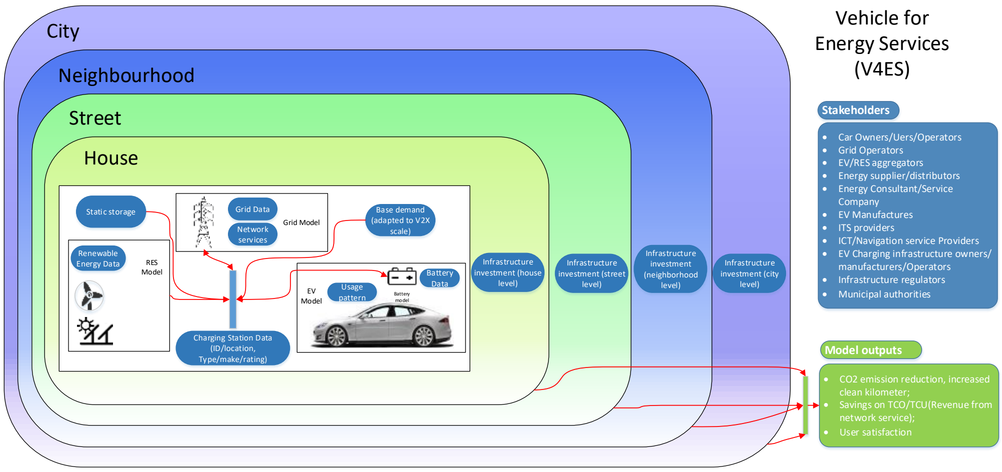
Interreg
North Sea Region
SEEV4-City
European Regional Development Fund
EUROPEAN UNION

# Business Models for SEEV4-City Operational Pilots




**Subtitle: From a generic SEEV4-City business model towards improved specific OP business models.**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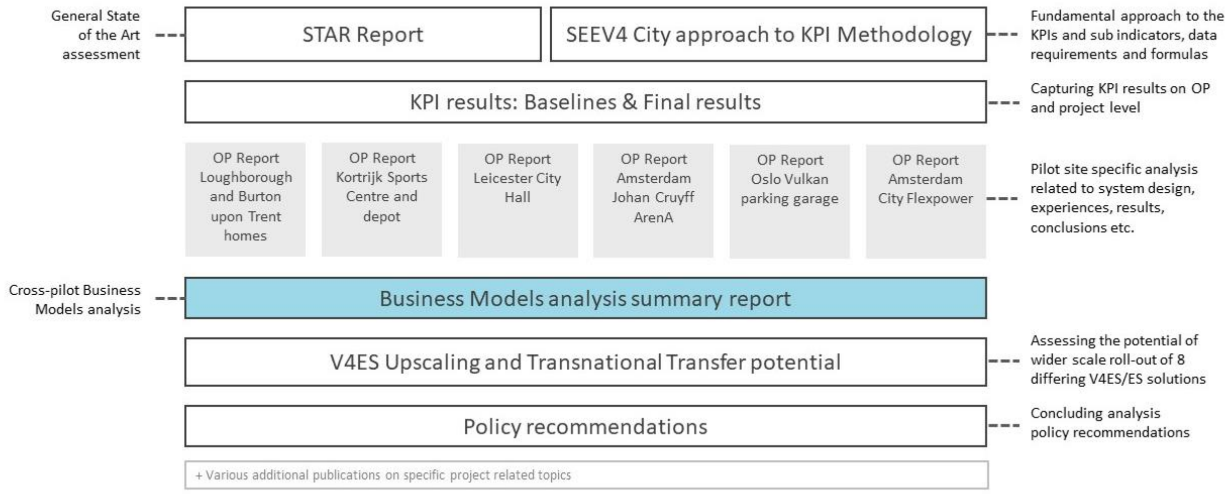
# Executive Summary

This report, led by Northumbria University, provides a final analysis by project partners regarding Business Models for SEEV4-City Operational pilots. It is part of a collection of reports published by the project covering a variation of specific and cross-cutting analysis and evaluation perspectives and spans 6 operational pilots. This report is dedicated to the analysis of business models relating to the integration of Electrical vehicles and renewable energy. Below an indication of the set of repots is provided, including an indication where this report fits in.




The North Sea Region (NSR) of Europe is advanced in the uptake of both electric vehicles (EV) and renewable energy sources (RES). Nevertheless, the developments of increasing amount of EV and RES creates a challenge. Renewable energy supply availability does not match the electricity demand for charging electrical vehicles. Due to availability and the timing mismatch between the demand and supply of renewable energy, electrical vehicles are not currently much charged from RES. Further, timing differences between demand and local renewable energy generation leads to inefficient grid use and possible instability problems. Increasing numbers of electrical vehicles and renewable energy installations aggravate the problems, if not adequately controlled. The challenge is to structure the system and control it in a way that EVs are charged by (including locally produced) renewable energy. Technically, this system is within reach but appropriate business models, regulation, policies and incentives as well as disincentives (for conventional vehicles) are still needed. So far, these are only partially available and under development and testing.

Electrical vehicles and renewable energy, in combination with Smart Information and Communication Technology (ICT), can turn challenges into solutions. These systems are best implemented within the concept of 'electric Vehicle for Energy Services' (eV4ES) or as it is commonly known V4ES (which will be used in the rest of this report). Within SEEV4-City project, different levels of V4ES are integrated to:

1. Promote and prepare wider roll out of clean and zero-emission electricity for EV with the help of V4ES;
2. Demonstrate the business potential of EV where EV and RES are integrated in operational V4ES systems.

The main aim of the SEEV4-City project is to develop the concept of V4ES into sustainable (commercially and socially viable) business models to integrate electric vehicles and renewable energy into combined Sustainable Urban Mobility and Energy Plan(ning) (SUMEP).

The objective of this report is to introduce a generic SEEV4-City business model – which considers all necessary stakeholders – and to explore how this has been reflected by operational, real-life applied specific Operational Pilot (OP) circumstances; and accordingly formulate and propose improved business models.

The SEEV4-City project has implemented - with challenges and successes along the way and potentially also some lasting impacts - different aspects of V4ES to overcome some of the key barriers to EV adoption and also deal with potentially negative impact for the grid from increased demand for EV charging. The project aims to change this impact into actual grid assets and well as (commercial) opportunities for expansion of EV4S, in the context also of increasing digitalization and trends of both energy-as-a-service and mobility-as-a-service. Alternative mobility concepts with EVs are only a small part of SEEV4-City, however.

In this project, Smart Charging and V4ES (including V2G) was conducted and analysed in four different types of environments and levels:

1. Vehicle2Home (V2H);
2. Vehicle2Street (V2S);
3. Vehicle2Neighbourhood (V2N);
4. Vehicle2Business (V2B).

The SEEV4-City approach also represents different types of V4ES applications; all important in the total commodity shift where RES and EVs and in some case a stationary BESS are used together with Smart ICT for Demand Supply management.

The four different SEEV4-City scale levels have the following issues explored, with varying depth and details, in the Operational Pilots.

1. Implementation of RES to charge EVs and a stationary battery energy storage;
2. Use of EVs for storage of electrical energy;
3. Variation in EV charging in response to local or central (grid) renewable energy generation;
4. Vehicle-to-Grid (V2G) applications;
5. Balancing the grid (supply-demand);
6. Energy market participation;
7. Provide back-up services.

It is worth noting that these Operational Pilots are experimental, and the point has been made by some OP Partners that the costs incurred here are higher than one would expect in a non-innovation set-up. They have also pointed out that no follow-on project will be exactly like one in the SEEV4-City project. Also, it is clear that the revenues landscape is still fully evolving and transforming and needs some policy and regulatory change at both EU and national level from the perspective of commercial parties at least.

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## Glossary

| Abbreviations | Terms |
|---|---|
| B2B | Business to Business |
| B2C | Business to Consumer |
| BESS | Battery Energy Storage System |
| BEV | [full] Battery Electric Vehicle |
| BSS | Battery Static Storage |
| CPO | Charge Point Operator |
| CPP | Critical Peak Pricing |
| DFFR | Dynamic Firm Frequency Response |
| DNO | Distribution Network Operator |
| DSM | Demand Side Management |
| DSO | Distribution System Operator |
| EA | Energy Autonomy |
| EMS | Energy Management System |
| ESS | Energy Storage System |
| EV | Electric Vehicle |
| EVSE | Electric Vehicle Service Equipment |
| FCR | Frequency Containment Reserve |
| FFR | Firm Frequency Response |
| FiT | Feed-in Tariff |
| HEV | Hybrid Electric Vehicle |
| HPC | High-Performance Charging |
| ICE | Internal Combustion Engine |
| ICT | Information and Communication Technology |
| IREA | International Renewable Energy Agency |
| ITS | Intelligent Transport Solution |
| KPI | Key Performance Indicator |
| LV | Low Voltage |
| MaaS | Mobility as a Service |
| MV | Medium Voltage |
| NPV | Net Present Value |
| NSR | North Sea Region |
| OCPP | Open Charge Point Protocol |
| OEM | Original Equipment Manufacturer |
| OLEV | Office of Low Emission Vehicles, UK |
| OP | Operational Pilot |
| OSCP | Open Smart Charging Protocol |
| PCP | Personal Contract Purchase |
| PEV | Plug-in Electric Vehicle |
| PHEV | Plug-in Hybrid Electric Vehicle |
| PV | Photovoltaic |

| | |
|---|---|
| RES | Renewable Energy Sources |
| RoI | Return on Investment |
| SC | Smart Charging |
| SFFR | Static Firm Frequency Response |
| SoC | State of Charge |
| TCO | Total Cost of Ownership |
| TCU | Total Cost of Use |
| ToU | Time of Use |
| ToUT | Time of Use Tariff |
| TSO | Transmission System Operator |
| V2B | Vehicle to Business |
| V2C | Vehicle to City |
| V2G | Vehicle to Grid |
| V2H | Vehicle to Home |
| V2N | Vehicle to Neighbourhood |
| V2X | Vehicle to Anything |
| V4ES | (electric) Vehicle for Energy Service (eV4ES) |
| VRE | Variable Renewable Energy |

# 1. Towards Successful Businesses Models

## 1.1. *Background*

The SEEV4-City project [1] aims to support the transition to a low carbon economy in European cities, combining electric transport, renewable energy (generation, storage and consumption), electricity grid and smart energy management [1] [2]. Due to the nature of the Operational Pilots (OPs), the only renewable energy source (RES) fully considered in the SEEV-4 project is PV, although the OPs may also draw on regional or centrally produced and distributed RES in other forms (hydro and wind, in particular).

According to [3], the more cooperation across Europe is achieved to produce renewable energy, the lower is the increased cost – at the beginning at least – of integrating RES into the electricity generation mix (with decarbonisation gains), though administrative issues and a fair sharing of costs and benefits need to be addressed. This includes workplace EV charging from renewable energy, though not as yet locally-produced but transferred to the workplace or neighbourhood in these operational pilots [4] [5] [6].

The SEEV4-City project consists of six operational pilots in the EU Interreg North-Sea region (NSR) countries, of different scales and with different complexities – as shown in Figure 1. These are:

(a) Household-based Loughborough (Phase One, V2H) and latterly Burton-upon Trent (Phase Two, V2G) pilots, UK;

(b) Kortrijk municipal depot and sports complex pilot (V2B), FL/BE;

(c) Car parking garage pilot (on the Vulkan estate in Oslo) (V2N/V2C), NO;

(d) Leicester City Hall pilot (V2B), UK;

(e) Amsterdam Arena events and energy hub pilot (V2B/V2G), NL and

(f) City of Amsterdam public EV charging-posts pilot (V2N/V2C), NL.

The six operational pilots in four different countries (the United Kingdom, Belgium, Norway and the Netherlands) involved in this project use electric vehicles (EVs), battery energy storage systems (BESS) and PV-systems to support the energy infrastructure (including the electricity grid) with a range of services. In some cases (a and e), enabled smart charging and bidirectional charging (V2G) are used to provide energy services. Some of the pilots (a and b) have used the EV batteries as short-term storage for renewable energy (PV) generation. Some pilots also have stationary batteries associated with them, either to store temporarily on-site generated renewable (solar) energy (a, b and e) or to store temporarily electricity taken from the central grid at off-peak times and thus at cheaper times, and also to supply electricity to either EV charging infrastructure or building's electricity demand to reduce peak demand of the building/ infrastructure (c).

Collectively these functions are defined as 'electric Vehicle for Energy Services' (eV4ES), or simply V4ES as it is commonly used, where the associated infrastructure would not be there if it was not for the EVs in place. In order to successfully implement V4ES and promote Sustainable Urban Mobility and Energy Plans (SUMEPs), which are a combination of the exiting tools of Sustainable Urban Mobility Plans (SUMPs) and Sustainable Urban Energy Plans (SUEPs), policy innovations and the underlying technological advancements are needed, as well as feasible business models. One of the key objectives of the SEEV4-City project is to develop feasible business models (the criteria for what 'feasible' implies may differ for different types of organisations) for a range of different contexts.

1 http://www.northsearegion.eu/seev4-city/

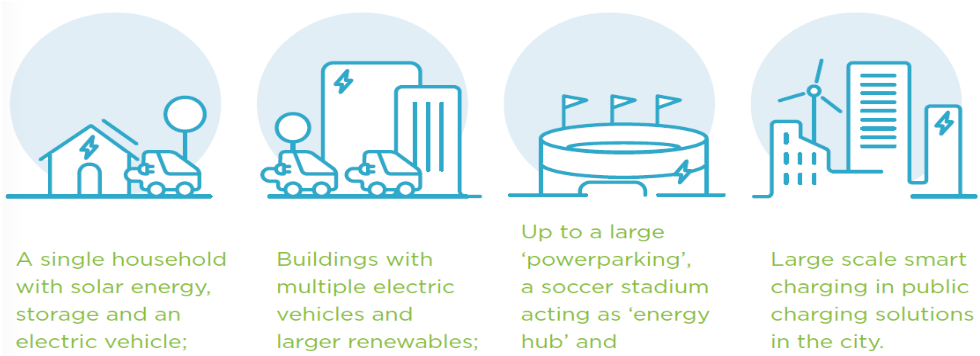


**Figure 1: SEEV4-City scales**

## *1.2. Integration of EV, RES and battery storage*

If one considers business models described in the literature, these can be argued to be needing either adapting or, in contrast, development from scratch in the field of application of new technologies and innovations [7-10], trends, markets and contexts (regulation, policies). This is also the case in the fields of mobility and energy services, which are both affected by big data, digitalization, electrification with an increased central grid penetration of renewable energy sources (RES), and distributed local renewable energy generation by 'pro-sumers' (users that are producers and/or consumers of electricity).

A significant deployment of EVs is now seen around the world. This is currently still in rather low to very low percentages of the entire vehicle stock, albeit with rising shares of newly registered vehicles in a number of key countries, including in Europe. In most of the mature industrialized countries, as well as in a number of key recently industrialised and still industrialising ones (China, India, Brazil), measures to facilitate the penetration of EVs in the car and van market are undertaken, with ambitious aspirations or at least nominal targets of EVs' fleet share set by governments or advisory bodies. Electro-mobility or e-mobility refers to vehicles that can be plugged to the electricity grid and may or may not have an auxiliary internal combustion engine (ICE). Electro-Mobility, as part of the landscape of ultra-low emissions vehicle-based transport, has received much and increasing attention in recent years [11], mostly in urban environments although with a noticeable rise in interest in commuting and rural hinterland environments also. The SEEV4-City project only covers road transport, specifically car and vans, though e-buses are also an important growth field [12] and are now at times also discussed for grid-services.

This report is particularly focused on the emergent field of electric Vehicle for Energy Services (eV4ES), that is the use of electric vehicles to support the energy infrastructure with a range of services, including Vehicle-to-Building (V2B), smart charging and V2G (bi-directional power flow) to support the electricity grid.

A top priority of public authorities at all levels is stimulating clean transport solutions powered by clean renewable energy. The electrification of road transport has several underlying motivations. The most obvious one is environmental concerns. According to the European Environment Agency [13], the major environmental impacts of vehicles include greenhouse gases, air pollution, and noise (as well as land consumption for the transportation infrastructure). While Green House Gas (GHG) emissions from all other major economic sectors have fallen (including the energy sector) in recent decades in the European Union, those from transport actually increased from 2016 to 2017. By the substitution of ICEs (petrol or diesel), tailpipe emissions can be completely avoided with full battery EVs, though for Hybrid Electric Vehicles (HEVs) this depends on the degree of electrification and driving modes. Besides, the decarbonization and cleaning that EVs can achieve depend on the energy mix to charge EVs as well as manufacturing of components. In fact, manufacturing grid components also cause $CO_2$ emissions and by deferring grid investments with controlled charging (Smart Charging or Vehicle-to-Grid), these can be saved.

It has been argued by some researchers, and can be substantiated by the efforts of central and regional/local government by way of a range of subsidies and support mechanisms, that the modern/most recent EV market has been socially constructed by politics [14] [15]. For some time, and until recently in most countries, the rise of the PV/solar energy had also been supported in a similar vein, though the recent declines in subsidies has been offset by increasing competitiveness if a number of factors otherwise turn out favourable [16].

Both from an environmental and a modified cost-of-ownership and cost-of-use perspective [17], increasing attention has been directed at charging of electric vehicles from renewable energy sources (both from the grid and distributed, i.e. local generation). Distributed RESs offer some advantages but also disadvantages, and need appropriate market design to effectively include, utilize and promote them [18]. This is where the Smart Grid concept comes in: A 'smart grid' is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable (central and distributed) energy resources, combined in an interactive manner in order to efficiently deliver a sustainable, economic and secure electricity supply [19] [20]. Essentially, a smart grid is an "intelligent" and active grid that instead of only providing power to the loads also optimizes the energy flow, which can be bi-directional, making the consumers more interactive and smart entities: “pro-sumers”. When considered profitable, electricity can be generated locally, making the most of what is called distributed generation (small generators often aided by local storage). The energy is often generated by photovoltaic (PV) systems (as micro wind generators are often not suitable in urban locations); and may be supported by stationary batteries (BESS) which store the energy that is not consumed during the day and provide it in a delayed time. This is an evolution of the conventional electrical grid towards a system that optimizes the benefits of the whole structure: these include the minimization of the losses, the maximization of the profits of the components, stabilization of the grid, improvement of the safety, reliability and quality of the service.

Energy storage is also becoming important for the increased utilisation of intermittent (fluctuating) generation from RES, especially solar and wind energy [21]. The ability to store energy can also level out the demand curve for the electricity grid (peak shaving) which leads to a decrease in the peak requirements for energy production. In addition, an intelligent energy storage system (ESS) via EVs is also important [22], preferably with renewable energy aided by energy policy [23] [24] but drawing on a balance where and when needed in a smart-grid environment [25]. The decarbonisation of the electricity used for EV charging is also of high significance to $CO_2$ emissions. This opens up a new perspective on what EVs can represent for both the electricity system and the transportation system, and can help to achieve this goal - with renewable energy enhancing this by a positive interaction between the domains [26] [27].

We are now seeing – alongside supportive research-based monographs such as by [28] – review articles in leading academic journals on 'the use of parking lots to solar-charge electric vehicles [29]. There is also an increasing interest not just in e-bikes, but also solar e-bikes [30].

The availability and timing mismatch between the electricity demand and renewable energy generation (e.g. solar power) is an actual concern for renewable energy integration. Electric transportation presents both a challenge and an opportunity going forward, which is not just a technological but also a systems governance and behavioural one at organisational, household and individual level [31]. Through smart charging [32], EVs offer benefits for incorporating renewables by matching up the charging profile with the renewable generation, and at the same time decarbonisation is achieved by charging EVs from renewable energy. If EVs are further enhanced with V2X functionalities, the renewable-integration benefits can be increased, and the use of EVs as supply-side resources is also likely to reduce the investment costs required in other flexible power plants to accommodate renewables. The benefits do however depend on the scale of EV adoption. This needs to be much higher than currently observed, given the significant infrastructure investments and societal and behavioural changes required for synergistic benefits to materialise at a scale useful for electric power systems [33]. The EV industry is experiencing an innovation race, with established and new OEMs competing around design considerations, technological challenges and functionalities, platforms and costs for itself and consumers [34-38]. There is a great potential to couple electric vehicles, local energy systems, and personal mobility in the city, which can not only improve air quality and mitigate climate change – but also grow new business models. New mobility concepts are also needed for an increased uptake of EV (including fleets and carsharing) and towards interactions with smart homes and buildings [39] [40].

The literature on business-models for electric vehicles, until quite recently, was splintered, fragmented and not holistic in terms of looking at a full range of stakeholders in the business models. The evolution of the automotive industry (so-called Original Equipment Manufacturer or OEMs) towards alternately-fueled vehicles, including by electricity (EVs) has attracted much academic, commercial consultancy and public policy attention. This has focused on OEM fleet-wide business models (including $CO_2$ emission caps by regulators across fleets and using renewable energy) as well as different EV architectures, market segments and prices. The interest is also in Research & Development (R&D), piloting, and financial subsidies or tax incentives in different forms to either OEMs directly or to purchasing or leasing consumers (organizations, institutions, fleets, car-sharing or individuals) [41].

However, with emergent business fields and complex radical innovation areas where there is at the beginning an undeveloped network and ecosystem of product and services providers for both Business-to-Business (B2B) and Business-to-Consumers (B2C), a firm/company centric perspective only falls short in both analysis and so-called collective or collaborative ecosystems and infrastructure building (in the wider sense than just physical) [42]. Individual firms face a paradox when aiming to successfully develop and implement innovative technologies (for instance around sustainability transitions in the domains of energy and transport) in that they need to collaborate with other industrial and commercial actors. They need to do so in the wider innovation ecosystem around standards development, at least eventually interoperable products, pool systems-level knowledge and resources, and coalesce to compete (and also lobby around public investment) against other feasible technologies (for instance, hydrogen in the ultra-low emission vehicle case). Firms/companies can create conditions conducive to doing this efficiently in a network-level organized manner which limits the risks of collaboration with their competitors, and enables them to develop competitive products and services either themselves or together with their partners of choice [43].

A co-evolutionary analysis approach based on a social-technical analysis of the innovation path is presented in [44], seeking to explain the (re-)emergence of electric and hybrid electric vehicles in the 1990s in quite a different way to many economists that see the reason for the dominance for many decades now of the internal combustion technology mostly from processes of learning and economies of scale, namely by focusing on the interrelation with changes in the social and regulatory context.

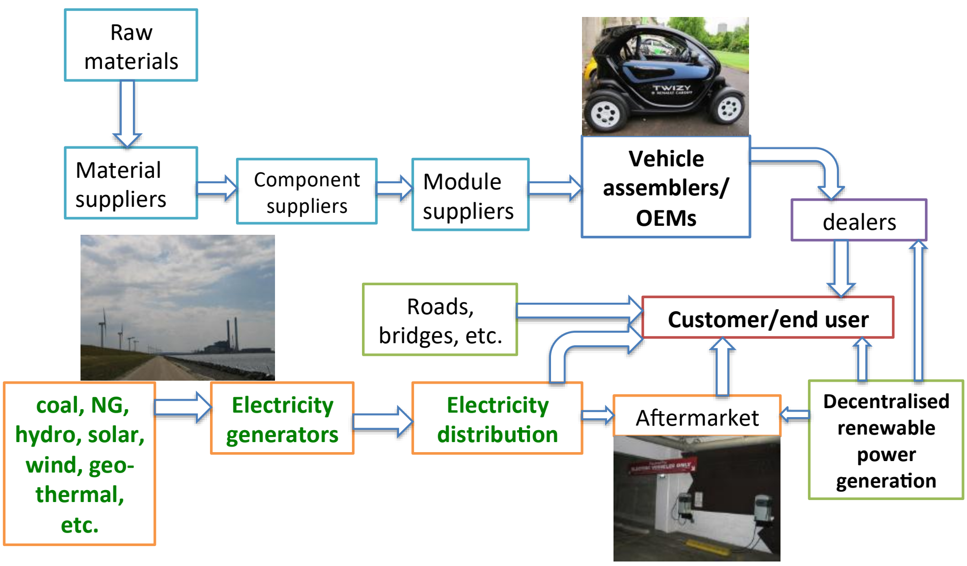


**Figure 2: Value chain of the EVs business model [45]**

Comparing the value chains of the automotive business model for ICE vehicles and for EVs (see Figure 2), the principal difference is due to the vehicle drive-train and power source. The battery pack and its associated energy exchange unit, i.e. the charging/discharging infrastructure, and the energy supplier are the new components brought in by the EV business model [45]. Another key area is the need for safe and reliable electric vehicle supply equipment (EVSE) [46].

The literature on business models and transitions in the EV and energy industries often focuses on a particular part of the overall industrial ecosystem, be it the charging infrastructure [47] [48], batteries [49], energy services providers, or more recently also automotive dealerships [50] [39].

