicle : Of course, the numbre of vehicles that can be plugged in the same time will impact the results.

Therefore, the value of an EV aggregate will have to be assessed by developing further the model and considering additional constraints specific to vehicle aggregation. Energy and power available at any time should be taken into account to trade energy in the market considering EV connections and disconnections.

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Before joining EDF Energy, she worked as a R&D engineer in EDF R&D – France, where she was leading a project dedicated to Electric Vehicles. In this particular project, she was involved in 2 different EVs demonstrators (KLEBER, 75 PHEVs - SAVE, 100 EVs).



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