A major and continuing area of interest has been business model development for electric vehicle charging infrastructures, both on-street (public), at commercial locations for public use (including retail and car parking facilities), at business locations (workplaces) and for home charging. For neighbourhood and on-street (public) EV charging station planning, there have been two types of approaches pursued by local authorities and also ever more increasingly private commercial providers: predict location-based demand, e.g. through Geographical Information Systems, mobility and socio-demographic data and genetic algorithms [51], and/or respond to location-specific articulated demand.

As noted in a recent consultancy research report [52]: 'we are still very much in the early stages of this EV revolution. Creating an environment that allows people to charge easily and where charging fits into their way of living will be fundamental to catalysing EV demand.' From the Charge Point Operator's (CPO's) view, the PWC's report [52] identified different strategies, approaches and business models. This is set in the overall industry landscape of:

- Nascent and fragmented market in evolution with multiple business models providing diverse charging solutions;
- Several large players, with many new market entrants;
- Early signs of market consolidation;
- Venture capital and private equity funding underpinning current growth;
- Strong policy support at international and local level in terms of decarbonisation.

BESS can also provide services at a customer level, which provide direct benefits to the user; these are Time-of-Use (ToU) bill management, increased PV self-consumption, demand charge reduction and backup power. ToU bill management is exploited at the best when electricity purchases are shifted from peak hours to off-peak hours with lower rates. BESSs can provide backup power, paired with a local generator in case of grid failure. The value coming from these services, go directly in the customer's pocket, but also Independent Services Operators (ISOs) and utilities receive benefits, such as a reduction in the peak of the load profile.

The value that BESSs can deliver through all these services heavily depends on variables that are specific to the level where the assets are placed. It can be at transmission level, where BESSs can provide peak power, at distribution level, where upgrades can be deferred and finally, behind the meter where services like demand charge reduction can be provided. Energy storage can provide more services, the further downstream it is located in the electric system. When the storage is placed at the transmission level, it loses the ability to provide services behind the meter and accordingly it cannot provide services from the utility level downwards. Although behind the meter is the ideal position for BESSs, the regulatory framework (rate-related rules) does not allow BESSs located at customer level to access the market. But through specialised aggregators and grid energy services providers (such as The Mobility House for the ArenA in Amsterdam SEEV4-City OP) this may well make sense.

Commercial aggregators of either EV batteries and/or battery stationary storage that are providing grid-facing and consumer-facing services can be part of the expanding forms of 'platform economics' [53]. The emerging relationship between utilities and platform, software and technology energy services companies to monetising EVs through grid services is part of this landscape [54].

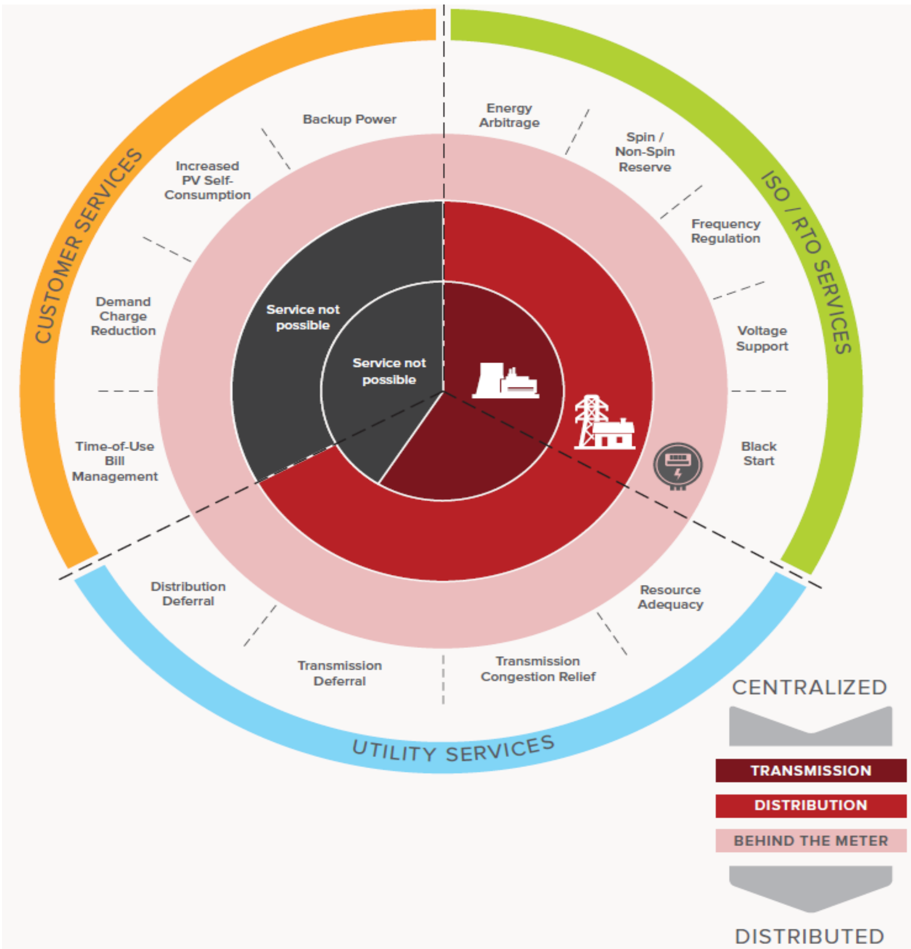


**Figure 3: Ancillary services approachable by (stationary) battery systems [55]**

Both RES and BESS are becoming cheaper and more competitive, and can help each other [56]. The projections report by the International Renewable Energy Agency (IREA) [56] on electricity storage and renewables concerning costs and markets to 2030 argues for a fundamental transformation in terms of an upcoming and accelerating energy transition, boosting both solar and wind power generation. The IREA couples falling costs of renewable power generation with decarbonisation imperatives in end-use sectors (such as direct energy uses in industry, transport and residential and commercial buildings) and derives from this the crucial importance of energy storage to facilitate "deep decarbonisation". Storage-based and rapidly improving batteries and related technologies are seen to enable greater system flexibility - described as "a key asset as the share of variable renewable energy (VRE) increases". The IREA report argues that this electricity storage (with very high levels of VRE penetration over days, weeks and months) is the basis of a transport sector dominated by EVs), enables effective 24-hour off-grid solar home systems and supports 100% renewable micro-grids. The IREA report highlights the range of ancillary services required by electricity systems to ensure a smooth and stable operation:

> Supply and demand need to be balanced in real time in order to supply quality (e.g., maintaining constant voltage and frequency), avoid damage to electrical appliances and maintain supply to all users. All electricity systems require a degree of flexibility services, which allow grid operators to react to unexpected changes in demand or the loss of large chunks of supply (e.g. large power stations tripping offline, loss of an interconnection). [See Figure 3]

# 2. The SEEV4-City Generic Business Model

## *2.1. Principles and conceptual framework*

The term business model is usually used to describe and capture the fundamental logic (both internal and outward-facing) of an organisation (often, but not necessarily, a commercial one), firm, company or product(s)/ service(s) offering(s) of those. This would detail what value proposition is created and offered for clients/customers/users and also partners (including in franchise models). It would also answer the question as to how value created accrues back to the organization in question. This may be in the form(s) of (a combination of, in the best scenario reinforcing each other) sales/turnover/revenues and (at least after an establishment duration or in good/stable phases) profits/surplus (to be reinvested in part or full, depending on the type of organization and their strategy), market share, visibility, higher attractiveness as a co-operation partner for others, client/user/customer loyalty [57], possible expansion of business fields or size of organization, and strategic positioning as a stakeholder for instance for government [58].

There is no fixed definition of the term business model. This originated in the 1970s in the disciplinary context of economic informatics, but became popular and more widespread – with somewhat changed meanings since, partly in the context of the rise of the 'new economy', digitalisation and platform economics - since the 1990s [59] [60]. A business concept can be distinguished from a business model in that it is foremost directed at external target groups (including investors). A business concept can also be a fully formulated business idea, and in this iteration is only a more detailed extension of a business idea. Since the early 2000s, there have been efforts to translate the notion of a business model also to the field of strategic management, with the aims to develop and provide integrated deriving of decision-making support tools with (substantially) revised instruments of strategic management [59]. More recently, a sustainability literature around business models has also been prominent, including internalisation of the dimensions of environmental costs and Corporate Social Responsibility (CSR). The literature is also increasingly focusing on future-facing innovations and environmental sustainability [61] [65].

A business model is said to abstract how a business works. Depending on the aims of the business model development, this can be a partial focus which considers only a particular economic sector (or even particular components in this) or it can take a more universal approach. A business model can also be viewed as a simplified description of the strategy of a commercial enterprise, constituted by the three elements of product/services and market combination, implementation and configuration of value adding activities, and their income generation mechanisms [60]. Within the elements of product/services and market combination, the organisation/company/firm defines which products and services are to be offered on which markets and how the transaction relations with clients/customers/users are designed. The value creation structure of an organisation/company/firm is a result of the implementation and configuration of value creation/adding activities. An important dimension here is the depth/stretch of the organisation's/company's/firm's value creation/adding chain, as is the integration mode of the organisation's/company's/firm's value creation/adding chain with and into that of their suppliers (and indeed also very much the other way-round) and clients/customers/users. This is true both for B2B as well as Business to End (rather than Intermediate] Consumer. The element of the income generation mechanisms defines the nature and relationships of the income generation sources, as well as the forms of income achieved.

The overall aim of a business model is to create a use value for clients/customers/users, and also to realise a lasting competitive advantage for the organisation/company/firm [60].

A business model is meant to serve as the foundation on which an organization can differentiate itself or its products/services from others operating in the same market/industry so as to achieve competitive advantage, ideally and sustainably for itself and its clients/customers/users and partners. The business model also captures which internal resources and competencies, as well as the requisite transactions (and un-traded interdependencies), are involved in value creation [66].

A business model is typically constituted of several components, comprising clients/customers/users, the products/services, the actual way offerings of products/services are produced (including the resources and partners involved) and financial aspects (costs and revenues – which can have multiple forms of origin -, and perhaps also subsidies/grants) [67] [68] [60].

One established model to describe this, and to provide a framework for analysis, is the "Business Model Ontology Canvas" [69]. This has been used [70] to explore possible future scenarios for new business models for electric mobility.

In the "Business Model Ontology Canvas", typically the nine following dimensions are recorded and represented, and then brought into relation with each other.

- The "value proposition" which is brought to the market (for-profit, or non-for-profit);
- The "client segments" which the value proposition is targeting/meant to be attractive for;
- "Communication and distribution channels" to reach clients/customers/users, and to offer/provide the value proposition to them;
- The established (or forming) "client (customer/user) relationships";
- The "key resources" which enables the business model;
- The "key activities" which are necessary to establish/maintain the business model;
- The "partner network" and the partner(s)' motivation to participate in the organisation's (or a mutually shared) business model;
- The "revenue flows" (income) which are generated by the business model;
- The "cost(s) structure" which results from the business model [71].

Analysis would also often, and for good analytical and risk control reasons, include a supply chain analysis, including by commercial industry analysts and research consultancies, as well as academic and policy/ lobbying sources [72].

In the context of a strategic analysis of an organisation/company/firm, a number of dimensions are explored. These give the general (sector/industry/field) conditions and requirements, which are valid across – for instance – the field of electro-mobility, smart grids etc. The influence factors can be stated and analysed as political, regulatory/legal, economic, socio-cultural, technological and environmental/ecological [60]. Partly, these can also be understood to be societal and even international or 'global' mega-trends [73]. But this also means that business models for the same sector, or even the same global/international organisation (company/firm) may have to be (even substantially) modified and differentiated in different countries (or perhaps even to a degree within federalised countries within those). This also applies in the field of electro-mobility [74], the integration of RES into the grid [75] and the coupling with electro-mobility through centrally and/or locally produced renewable energy, within the overall context and objectives of resource efficiency through the integrated use of key innovative technologies [76].

A business model innovation can be triggered by internal/endogenous and external/ exogenous factors. This includes, for instance, new business models of competitors [60]. It can also be for a new field that is triggered by newly emerging business activities, such as with regard to the second-life use of automotive batteries [77]. Furthermore, a stakeholder analysis is often pursued as an analytical tool. This is true not only in terms of (relative) 'winners and losers' through 'disruptive technologies or innovations' (which could lead to full displacement, radical change in demand and also the supply change, or new additional business fields for a parallel transition period) [78], but can also involve at the same time competition and (enforced, necessary or strategically chosen) collaboration, resulting in coopetition, as in the smart grids industry [43].

A conceptual framework for V4ES business models is illustrated in Figure 4 to cover services at the level of household, business buildings, street/neighbourhood, and city-scale, where the range of associated stakeholders for business model development are identified on the right hand margin. Within V4ES, EVs are used to provide different services to various targets; these can be satisfaction of household energy demand, RES integration, energy autonomy (EA), efficient transportation services and network or grid service provision.

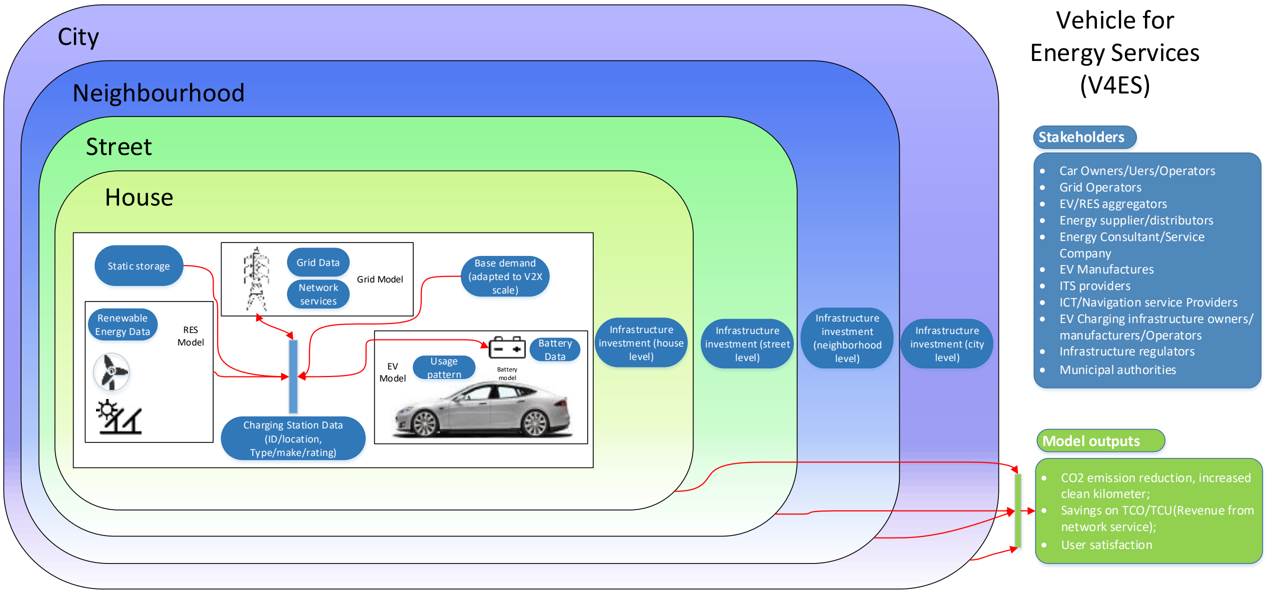


**Figure 4: V4ES generic business model conceptual framework for SEEV4-City project**

## 2.2. *Pillars and basic structure of the generic business model*

Four business model pillars, as shown in Figure 5 are proposed in line with the three KPIs of SEEV 4-City project to measure the improvement achieved in energy autonomy, carbon footprint savings (i.e. reduction in $CO_2$ emissions), and grid infrastructure deferral (or even possibly avoidance), as well as the overall cost-effectiveness of modified Total Cost of Ownership / Total Cost of Use (TCO / TCU).

Based on the generic business model structure shown in Figure 6 (developed in the SEEV4-City State-of-the-Art report), detailed business models tailored for each pilot are then derived from an interpretation of the SEEV4-City baseline and results report, the KPI methodology report as well as the operational pilots implementation monitoring and analysis reports. This facilitates the analysis and evaluation of the value added and also to propose further possible improvements and optimisation, taking into account the involved stakeholders along each of the pillars of Figure 5.

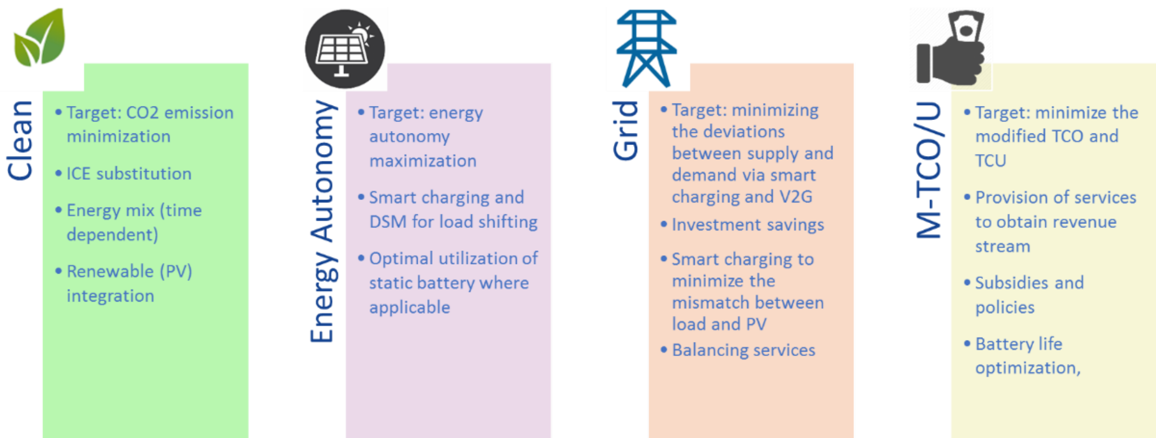


**Figure 5: Business model pillars**

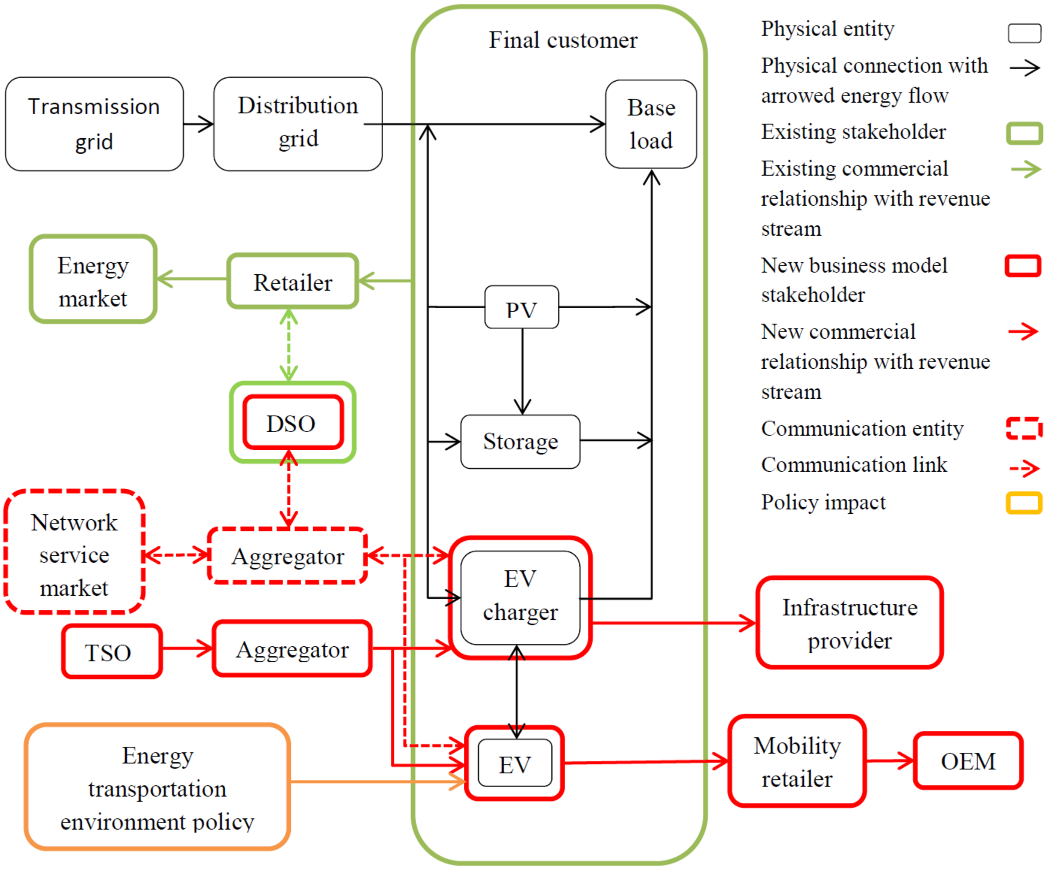


**Figure 6: SEEV4-City generic business model structure**

The generic EV business model includes the commercial and non-commercial relationships between the associated stakeholders, based on the direction of energy flow. Sometimes, the field of electric mobility is divided in four main areas of the overall ecosystem: (1) electric vehicles; (2) electricity; (3) charging infrastructure and (4) (complementary) services.

From the perspective of SEEV4-City, this needs also to cover (as reflected in the project's KPIs) strategic environmental, public health and economic objectives set by the European Union, national governments, regional/ local public authorities, and associated regulators. Please see also the SEEV4-City Upscaling and Trans-Nationality report.

# 3. Methodology for Analysis of Individual Business Models

Based on the SEEV4-City generic business model (see Figure 6), more detailed business models for each OP were then derived from an interpretation of the SEEV4-City baseline report and ongoing operational pilot implementation monitoring and operational analysis reports. It is assumed that these are the currently implemented business models, although they were not documented in this format and expression by the SEEV4-City partners and local OP partners themselves. Therefore, they are an interpretation and abstraction of the business thinking and implementation on the ground by the report authors. These assumed current business models, which were presented for verification to all SEEV4-City partners and also the respective local OP partners through them, are thus called 'derived' business models.

This derivation of models facilitates the analysis and evaluation to understand value added, and is undertaken also in order to propose further possible improvements and optimisation, taking into account the involved individual OP stakeholders. This process is represented in Section 4 as 'proposed' business models for the respective individual OPs. These may have been partly adopted and implemented during the course of the SEEV4-City project for a specific operational pilot, representing an improvement/optimisation feedback loop since conceiving of a specific OP, implementation, monitoring, analysis, (interim) lessons learnt and subsequently modifying the implemented business model in part now or for the future (after SEEV4-City formally ends, and hence representing a post-project impact).

The respective OP-specific business models were developed in two stages, namely a 'derived' business model based on the operational pilot setting as of the baseline report and then also changes implemented during the course of the OP's SEEV4-City projects, and a 'proposed' business model where further improvements and optimisation are potentially achievable from, for instance, additional hardware (such as a V2G charger with controllable bi-directional power flow) and software (e.g. IT profiles and algorithms) installed, and/or new ways of operating and targeting (net) value added.

Each individual OP-specific section starts with an overall description of the operational pilot, based on data obtained in the OP (or at least its baseline and procurement preferences documentation, in the case of the Leicester City Hall OP). This in some cases is in distinct phases and at times even at different local sites, and in multiple cases also simulations/projections due to significant delays in implementation (not least due to Covid-19 impacts).

Key (core) stakeholders are identified for each individual OP, in a table provided for each OP.

Where it is available to the report authors at the time of writing, key relevant information (in tabular form) on the respective OP's initial specifications or Baseline is provided. Please also refer to the SEEV4-City Baseline and Results, KPI Methodology, as well as the SEEV4-City Upscaling and Transnationality reports [2].

A business model structure is presented for each individual OP, and also for different distinct phases where this is necessary and/or it is required to make sense. This is done in the form of an explanatory and evaluative text, a table and also a diagrammatic figure. For the latter, the convention of a solid border of stakeholders with solid connections is adopted for the derived business model structure. The additional components introduced by the proposed business models are shown by dashed lines/borders in the associated structure illustration, and are also fleshed out in the additional tables of text on the value proposition and breakdown of costs and revenues (as and when available to the report authors). This is done based on the information made available/disclosed to the report authors, in at least a qualitative manner, and also – where at all possible – at least partially also in a quantitative way. This information is presented in a table, which also indicates where commercial and business relationships are not transparent to the report authors and no evaluation or conclusions can be therefore advanced.

[2] http://www.northsearegion.eu/seev4-city/

The proviso here is that whilst a significant – but certainly not full, and not currently for all operational pilots – amount of information was available to the report authors with regard to expenditure (costs) for implementation and running of the operational pilots, the information on revenues was significantly more limited, and currently sparse or undifferentiated between operational pilot stakeholders for a number of the operational pilots. It is also the case that incurred costs were not all charged against SEEV4-City by all stakeholder for each operational pilot, partly because of their own preferences and motivations (not necessarily transparent to the report authors), or also because of limited SEEV4-City budget available for project partners and operational pilots. This means that the 50% match-funding for eligible investments and expenses for costs of the operational pilots available (retrospectively after periodic financial reporting, less any deductions made – small in this case – for partnership organisation reporting not in line with the detailed NSR Interreg rules on this) was not comprehensive across the board. Some of those costs are also in-kind costs, and were never monetised to the SEEV4-City project and an individual OP and also to the report authors (and perhaps also not internally in a financial or even qualitative way in all cases, for instance for the City of Kortijk or at least partly in the Oslo Vulkan car parking garage).

It also has to be recalled that the project partnership overall is diverse, with a mix of three higher education institutions (fundamental and applied research), two not-for-profit research consultancies, two policy and business interests and best practice networks, as well as three (very large to substantial) municipalities. Furthermore, the actual mix of local core partners for each operational pilot is also very diverse, and not all those local partners were actually financially recompensed out of the SEEV4-City match-funding available to an OP via the respective operational pilot key SEEV4-City partner. This included a mix of local authorities (e.g. the city of Kortrijk hosting an OP by KUL, but not formally or financially being a SEEV4-City partner), commercial consultancy companies and real estate and service/innovation companies (e.g. The Mobility House, in connection with the Johan Cruijff ArenaA company itself which is in effect an innovative real estate and facilities company, with ambitions to become an international consultancy company and neighbourhood electricity trader) [3], Eaton (a multinational battery storage energy service company - as well as Nissan who work closely with Eaton), and likewise for the Vulkan car parking OP in Oslo Aspelin Ramm (a Oslo real estate company and developer) and Fortum Charge & Drive (a Swedish multi-national company active in the Nordic markets around electric vehicle and battery storage systems).

With regard to the commercial companies and subcontractors, it was difficult or impossible for the report authors to delve into relevant commercially sensitive relationships and financial cost, especially (the sharing of) revenue information, and hence also very difficult if not impossible to perform a profitability and Return on Investment (RoI) analysis for the operational pilots. In this sense, where made transparent and available, at the least the qualitative nature of business relationships had to suffice, and statements – where made before and at the end of the operational pilots – had to be cautiously accepted. For data-driven analysis, to the degree that was available and reliable, please refer also to the respective SEEV4-City final Operational Pilots analysis reports.

[3] Additionally, there is also Energy ArenA – a joint venture formed by the Johan Cruijff ArenA, The Mobility House (TMH) and the Amsterdam Climate Fund (AKEF)

# 4. Analysis of Business Models Specific to Individual SEEV4-City Operational Pilots

## *4.1. Loughborough/Burton-upon-Trent (UK) – (V2H/V2G)*

This OP is the smallest in the range of SEEV4-City, demonstrating the added value of firstly a behind-the-meter system in Phase 1 at Loughborough (V2H) and then V2G in Phase 2 at Burton-upon-Trent, both with a stationary battery ESS for improved local renewable energy generation from PV and consumption of this self-produced solar energy in the respective household. A single household was progressively equipped with 'smart' technologies, beginning with a PV system, a battery ESS and an electric vehicle and later adding a bespoke V2G charging unit. The incremental addition of smart technologies has enabled the true impact and value of each to be assessed both individually and in combination, providing a better idea of how the technologies interact and complement each other. This will enable future home owners to identify the best technology combinations to meet their needs. Overall, this 'Living Lab' experiment in both homes (sequentially, with different householders) has enabled the trialling of cutting-edge systems in a safe, monitored environment, while also allowing collection and analysis of high-quality data which will be invaluable in the future deployment of domestic V2H and V2G systems (and V2X in general) [4].

Table 1 lists the stakeholders that were involved in the pilot operation, where the key components such as the PV system and the EV were owned by the householder (a Cenex UK staff member), and the V2G charger by Cenex UK (but then passed on to the householder), and the ESS by a 3rd party (Moixa). Moixa also owned and operated the Energy Management System (EMS), which scheduled the power/energy flow of the controllable components in order to optimise the return of investment. It is noted that the V2G charger was part of the pilot (albeit inherited from a previous Cenex UK project, namely EFES), and that V2G was in principle available although it was never activated in the Loughborough pilot operation. This was due to technical reasons and the need for a software service provider and/or aggregator too in order to export to the grid.

**Table 1: Stakeholders involved in the Loughborough / Burton-upon-Trent overall operational pilot**

| Roles | Stakeholders |
|---|---|
| **House owner, PV owner, EV owner** | Householder (a respective Cenex UK staff member) |
| **V2G charger owner** | Cenex UK (but subsequently passed onto the householder at Loughborough) |
| **Battery energy storage system (ESS) provider** | Moixa for both Loughborough and Burton-upon-Trent |
| **ESS management operator** | Moixa for both Loughborough and Burton-upon-Trent |
| **V2G management operator** | Not functional for Loughborough; Ovo Energy for Burton-upon-Trent |
| **Aggregator** | Ovo Energy – at Burton-upon-Trent |
| **Distribution Network Operator** | Western Power Distribution (WPD) |
| **Transmission Network Operator** | National Grid |

The associated business model structure that depicts the direction of flows of energy and communication signals, as well as the associated commercial relationships between the above-mentioned stakeholders are illustrated in Figure 7.

[4] https://www.seev4-city.eu/projects/loughborough/

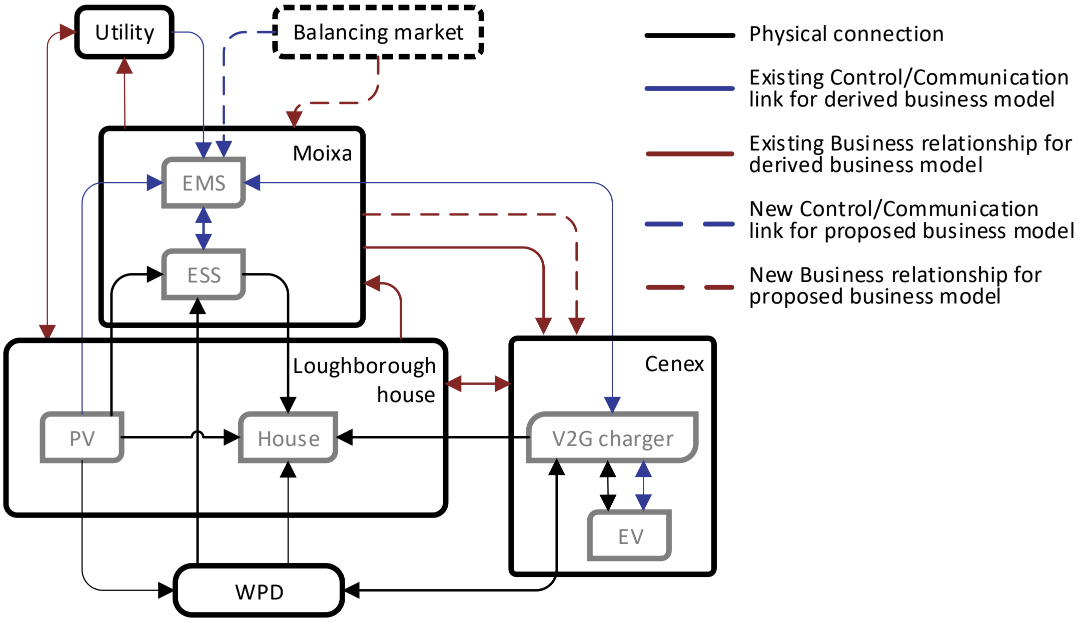


**Figure 7: Business model structure for the overall Loughborough /Burton-upon Trent operational pilot (V2G only put into practice at Burton-upon-Trent from February 2020)**

A summary of the changes made in Phase 2 (Burton-upon-Trent), as compared to Phase 1 (Loughborough) of this OP is given in Table 2.

**Table 2: Comparison of Phase 1 at Loughborough and Phase 2 at Burton-upon-Trent**

| **2016-2018**<br>**Loughborough (Phase 1)** | **2019 – to date**<br>**Burton-upon-Trent (Phase 2)** |
|---|---|
| 4 kWp PV array | 3.86 KWp PV array |
| 2 kW stationary battery<br>▪ 400 W fixed input/output | 3 kW stationary battery<br>▪ 780 W variable input/output |
| Prototype control system – partly by Moixa | Commercial control system by Moixa |
| 2012 24 kW Nissan Leaf EV | 2018 40 kW Nissan Leaf EV |
| V2G unit (inherited from the EFES project)<br>▪ Never actually worked in V2G mode | V2G unit from electricity supplier Ovo Energy (manufactured by Indra) – as part of the Sciurus project |
| First domestic V2G unit in the UK<br>▪ Very early technology, which suffered from reliability issues | Market-ready<br>▪ backed by commercial Service Level (SA) agreement, guarantees and warranties; therefore, a better reliability is expected |
| Local authority planning consent not required | Local authority planning consent not required |
| DNO (Western Power Distribution) Grid Connection Agreement: 6 kW charge [export power never needed to be defined, but presumably would not have been higher than at Burton-upon Trent] | DNO (Western Power Distribution) Grid Connection Agreement: 6 kW charge but limited to export power of 3.68 kW |
| Electricity standing charge of 28.77 p/day | Electricity standing charge of 28.77 p/day |
| Electricity tariff price 16.12 p/kWh | Electricity tariff price 16.12 p/kWh |
| PV export tariff of 5.38 p/kWh | 5.38 p/kWh normally – but increased to 26 p/kWh during participation in the Sciurus project |

### 4.1.1. Loughborough (UK) – (V2H)

The Loughborough operational pilot (Phase 1) of the overall OP consisted of a single household equipped with a roof-top PV system, which regularly produced more energy than house demand during the day due to a demand/generation misalignment. Thus, an EV (Nissan Leaf) and a stationary BESS were used to help make better use of the local PV generation. The Loughborough pilot was the smallest of all SEEV4-City pilots, aiming to demonstrate the added value of smart charging, Vehicle to Home (V2H) and a BESS for optimised renewable energy generation and consumption in households. Owing to technical problems with the hardware, the V2H/V2G functionality was not available during the project.

***Current (derived) business model***

The derived business model structure for the Loughborough (Phase 1) setting of the overall OP is illustrated in Figure 7. PV generation is controlled by the EMS to first supply the household demand, and if satisfied to charge the BESS, and then to export back to the grid if the BESS is full. In principle, Moixa, via the EMS, was able to involve the householder's EV (via the V2G charger and the BESS (owned also by Moixa) to carry out energy arbitrage by responding to a variable tariff from the utility. The associated beneficiaries in this case would be the householder (electricity bill savings, though in fact they went up, due to extra consumption) and the EV owner (reduced charging cost), as shown by solid bordered entities and solid connections in Figure 7. For Moixa, this was innovation gained from testing pre-market equipment, for Cenex UK insights that supported their technology and innovation consultancy (not-for-profit) business built-up for the future, and for Western Power Distribution (the DNO) a reduced strain on the local network, albeit very marginally. As no V2G was ever conducted, no aggregator was ever involved in this phase of the overall OP. An additional income for the Loughborough householder was the Feed-in Tariff (FiT) payment due to the share of the PV generation exported to the grid. The householder did not have to worry about battery degradation of the stationary BESS, as this was covered by Moixa as part of their innovation trial. Similarly, battery degradation of the EV they owned (due to additional cycling if V2H/V2G had been possible), as this is potentially fully or largely covered by the warranty from the OEM (Nissan).

***Proposed business model***

An additional value proposition from network service provision could have been generated by enabling the V2G functionality, which did not turn out to be possible due to technical issues. As mentioned earlier, the V2G charger was initially part of the pilot setting so no extra upgrading cost of the hardware was required in this case. As such, a proposed business model is developed on top of the derived model, where V2G would be enabled and the EV battery energy, when parked and connected, would be controlled by the EMS (and the EV charger), to provide network services in the balancing market. In this case, the balancing market would become an additional stakeholder and Moixa would essentially be the assumed aggregator. Their associated involvement has also been illustrated in Figure 7 above by dashed lines. The revenues that would be able to be obtained would then be shared by the involved stakeholders, namely Moixa with the householder (a Cenex UK staff member).

The derived and proposed business models for the Loughborough OP (Phase 1) are qualitatively developed, including the value proposition and a detailed breakdown of the cost and benefits for each stakeholder; this listed in Table 3**.**

**Table 3: Business model for the Loughborough operational pilot**

| Attributes | Functionalities of the derived business model | Additional functionalities brought by the proposed business model |
|---|---|---|
| **Key potential activities** | Energy management | Network service provision (nights and weekends) |
| **Value proposition** | 1. Income from PV generation due to FIT;<br>2. Electricity bill saving due to PV self-consumption and energy management;<br>3. Reduced charging cost due to PV self-consumption and energy management. | Revenue from network service provision |
| **Cost structure** | 1. Householder: investment cost for PV and the EV (prior to setting up this OP);<br>2. Moixa: investment cost for V2G charger, ESS and EMS, operation cost of EMS;<br>3. Cenex UK: investment cost for management and analysis of the V2G charger -which was then passed onto the householder);<br>4. WPD as the DNO: Possible management involved in the approval of the installations (e.g. PV and EV chargers) in the pilot. | Would need an aggregator in place and approval of WPD as the DNO |
| **Revenue stream** | 1. Householder: FiT, and electricity bill savings due to PV self-consumption, but apparently electricity bills went up;<br>2. Moixa: revenue from energy arbitrage, if V2G was actually implemented (no actual income);<br>3. WPD as the DNO: reduced network losses as well as savings in network upgrading cost due to PV self-consumption (marginal). | 1. Moixa: revenue from network service provision;<br>2. Cenex UK: there was no actual revenue from network service provision, but it is understood that Cenex UK would have waived this in favour of Moixa. |

### 4.1.2. Burton-upon-Trent (UK) - (V2G)

Phase 2 of this OP at Burton-upon-Trent is an extension of the Loughborough pilot (Phase 1) described earlier. As in Phase 1, a single household is involved, equipped with a roof-top PV system, an electric vehicle (a newer generation Nissan Leaf, with a 40-kWh battery) and a stationary BESS to help make better use of the local renewable generation. However, the hardware is more modern and this pilot actually carried out V2G operations, which was never possible at Loughborough (Phase 1) due to technical issues experienced with the very early technology. The V2G functionality provided extra storage resource and control flexibility that allowed better energy management.

The Burton-upon-Trent OP was set up as part of the Sciurus project, funded through Innovate UK (a UK Governmental agency) by OLEV and BEIS (a UK inter-Departmental agency and a UK central Government Department), in partnership with Ovo Energy, Nissan, Indra and Cenex UK. The Sciurus project deploys 400 V2G chargers (reduced from the original aspiration of 1,000) with domestic participants who own/lease a Nissan Leaf EV. It also includes the development of a grid balancing platform to provide electrical support to grid operators during peak energy demand times. Furthermore, the Sciurus project explores and tests commercial propositions to identify viable long-term business models. Finally, consumer behaviour and receptiveness are assessed to provide insights into EV owners' (leasers') attitudes and their response to V2G products and services. The Sciurus project seeks to demonstrate that V2G technology works at a residential level, to prove the business case of residential customers participating and benefiting from V2G service provision, and finally to demonstrate the value of V2G to vehicle manufacturers. The project partners will develop and build technologies in the UK, establish a UK supply chain and secure the position of the UK in this rapidly growing market. The results of the Burton-upon-Trent trial using an Ovo Energy V2G charger are made available to the SEEV4-City project.

The Sciurus project is intended for Ovo Energy electricity household customers with a 30 kWh Nissan Leaf EV or a newer model. A basic payment of 30 p/kWh is earned by Ovo Energy for energy exported to the grid, measured through the provided Ovo Energy smart meter. For customers in the trial who have solar or other micro-generation systems, Ovo Energy pays 26 p/kWh for energy sold back to the grid, as measured by the provided Ovo Energy smart meter. This includes all of the energy exported from micro-generation, as well as the energy exported via the V2G charger:

- Household energy results are only available for Burton-Upon-Trent for the period since 22nd October 2019 (no summer data is available) and then from the 2nd February 2020 onwards when the V2G charger was installed.
- As PV generation is used to supply home demand, there is no energy import from the grid to the home when excess PV generation occurs. Stationary battery storage is used to increase household energy autonomy on top of self-sufficiency from PV generation. PV energy is delivered preferentially for household consumption, then to the storage battery (when available) with any surplus being exported to the grid.
- As described in the Loughborough/Burton-upon-Trent OP analysis report[4], extrapolating from available data for V2G (1st - 3rd April 2020), the expected annual profit for the householder is £96 per year. This profitability for the householder ignores depreciation costs on hardware since this is funded by Ovo Energy as part of the Sciurus project, but it does account for electrical losses of 10.44% as well as battery degradation costs and of course energy imported from the grid. No additional aggregators costs are to be deducted here, as Ovo Energy has taken on the role of the aggregator in this set-up. The 26 p/kWh payable to the household & EV triallists by Ovo Energy arises under the terms and conditions of the Sciurus project funded by Innovate UK.

The derived and proposed business models for Burton-upon-Trent OP (Phase 2) are developed as shown in Table 4, including the value proposition and a breakdown of the types of cost and benefits for each stakeholder.

**Table 4: Business models for the Burton-upon-Trent operational pilot**

| Attributes | Functionalities of the derived business model | Additional functionalities brought by the proposed business model |
|---|---|---|
| **Key potential activities** | Energy arbitrage | Network service provision (nights and weekends) |
| **Value proposition** | 1. Income from PV generation due to Ovo FIT payable to householder;<br>2. Electricity bill saving due to PV self-consumption;<br>3. Reduced charging cost due to PV self-consumption and energy arbitrage. | Revenue from network service provision |
| **Cost structure** | 1. Householder/Cenex: investment cost for PV, which was shared;<br>2. Ovo Energy investment cost for EMS and V2G charger, operation cost of EMS;<br>3. Cenex: investment cost for EV, BESS and WPD: management involved in the approval of the installations (e.g. PV and EV chargers) in the pilot. | |
| **Revenue stream** | 1. Householder: Ovo Energy FiT (revenue accruing from Ovo on energy arbitrage, as metered by Ovo), and electricity bill savings due to PV self-consumption;<br>2. Ovo: revenue from energy arbitrage;<br>3. WPD: reduced network losses as well as savings in network upgrading cost due to PV self-consumption. | Ovo Energy: revenue from network service provision |

***Current (derived) business model***

The associated business model structure that depicts the direction of flows of energy and communication signals, as well as the associated commercial relationships between the stakeholders, is similar to the now-concluded Loughborough phase of the overall OP. Excess PV generation is stored in the BESS and then exported back to the house if the consumption exceeds local generation. Ovo Energy independently controls the EV (via the V2G charger) to carry out behind-the-meter energy arbitrage and provide grid services. The associated beneficiaries in this case are the householder(s) via savings on their electricity bill and lower-cost EV charging, as well as Ovo as the aggregator. Ovo Energy keeps the direct revenue from grid services, sharing value back to the householder(s) via the tariff pricing. The householder keeps any benefit from the generation and storage activities.

For more details on the Cost-Benefit analysis of V2G at Burton-upon-Trent, please refer to the Loughborough/ Burton-upon-Trent OP final report.

***Proposed business model***

The V2G EV charger is part of the Burton-upon-Trent overall OP (Phase 2) setting so no extra upgrading cost of the hardware is required in this case. A marginal feasible improvement may be to allow the BESS and the V2G systems to communicate with each other, which they currently do not do. EV battery energy, when parked and connected, could be controlled by the EMS via the EV charger to provide network services in the balancing market and to factor-in activities in the home. The EV charger independently tracks the aggregated Firm Frequency Response (FFR) signals for supplying surplus electricity to the grid, when appropriate. In practice, the BESS and the V2G EV charger do not seem to be in dis-harmony, despite the potential for them to be so.

Based on V2G activity over a period of a few days in April 2020, the following notion of (optimistic) V2G profitability at the Burton-upon-Trent OP may be calculated as follows:

Period 1st -3rd April 2020 electrical import = 42.535 kWh

Period 1st -3rd April 2020 electrical export = 25.692 kWh

Period 1st -3rd April 2020 electrical energy gained by EV battery:

Difference in State-of-Charge (SOC) = 31% (56% - 25%)

Battery capacity = 40 kWh

Energy gained by EV battery = 12.4 kWh

Losses = 42.535 - 25.692 - 12.4 = 4.44 kWh or 10.44% of energy input

So, for V2G ignoring EV battery SOC gain energy input = 25.692 kWh*110.44/100 = 28.37 kWh

Cost of importing energy from the grid: 28.37 kWh @ 16.12p /kWh = £4.57

Battery degradation costs: 5.3p/kWh of throughput = 28.37*£0.053 = £1.50

Revenue: 26p/kWh from Ovo Energy= 25.692*£0.26 = £6.68

Profit: £6.68-£1.50-£4.57 over 55.5 h = £0.61

Annual profit: £96 per year.

This figure is ignoring depreciation costs on hardware since this is funded by Ovo Energy as part of the Sciurus project. No additional aggregators costs are to be deducted here, as Ovo Energy has taken on the role of the aggregator. The 26 p/kWh from Ovo Energy referred to above are payable to the household/ EV triallists is part of the terms and conditions of the Sciurus project funded by Innovate UK.

As compared to the Loughborough OP setting (Phase 1), the Burton-upon-Trent OP (Phase 2) setting has better demonstrated SEEV4-City KPIs in increased energy autonomy, reduced tail-pipe 'zero-emission' kilometres and potential grid investment avoidance, (see the SEEV4-City Baseline, Evaluation and KPI Methodology reports as well as the Loughborough/Burton-upon-Trent OP analysis report [5]).

Comparing Phase 1 and Phase 2 of the overall OP, the technical solution at Burton-upon Trent (Phase 2) is more robust than Phase 1 at Loughborough and is commercially supported, giving it an expected lifetime beyond this project.

In the analysis of Phase 1 of this pilot (at Loughborough), Cenex UK and UNN identified a number of problems, solutions and areas for improvement which have been implemented in the Phase 2 at Burton-upon-Trent. These were:

- Simplicity in the technical solution: Reducing the number of components and the number of supplying companies. This was achieved by using off-the-shelf solutions in Phase 1;
- Commercial: Ensuring there is a financial case for the trial by setting up a commercial framework. The Phase 1 trialist (the householder, a Cenex UK staff member) experienced an increase in energy bills. This was avoided in Phase 2 by procuring commercial propositions in Phase 2, which came with their own benefits and tariffs. This, in turn, encouraged more realistic consumption behaviours by the participant;
- Taxation: Employees seem be often like ideal trialists (willing and enthusiastic) but Inland Revenue benefit-in-kind rules can make it expensive for them. Since the householder was a Cenex UK staff member, a provision was needed to be found through accountants to satisfy UK tax law around the economic benefits accruing from 'Benefits-in-Kind' to the householder created by the involvement of Cenex UK to site the equipment at this household, with an agreed share among

[5] http://www.northsearegion.eu/seev4-city/

themselves (Cenex UK is understood to likely be waiving this in such circumstances). Cenex UK / SEE4-City have derived a policy recommendation to address this issue. A summary of the Benefit-in-Kind rules [6] is given below, which covered in depth in the policy recommendation and roadmap report [8].

*Context*:

- Added value of participatory R&D processes (i.e. companies test emerging products/services on their employees), namely:
    - Engagement and commitment with the process by the employees involved;
    - Access to a patient test user population but also a population with contextual knowledge on par with potential Early Adopters;
    - Companies have the first-hand experience of the benefits and flaws of the technology and how the service evolves;
    - In-house testing protects the companies' brand by allowing managers to judge when the development is sufficiently mature to be released to the general public/on the market.

*Existing barriers*:

- SEEV4-City has observed that the Benefit-in-Kind system works as a barrier to the type of employee R&D approach described above;
- Unlike employers, who can benefit from UK Corporation Tax Relief for R&D, employees who want to participate in the research and development are subject to increased income taxation [7];
    - To the SEEV4-City project's knowledge, no equivalent for employees exists for the Corporation Tax Relief in the UK for R&D (which can be applied to a proportion of an organisation's R&D expenditure). This presents a barrier to innovation.

*Recommendations:*

- SEEV4-City recommends the creation of a zero-BiK-rate for a limited number of employees receiving benefits from innovative products/services that advance knowledge or capability in a field of science, technology or social/environmental service, or projects that help resolve scientific, technological uncertainties or basic usability uncertainties;
- This should be limited to a small number of staff members to prevent abuse of the system and should be subject to employees volunteering to test the product, service or offering, and the item being tested remaining the property of the company.

*Innovation Potential:*

- This would potentially accelerate early testing, without undermining the taxation system, help to avoid that smaller less-mature companies fall foul of the current rules.

This would also bring about a balance between the benefit available to companies and the benefit available to their employees.

[6] In the United Kingdom (UK), Benefit-in-Kind (BiK) rules is a particular scheme in the taxation system to avoid companies flouting national tax rules by rewarding their employees with items or services, rather than money (which would reduce their tax burden).
[7] The Loughborough / Burton-upon-Trent pilot, run by Cenex UK, experienced this first-hand

## *4.2. Kortrijk depot and sports field complex (FL/BE) – (V2B)*

The Flemish city of Kortrijk in Belgium is ambitious in the field of energy sustainability, and strives to be the first city in the Flanders region to become energy neutral. The Kortrijk operational pilot offers a scale of a unique set of business buildings in a connected complex to share practical experience in achieving a more sustainable energy system [8]. This pilot consists of a municipal sports facility (Wembley Heule), a depot (referred to as 'number 102') for city services, a PV-installation, a smart EV charging station with one Nissan E-NV200 (an electric delivery van with regular daily driving patterns (for which the base location was changed by the city of Kortrijk during the OP) within the OP pilot boundary, and a BESS. The latter (BESS) could not be physically brought onto the actual OP site in Kortrijk, due to a number of markets, technical safety and Covid-19 delays. Electric vehicle bicycles and an e-bike charging station were added to this project in terms of data integration from the KUL campus in Ghent rather than physically at the OP site (due to Covid-19). The Kortrijk pilot aims to demonstrate the benefit of smart (controlled) charging (SC) and Vehicle-to-Business (V2B) to better integrate renewable energy generation, reduce carbon footprint, alleviate local power system stress and achieve an economically feasible solution to the integration of electrically-powered transportation and renewable energy integration. It also aims to reduce energy flow from and to the grid, in order to reduce energy costs and increase energy autonomy which are their main motivations.

The Kortrijk operational pilot, although a rather small test case when compared to the other pilots, offers a unique set of circumstances to share practical experience in achieving a more sustainable city energy system. Consisting of municipal sport facilities, a depot for city services, a PV installation of 78 kW, a smart EV charging station and currently one Nissan E-NV200 (an electric delivery van), the pilot aspires to become a small virtual power plant. The energy produced by the PV installation is used by the depot and sport facilities, with any excess energy captured by the EV, stationary battery or e-bikes on site to be used when necessary, excess PV power being injected into the grid.

The regular driving hours of the mailperson and their daily predetermined route provide clear boundaries to implement smart charging algorithms. The expected rise in energy autonomy during the life-time of the SEEV4-City project is limited (as no additional PV is installed), yet a $CO_2$ decrease between 5 and 15 tonnes is expected. These numbers will only increase when more EVs are purchased by the city of Kortrijk. Plans for expansion to other city service buildings are already being considered, and fit in with the ambitious plan of being the first Flemish energy neutral city.

Table 5 below lists the stakeholders that are involved in the pilot operation, where the system components are owned by different stakeholders. After many different implementation and procurement effort twists and changes, KU Leuven now owns the BESS and the EMS (all subsidised by the SEEV4-City project), whereas the PV system belongs to the City of Kortrijk, which is eligible for a Green Certificate under the Flemish/Belgian renewable energy policy. The EV in use (a postal delivery van) in this case is contract-leased by the City of Kortrijk, which means that the risk of battery life is taken on by the OEM under the leasing contract. As such, the EV user (organisationally speaking, the City of Kortrijk) could share the benefit by providing network services and energy arbitrage without worrying about the battery degradation cost. It is also worth noting that Flemish customers are charged for the network cost by the Distribution System Operator (DSO) and the TSO based on their peak load; the detailed charge depends on the associated network operator, and this cost will show on the electricity bills. It is further worth noting that there is also a charge for feeding into the central grid in Flanders/Belgium [9]. The combination of the

[8] https://www.seev4-city.eu/projects/kortrijk/

[9] The TSO is Elia (high-voltage transmission of electrical power). The structure for Flanders is: DSO = Fluvius (merger of Eandis with Infrax), DNO = Gaselwest.
For context: there is no website for Gaselwest or any of the Flemish DNOs, as in reality they form part of the DSO (Fluvius). This is a legacy of the historical ownership structure of the Belgian (distribution) grid.

network cost and the injection fee should, in principle, encourage energy autonomy - especially on energy arbitrage.

According to the Kortrijk OP Analysis Report [79], this is a Vehicle-to-Building or Vehicle-to-Business (V2B) pilot, known in another context as a 'behind-the-meter' implementation. The goal in this OP is to adjust power flows behind the main site meter and no significant revenue is expected from exporting stored or excess PV energy to the grid, not least also due to the current Flemish/Belgian regulatory context. During the first phase of the operational pilot, a controllable external EV charger by KEBA (KEContact P30wallbox) was used which had only V1G (i.e. smart charging only) capabilities and is not V2G (bi-directional charging) capable. The KEBA EV charger in question allows an EV to be smart charged on a single phase, with a maximum power draw of 6.6 kW. From autumn 2018 onwards, an external V2G charger prototype was provided to KU Leuven free of charge by the Belgian EV charging company eNovates for use at the Kortrijk pilot (provided KUL takes and makes available to them certain measurements).

A further twist to this operational pilot, which was intended to be placed at the Kortrijk OP site after Covid-19 restrictions are lifted (which may now not occur now in the life-time of the SEEV4-City project), is a proposed e-bike charging station with smart charging capabilities. This is currently being explored and investigated by KUL, with final adjustments of the specifications still possible.

**Table 5: Stakeholders involved in the Kortrijk operational pilot**

| Roles | Stakeholders |
|---|---|
| **Building owner, PV owner** | City of Kortrijk |
| **EV user** | Delivery van (owner is the City of Kortrijk, perhaps leased) |
| **BESS owner** | KU Leuven |
| **EV charger & BESS management operator** | KU Leuven |
| **Distribution Network Operator** | Fluvius/Gaselwest |
| **Transmission Network Operator** | Elia |

***Current (Derived) business model***

The associated business model structure that depicts the direction of flows of energy and communication signals as well as the associated commercial relationships between the above-mentioned stakeholders for the Kortrijk operational pilot is illustrated in Figure 8. There are some similar physical connections and communication links to the Leicester OP (described in Section 4.4) due to their common scale with a similar value proposition, but the unique ownership of the various system components in this case has led to the rearrangement of the business relationships among the stakeholders here. Another major difference is the technical limitation of the EV to participate in the key activities due to the technical constraints of the initial EV charger which was incapable of smart charging and V2B/V2G, though that was resolved with installing the V2G charger subsequently. In addition, a reduction in electricity bill is also achievable by load levelling via a BESS, controlled by the EMS, due to the large size of the PV system.

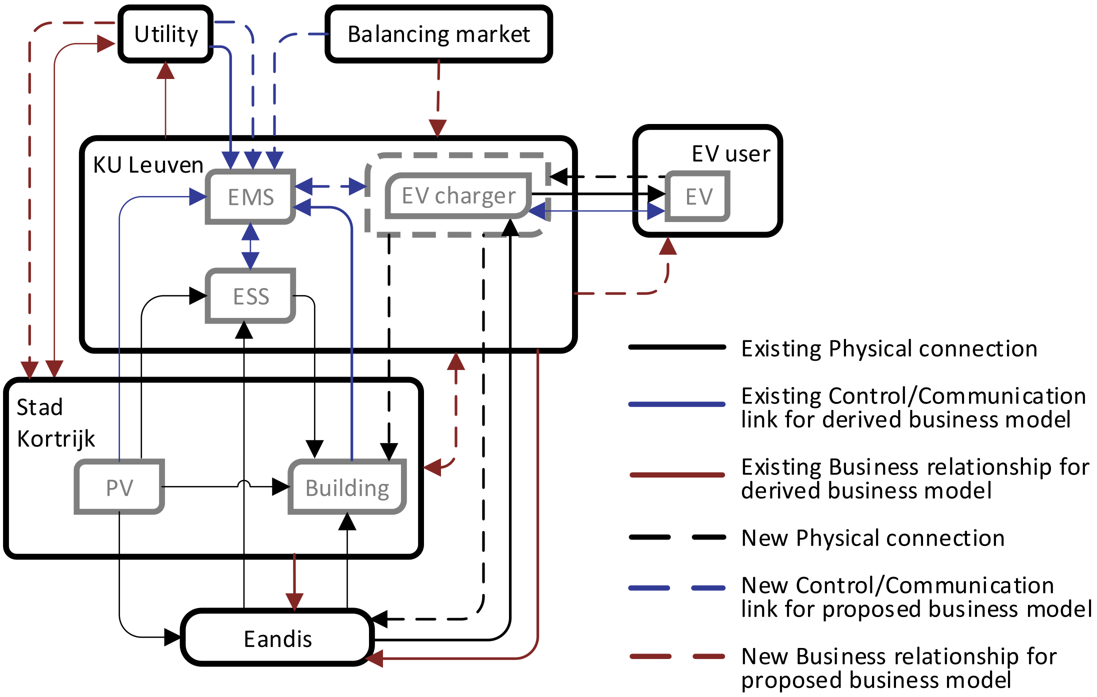


**Figure 8: Business model structure for the Kortrijk operational pilot**

[Note: Eandis has now merged to become Fluvius]

The functionalities of the current (derived) and proposed business models for the Kortrijk pilot are presented in Table 6, where the value proposition shares common areas with the Leicester City all OP, but the associated cost and revenue are structured differently to the involved stakeholders (i.e. asset owners).

**Table 6: Business models for the Kortrijk operational pilot**

| Attributes | Functionalities of the derived business model | Additional functionalities brought by the proposed business model |
|---|---|---|
| **Key activities** | 1. Energy autonomy maximization;<br>2. Energy arbitrage (using BESS);<br>3. Load levelling (using BESS). | 1. Energy arbitrage (EV);<br>2. Load levelling (EV);<br>3. Network service provision (nights and weekends). |
| **Value proposition** | 1. Income from PV generation due to Green Certificate held by City of Kortrijk;<br>2. Electricity bill saving due to PV self-consumption and energy arbitrage and load levelling (using the stationary battery ESS);<br>3. Grid injection fee minimization due to PV self-consumption;<br>4. Reduced charging cost due to PV self-consumption. | 1. Electricity bill saving due to PV self-consumption and energy arbitrage (using EV), and load levelling (using EV);<br>2. Reduced charging cost due to energy arbitrage;<br>3. Revenue from network service provision (FCR). |
| **Cost structure** | 1. City of Kortrijk: investment cost of the PV;<br>2. EV user: rental payment for EV according to the contract lease (though the City of Kortrijk may have purchased the EV outright);<br>3. KU Leuven: investment cost on original EV charger, battery ESS and EMS (which was to be procure from the market, then self-developed, and then in the end procured with additional KUL work performed to make it useable), operation cost of EMS;<br>4. Eandis [now part of Fluvius]: management involved in the approval of the installations (e.g. PV) in the pilot. | 1. KU Leuven: upgrading cost of V2G charger (though in the end turned out to be a V2G charger lend for free from innovation/technology company for certain measurements on it in return);<br>2. Eandis: management involved in the approval of the installations (e.g. EV chargers) in the pilot. |
| **Revenue stream** | 1. City of Kortrijk: Green Certificate, electricity bill savings (via PV self-consumption, and battery ESS) - though initially the electricity costs went up when switching to the Spot prices away from a fixed price;<br>2. EV user: reduced EV charging cost (via PV self-consumption);<br>3. KU Leuven: revenue from Energy arbitrage (using the battery ESS) if KUL would be allowed to gain such revenue. In practice, due to the university/public funding statutes, KUL would not receive such revenues. Instead these would go to the pilot location, in this case the City of Kortrijk;<br>4. Eandis [now part of Fluvius]: reduced network losses (due to load levelling) as well as savings in network upgrading cost due to PV self-consumption. | 1. City of Kortrijk: Green Certificate, electricity bill savings (via EV);<br>2. EV user: reduced EV charging cost (via energy arbitrage), shared revenue by KU Leuven from network service provision;<br>3. KU Leuven: revenue from Energy arbitrage (using EV) and network service provision as the aggregator. |

***Proposed business model***

As shown in Figure 8, with the upgrade of the EV charger to a higher functionality, new activities, such as energy arbitrage and network service provision, would become available to the EV owner via V2B and V2G respectively. However, this was without carrying out apparently unlogic outcomes caused by programming faults in operation – and thereby losing the trust of the e-van driver who afterwards by-passed any V2G functionality. As mentioned earlier, the EV user in this case is a unique stakeholder without concerns in regard to the battery degradation due to different service provisions (due to leasing the vehicle, though potentially the lease price and conditions may change, which would result in a change in their non-consideration of battery degradation). As such, by allowing the EMS (owned by KU Leuven) to control the EV's battery energy, the EV user would in principle be able to share with KU Leuven the profits obtained from energy arbitrage and network service provision. Additionally, the City of Kortrijk could reduce the network cost part of the electricity bill by reducing the peak demand using the EV in addition to the stationary battery ESS, and a share of the savings could then be passed on to KU Leuven (unless theirs is purely an innovation research gain for publication) and the EV user accordingly. Latterly, the City of Kortrijk decided to base the e-van at Kortrijk City Hall, and thus no longer available at the specific depot OP site.

According to the final OP analysis report by KUL:

- Electricity demand on site are subject to significant seasonal mismatch, with peak PV generation in summer coinciding with minimum demand, and maximum demand in winter coinciding with lowest PV generation. While increasing PV capacity and the amount of available storage (either in EVs or BESS) is possible, it becomes rapidly uneconomic to do so. Instead, increased flexibility of demand (demand side-management), and energy efficiency measures may prove to be much more cost-effective to implement." [79, p. 25]. Furthermore, "while the performance of the EMS roughly meets expectations, further improvements could be based on demand and generation predictions, e.g. via machine learning algorithms. In this way, PV export to grid could also be further optimised ('peak export shaving') [79, p. 25].
- The EV's [a Nissan eNV200 van] V2G operation could result in a net gain of € 219 on annual energy costs (including transmission, distribution and taxes), primarily due to energy arbitrage, charging at low prices or with otherwise exported PV energy, and discharging at peak times. However, this gain excludes the associated hardware and software to obtain these benefits, such as the V2G charger, or the EMS to manage the power flows. Similarly, the [stationary] BESS can provide an annual energy cost saving of € 70. By contrast, the option of energy efficiency investments in relighting, can achieve a reduction in energy demand by 20 MWh per year and an associated annual energy savings of approximately €2,000." "The financial and energy impacts of the Kortrijk OP changes is shown in [Figure 1 in the Kortrijk OP analysis report, on p. 3 [10]], showing the limited financial returns for the Kortrijk OP over one year. This is important as it reduces the likelihood of these measures being implemented, unless significant improvements can be made to the business case, either through subsidy support, or through cost reductions in components, both for V2G chargers, stationary storage, or a combination of all of these [Based on 2016 data].
- Taking the view of the V2G-enabled EV as a 'battery on wheels', the simulated operation of the Kortrijk OP demonstrates that this can be complementary with a BESS: the BESS can address variability in the net demand of the site while the EV is not available for V2G. When the EV is onsite, it can coordinate with the BESS to reduce peak demand. A further option would be to have either the BESS or the EV to provide frequency services while the other reduces peak demand. Given the power and energy ratings of the EV and the BESS for the Kortrijk OP, it is not yet economical for the Kortrijk OP to provide frequency support services. Instead, the solution in Belgium has been for aggregators to include such flexible capacity in their portfolios and then share part of the financial return with the asset owner. This

[10] http://www.northsearegion.eu/seev4-city/

could potentially conflict with the EMS functionality as currently developed and would be subject to further study [79, p. 45].

- Similarly, while the replacement of the diesel van at the Kortrijk OP by an EV with V2G capabilities results in a net $CO_2$ reduction of 1.7 tonnes, a larger $CO_2$ reduction is possible by replacing internal combustion engine vehicles by ebikes for commuting, achieving a net reduction of 6.4 tonnes for three ebikes. From the cost-benefit analysis, it is seen that the policy framework for mobility in Flanders still needs work to stimulate low-carbon (active) mobility, as an employee who switches from driving to work with a car to an ebike ends up nearly 4.8 c€/km out of pocket (a loss of € 456 for an annual commuting distance of 9,200 km, when replacing a car by an ebike), due to ebike commuting being provided less fiscal support [79, p. 2].
- "The prices used for price-based decisions are EPEX SPOT (day-ahead) prices, as the Kortrijk OP's electricity contract is based on these" [79, p. 2].
- The start of the EPEX spot price (or, as it was formerly known, Belpex spot) contract for the Kortrijk Operational Pilot was in January 2018, with much of 2017 (and possibly a bit of 2016) geared towards preparing the necessary changes to take advantage of the spot price. The practical change in how energy was purchased was after the start of SEEV4-City. Cost-wise, this was a mixed picture, as spot prices were very high for the periods where one or more nuclear power reactors in Belgium were out of service for multiple months. Once these issues were resolved, using EPEX spot turned out cheaper again (as expected, hence the switch towards spot prices) [11].

As stated in the OP report:

> The electricity bill for a consumer which obtains its energy from a medium voltage connection between 1 kV and 26 kV consists of the following broad categories:
>
> 1. Energy costs (peak & off-peak tariffs, OR via EPEX spot market);
> 2. Distribution costs, with peak & off-peak tariffs;
> 3. Transmission costs, with no distinction between peak or off-peak tariffs;
> 4. Variable taxes & levies, typically based on energy consumed;
> 5. Flat, additional taxes and
> 6. Additional fees, e.g. meter reading payments, fee to the energy supplier. [79, p. 32]
>
> Even if a customer buys electrical energy on the spot market, electricity distribution tariffs currently make a distinction between peak ('daytime') and off-peak ('night-time') periods. For the area where the Kortrijk OP is located (Gaselwest), peak times are between 6:00 (inclusive) and 21:00 (exclusive), Monday-Friday. All other times, weekends and public holidays are seen as off-peak times. [79, p. 33]
>
> Peak demand charges are levied on both distribution and the transmission component of electricity, based on the same measured peak demand value: the peak demand value is a rolling 12-month highest value recorded, averaged over a 15-minute interval, and includes the billing month. For example, for billing in March 2020, the peak is determined from April 2019 up to and including March 2020. The consequence of this rolling 12-month peak value is that this peak is carried along for subsequent months. This means that most of the financial benefits as seen in the energy bill due to peak shaving for the peak power component would only materialise a full year later. [79, p. 33]
>
> For the Kortrijk OP, the E520 peak demand component for transmission sets approximately 90% of the transmission charges, whereas the E210 peak demand parameter for distribution determines approximately 80% of the distribution charges. As such, it is worthwhile for the Kortrijk OP to further look into avoiding demand peaks, and this conclusion extends to other entities with similar energy and power consumption profiles. With the EV's V2G, BESS and three ebikes, the peak demand in the year is reduced from 146 kW to 138.6 kW (-7.4 kW, or -5% of peak demand). Regarding injection of PV power to the grid,

[11] B. Herteleer, e-mail communication on 25/05/2020

> this is decreased from 57 kW to 52.9 kW (-4.1 kW, or -7% of the injection peak). The combination of the EV with V2G, BESS and ebikes thus reduces the overall power volatility of the system, as both demand and injection peaks are topped off. [79, p. 34]

Based on a simulation, and historically measured 2016 data, "for the Kortrijk OP, a reduction in peak demand of -7.4 kW (-5%) was achieved, primarily due to V2G discharging of the EV at the appropriate times." [79, p. 3]

> With the vast array of possible options available for organisations such as the city of Kortrijk, the cost-effectiveness of these need to be understood to take the appropriate decisions. As discussed below, there is a logical sequence that can be followed, which overall results in the lowest costs and the highest benefits. By contrast, applying the measures haphazardly at best leads to inefficient and ineffective outcomes, and at worst to a misallocation of capital. The logical sequence is to invest in: 1. Complete avoidance of energy use through substitution or re-engineering, e.g. replace a vehicle by a bicycle, or avoid the need for physical travel through digitalisation; 2. Energy efficiency measures: use less energy for the same outcome; 3. Flexibility of energy consumption to capture lower prices and lower $CO_2$ emissions (demand side management, possibly enabled through an EMS); and, 4. Energy storage. From this sequence, it can be seen that the Kortrijk OP has primarily focused on points 3 and 4, yet the first two elements of the list should not be forgotten. [79, p. 35]

The overview of equipment used for the Kortrijk OP is provided in Table 7, without staff (or transportation) costs at either KUL or the hosting City of Kortrijk. Some of the equipment costs were own contributions from KUL (outside of SEEV4-City budget), but Table 7 below gives an overview of what the costs would have been had all items been purchased new for the pilot. This also excludes typical equipment, such as laptops and associated software used by staff who have worked on SEEV4-City.

**Table 7: Cost of equipment (other than KUL standard IT and software)**

| | Unit cost ex VAT (€) | Amount | Total cost ex VAT (€) | Comment |
|---|---|---|---|---|
| KEBA EV charger (KEContact P30wallbox) | 1,200.00 | 1 | 1,200.00 | Was superseded by the V2G charger below |
| eNovates V2G charger<br>[the actual price is not clear; the value given is the average of quotes from other V2G OEMs (quotes from Jan-Feb 2020) | 10,000.00 | 0 | - | Lent to KUL by eNovates, not charged to KUL. Typical cost from quotes received |
| AC measurement units | 2,240.00 | 1 | 2,240.00 | |
| Datalogger, current transformers etc. | 1,200.00 | 1 | 1,200.00 | |
| Stationary battery and BMS | 4,700.00 | 1 | 4,700.00 | |
| Stationary battery enclosure | 2,200.00 | 1 | 2,200.00 | |
| Small consumables battery | 1,500.00 | 1 | 1,500.00 | |
| Bi-directional inverter | 3,800.00 | 1 | 3,800.00 | |
| E-bikes | 2,500.00 | 3 | 7,500.00 | Typical purchase cost of ebikes. Some available via KUL on a monthly rental fee |
| E-bikes docking stations | 8,000.00 | 1 | 8,000.00 | |
| Mechanical docking e-bikes | 1,300.00 | 1 | 1,300.00 | |
| E-bike charging hardware | 5,000.00 | 1 | 5,000.00 | |
| **Total** | | | **38,640.00** | |

### 4.3. Oslo Vulkan car parking garage (Norway) – (V2N/V2C)

The Oslo Vulkan car parking garage OP, representing the vehicle to street/neighbourhood (V2N) - and perhaps even partly V2C - scale, is one the largest and most advanced EV charging garages in Norway and Europe. The Oslo Vulkan car park OP is an embodiment of the expected fusion between building, energy and transport sectors, in order to boost clean electrification of transport for all EV users. With over 100 EV charging outlets, including two rapid DC chargers (each with two outlets), and with an additional battery energy storage (BESS), this innovative parking garage services both residents, professional (craft & services) users, several car rental companies as well as shared 'car-to-go' offer (by the Norwegian railways company), and members of the public driving in and out of Oslo [12].

Table 8 below lists the stakeholders that are involved in the pilot operation, where Aspelin Ramm is the real estate company that developed and largely owns the overall Vulkan estate, which includes the residential/commercial building complex, the car parking garage, the 104 EV charging connection points, and the BESS supporting this.

Fortum uses the car parking garage as an innovation test bed for smart management of EV charging and a connected battery storage system. Oslo City Council currently rents 100 car parking spaces overnight for local residents, in order to avoid the investment of on-street EV charging installations – though it is not clear whether this arrangement will be maintained in the longer term beyond the current contract end date of June 2022. One Park is the car park manager for Aspelin Ramm.

**Table 8: Stakeholders involved in the Vulkan car parking garage Oslo operational pilot**

| Roles | Stakeholders |
|---|---|
| **Building owners** | Aspelin Ramm, private individuals, and in part also the Norwegian parliament |
| **EV owners** | Private: residential<br>Non-residential: craft & service, several commercial car rental companies, including by Norwegian railways, taxi companies |
| **EV chargers and battery storage owner** | Fortum Charge & Drive |
| **EV charger, battery storage, and local smart grid operator, as well as electricity purchaser** | Fortum Charge & Drive |
| **Car parking manager** | One Park |

The 50 kWh BESS (by Ferroamp) at Vulkan is currently configured for peak shaving. The built-in peak shaving algorithm uses two thresholds, one charge threshold and one discharge threshold. The total power (current) feeding the Vulkan EV car parking installation is used as input. Therefore, the Ferroamp BESS will react to the total power/current consumption by both the DC and the AC chargers. If total import power for this exceeds the discharge power threshold, the stationary battery will start to discharge to the EV chargers to try to keep import power at the threshold. If import power is below the charge threshold set, the stationary battery will charge from the grid. Thus, the peak shaving is based on real time measurements of the EV charging infrastructure power consumption.

In addition, a phase balancing function is included in the control algorithm of the 3-phase inverter. This function is sensing the total (grid) 3-phase currents and transfer energy between the three phases (depending on the level of imbalance) to minimize the imbalance and reduce peak grid currents. The maximum current balancing level of the present inverter is about 40 A. So, for example, in a scenario where grid 3-phase currents are 340 A, 280 A, 280 A, this could be balanced to: 300 A, 300 A, 300 A. The

[12] https://www.seev4-city.eu/projects/oslo/

phase balancing function does not need to cycle energy through the batteries to operate and is essentially independent of the EV batteries, although some of the inverter capacity is used when the EV batteries are used for balancing service. Charging and supporting EV battery operation is prioritized, when inverter capacity is needed.

The BESS was adjusted in early/mid-March 2020 to discharge when the total power demand is above 270 kW and charge when this is below 250 kW. This seemed to be the best way to use the relatively small capacity of the battery since the consumption in the garage has increased significantly over the last years (to approximately 3,000 kWh per day prior to Covid-19 on a week-day). Two of the battery modules (out of a total of 7) are currently faulty (and are said to have reduced in capacity by 60-70%), and have been so for a while. They are not currently proposed to be exchanged, which is a decision Fortum would have to make. The stationary battery had completed about half of its specification 2,000 cycles in March 2020 (but no real data is available to the report authors on the battery's State of Health). The BESS was very expensive 3 years ago but would now be reduced in price (with maintenance and instalment included) to about half of that if purchased and installed now [13].

The charging power at the AC outlets may vary from 3.7 kW to 22 kW, depending on the EV, and the total load of the EV chargers. The power given to the EV chargers will be limited if the total consumption is close to 1250 A as per a supplied schematic, which is the limit of the main grid feeder, but consumption has so far never reached this level. The BESS will shave the peak before this, but the amount of energy stored is limited to 50 kWh. The distribution of energy between the EV chargers are calculated by an algorithm, although Fortum Charge & Drive as the operator does not have the details for this (which was apparently sub-contracted to another company). Fortum Charge & Drive's responsibility as an innovation solution provider is limited to the EV charging, BESS and associated power capacity for the car parking garage. Fortum Charge & Drive apparently have no knowledge of other electricity loads in the building [14].

EV charging tariffs are separate from car parking fees per se, and are collected by One Park. These are according to a pre-defined price policy (by Fortum), and the EV charging tariffs (for the AC chargers in particular) may vary with time. Currently (and for a while now), this is a static tariff policy for the AC chargers, and the technology installed at Vulkan car parking garage will not allow different tariffs based on dynamic tariffs in the external electricity market, which are in any case not currently as yet possible in the Norwegian regulatory system.

Across the city, Oslo City Council have decided that all EV users have to pay for EV charging. The first locations were made ready for user payment from March 3rd 2019. By 31st December 2019 nearly all EV charging sites were charging a small user payment of NOK 10 per hour (incl. parking) on day time (9.00 – 20.00), and NOK 5 per hour during night time (20.00 – 09.00). In this regard, Oslo City Council will start charging a user payment for overnight charging for residents at Vulkan of NOK 5 per hour during night (100 places) and this will most likely be implemented in the autumn of 2020. They currently cover the EV charging cost in a business arrangement with Fortum Charge & Drive, and presumably these residents have access to parking as such already built in to their property or flat rental contracts with Aspelin Ramm. The goal is to bring this in line with the general policy for on-street EV charging across Oslo.

A potential addition to the EV charging infrastructure with more high-powered (50-100 kW) rapid chargers was decided against by Oslo City Council in November 2019 (as it was deemed not necessary for the project objectives and measurable KPIs). There was municipal budgetary pressure to invest in other on-street and housing association EV charging stations, leaving such decision – and the investment costs – to be considered by Aspelin Ramm and/ or Fortum, partly due to the suggested lack of (qualitative and quantitative) data/ insights on demand for such an installation.

Another important aspect is that Vulkan is private ground owned by Aspelin Ramm. The municipality of Oslo has a rental agreement with Aspelin Ramm for use of the premises, but this agreement expires in June 2022. As per today, we do not know if we are to extend this agreement. Hence, we (Oslo City Council) question whether

[13] Communication by Bjoern Jernström of Ferroamp, 16/03/2020, in an e-mail

[14] Communication by Goran Vollan of Fortum Charge & Drive, 15/03/2020, in an e-mail

it is a good idea to invest more on the premises. There is a high demand for electrical charging on public ground in Oslo and we are working hard to fulfil both the public demand and political requirements / targets. We have limited resources and it is therefore crucial that we prioritize to invest in areas where the demand is most critical. Further, we believe that Aspelin Ramm could invest in high performance chargers at Vulkan after the project end if they find the benefit to exceed the cost of investment. [15]

***Current (Derived) business model***

The current (derived) business model complies with the overall aim of the operational pilot to achieve energy cost minimization and load balancing for the local power network. The Vulkan parking garage serves both residential and commercial EV owners/users, which can choose to charge from the 100 AC (now flexible) charging outlets and the 4 DC quick charging connections. Fortum Charge & Drive (through the subcontractor Ferroamp) installed a BESS, which is controlled to supply power for the EV charging infrastructure during EV charging peak demand. The BESS is recharged from the grid at demand trough, and by reducing the volume of energy charged in a month at peak prices thus (under the new Norwegian) electricity tariff system saving on Fortum's energy bill for powering the EV charging infrastructure (where Fortum Charge & Drive procures the electricity through another part of the overall Fortum company).

From the business relationship aspect, the owners of the residential and the commercial EVs are priced under different/separate payment schemes for charging and parking, and the associated payments are settled with Fortum for EV charging and One Park purely for parking, respectively. Fortum Charge & Drive, Aspelin Ramm and the building residents would then settle their payment with the local energy utility for their respective consumptions. In addition, the Oslo City Council has rented 100 places from Vulkan car park to benefit the local residents, by providing free EV charging from 5 p.m. to 9 a.m. A business model structure that depicts the direction of flows of energy and communication signals as well as the associated commercial relationships known to the report authors between the stakeholders is derived for the Oslo Vulkan car parking garage pilot and is illustrated in Figure 9 below.

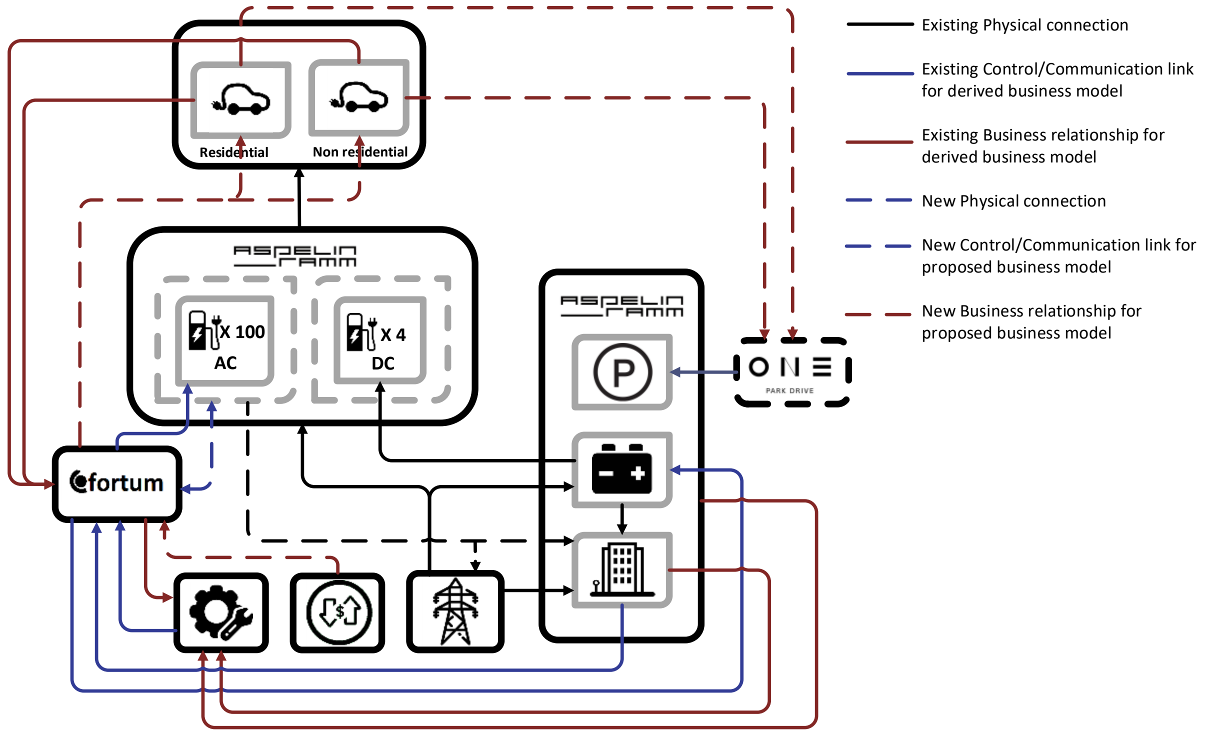


**Figure 9: Business model structure for the Oslo Vulkan car parking garage operational pilot**

The associated functionalities of the current (derived) and proposed business models for this pilot are presented in Table 9 below.

[15] e-mail from Nora Ekern of Oslo City Council on 26/11/2019

**Table 9: Business models for the Vulkan car parking garage Oslo operational pilot**

| Attributes | Functionalities of the current (derived) business model | Additional functionalities brought by the proposed business model |
|---|---|---|
| **Key activities** | 1. Smart management of EV charging<br>2. Energy arbitrage (via BESS, smart charging) | 1. Smart management of building energy;<br>2. Energy arbitrage (via V2N/V2G) and network service provision;<br>3. Smart parking management (perhaps, by One Park – but no information on this provided to SEEV4-City). |
| **Value proposition** | 1. Reduced electricity bill and charging cost due to energy arbitrage (via BESS and smart charging) | 1. Reduced electricity bill and charging cost due to energy arbitrage (via V2N/V2G);<br>2. Revenue from network service provision. |
| **Cost structure** | 1. Fortum Charge & Drive: Investment cost on smart chargers;<br>2. Oslo City Council: rent payment of 100 places (for residents, to alleviate on-street EV charging demand elsewhere) at Vulkan car parking garage to Fortum;<br>3. Aspelin Ramm: Investment cost of BESS and energy management system;<br>4. EV owners/users: acceptance towards third party (Fortum Charge & Drive in this case) control. | Fortum Charge & Drive: Investment cost on V2G chargers |
| **Revenue stream** | 1. Fortum Charge & Drive: reduced energy cost via energy arbitrage (via smart charging);<br>2. Reputational gain as a leading EV city; plus, avoidance/ deferment of otherwise necessary investment into/ provision of on-street EV charging infrastructure;<br>3. Aspelin Ramm: shared savings with Fortum of building electricity bill;<br>4. EV owners/users: reduced charging cost in return for the acceptance of Fortum's control (by using their chargers with the software installed to use them);<br>5. The net profit from EV charging (after deduction of costs, incl. electricity) is divided 50/50% between Fortum Charge & Drive and Aspelin Ramm. Oslo City Council is paying for the electricity used on evening and night time;<br>6. From parking only: Aspelin Ramm through Vulkan Oslo AS (a company they fully own) have a rental agreement with OnePark. OnePark pays for the use of area. Vulkan AS pays for the use of the parking system (AutoPay and meters). Net-profits for parking are divided between Vulkan AS and OnePark as a yearly percentage of turnover parking revenues (both short term, long term parking etc.). | 1. Fortum Charge & Drive: reduced energy cost via energy arbitrage (via V2N / V2G); revenue from network service provision;<br>2. EV owners/users: shared revenue from Fortum by network service provision. |

***Proposed business model***

On top of the current (derived) business model, the proposed one further improves the pilot's target of energy cost minimization and load levelling as well as exploring the opportunities of further revenue by upgrading to the V2B and V2G functionality. However, it is worth noting that the current regulatory landscape for V2G (discharging to the grid from EV battery) has not yet been established in Norway so far. In addition, smart management of the car park (by One Park) is also proposed to maximise the utilization of the car park, so as to promote the utilization of EV chargers and to recover the cost of investment on EV chargers and the BESS [80]. A return of investment for Oslo pilot was expected by the OP partners in approximately 10 years, which was planned to be reduced to 8 years with the investment from SEEV4-City project. It is not known to the report authors if this is to be achieved by the current business model, even if one takes the Covid-19 disruption out of the picture.

## 4.4. Leicester City Hall (UK) – (V2B)

The Leicester City Hall OP consists of a five-storey office building (Leicester City Council's headquarters) with a roof-top PV installation, four EVs (all Nissan Leaf, though with different battery capacities), EV chargers (after significant implementation delays, plan to procure V2G chargers for V2B use). Prior to the commencement of this operational pilot, Leicester City Council had 7 fully electric vans and 10 fully electric cars, of which 4 (full battery electric vehicles or BEVs) are part of this OP.

The aim of the OP is to demonstrate controlled and bi-directional charging at an office location, i.e. V2B, and to increase energy autonomy (which reduces the carbon intensity and improves the cost profile of the Council's EV operations) and clean km driven (through ability to estimate amount of solar in a daytime top-up charging, and the rest of the electricity coming from for certified renewable energy Leicester City Council pays for as its mains supply) [16]. In terms energy autonomy, the PV (which cannot be expanded at the roof-top of Leicester City Hall due to space restrictions), produced just over a quarter of the EV energy demands during the baseline.

The initial installation will not prioritise PV for EVs. However, for the virtual solar carport concept, PV production would be prioritised to charge EVs, and self-sufficiency would be defined as:

$$Self-sufficiency = \frac{Amount\ of\ local\ PV\ production\ used\ for\ EV\ charging}{Total\ energy\ used\ for\ EV\ charging}$$

In terms of avoided grid investment, there may be a minor contribution, by EVs discharging to City Hall [V2B] during the evening high demand periods, and scheduling [i.e. smart charging] the principal EV recharge for overnight; all of which helps flatten the electricity demand curve. Such practice multiplied/scaled up across the city would contribute to peak shaving. However, Leicester City Hall itself has insufficient roof area to install a significant additional amount of PV generation. Therefore, the renewables output will remain small, preventing significant reductions in peak grid demand and hence the need for grid reinforcement. Leicester OP was to be V2G, but due to time lost in confirming a site for the project, it was decided to switch to a V2B specification for now at least, which avoided the aggregation element.

Table 10 below lists the stakeholders that are involved in the pilot operation (once implemented). The main stakeholder, Leicester City Council, will own all the non-grid side assets - though some are still to be procured. The pilot intends to maximise the use of PV energy to charge the EVs, and so seeks to maximise the amount of ultra-low km powered by local renewable generation (through the ability to estimate amount of solar in a daytime top-up charging, i.e. the concept of a (virtual) solar carport. The energy management system (a new EMS, still to be procured) will need to be programmed to permit the use of PV generation to be prioritised in the following order:

[16] https://www.seev4-city.eu/projects/leicester/

1. EVs – when solar generation and EV demand coincide;
2. BESS – to be confirmed (but indications are, not in the first implementation phase);
3. Leicester City Hall;
4. Grid – to gain revenue from FiT (although this is unlikely to happen due to the small scale of PV installation compared to the building consumption).

**Table 10: Stakeholders involved in the Leicester City Hall operational pilot**

| Roles | Stakeholders |
|---|---|
| **Building owner, EV owner, PV owner, smart / V2G owner, BESS (potentially, at some point in the future) owner** | Leicester City Council |
| **Smart/V2G charger provider** | To be procured |
| **Energy management system provider/operator** | To be procured |
| **Distribution Network Operator** | Western Power Distribution (WPD) |
| **TSO** | National Grid |

In addition, Western Power Distribution (WPD) as the local distribution network operator is another project stakeholder. According to Leicester City Council (LCC), a formal application to generate from V2B system would be made via the ENA website. LCC's installer would seek authority from WPD and WPD would work to provide G99 approval once the formal application is received. WPD say they do not envisage needing to provide any new equipment as new supply is not needed. This V2B system is a behind the meter project with no intended export to grid (at least in the derived business model). Cenex UK advise export can be avoided by steering the charging/discharging profiles from the EVs to match the building's demand. CT clamps would provide the V2B control interface with mains import and solar generation data, which permits it to work out what power to discharge to avoid any export to the grid beyond the parameters agreed with WPD. However, WPD want LCC's existing generating capacity agreement to be increased to cover both the PV and the V2B system which they state has the potential to export to the grid. The PV does not export to the grid at any time because even at baseload periods, City Hall's demand is sufficient to consume any solar generation (and additionally LCC did not register in the PV installation in time for the Feed-in-Tariff scheme).

***Current (derived) business model***

The business model structure that depicts the direction of flows of energy and communication signals, as well as the associated commercial relationships between the stakeholders, is derived for the Leicester City Hall OP as per the stated intended implementation design at present and illustrated in Figure 10 and functionalities represented in Table 11 below. It can be seen that the EMS is at the core for communication and control with different components in the Leicester pilot, such as the power flow from the PV to the EVs and the building as part of the solar carport as described above. Benefiting from the current renewable energy policy in the UK, the PV installation in Leicester pilot is eligible for the FiT tariff for export to the grid. Additionally, the EMS also controls the EV charging profile by responding to the dynamic price from the utility, in order to minimise the charging cost.

Leicester Council pays for certified renewable energy as its mains supply.

Three more EVs are coming to Leicester City Hall, although they will not be V2X capable.

When the EVs return to City Hall during their working day they can benefit from top-up charging. Between 4 p.m. and 11 p.m. (DUoS Red & Amber periods) they will be available for V2B bi-directional charging.

In relation to day time top-up charging there seems to be an ever-present tension between minimising EV charging cost and maximising the amount of electricity charged when an EV returns to base during a working day. As the V2B system permits a principal overnight recharge on a cheaper rate, and EV evening discharging reduces Leicester City Council's need for peak price electricity, one may want to favour maximising the charge amount over minimising costs from top-up charging. However, variable charge rate functionality along with weekend charging should be used to maximise the amount of solar energy in an EV's charge.

Leicester City Council apparently does not obtain any FiT payments because it did not register the roof-top PV array in time.

Leicester City Council thinks it worthwhile to consider possible further development of the upcoming V2B installation at Leicester City Hall (which does not include prioritising PV for EVs) or EV4ES schemes elsewhere in Leicester, in the sense of the PV generation as comprising a 'virtual carport' in which it is assumed that PV output is preferentially used to charge the available four EVs. In fact, no such physical carport exists at Leicester City Hall, but the electrical measurements can reveal the performance of an actual carport with the EV charging fed directly from the PV output, rather than flowing through the City Hall distribution system.

Also, the V2B control interface to be installed at Leicester City Hall will be specified to gauge EV battery State of Charge (SoC). There is a balance to be struck between minimising charging costs and maximising the amount of charge when an EV returns to City Hall during a working day.

Charging the EVs at weekends would help maximise the use of PV to charge the EVs. There is also the matter of battery management good practice to consider; and then to decide where the balance of operational/financial advantage lies.

At present all EVs will be fully charged by mid/late evening, but they are not required until 7 a.m. at the very earliest the following day. With the V2B scheme as designed, after discharging to City Hall/ onwards from 23:00 the EVs recharge from the mains on the Council's cheaper overnight rate. There may be scope here to use the smart functionality of the new bi-directional EV chargers to achieve some battery management good practice. Therefore, the EVs could be brought up to 50% SOC by the early hours of the morning and held here until 4 or 5 a.m. when the remainder of the charging is completed.

In the current OP, specifications the EVs are available for V2B operations between 4 p.m. and 11 p.m., (although all four EVs may not have returned and been connected until closer to 6.30 p.m.) According to the Leicester City Council specified requirements, any V4ES duties must allow all four to be fully charged by 7 a.m. the following morning.

Normally the EVs are only used in weekday office hours and not at weekends. Therefore, at weekends and on Bank Holidays (with city council office closed and EVs not used) charging would either be split between the night of the last working day and the night of the next working day, or fully take place during the latter. However, if the battery management approach is taken there will be little or no opportunity for EV charging to benefit from weekend solar generation. To date, no batteries on any of LCC's EVs (mostly purchased in 2016) have needed replacing.

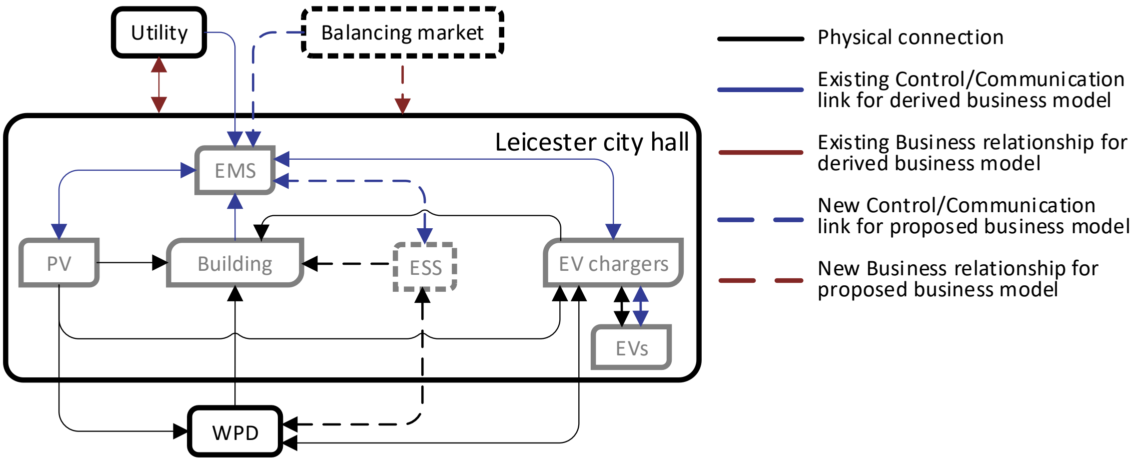


**Figure 10: Business model structure for the Leicester operational pilot**

The derived and proposed business models are focused on the aim of a (virtual) solar carport and the recovery of investment.

**Table 11: Business models for the Leicester City Hall operational pilot**

| Attributes | Functionalities of the derived business model | Additional functionalities brought by the proposed business model |
|---|---|---|
| **Key potential activities** | 1. (Virtual) Solar carport;<br>2. Smart charging. | 1. Energy arbitrage;<br>2. Network service provision (nights and weekends). |
| **Value proposition** | 1. Income from PV generation due to FiT;<br>2. Electricity bill saving due to PV self-consumption;<br>3. Reduced charging cost due to PV self-consumption and smart charging;<br>4. Clean km driven. | 1. Energy arbitrage via an enlarged BESS and EVs could bring further savings in electricity bill and charging cost;<br>2. Revenue from network service provision. |
| **Cost structure** | 1. Leicester City Council: investment cost on PV, smart/V2G EV chargers;<br>2. WPD: network upgrading cost to accommodate the installations (e.g. PV and EV chargers) in the pilot. | Leicester City Council: investment cost on battery BESS. |
| **Revenue stream** | 1. Leicester City Council: FiT (apparently none, as registered too late), electricity bill savings, charging cost savings;<br>2. WPD: reduced network losses due to PV self-consumption. | Leicester City Council: energy arbitrage, network service provision. |

***Proposed business model***

As mentioned earlier, the V2G chargers are still to be procured. When the V2G chargers are in place with its function activated, the EVs could start to potentially bring in extra revenue by network services provision (especially during nights and weekends when the EVs are mostly available). The EMS may play the role of interface with the aggregator to enter the balancing market [81].

This is the extra value proposition in the proposed business model, which is presented accordingly in Figure 10 by dashed lines and additional functionalities described in Table 11.

In addition, it is noted that BESS is not considered in the business model since it is still undecided (and apparently unlikely in the first phase) if a BESS will be part of the pilot installation (as it would have to be of a considerable size to be worthwhile technically, considering the investment costs). Another value proposition in case the additional BESS is installed, i.e. the proposed business model, would be the further savings in electricity bill via energy arbitrage, which may in turn over time recover the return on the associated investment.

A stationary battery storage (BESS) of c. 30 kWh size was considered for the Leicester OP; fed from the PV to assist day time top-up charging and also the principal overnight recharge. This was not considered value for money (by Cenex UK advising Leicester City Council) given the small size of the BESS considered and the electrical losses (between the PV on the 5th floor, the BESS and the EVs), although no calculations were done to demonstrate this. However, Leicester City Council's decision was made entirely in the context of developing a V2B system, with no intended export to grid. If Leicester City Council ever moved to V2G at Leicester City Hall or went for V2G at other locations, an added value proposition could be selling on BESS stored solar energy to the grid at peak energy times. Presumably the BESS would need to be of a big enough size to make money despite the energy losses involved. Then again, calculations could be done to identify the size of BESS that would be economical to work with the current V2B design.

In the context of the continuing roll out of EVs into the Council fleet, Leicester City Council are currently considering having a 'bi-directional fleet' of Leafs all with battery size 30 kWh+. To meet operational needs, longer charging times may not be available during the working day. However, starting the day with a full 30 kWh+ battery should allow greater absorption of available solar energy by slower top-up charging without range anxiety; particularly if average daily mileage doesn't increase much.

In any case, the V2B specifications drawn up by Leicester City Council for the tender and procurement process includes the estimated annual generating amount from the current four project EVs discharging = c.15,000 kWh. Cenex UK think that the estimate is valid. As per the current V2B design this amount represents a potential cost saving for Leicester City Hall as it can replace peak period energy drawn from the mains. With a V2G system it might be more profitable to sell this amount for network services to the grid. It is estimated that the average daily discharge available from the four EVs is c. 60 kWh.

Although Leicester City Council staff are working on ways to reduce the baseload demand it will still exceed what can be discharged from four EVs at Leicester City Hall - or even the discharge amount if all 12 spaces in this small car park had a bi-directional charger. Given that the baseload represents such a sizeable demand during the peak energy price period, the rationale for moving from V2B to V2G at this site is by no means clear-cut.

The current specifications are for a charging output of c. 7 kW and discharging output of c. 10 kW, but variable rates are also specified. Smart chargers with variable charge (& discharge) rates already specified in the OP procurement brief; which will allow a greater absorption of the available solar energy. During the day when EVs are back at City Hall for top-up charges, it may not be operationally desirable for these to take longer due to a lower charging rate. However, as Leicester City Council have had no situations so far where an EV has run out of energy on a trip, smaller top up charges may not be a problem. Furthermore, the number of Leicester City Council premises with EV chargers is set to at least double from five to ten in 2020 – and all EVs being supplied with a 'visitor' RFID card would ensure that emergency top-ups were available around Leicester to enable an EV to get back to City Hall.

Maximising the self-sufficiency of EV charging would require a range of measures, coupled with PV prioritisation; with a direct feed (PV to EV) - as per the derived and proposed business models. The Leicester City Hall car park is small, with only about 12 parking bays in total. Currently five bays are served by charge points, although at the start of summer 2020 only the four operational pilot EVs were based there. It is now proposed to make Leicester City Hall an EV charging hub for Council EVs based in the city centre. Three more conventional charge points are expected to be added by the end of the summer of

2020, and the V2B chargers (anticipated to be operational by the end of 2020/21) will now be additional to, rather than swap-outs, for the original EV chargers. Therefore, by the time the V2B system goes live most of the parking bays will be served by one or other type of EV charger, and it is likely that at least three more EVs will be based at City Hall – making at least seven in total. As it is not possible to increase the size of the PV array at City Hall this will mean that the amount of solar energy reaching each EV is set to fall. To best mitigate against this, and in the light of Leicester City Hall becoming an EV charging hub; a move to prioritise the PV for EVs via a dedicated direct link and a ranked set of alternative uses could be justified.

The PV installations in development to support EV charging at two multi-storey car parks sound similar to the carport concept: Newarke Street car park = 85 kWp; and Haymarket car park = 240 kWp. [Leicester City Hall PV = 24 kWp]. Nottingham City Council are proposing a feasibility study into the use in Leicester of the interoperable Energy Management System being developed for their Clean Mobil Energy EU Interreg project. A relevant site would include a number of different energy assets (e.g.: smart/V2G chargers, battery storage, renewable generation, building with BMS etc. The feasibility study would not focus solely on V2G, but potentially a lot could be learnt from a report; including information on aggregators.

For EV4ES it is desirable to have a long period of connection between the EVs and the EV chargers, to enable smart charging to utilise as much PV as possible, and to maximise the potential to carry out V2G services. However, in the context of the transport use requirements of the fleet EV operations at Leicester City Hall, long day-time connections are unlikely.

Currently, the most profitable ancillary service in the UK is considered to be Frequency Regulation, though the value and share of this market may shrink in the future. In addition, frequency regulation requires shallower battery cycling compared to other V2G services such as peak shaving and therefore is less harmful for the battery's state of health. To carry out V2G activities at Leicester City Hall it will be necessary to have separate metering for the V2G chargers because the City Hall baseload always exceeds planned V2G output so without separate metering the V2G output would be 'swamped'.

Out of the three frequency regulation response options in the UK, Firm Frequency Response (FFR) may be currently most interesting due to its tender based procurement process and low entry capacity requirement, though again the value and share of this market may change in the future. FFR in the UK exists in 2 main variants, Dynamic Firm Frequency Response (DFFR) and Static Firm Frequency Response (SFFR). SFFR is the simplest and most widely used form of frequency balancing service in the UK. Participants agree to respond to a change in the frequency from 50 Hz to 49.7 Hz or 50.3 Hz by exporting or importing energy for a period of up to 30 minutes. These events can be caused by power outages and tend to be irregular at between 7 – 12 times a year. DFFR concentrates on managing the system frequency under normal operating conditions and tracks precise grid frequency through high and low frequency periods. Participants in DFFR are paid to both ramp up their load on the grid i.e. increase their energy import, as well as ramping down, exporting energy, during times of frequency imbalance, to restore the grid to 50Hz optimum operating frequency. They begin to deliver a response within 2 seconds and usually complete their response within 10 seconds, although this can last for a few minutes. Both types of FFR are procured via monthly tenders and the successful providers are rewarded with an availability fee (a payment being made based on power committed and the period for which the commitment is offered) and for DFFR a regulation energy fee (a payment based on the actual energy consumed/provided). For SFFR the costs of energy interchange may be neglected, being infrequent. Please see the Leicester City Hall OP report for further details. The regulation asset for primary dynamic frequency response must respond within 2s from the provision request and provide all of the power requested within 10s followed by continuous provision for a further 30s, which is technically feasible for EV fleets. The FFR commitment period from 11 p.m. – 7 a.m. was an appropriate time for the service to be contracted due to the compatibility with the user requirement for transportation in the Leicester City Hall operational pilot, judged on the historical data on EV GPS and driving data. In addition, overnight primary FFR provision between 11 p.m. – 7 a.m. is currently deemed the most valuable by the UK's National Grid. The contracted amount of power was set at the maximum EV discharging rate of the V2G units proposed to be installed in the City Hall (4 x 7 kW, due the limit insisted on y WPD in the G99 connection agreement), and it was assumed that these EVs are part of an aggregated balancing unit in order to meet the entry capacity requirement of 1.0 MW (but aggregation costs were not considered here). The availability payment was obtained from a post-tender report in November 2017, and the wholesale market index price was used for a calculation undertaken and documented in the Leicester City Hall OP report.

The droop frequency control characteristic is taken into account, where the power requirement responds linearly to the frequency deviation within 50±0.2 Hz, with a dead band of ±0.015 Hz. This would require a variable rate EV charger, or variable numbers of EVs committed. The technical feasibility of the former operation is supported by the current standard IEC 61851 in the form of 1 A-discrete modulation. As such, the annual economic evaluation for the period from March 2018 to March 2019 was calculated. with detailed cost and profit terms. FFR in this case is demonstrated to be profitable at a total cost benefit (£) per EV of £442.53, ignoring capital costs (as the EV is already paid for the main use, which is transport), even when battery degradation cost is considered. For the alternative of SFFR, the FFR commitment period from 11 p.m. – 7 a.m. was an appropriate time for the service to be contracted due to the compatibility with the user requirement for transportation in the Leicester City Hall pilot. FFR providers can expect to be called upon some 7-12 times per year with an estimated 6 hours of operation per year, with a maximum of 30 minutes per period of operation. As each use involves only a small exchange of energy with the Grid, (a maximum of 5 kWh with a 10-kW charger over a period of 30 minutes), provision of FFR is only slightly harmful to the battery's state of health. Accordingly, the aspect of battery degradation can be neglected. It appears that the UK current average value of SFFR is £15/MW/h as of March 2020. The total cost benefit situation for SFFR provision per EV is calculated in the Leicester City Hall Operational Pilot as £438.00. Therefore, it is found that the net financial benefits of SFFR and DFRR are virtually the same, DFFR having a very slight advantage. Please see the Leicester City Hall OP report for full details. However, in order to operate DFFR the hardware requirements are more stringent and therefore more expensive, so for the purposes of this report SFRR is preferred.

**Table 12: Leicester City Hall OP hypothetical FFR provision tender details**

| | | **Value** |
|---|---|---|
| **Contracted period** | | 11 p.m. - 7:00 a.m. |
| **Annual contracted available hours @ 8h/day** | | 2920 |
| **Annual available contracted amount (4 EVs)** | | 4 x 7 x 2,920 kWh = 81,760 MWh |
| **Contracted type** | | **Primary Dynamic Frequency Response** |
| **Availability payment** | | 23.03 £MW/h |
| **Energy payment (£/MWh)** | **Regulation up** | $p_e = E_r * 1.25 * PXP$ |
| | **Regulation down** | $p_e = E_r * 0.75 * PXP$ |
| **Contracted type** | | **Static Firm Frequency Response** |
| **Contracted period** | | 11:00 p.m. - 7:00 a.m. |
| **Availability payment** | | 15.00 £MW/h |
| **PV Cost and expected lifespan** | | £42,000/25 years |
| **Estimated unit cost of proposed V2B chargers** | | £12,000 |
| **Estimated installation costs of V2B units** | | £10,000 |

Furthermore, a cost and benefit analysis in terms of the Net Present Value (NPV) for the proposed business model, which includes proposed V2G via FFR provision, is undertaken in the Leicester City Hall OP research. The assumed lifetime of the V2G bi-directional chargers is as per industry standards. In the

Leicester City Hall OP, the cost of the PV installation is not relevant since it was present prior to the commencement of the SEEV-4 project. The actual eventual costs of the V2G chargers are not at present known, so precise numerical calculations cannot yet be carried out. However, on the understanding that four 10 kW bi directional chargers (but limited to 7 kW charging through the WPD G99 connection agreement) will be used, it is possible to discuss the likely financial implications of this part of the project in terms of the NPV. If at the commencement of a project the NPV is positive, the project is deemed financially viable. On the basis that each FFR intervention will last for at most 30 minutes, the maximum energy to be supplied per intervention is merely 5 kWh, with a 10 kW charger. It is felt that perhaps 10 such interventions per year will have a negligible effect on EV battery life even with the smaller 24 kWh Leaf EV. The limiting factor in attempting to obtain revenue from FFR is the V2G charger capacity, and not the size of the EV battery. Newer models of the Nissan Leaf are now available with batteries of 40 kWh and also with 62 kWh, whose guarantee is not affected by carrying out V2G operations. Replacement of the existing EVs with newer equivalents with a larger battery pack will not in itself increase the revenue available from FFR. However, FFR revenues may fall over time due to competition from other provision sources (such as stationary batteries) and it is impossible to guarantee that future income streams will be maintained. Alternative V2G propositions may become economic, involving a larger amount of energy exchange, and in these circumstances EVs with a larger capacity battery may be at an advantage.

NPV was used in the Leicester City Hall OP report to analyse profitability, being an international industry standard method for conducting such an assessment. NPV provides the current monetary value of a potential investment project by converting the yearly cash flow throughout its lifetime to the present value using a discount rate. An investment with a positive NPV will be profitable, prior to the non-accounted aggregation costs, whereas an investment with a negative NPV will result in a net loss. In September 2019, Cenex UK estimated that the four V2G for use of V2B chargers unit costs would be c. £12k apiece, including hardware & software. Adding some £10k for associated civil engineering, this gave an estimated cost of four V2B chargers of c. £60k. The actual eventual price is not known at present, since tendering is continuing [17].

What can be done is to start from the annual revenue accruing from FFR and calculate from this figure the maximum present investment cost for the project to be economic.

As reported in the Leicester City Hall OP report, it is found that the net financial benefits of SFFR and DFRR are virtually the same, with SFFR having a very slight advantage at 7 kW. Also, in order to operate DFFR the hardware requirements are more stringent and thus more expensive. Therefore, for the purposes of this report SFRR is to be preferred.

The cost and benefit analysis presented here in terms of the NPV for the proposed business model, which includes proposed V2G via FFR provision. The assumed lifetime of the V2G bi-directional chargers is as per industry standards. In the Leicester City Hall OP, the cost of the PV installation is not relevant, since it was present prior to the commencement of the SEEV-4 project. The costs of the V2G chargers are not definitely known at present, but in September 2019 Cenex UK estimated that the V2B units would cost approximately £12,000 each, including hardware and software. Thus, the intended four chargers would cost some £50,000, plus some £10,000 for associated civil engineering etc; i.e. approximately £60,000 (~€67,000) in total. Precise numerical calculations cannot yet be carried out. However, on the understanding that four 7/10 kW bi-directional chargers will be used, it is possible to discuss the likely financial implications of this part of this intended set-up in terms of the NPV. If at the commencement of an intervention the NPV is positive, the intervention is deemed financially viable. FFR is thought to be the most profitable ancillary service in the UK for EVs, though the value and share of this market may shrink in the future. FFR requires shallower battery cycling compared to other V2G services such as peak shaving. The financial implications of FFR service provision are investigated here, in terms of economic feasibility. To carry out V2G it will be necessary to have separate metering for the V2G chargers, because the City Hall

[17] In September 2019 Cenex UK estimated that the V2B unit cost would be c. £12k a piece; including hardware and software. If this were to hold, the intended four chargers would cost c.£50k, plus some £10k for associated civil engineering cost etc; i.e. c.£60k/ ~€67k in total.

baseload always exceeds the proposed V2G output so without separate metering the V2G output would be 'swamped'.

On the basis that each FFR intervention will last for at most 30 minutes, the maximum energy to be supplied per intervention is merely 5 kWh, with a 10-kW charger limited to 7 kW as per the G99 connection agreement. It is felt that perhaps 10 such interventions per year will have a negligible effect on EV battery life even with the smaller 24 kWh Leaf EV. The limiting factor in attempting to obtain revenue from FFR is the V2G charger capacity, and not the size of the EV battery. In view of the fact that the proposed V2B chargers are rated at 7 kW charging and 10 kW discharging the smaller rating must be used. Newer models of the Nissan Leaf are now available with batteries of 40 and 62 kWh, whose guarantee is not affected by carrying out V2G operations. Replacement of the existing EVs with newer equivalents with a larger battery pack will not in itself increase the revenue available from FFR. However, it is felt that FFR revenues are falling over time due to competition and it is impossible to guarantee that future income streams will be maintained. Alternative V2G propositions may become economic, involving a larger amount of energy exchange, and in these circumstances EVs with a larger capacity battery may be at an advantage.

NPV is used in this report to analyse the profitability of the Leicester City Hall pilot, being an international industry standard method for conducting such an assessment. NPV provides the current monetary value of a potential investment project by converting the yearly cash flow throughout its lifetime to the present value using a discount rate. An investment with a positive NPV will be profitable, prior to the non-accounted aggregation costs, whereas an investment with a negative NPV will result in a net loss. NPV is defined by Equation:

$$NPV = \sum_{i=1}^{N} \frac{Yearly\ cash\ flow}{(1+r)^i} - Investment$$

where the *yearly cash flow* during the investment lifetime of *N* years (*N* = 10 in this case) is converted to the present value using a discount rate, *r*, of 2%. The investment and return terms are detailed in the Leicester City Hall OP report for three cases, namely the baseline, smart charging and eV4ES which includes additional FFR provision in addition to smart charging.

The precise cost of the 4 V2G chargers is not known at present, since tendering is continuing. What can be done however is to start from the annual revenue accruing from SFFR and calculate from this figure the maximum present investment cost for the project to be economic.

Certain assumptions must be made:

- For the purposes of the following calculation, based on observed usage patterns, it is assumed that the 4 Nissan Leaf EVs based at Leicester City Hall can without inconvenience be each be parked there connected to a bidirectional 7/10 kW EV charger between the hours of 11 p.m. and 7 a.m. daily;
- The services of an aggregator are available. The costs of the provision of the aggregation service are not included in this calculation;
- The rate of interest applicable is 2%. Given the present unstable economic position this is felt to be reasonable;
- The lifetime of the proposed bi-directional charging equipment is 10 years;
- The most profitable form of V2G is FFR;
- V2G induced battery degradation in the 4 Nissan Leaf EVs will be small; accordingly, its financial effects have been ignored.

*Calculation:*

4 EVs connected via 7/10 kW bi-directional chargers for 8 hours daily = 81,760 kW/h yearly; given that the charging rate and the discharging rates differ, the lower rate is used here.

At £15 per MW/h, annual revenue/cash flow = £1,226.40

NPV of an investment is given by the following formula:

$$NPV = \sum_{i=1}^{N} \frac{Yearly\ cash\ flow}{(1+r)^i} - Investment$$

For an investment to be *just* profitable, one can rearrange this with NPV = 0:

We have assumed that N=10 annual revenue = £1,226.40 and r=2%.

Therefore, required investment should not exceed £11,015.90. Anything larger than this will result in negative NPV.

It is noted that this does not include an aggregator for the V2G (exporting to the grid) activity, which Leicester City Council would have to find (and share some financial benefits with).

Leicester City Council could perhaps learn in this regard from the regional neighbour Nottingham City Council, who are gathering experience as part of the EU NWE Interreg CleanMobilEnergy project.

A scheme is currently being developed by Leicester City Council for a multi-storey car park in the city centre to include an 85 kWp PV array, as well as another to perhaps include 240 kWp. This will supply energy to conventional charge points at the car park, but does have the potential for future development along the lines of the derived or proposed business models of this report.

## 4.5. Johan Cruijff ArenA (NL) - (V2B/V2G)

The Johan Cruijff ArenA (JCA) is a big events location in Amsterdam, where national and international football matches, concerts and music festivals take place. Thanks to a PV installation, Amsterdam Arena produces about 10% of the energy it consumes. However, there is still a problem of mismatch between production and consumption. Johan Cruijff ArenA has very large power consumption during sports events or concerts which usually take place in the evenings, whereas solar power is produced during the day. At sunny summer days this results in excess energy supply during the day. Part of this energy is consumed by the JCA, the other part is fed back to the energy grid. Johan Cruijff ArenA also, by law, has to have a back-up power provision in the case of emergencies during events in particular This used to be diesel generators, but this function can now be taken on by a stationary battery storage installation. The Johan Cruijff ArenA is already one of the most sustainable, multi-functional stadia in the world and is realizing even more inspiring smart energy solutions for the venue, it's visitors and neighbourhood. The Johan Cruijff ArenA presents a complex testbed for innovative energy services, with a consumption of energy comparable to a district of 270 households. Thanks to the 1 MWp solar installation on the roof of the venue, the JCA already produces around 12% of the energy it needs, despite the high-power consumption during major sport events and concerts for up to 68,000 visitors. The other share of electricity is generated through certified regional wind energy. The JCA has invested in both energy storage and V2G applications-The large renewable production ensures a massive supply of clean energy to charge EVs, which translates into an increase in clean kilometres for their visitors. The Energy Storage System is unique. This is the first time that such a variety of applications are combined in one EV battery-based storage system. Currently, similar systems are focused on single purpose applications either focusing on building support or grid services. The Energy Storage System of the Johan Cruijff ArenA addresses several applications in parallel. Replacing traditional energy plants is the main $CO_2$ emission reduction contribution along with load management, peak shaving, back-up services and V2G support. The solar panels, the energy storage system, the new main distribution panels and the bi-directional EV chargers are connected together to the Energy Storage System, which means that in the future electric vehicles can power events and be charged with clean energy through the Johan Cruijff ArenA's Energy Services. These and other experiences and results can serve as a development model for other stadiums worldwide [18].

As part of the SEEV4-City project, the Energy ArenA – a joint venture formed by the Johan Cruijff ArenA, The Mobility House (TMH) and the Amsterdam Climate and Energy Fund (AKEF) - now has installed a big storage unit, consisting of 148 Nissan Leaf EV batteries, 40% of which are second life batteries. This storage unit can help to reduce energy volatility [82] [83] [19].

The Mobility House is a German company working trans-nationally on smart energy management, and in particular realizes solutions for uni- and bi-directional charging, also known as V2G and Vehicle-to-Home/Building (V2H/ V2B) to stabilize the power grid [84].

The Mobility House worked with Dutch company BAM and Eaton to construct the stationary battery system now in place, which is partly there to replace diesel generators as the back-up power facility (legally required for the stadium/ events venue), but also to make more optimal use of the PV system. The diesel generators have a capacity of 0.66 MVA. There is a 1 MWp PV system in place at the ArenaA. On match-days /event days, the power demand typically is 3 MW. On off-days, power demand is around 0.8 MW, mainly due to office facilities, cooling and grass growing lights. The energy storage system now in place has 3 MW power capacity and 2.8 MWh storage capacity from 148 Nissan Leaf EV batteries

Since end of the year 2019, visitors to the JCA can actively contribute to the power supply of the arena with their electric vehicle - by intelligently integrating their car into the stadium's power grid. The ArenaA set-up now combines a total of 14 AC 22 kW chargers and 1 10 kW bidirectional charger with the existing 3 MWh stationary battery storage, consisting of 148 Nissan Leaf batteries, and the 1 MW PV system on the roof of the arena - using the innovative Charging and Energy Management system/tool/application by The Mobility House [84].

To summarise, The Mobility House aims to implement an overall business model for the ArenaA with five different value streams:

1. Optimal PV integration;
2. Back-up Power: This is required by Dutch national and Amsterdam local regulations, in case there were to be an electricity black-out at the venue – particularly at big events – so as to ensure safe evaluation etc. The diesel generators, their diesel fuel consumption and associated $CO_2$ emissions can this be replaced;
3. Grid Services: Currently, this is in the mainly targeted at Frequency Containment Reserve (FCR) by having pre-qualified and now bidding to TenneT, the TSO active both in the Netherlands and Germany on the European power markets. This will utilise the stationary battery storage unit in the main;
4. V2G: JCA did lease 2 BEVs (Nissan Leafs) and showcased two V2G use cases in December 2019:
    a. JCA: during a public launch event on 9th December 2019, a Nissan Leaf was discharged automatically, using the smart charging control software from The Mobility House. The EV battery supplied 10 kW power to the stadium, thus powering the meeting room and facilities needed during the launch event.
    b. Vehicle-to-Grid: During the Christmas holiday period, between 20 and 27 December 2019, a Nissan Leaf was connected to the bidirectional charger for a whole week and provided continuous grid services. This demonstrated the potential of bidirectional EVs to support the future energy system in balancing volatile energy production from renewable sources. It also demonstrated the real-life economic potential. The value of the grid services provided within

[18] https://www.seev4-city.eu/projects/johan-cruijff-arena/

[19] https://www.seev4-city.eu/projects/johan-cruijff-arena/; https://www.eaton.com/de/en-gb/products/energy-storage/amsterdam-arena-success-story2.html

this one week equalled 50 Euros (based on the reference auction price for frequency response services during that period). It also demonstrated the key challenge of V2G: On 22 December, for a period of 5 hours, someone unexpectedly took the Nissan Leaf for a ride and interrupted the grid service. In the future, large numbers of EVs connected to a grid and aggregated by energy service suppliers will be able to absorb such fluctuations and provide for a stable contribution of grid services. JCA did install a number of V2G chargers, which was a procurement challenge as the first set obtained did not function and had to be returned to the provider. The second batch proved to be functional, but Covid-19 lock-down restrictions have prevented further use by visitors since March 2020 and during the now postponed European football championship, as well as other major games.

5. Peak Shaving: Here the increased self-consumption/ energy autonomy of the ArenA will reduce the amount of electricity needed from the grid during events. The objective is a reduction of peak power by approx. 10%. This will lead, within the Dutch system, to reduced electricity bills for the ArenA, by approx. €10,000 p.a. [82] [83].

   The intelligent software control developed by The Mobility House enables electric cars of stadium visitors – given the owners' consent – not only to receive power from the charging station, but also to feed electricity back into the stadium's electrical infrastructure. "Vehicle-to Grid" is an important milestone on the way to a more sustainable energy supply. In the future, over 2,000 parking spaces at JCA (owned and managed by the City of Amsterdam through their Parkeergebouwen Amsterdam) will be successively equipped with intelligent EV charging infrastructure. The stadium will thus be expanded into an energy hub – using electric car batteries to help store electricity from renewable energies and thus relieve the power grid. The energy from the cars reduces the amount of electricity drawn from the grid when the stadium's electricity load is extremely high, for example during a Champions League game. As a consequence, electricity bill costs are reduced. In addition, this energy supplements the battery storage, which is available as an emergency power supply for the JCA in the event of a power failure (blackout). The Amsterdam fans thus have the unique opportunity to support their club also in the form of providing electrical energy. In this way, they also stabilise the electricity grid and promote the use of renewable energies. The system also ensures that the car battery is recharged in time when visitors return home. The use of electric vehicles as an innovative energy source is a system promoted by the European Union and is also in line with Amsterdam's goal of becoming the V2X capital of Europe. The project is the result of collaboration between BAM, The Mobility House and Johan Cruijff ArenA and is supported by SEEV4-City, an initiative of Interreg North Sea Region and the Amsterdam Climate & Energy Fund. For The Mobility House, this project represents a further milestone in the intelligent integration of vehicle batteries into the energy system and complements the existing V2G, smart charging and battery storage projects that have been implemented in recent years with partners such as Daimler, Renault, Nissan, Audi and others. [84]

Another way to look at this operational pilot is through two lenses, firstly the big battery storage unit, and secondly the V2G facility.

***The big stationary battery energy storage system (BESS):***

Eaton, one of the partners at the Amsterdam Energy ArenA, describes their overall proposition as follows:

> The demand for power on match, or event days, for stadiums and arenas can increase to over 5-fold on the usual base load of consumed energy. Managing the peak demand for power is critical for both the venue but also the stability of the local grid. With local energy networks often working near to capacity, stadiums and arenas need to ensure a resilient power supply is available for the duration of the event. To reduce or mitigate the risk of power outages and minimise peak demand charges, stadiums and arenas often use alternative energy sources, such as diesel generators. Energy storage provides an attractive alternative to diesel generated power from both a cost and environmental perspective. Renewable solar or wind power, generated on site by the venue, can be stored by the batteries and used when required; thereby optimizing the use of available renewable energy. Even if there are no renewable

> sources, batteries can be charged during periods of low demand and used to reduce peaks during a major event. [85]

Eaton also state that at the ArenaA they did:

> Implement one Europe's largest energy storage systems in a commercial building. With a minimum capacity of 3MWh, that can be upscaled when necessary, the storage system functions as an emergency power supply, captures peaks in energy demand and ensures the stability in the regular energy network. 4,000 solar panels on the stadium roof provide renewable power that can be stored and then used at peak times. The energy storage capability enables the Amsterdam ArenA to peak shave when required, whilst also balancing the electricity grid and reducing their dependence on diesel generators. Future aspirations are to play a central role in the development of a local smart energy grid supplying energy to other commercial buildings. [85]

The Arena A's big stationary battery energy storage unit, composed of 148 predominantly new and 40% second-life Nissan Leaf batteries, enables the JCA to do FCR (Frequency Control Regulation). In addition, ArenA also implements peak shaving using the stationary battery storage unit. As such peaks are flattened, and there is less volatility on the grid. This is beneficial for the TSO (netbeheerder – TenneT) because they have to deal with less volatility in the grid, and see more frequency stability, so they do not have to purchase from coal or gas power plants. TenneT pays money to the JCA for the FCR service provided with the storage unit. All FCR auction results are published on the dedicated web page [20]. The average price in 2019 was 2,653 €/MW/week. The BESS was operated on the market most of the year, with the exception of event days / weeks. The auction was based on a 1-week bid until 30th June 2019. After that, daily bids were introduced. From 1st July 2020, the auction is even more dynamic providing 6 results for each day (4-hours periods).

Costs of the pilot occurred for the purchasing of the stationary batteries for the big storage unit. Another party (The Mobility House – TMH) has set up the battery control system and created all interfaces required for applying the use cases. TMH's benefit was that they gained experience and that they can use the project to showcase their technical possibilities to clients, which they frequently invite to the JCA for viewings. As a compensation for the daily bidding of ESS capacity on the FCR market, system monitoring and reporting to TenneT, TMH also receives a renumeration that is based on the monthly FCR revenues. The exact costs of the Operational Pilot are arguably of no consequence to the SEEV4-City project outcomes on business models – what matters is whether a business case can be made or not. There are many variables that only apply to this specific case and those exact details will not help any future projects. According the JCA and TMH the cost for stationary battery energy storage is roughly €650 k per MWh. This is close to what the Operational Pilot paid but because of the additional use cases such as Back-up power, integration of V2G and FCR services, the real cost in this Operational Pilot was about 50% higher, especially in terms of hours put in by each of the partners. Break even should be after 10 years for the business case.

[20] https://www.regelleistung.net/ext/?lang=en

**Table 13: Battery energy storage costs and benefits for the ArenaA OP in Amsterdam**

| Stakeholders | Type of organisation | Costs | Benefit: revenue (income) OR cost savings |
|---|---|---|---|
| **ArenaA** | Real estate company - events location | The price of the 148 EV Nissan Leaf batteries – a mix of predominantly new and 40% second-life.<br>The BESS was purchased by Amsterdam Energy ArenA (AEA). Prices were competitive but within market range. Eaton contributed some extra work as part of the innovation partnership. | Emergency back-up energy provision (could / would replace diesel generators, so an increase in sustainability and CSR-related publicity gains from that to position better in the market (including as an internationally trading consultancy company).<br>Peak shaving: reduced electricity bills for ArenaA.<br>Additional benefit: ability to undertake grid-facing energy services, with income payments from TenneT for FCR. |
| **TenneT** | TSO | All FCR auction results are published on https://www.regelleistung.net/ext/?lang=en. The average price in 2019 was 2,653 €/MW/week. The ESS was operated on the market most of the year with the exception of event days / weeks. The auction was based on a 1-week bid until 30th June 2019. After that daily bids were introduced. From 1st July 2020, the auction is even more dynamic providing 6 results for each day (4-hours periods). | Benefit: less volatility in grid (peak shaving and FCR)<br>cost savings: lower costs to stabilize demand and supply, less investments in grid needed. |
| **The Mobility House** | (Trans-nationally active) IT/ smart energy management company | Installation of storage unit; development and application of algorithms. | Benefit: better reputation; showcase; experience gained.<br>Income: share of FCR revenues.<br>Possibly increased demand for their services from (potential) clients. |
| **Eaton** | Battery storage system innovation/ provider | None that are not covered by their income, according to JCA | Benefit: Reputation and development of expertise;<br>Income: Eaton was paid for the ESS equipment and annual maintenance. |
| **Amsterdam Climate & Energy Fund (AKEF)** | (Municipal) Investment fund | AKEF acquired an equity share in AEA and provided a loan for the ESS debt financing. | AKEF acquired an equity share in AEA and provided a loan for the ESS debt financing. |

| Indirect stakeholders | Type of organisation | Costs | Benefit: revenue (income) OR cost savings |
|---|---|---|---|
| **City of Amsterdam** | Local municipality | According to JCA, there were no costs incurred by the City of Amsterdam. | Benefit: contributes to Amsterdam's climate goals (Amsterdam Climate Neutral 2050 programme). |
| **Dutch Government** | Central government | | Benefit: contributes to the Netherland's climate goals. |

***The V2G facility:***
Amsterdam Arena provides two-way EV charging poles in their parking garage. When customers such as football supporters or concert-goers come to the Amsterdam Arena Stadium for events with their EVs, they can offer to supply their battery's energy to the Arena's grid, so that the Arena can cover their peak energy demand (which occurs during these events). Benefit for the event customers in the JCA parking deck (with 300 spaces for skybox owners and VIPs) are still to be decided and may be reduced parking fees or perhaps alternatively publicity for the EV owner participants instead of a monetary value. Parking fees are for the city who own the parking garage (with 2,000 spaces). JCA can provide free catering or publicity for participants or another non-monetary compensation.

**Table 14: V2G-related costs and benefits for ArenA in Amsterdam**

| Stakeholders | Type of organization | Costs | Benefit: revenue (income) OR cost savings |
|---|---|---|---|
| **Amsterdam Energy ArenA** | Real estate company | Provision of parking space and investment into/costs of charging poles. | Benefit: peak shaving; more energy supply during peak hours. |
| **The Mobility House (TMH)** | Charge point operator and smart charging and energy management system operator. | Cost for V2G charger €20k and software development costs of €30k. | Reimbursed for part of the development costs by JCA and SEEV4-City.<br>Monthly fee for CPO services & maintenance. |
| **EV owners** | Private owners/ users | Cost to recharge their EV's battery (elsewhere). | Income: this may be a feed-in fee paid to them or reduced parking fees. |
| **Liander/ Alliander** | Distribution System Operator | Cost savings: they need to invest less in LV cables and transformers/ the distribution system. | |
| **City of Amsterdam** | Provision of parking spaces: In the parking garage underneath the stadium are 2,000 parking spaces owned by the city.<br>TMH are participating in a project to install 20 V2G chargers there that will be connected to JCA/storage. | | |

The Mobility House (TMH) plans to implement peak shaving as a use case for the battery in the course of 2020/21. Based on the analysis of 15min power measurements in 2019, they should be able to reduce the ArenA's maximum peak load by 300 kW – 10% of the total max load [86].

On the EV charging side, TMH have implemented smart charging with 14 regular EV chargers + the bidirectional charger. Due to the relatively low overall power, this has no implication for (local) grid planning but has reduced the costs of the local energy infrastructure (mainly cabling) at the ArenA by ~€15k [21].


**Figure 11: The Amsterdam Energy ArenA and its partners**

**(image from https://www.johancruijffarena.nl/international-activities/amsterdam-energy-arena.htm)**

## *4.6. Amsterdam City (NL) – (V2N/V2C)*

The City of Amsterdam is preparing for an expected increase in the number of EVs and more locally generated renewable energy. In March 2017 Amsterdam started a 'flexible charging' or (Flexpower) operational pilot with its partners Vattenfall (previously Nuon), Liander, ElaadNL and the University of Applied Sciences with several distinct phases, two of which (Flexpower 1 and Flexpower 2) fall within the SEEV4-City project.

By steering the charge flow of EVs peak loads can be reduced and EV electricity demand can be matched in part to the availability of locally produced sustainable energy. The design of the current electricity grid did not take into account the arrival of EVs. At this stage there is no direct problem but an uncontrolled increase of chargers on the low voltage grid might lead to peak demands that exceed the local grid

[21] e-mail communication from Jan Winkler, 30/01/2020

capacity. Therefore, it is necessary to start investigating how smart charging can help to overcome this problem.

The goal of the overall Flexpower work is to gain insight in the potential of smart charging and, even more important, what is needed to utilize the full potential of smart charging and what are the restrictions to implement smart charging on large scale. For the SEEV4-City project, Amsterdam wants to look at the opportunity to outbalance supply and demand of renewable energy production on a local level on Flexpower profiled charging stations.

The overall benefits of the pilot are: increased local grid peak demand stress, and by motivating and serving more EVs increased clean kilometres and $CO_2$ emission reduction and a cleaner (air pollution) environment [22].

**Table 15: Stakeholders involved in the Amsterdam City operational pilot**

| Roles | Stakeholders |
|---|---|
| **Local public and planning authority** | City of Amsterdam |
| **DNO - Utility company operating in the distribution of electricity** | Liander (part of Alliander group) |
| **Energy production and supply company** | Nuon – now Vattenfall |
| **EV drivers and householders** | Largely private EV drivers, and also largely private householders (but also perhaps public employees and office also) |
| **Charge Point Operator** | ? |
| **Local PV / solar energy producers** | A range of actors across (the parts of) Amsterdam |

Liander is a Dutch utility company operating in the distribution of electricity and natural gas in parts of the Netherlands. Liander NV is the largest utility company in The Netherlands, managing the energy network in Amsterdam, and the provinces of Noord-Holland entirely, as well as in large parts of Flevoland, Friesland and Zuid-Holland. Liander was split from the Nuon group in 2008 and since November 2008 has operated under the new name Liander. Nuon continues to operate as a production and supply company, under the name Nuon Energy and now Vattenfall. Alliander is a group of companies. Grid manager Liander is responsible for properly distributing energy across all their grids every single day. All the shares in Alliander N.V. are directly or indirectly held by Dutch provincial authorities and municipalities.

ElaadNL is a Dutch non-for-profit (Stichting or Foundation) knowledge and innovation centre in the field of (smart) charging infrastructure in The Netherlands. Through their mutual involvement via ElaadNL, the grid operators prepare for a future with electric mobility and sustainable charging. It is their mission to make sure that everyone can charge smart. ElaadNL monitors the EV-charging infrastructure and coordinates the connections between public charging stations and the electricity grid. Starting in 2009, the E-laad Foundation established a network of more than 3,000 public charging stations for electric cars across the Netherlands. In 2014 the foundation split up its activities into two separate platforms, namely ElaadNL and EVnetNL. EVnetNL is now responsible for managing the existing charging points together with municipal partners. ElaadNL continues the foundation's efforts to expand research and stimulate innovation regarding smart charging and the use of sustainable energy for EVs.

A summary of the changes made in Phase Two (Flexpower 2), as compared to Phase One (Flexpower 1) is given in Table 16:

[22] https://www.seev4-city.eu/projects/amsterdam/

**Table 16: Comparison of Phase 1 (Flexpower 1) and Phase 2 (Flexpower 2) at Amsterdam City**

| Phase 1 (Flexpower 1) | Phase 2 (Flexpower 2) |
|---|---|
| The connections for the EV charging stations with the Flexpower profile were upgraded from the 3 × 25 A category to the 3 × 35 A category.<br>The firmware of the charging stations has been updated from OCPP (Open Charge Point Protocol) 1.5 to OCPP 1.6 to allow time dependent current limits and remote configuration.<br>The 16 A fuses which were present on individual sockets were removed, and the distribution of current over the sockets was fully controlled by software. This has the advantage that the full current of the station is available when only one socket is connected, while this was previously limited by the fuse. | Changes to the Flexpower EV charging stations maintained. |
| The Flexpower 1 profile was static and pre-determined both in terms of current level as well as time of day. Therefore, the Flexpower 1 smart charging profile has a similar effect as a 'time-of-use' EV electricity price with fixed off-peak and peak times, as opposed to a dynamic profile where power levels are varied based on real-time conditions (such as market prices or grid congestion).<br>In Flexpower 1 during peak hours, that is between 7:00 to 8:00 in the morning and between 17:00 to 20:00 in the evening, the charging current available at the Flexpower 1 EV charging stations was limited to prevent overload and thus increased costs for the operators. Outside these hours the current was set to 35 A, a value increased compared to the Reference (standard, without the Flexpower 1 profile uploaded) stations.<br>Only during peak hours (between 16.30 and 19.30), when other devices (such as devices in households) demand more power, the EVs are charged slower and with less power. | The current limitations in the morning were lifted and were shifted from 17:00 – 20:00 to 18:00 – 21:00 in the evening to better counteract the household load on the grid.<br>In this pilot phase, a higher charging current of 35 A is offered overall, but with limitations around the morning (20 A) and the evening peak hours (6 A). |
| | The current limit during the day was linked to the weather forecast in Amsterdam. When a high intensity of solar irradiation was expected, a higher current limit was applied on the charging stations than when a low solar irradiation was forecasted |

### 4.6.1. "Flexpower 1"

The pilot began with public charge stations, with two sockets each, in the centre, the West, New West and South of Amsterdam. The charging speed was adjusted on the basis of the use of the local electricity grid. At the start of the test, at the charging stations where the altered profile (Flexpower 1, as opposed to the standard as Reference) was successfully uploaded, the charging speed for EVs was increased during 00.00 – 07.00 hours, 08.00 – 17.00 hours, and 20.00 – 24.00 hours (outside peak-hours). This means they are being charged faster than normal at this time of the day. Only during peak hours (between 16.30 and 19.30), when other loads (such as devices in households) demand more power, the EVs are charged more slowly and with less power. With this method more EV drivers in principle can use the same charge point and fewer public charge points may be needed. The overall benefits of the pilot are: reduced local grid peak demand stress, and by motivating and serving more EVs increased clean kilometres and $CO_2$ emission reduction and a cleaner (air pollution) environment [23].

The primary optimization objective was operationalized by providing a varying charging profile (called Flexpower 1) in which the charging current was varied during the day according to peak and off-peak hours. The Flexpower 1 profile was created specifically for this project. The Flexpower 1 profile was static and pre-determined both in terms of current level as well as time of day. Therefore, the Flexpower 1 smart charging profile has a similar effect as a 'time-of-use' EV electricity price with fixed off-peak and peak times, as opposed to a dynamic profile where power levels are varied based on real-time conditions (such as market prices or grid congestion). In Flexpower 1 during peak hours, that is between 7:00 to 8:00 in the morning and between 17:00 to 20:00 in the evening, the charging current available at the Flexpower 1 EV charging stations was limited to prevent overload and thus increased costs for the operators. Outside these hours the current was set to 35 A, a value increased compared to the Reference (standard, without the Flexpower 1 profile uploaded) stations [87] [88].

Of the 2100 public charging stations present at the time of the Flexpower 1 project January–September 2018) Amsterdam (which has risen now to well over 3,000), 102 were selected for a split-run testing. 50 of the charging stations were used as reference with a constant available charging current of 25 A. The other 52 were deployed with a time dependent current limitation.

Public EV charging stations are an important facility in Amsterdam since most households do not have their own driveway. Average occupancy rate on these public EV chargers is about 40% but can increase up to 80% for particular neighbourhoods during the night. The infrastructure is built on 3 × 25 A connections (three phases with a current limit of 25 A), which constitute the standard connection category for Dutch households. It is financially advantageous for the charging point operators to use this connection category for charging stations since the costs of this type of connection are €252 per year compared to €949 per year for a 3 × 35 A connection. All these rates are legally fixed, as well as the delivery time of newly requested connections. The impact of a public EV charging station using such a connection on the electricity grid is very different than that of the average household. Peak loads of up to 17 kW are possible for EV charging, while a Dutch household consumes on average around 1 kW. This potentially has severe implication for the stability and reliability of the local grid. A second reason to moderate the current implementation is that many newer and more advanced EVs support charging at higher currents than 25 A, thus making higher connection categories attractive for end users [87] [88].

The Flexpower 1 profile describes how the current limitation, which is kept the same for each of the three phases, changes over the course of a day. The profile is roughly the inverse of the average consumption pattern of Dutch households which has a small peak in the morning and a large peak during the evening hours. The Flexpower profile can as such be interpreted as the remaining capacity of the grid available for EV charging. A large amount of power is available during periods of low household demand (during the night and the middle of the day), but there is less power available during the morning and evening peak consumption periods. The charging behaviour of consumers is very different during weekdays compared to the weekend. The evening peak is lower and starts earlier during the weekend and there is no morning peak. These strong differences make it difficult to interpret aggregated results over the whole week. Weekends have a lower peak load and better overlap with solar power generation, therefore pose less of a problem for the grid than weekday sessions [87] [88].

Several technical modifications had to be performed in order to make the existing charging stations in Amsterdam suitable for a smart charging profile that exceeds 25 A. The connections were upgraded from the 3 × 25 A category to the 3 × 35 A category. The firmware of the charging stations was updated from OCPP (Open Charge Point Protocol) 1.5 to OCPP 1.6 to allow time dependent current limits and remote configuration. Another modification was removing the 16 A fuses present on individual sockets, and controlling the distribution of current over the sockets via fully controlled software. This has the advantage

[23] https://www.seev4-city.eu/projects/amsterdam/

that the full current of the station is available when only one socket is connected. The charging station model used in the pilot was the EVBox PublicLine [87] [88] [89].

Analysis of the Flexpower 1 pilot data showed an overall positive impact on users and positive results in terms of relieving some stress on the local power grid. Outside the limitation hours EVs charged faster and a higher number of EVs reached a full battery using the Flexpower 1 profile compared to the reference profile. Even if an electric battery did not reach a full charge nonetheless a higher amount of energy was transferred to it. Most of the charging volume associated with the BEVs was able to be shifted until after the Amsterdam household energy consumption peak without negatively affecting EV users. Consequently, the Amsterdam City SEEV4-city pilot was successful in postponing the EV charging peak until later on in the evening, thus causing it to occur daily only after the peak in household demand. This improved the utilisation ratio of the low voltage electrical network and avoided grid reinforcement investments. Most of the BEV users showed a reported improvement in charging comfort [87] [88].

There are many different EV models on the market with different charging characteristics, with different numbers of phases that a vehicle uses to charge (1-phase, 2-phase and 3-phase models) as well as the maximum current that an EV can use (16 A, 25 A and 32 A). Dominant in the Dutch EV-fleet are plug-in hybrid electric vehicles (PHEVs) in the 1 × 16 A vehicle category. This is largely due to tax exemptions that favoured PHEVs on a similar level as BEVs [90] [87] [88]. With PHEVs having close to 70% of the EV market share in The Netherlands (January 2019), the 1 × 16 A category is dominant in the Flexpower 1 analysis. Due to an electric Car2Go sharing platform in the city of Amsterdam (300 Smart EVs) the percentage of 3 × 32 A chargers is likely slightly higher than in other parts of the Netherlands. The EV fleet composition in the Flexpower 1 pilot is likely to be representative for the rest of the Netherlands [87] [88].

The available power a charging EV will experience also depends on the occupancy of the station. If two cars are simultaneously connected on both sockets, the current of the charging station has to be shared when the total number of connected phases exceeds 3 (for example a 1 × 16 A and 3 × 16 A model). The software can provide full power to both sockets only if three phases or less are charged [87] [88].

Results also depend on the type of vehicle and the user behaviour. If users would choose to pick up their car sooner because it has charged faster, a larger number of vehicles can be served by the same charging station and the total energy sales would be higher. Moreover, for EVs with large enough batteries to cover multiple trips, the higher charging speeds may convince users to connect their vehicles less often. This would also result in more vehicles being served by the same charging station and lead to higher energy volumes. This was, however, not observed in the data [87] [88].

An important indicator for smart charging in practice is the extent to which EV users are positively or negatively affected by the provision of a Flexpower profile compared to the current standard static charging profile. In terms of the vehicle categories, the 3-phase and >16 A categories represent BEVs with higher charging current and larger battery capacity for which the new infrastructure should be beneficial. The large population of PHEVs (mostly 1 × 16 A category) are likely to be disadvantaged by lower charging current in peak periods. Even though PHEVs do not solely rely on their battery, it is important to investigate the impact on their charging opportunities. The question of which share of sessions are positively and negatively affected by the Flexpower profile can be operationalized in the amount of energy an EV can charge during connection for the transactions at both Flexpower 1 as well as Reference stations. Since the amount of energy is dependent on for instance battery size of the EV and/or the state-of-charge (SOC) of the batteries HvA preferred to analyse this indicator by looking at the average power per charging session. The average power is directly proportional to the amount of energy charged and is insensitive to effects of large batteries and SOC. Overall, 91% of the sessions were unaffected (including the completed sessions), 4% were positively affected and 5% were negatively affected. These numbers are dominated by the 1 × 16 A category which has by far the highest share in the current EV market. Moreover, the fact that all completed sessions are unaffected has a large impact on these numbers. When looking at modern EVs (i.e. only categories with >16 A or 3-phases), the numbers become 14% positively affected, 5% negatively affected and 81% unaffected (almost all overnight sessions are unaffected. Smart charging still has benefits in these cases because the timing of the charging can be optimized (e.g. delayed until late at night) without impacting the user [87] [88].

The results show a large difference between the theoretical charging limit and the practical charging speed realized. This discrepancy can be found for all categories and is an important insight to help make policy and models more realistic. This difference between theoretical limit and the charging speed in practice arises from the sum of many factors associated with the vehicle, with the charging station and the grid. It is difficult to say to what extent this result applies to different cities and countries as local circumstances may differ significantly for public charging infrastructures in terms of connection types, vehicle fleet composition and occupancy rates [87] [88].

The Flexpower 1 pilot showed that it is possible to limit the energy consumption within a 3-hour time window without a large impact on EV drivers, proving that smart charging is a viable solution for balancing the load on the electricity grid particularly if higher current levels are provided during off-peak hours. Since the consumer impact is positive specifically for more advanced vehicles (in terms of current limit and number of phases), the potential for applying this measure will increase further as fleet changes to EVs charging faster (higher current levels and/or more phases) [87] [88]. The Flexpower 1 results showed that the current implementation leads to a rebound peak. This is not necessarily a problem since the load of all other connections on the grid (such as households) may have reduced sufficiently by the time current limitations are lifted, but it is not necessary and could be avoided by applying a more gradual increase in the current limit after peak hours [87] [88].

The OP analysis results from Flexpower 1 showed that in the current situation the possibility of increasing charging volumes during the day is limited by the level of demand and technical limitations of most of the electric vehicles currently on the market. If the goal of better overlap of EV charging with solar power generation is to be realized, consumers need more incentives to charge during the day and increase the percentage of 'green' charging. [89]

Based on the current Flexpower 1 profile an average reduction of 1 kW per charging station was realized. This would translate to avoided grid investments of around €10,200 for the population of 102 charging stations for strengthening the grid in the long term." "The cost benefit analysis shows that for the CPO the business case for applying the Flexpower 1 profile is limited due to the higher annual grid costs. Allowing reduction of net impact be factored in as an incentive, this requires rethinking the regulatory context for grid operators in the Netherlands, for instance through enabling differentiation of grid capacity tariffs for off/on-peak hours. [89]

**Table 17: Overview of costs and benefits per stakeholder involved in the "Flexpower1" pilot**

| Stakeholders | Type of organisation | Costs | Benefit: revenue (income) OR cost savings |
|---|---|---|---|
| **Liander / Alliander** | Grid and Energy company | Investment in charging poles.<br>The public EV charging infrastructure is built on 3×25 A connections (3 phases with a current limit of 25 A), which constitute the standard connection category for Dutch households. It is financially advantageous for the charging point operators to use this connection category for charging stations since the costs of this type of connection are €252 per year compared to €949 per year for a 3×35 A | Benefit: lower peaks in energy usage, use of excess energy.<br>Cost savings: Less investments necessary in energy grid.<br>For the Flexpower OP an average reduction in peak demand of -1.1 kW was achieved per evening per charge point. |

| | | | |
|---|---|---|---|
| | | connection. All these rates are legally fixed, as well as the delivery time of newly requested connections. In time, the results of the Flexpower1 and 2 pilots may help to introduce a new rate in the legislation for a flexible connection (3×35 A with limitations). | |
| **Hogeschool van Amsterdam (HvA) – Amsterdam University of Applied Sciences (AUAS)** | OP coordinator | Costs for project management and applied research | Knowledge creation. SEEV4-City Interreg match-funding. |
| **Other residents** | Households | Benefit in the long run: cleaner air, because more people will switch to EVs. | Reduced charging time (due to increase speed allowed) during off-peak hours. |
| **The charging station model that is used in the pilot is the EVBox PublicLine** | Charging pole supplier | | Income: sales of poles |
| **City of Amsterdam** | Several technical modifications had to be performed in order to make the existing charging stations in Amsterdam suitable for the smart charging profiles that exceed 25 A. These were upgraded from the 3×25 A category to the 3×35 A category. The extra costs associated with this upgrade were sponsored by the municipality of Amsterdam. The firmware of the charging stations has been updated from OCPP (Open Charge Point Protocol) 1.5 to OCPP 1.6 to allow time dependent current limits and remote configuration.<br>Another modification that was made is that the 16 A fuses which were present on individual sockets were removed, and the distribution of current over the sockets was fully controlled by software. | | Increased grid stability and avoidance of cost for strengthening the grid.<br>The Flexpower 1 profile has the advantage that the full current of the station is available when only one socket is connected, while this was previously limited by the fuse. |

### 4.6.2. "Flexpower 2"

The city of Amsterdam has set the ambitious target of achieving local zero emission transport by 2030 for all transport modalities (including buses, city logistics, taxis, shared vehicles and private vehicles). The required expansion of charging stations will increase the load on the local electricity grid. Smart charging of EVs offers opportunities for better managing and incorporating this additional electricity demand by EVs within the boundaries of the existing grid.

Double occupancy (of charging stations by EVs) can lead to significantly lower charging powers per vehicle, as the available current of a charging station must be shared between two EVs. In Amsterdam, where public charging stations with two sockets are dominant, utilization data shows how average occupancy of these stations even close to 50%. During evening hours occupancy can reach up to 70%, making double-occupancy a significant factor for assessing the smart charging potential as well as its grid or consumer impact. Furthermore, EV models differ significantly in charging powers which influences the impact of varying charging current limits as is typically applied in smart charging schemes. For instance, EVs that allow high current charging (e.g. 32 A) are more affected by smart charging than EV models that are internally restricted to 16A. [89] [91]

In 2019 the project 'Flexpower 2' provided a follow up to 'Flexpower 1', by increasing the number of charging sockets from 104 to over 900 and providing a dynamic charging profile that changes on a daily basis based on expected solar irradiation" [89]. "A time-dependent current limit was deployed on 450 public charging stations in the city of Amsterdam where the current was reduced during the peak hours of household energy consumption (18:00 – 21:00), was increased during the night, and dynamically linked to the forecasted level of solar intensity during the day" [91]. "During the 'Flexpower 2' study, data was collected on about 10,000 users responsible for approximately 100,000 unique charging transactions on 450 public charging stations. The dataset contains transactions of BEVs (all-electric vehicle) as well as plug-in hybrid electric vehicles (PHEVs) since these share the same public charging infrastructure. The general public was informed of the project via stickers on the charging stations and a news campaign. However, no attractive or repulsive effect of Flexpower 2 stations can be found in the data, users have not changed their charging behaviour. [89] [91]

The smart charging profile that was applied in the 'Flexpower 2' follow-up study was changed on two main aspects compared to the preceding study: (i) the current limitations in the morning were lifted and were shifted from 17:00 –20:00 to 18:00 –21:00 in the evening to better counteract the household load on the grid, (ii) the current limit during the day was linked to the weather forecast in Amsterdam. When a high intensity of solar irradiation was expected, a higher current limit was applied on the charging stations than when a low solar irradiation was forecast. The Flexpower 2 smart charging pilot is unique as it combines a (i) higher than normal and (ii) a lower than normal power level. This can lead to both negatively as well as positively affected sessions (rather than only negatively affected sessions found in other smart charging pilots).

Data of actual charging transactions as well as smart meter data on Flexpower 1 stations and the reference stations was used to analyse to what extent flexible charging profiles reduced the impact of EV charging on the local grid and to what extent it affected the charging volume and charging speed for EV users. A detailed analysis of charging speeds of individual EVs was made while the impact of varying current levels on the actual charging speeds was assessed. Furthermore, double occupancy effects on charging speeds and impact of the Flexpower 1 profile were also evaluated. In this pilot a higher charging current of 35 A is offered overall, but with limitations around the morning (20 A) and the evening peak hours (6 A). This represents a scenario where EV drivers can profit from higher charging rates when the grid is underutilized but EVs have a lower contribution to the grid load during periods of high demand. This should benefit EV drivers, the grid operator and the charging point operator. It may also contribute to a better overlap with solar and wind production. Wind power is projected to experience rapid growth in the coming years: this significantly increase the urgency to apply demand response strategies of EVs to match charging demand with renewable energy generation. [87]

(Flexpower 2 is a) large-scale demonstration project, here time-dependent charging profiles are applied to more than 450 charging stations in the city of Amsterdam. Apart from the sheer size of this smart charging project, the Flexpower project is distinct in that charging is dynamically linked to solar intensity levels during the day while charging current levels are reduced during evening (peak consumption) hours. As such, the demonstration provides insights in the impact of dynamic charging profiles on (i) the match of sustainable energy generation and charging profiles, (ii) impact on the grid, and (iii) impact on EV users. A simulation model is presented based on empirical power measurements over a wide range of conditions combining the flexibility provided by simulations with the power of real-world data. [89] [91]

Results on the impact of the Flexpower 2 profile on (i) charging power per active session, (ii) charging power per station (which represents the total grid load contribution of EV charging), (iii) positively/negatively affected sessions on Flexpower 2 charging stations compared to the reference stations, (iv) the effect of dynamic current levels linked to solar intensity and (v) results of a simulation using measurements of real-world transactions as input were analysed. [89]

The results show a large difference between the theoretical charging limit and the practical power levels that are realized. For example, for the 1×16 A vehicles the actual charging power is stable around 3 kW, while the theoretical limit for 1×16 A is 3.7 kW. This discrepancy can be found for all categories and is an important insight to help make policy and models more realistic. This difference between theoretical limit and the charging power in practice arises from the sum of many factors, associated with the vehicle, the charging station and the grid. It is difficult to say to what extent this result applies to different cities and countries as the local circumstances may differ significantly for public charging infrastructures in terms of connection types, vehicle fleet composition and occupancy rates. Using measurements from real transactions for calibration, the simulation results for Flexpower 2 could be evaluated for different contexts. [89]

It was also shown that in the current situation the possibility of increasing charging volumes during the day is limited by the level of demand, low occupancy rates and technical imitations of most of the electric vehicles currently on the market. If the goal of better overlap of EV charging with solar power generation is to be realized, consumers need more incentives to charge during the day. [89] [91]

**Table 18: Overview of cost/benefits per stakeholder involved in the "Flexpower2" project [89]**

| Category | | Per station per year | Variables |
|---|---|---|---|
| **1. Structural costs and benefits** | | | |
| Grid connections costs | €700/station/year (3 x 25A → 3 x 35A) | -€700 | This is known to differ per country. This is currently under discussion in the Netherlands |
| Higher transaction costs | Not applicable | | This may vary among CPOs (IT backend) and applied charging stations (applied firmware) |
| Electricity margin (profit margin €0,05) | No clear difference found | | Different charging profiles and/or different fleet compositions will impact the cost/benefit of this factor |
| Grid deferral costs | -1,1 kW per station €100/kW investment deferred | +€100 | This varies per country. Deferred costs are likely higher in case of weak networks |
| **2. Pilot related costs** | €100-€115 | Not applicable for new charging stations | |
| Manual changes to charging stations | €46-€92 | | |
| Changes to backend – implementation OSCP | €20,000 – €40,000 | This largely depends on the capabilities of the IT systems of CPO | |

Most striking is the high grid connection costs that need to be made in order to allow premium charging speeds on off-peak hours. With €700/station/year this factor is an order magnitude higher than the other costs associated with Flexpower. Flexpower is likely to lead to limited changes in charging volumes per station; leading neither to financial benefits or costs in the current design of the smart charging profile. [89]

The higher grid connection costs are five times higher than the potential grid deferral costs – although this factor may vary largely between countries and between different networks within countries. As such it is safe to say that a smart charging scheme is most beneficial in cases where electricity networks are weak and investments for providing peak power to allow EVs to charge can be circumvented or postponed with a number of years [89]. Note that the possible benefits of applying Flexpower 2 then lie with the grid operators (or to a certain extent with the municipality in retaining grid quality), and not the CPO [91].

By alternating a lower current during peak hours with a current surplus during off-peak hours the Flexpower 2 profile was successfully able to suppress the load of EV charging on the grid by 1.1 kW per station during a designated time window with minimal consumer impact [89 [91].

In conclusion, from a CPO perspective the Flexpower 2 profile provides no direct benefits, which make it difficult to justify relatively high costs for increasing the grid connection to 3 x 35A. In order to make Flexpower 2 more attractive the deferred costs for grid investments should be factored in; broadening the scope of stakeholders to include grid operators. [89]

Annual grid connection costs are higher due to the 3 x 35 A grid connection used (compared to the regular 3 x 25 A for public charging stations). These tariff groups differ considerably in annual costs between the different grid operators in the Netherlands, where the price premium of the augmented grid connection can cost between €400-€700 per charging station (with 2 sockets) on an annual basis.

For the case of Amsterdam an annual addition of around €700 per charging station was applicable in 2019 (€256 for a 3 x 25 A connection versus €964 for a 3 x 35 A connection). This adds up to just over €300,000 for all 432 Flexpower charging stations in 2019). This is a significant investment. However, from the start of the FLexpower project it was the intention to explore the possibilities for a new tariff group: "3 x 35 A with limitations". This would allow to the higher off-peak power capacity, while retaining limitations in peak hours against a lower grid connection tariff. This complimentary tariff group is still under discussion. Overall, Flexpower 2 in the current design is not a likely strategy to increase charge volumes per station (and as such will have limited effect on the business case of the CPO). On the other hand, EV charging volumes are not likely to suffer significant reductions due to Flexpower 2, even if the grid connection is reduced to 3 x 25 A. Since the energy demand is expected to remain stable and because of the buffer effect of the EV battery, energy sales are unlikely to be heavily influenced by smart charging strategies. [91]

The main procurement-related topic relates to the upgrading of the grid connection from 3 x 25 A to 3 x 35 A. The additional cost for this upgrade can vary considerably per grid operator and per country. For the case of the City of Amsterdam this upgrade was around €700 per charging station annually (€256 versus €964), which adds considerable costs. It therefore forms a significant barrier for upscaling in case the grid related benefits cannot be compensated in some form. Although the grid operator possibly benefits from the use of smart charging, the Dutch Authority Consumer & Market (ACM) regulates the connection costs prices and states that this price must be equal for everyone in the Netherlands. [89]

Further improvements in the future beyond Flexpower 1 and 2:

> The ambitious renewable energy targets in Amsterdam and corresponding growth in EV market share will make a smart charging strategy unavoidable. The application of a time dependent profile should be implemented first in areas where there are many charging stations on a single transformer, which is likely the first weak spot in the grid infrastructure, or on known grid networks with limited capacity left.
>
> A dynamic approach would offer an optimal consumer service and more flexibility than the current static time-dependent profile. For example, a limit could be imposed on an area serviced by a single transformer, and only when the sum of all sessions passes this threshold would the charging rate be regulated accordingly. This avoids unnecessary charging rate reduction, but requires real time communication between the CPO and the sensor infrastructure, which is supported by the OCPP protocol, but this is not currently in place. A second possible improvement on the current one-size-fits all

implementation is to grant control to the consumer, possibly combined with a price incentive. The user knows their intentions best and it seems superfluous to train complicated and incomplete predictive models instead of just involving the consumer. Depending on the estimated connection time and amount of required energy an optimal profile can be calculated. This avoids the effect of impacting vulnerable charging sessions but reaches almost the same overall effect. [89] [91]

# 5. Conclusions and Recommendations

## *5.1. Conclusions*

This report has reviewed some of the literature in the field of electric vehicles (both BEVs and PHEVs), renewable energy from the central grid and locally produced (here largely solar) in the context of emerging business models for aspects of, and looking into some more overarching connections of the EV and RES industrial ecosystem. By way of consideration of some key trends and debates in this field, (potentially) competing and complimentary business models are discussed. The report moves from identifying some of the fundamental considerations of general business models towards the formation of business models relevant to the SEEV4-City project, and proposes a generic SEEV4-City business model around EVs that considers all relevant stakeholders. On this basis, after setting briefly out some analytical methodology tools for understanding more specific business models for individual OPs, an attempt is made – based on available information from OPs (which is sometimes partial) – to describe and characterise the specific business models of the respective OPs of the SEEV4-City project.

For each OP, two business models are presented. First, the current 'derived' business models, which are those understood to be put in place at the beginning of the respective SEEV4-City OP, and changes made to them during the life-time of the OPs. Second, improved business models are proposed. Some of the proposed business models are indeed partially implemented during the course of SEEV-City through feed-back loops and optimisation and others are likely to remain for future consideration and implementation after SEEV4-City project formally closes. These improved business models can serve as an inspiration for other projects and organisations in their search for viable business models. One should note that, due the heterogeneity of the SEEV4-City Partnership overall as well as the diversity of the composition of local partners and stakeholders across and in the respective OPs, that viable here does not necessarily mean profitable (or surplus-creating for the not-for-profits) but organisationally feasible and sustainable financially to meet key objectives against stated policies. This in turn should see the credit from internalising costs (including environmental) which have previously been externalised and not taken care of. Some of the OP business models reviewed in this report are likely to be able to meet (prior to Covid-19) roughly their planned returns on investment, for others it is more about identifying a more partially commercial set-up with reliable partners (including aggregators) which can monetise what previously was only hypothetical V4ES due to the small scale. For others, a policy reform is needed to benefit from, or not to be penalised inadvertently by, grid-facing energy interactions. Some form of net savings is found to be possible with a degree of electrical energy autonomy (behind the meter). In all circumstances, battery degradation needs to be factored in as well.

The success of V4ES also depends on battery cost (which is continually declining) and being able to accurately quantify the impact of V4ES on battery life. Battery degradation depends on several factors, including the chemistry of the battery, production and conditions of use. Thus, this is difficult to quantify and current estimates vary significantly. Accurately determining battery ageing mechanisms (degradation factors) and state-of-health will enable optimum charging/discharging control strategies without adversely impacting battery life, and permit economical V4ES. This will also improve the residual value of the EV and reduce the total cost of ownership of EVs.

A key for increasing the confidence of EV users to participate in V4ES is to have a dynamic model for battery state-of-health that can be used in real-time.

Finally, V4ES involves complex interactions between several stakeholders with potentially conflicting interests, which need to be carefully considered and optimized. There is no single business model that will fit all V4ES implementations. A successful and commercially viable V4ES business models need to be tailored so that all stakeholders involved can see benefits (win-win scenarios). Also, V2G value propositions in Europe may change over the next few years with refined legislation, competition in the market between (fleets of) EVs and stationary batteries and may do so differently in different countries [92].

The generic EV business model includes the commercial and non-commercial relationships between the associated stakeholders, based on the direction of energy flow. Sometimes, the field of electric mobility is divided in four main areas of the overall ecosystem:

1. Electric vehicles;
2. Electricity;
3. Charging infrastructure;
4. Complementary services.

From the perspective of SEEV4-City, this needs also to cover (as reflected in the project's KPIs) strategic environmental, public health and economic objectives (set by the European Union, national governments, regional/ local public authorities, and associated regulators) as well as become an important part of the V4ES industrial ecosystem. Please see also the SEEV4-City Evaluation, Upscaling and Trans-Nationality report [24].

As suggested by Figure 12, the different SEEV4-City KPIs of $CO_2$ emission saving (Clean transportation and energy infrastructure), EA and Grid Investment saving as well as the Modified Total Cost of Ownership/Use (MTCO/U) have different intensity of relationships with the respective business model pillars (see Figure 5) within them. The idea is that different supportive policies regulatory frameworks can made a contribution to stretch the contributions of the respective business model pillars to the KPIs if not in the derived business models then at least for the proposed ones, some of which are only feasible with a changed policy and regulatory landscape.

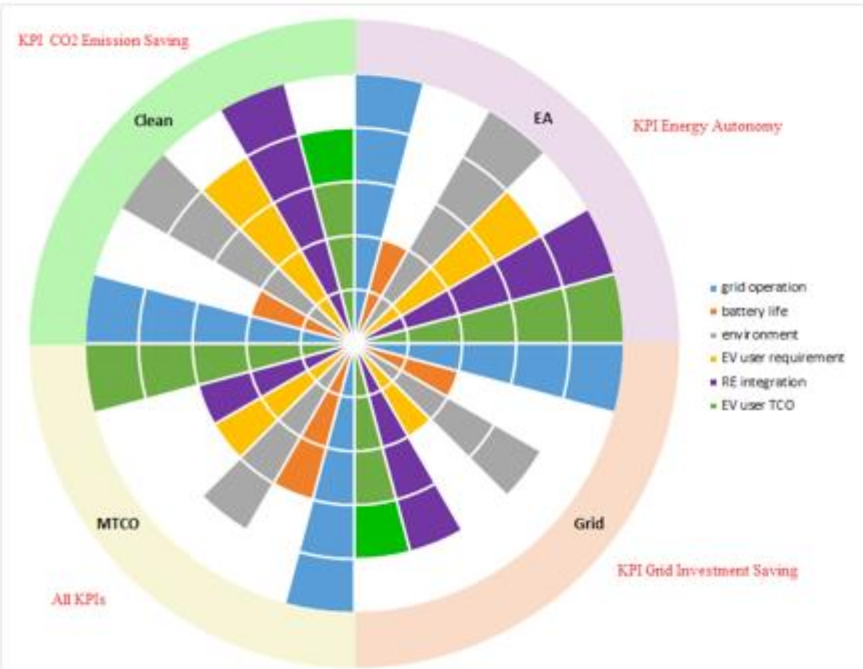


**Figure 12: Conceptual diagram of generic business model pillars contribution to KPIs**

The SEEV4-City webinar presenting insights of the project on the 22nd of April 2020 provided some additional reflections on some individual OPs as well as overall across the project. Furthermore, some key

[24] https://www.seev4-city.eu/publications/

insights into Smart Charging and Vehicle-to-Grid were presented by the SEEV4-City project and some other projects in Europe and beyond in the SEEV4-City webinar on this topic on the 6th of May 2020 [25].

One way to look across in a higher-level abstraction across the different SEEV4-City OPs was offered by Professor Robert van der Hoed in the final Stakeholders Validation webinar of SEEV4-City on 24 June 2020 (from minute 24:06 – to minute 32:00 in the recording). [26] This was done by considering three fundamental dimensions of Smart Charging [32] and Vehicle-to-Grid, namely by:

1. Duration (postpone, or cut and divide – both variants being feasible for shifting some EV charging);
2. Speed (power, which is energy over time);
3. Direction of EV charging; i.e. uni-directional or bi-directional (V2X, V2B or V2G).

This is then operationally also connected to different optimization strategies, including:

- Alleviating or at least not increasing electricity grid congestion (by reducing peak load/power demand through smarter EV charging);
- $CO_2$ emissions (better matching EV charging with Renewable Energy sources);
- Energy autonomy (increased self-sufficiency within the system boundaries, which may or may not mean increased self-consumption at an increased rate;
- Economics (reduced EV charging costs as savings and perhaps additional net revenues by a range of possible grid services, positively also affecting Return on Investment and Net Present Value).

The classification of SEEV4-City OPs would look different for the derived than for the proposed business models for the individual OPs. For the derived ones, one could arguably modify the classification from the final Stakeholders Validation webinar of SEEV4-City on 24 June 2020 as given in Table 19.

**Table 19: Classification of SEEV4-City OPs – derived business models**

| Smart Charging Strategy | Optimization Strategy |
|---|---|
| **Postponing EV Charging**- arguably not specifically applicable in SEEV4-City, with perhaps the partial induced exception for residents at Vulkan Oslo OP, and also Loughborough-Burton-upon-Trent OP | **Grid congestion / reducing peak power demand** – Flexpower Amsterdam, Johan Cruiff ArenA, and Vulkan Oslo car parking garage OPs; marginally at Kortrijk and perhaps Leicester City Hall, and if scaled up at Loughborough/Burton-upon-Trent across similar households |
| **Cut and Divide – dividing EV charging sessions –** arguably Loughborough/Burton-upon-Trent OP | **$CO_2$ emissions reductions –** all SEEV4-City OPs, though not all with locally generated Renewable Energy (RE) within OP systems boundary (and some with a mix of locally generated and central grid imported RE electricity sources); some OPs also enabled with a stationary battery energy storage (BESS) |
| **Slower Charging Strategy – compensated for by possible Faster Charging at off-peak times**- at Flexpower OP in Amsterdam | **Energy Autonomy / increased self-consumption and /or self-sufficiency** – Kortrijk and Loughborough/Burton-upon-Trent OPs |
| **Vehicle-to-Anything (V2X)** – Johan Cruiff ArenA, Loughborough/Burton-upon-Trent, and Leicester City Hall OPs | **Economics / reduce charging costs by matching with energy markets, and potentially gain net revenues by grid services** – Johan Cruiff ArenA**,** Loughborough/Burton-upon-Trent OP |

[25] http://event.seev4-city.eu/

[26] https://cenexgroup.nl/2020/06/26/replay-the-webinar-how-to-make-the-charging-infrastructure-and-local-electricity-grids-future-proof-june-24-2020/; https://youtu.be/pNQQFzvMNuk

The derived business models in terms of both the smart charging strategies and the optimization strategies have relationships to a degree with European but mostly currently national or even – as is the case for instance in Flanders – sub-national – regulation and policy. These can also to a degree be even more regionally and locally shaped on top of this. As Figure 12 conceptually conveys, regulations and policies may be used so that certain Smart Charging or Vehicle-to-Anything (V2X) enabling conditions may be modified in order to incentivise or imperative different optimization strategies change (for instance, less emphasis on self-sufficiency, changed minimum requirements for grid services for participating parties and different types of central grid energy tariffs). For some OPs, such as Vulkan Oslo car parking garage, this means that V2G could become viable and enabled beyond pure technological readiness. Other OPs could consider moving from a behind-the-meter V2B setting to (also) V2G in terms of grid services and exchanging energy with the central grid. As noted in the analysis of the individual OPs (section 4), the proposed business models for the different OPs partly ride on regulatory and policy changes over the next few years. Please consult also the SEEV4-City Evaluation, Upscaling and Transnationality report. This can also to a degree be assisted by European-level regulatory innovation and policy changes – please see SEEV4-City Policy and Roadmap report [27].

Das et al. [93] proposed a Multi-Objective Techno-Economic-Environmental Optimisation (MOTTEO) of V4ES for different EV charging strategies to define the synergies of four objectives: energy cost, EV battery degradation, grid net exchange and $CO_2$ emissions. The authors developed mathematical models of the objective functions and scenarios to represent interests of associated stakeholders. The conflicting objectives of stakeholders were resolved by multi-objective optimization with a multi-criteria-decision-making technique for some cases and scenarios. They found that smart charging results in reduced battery degradation but does not necessarily provide satisfactory cost improvement and environmental impact minimization. The benefits of bi-directional charging are found to be considerably higher (with revenue instead of a cost in terms of energy expense, and a reduction in demand peak) compared to smart charging if EVs should be available during most of the day (as well as the night). It is important therefore that bi-directional chargers (and PV generation) are available at different locations, including work places. Since battery degradation limits the performance along the other objectives, batteries should be operated under optimal conditions as much as possible (low SOC and charging rates). This could reduce battery degradation significantly as compared to uncontrolled charging. Uncontrolled EV charging is found to be the worst approach under all conditions. Under MOTEEO, the end-electricity users can increase their benefits by providing frequency regulation services and the DSO can improve the grid utilisation. However, there are maximum achievable benefits along the different objectives, and these do not occur simultaneously for all stakeholders. Therefore, there needs to be a cooperation between the stakeholders to increase the individual objectives as well as the overall social benefits. This suggests that a larger (or new) regulatory role must be in place to ensure that overall social benefits are achieved. The DSO should share the benefits gained from improved grid utilisation (investment cost deferral) by ensuring a revenue to the end-electricity user and the EV owner. The quantification of such revenue is case-dependent and each distribution network should be considered individually. Therefore, a collaborative decision process has been proposed. The implementation of a smart utility function under MOTEEO targets peak demand through combining the objectives of the end-electricity user and the DSO, achieving optimal grid operation while minimizing EV battery degradation.

Das et al. [93] demonstrated that a holistic decision-making process under MOTEEO is required, as not doing so will inevitably result in sub-optimal consequences for other stakeholders and in the longer term, affect the social licence of that stakeholder and/or technology. The MOTEEO framework allows costs and benefits to be quantified and are clear to various stakeholders. The application of a framework such as this in future energy systems can benefit all stakeholders, increasing the utilisation of renewable energy sources and integrating the energy and transportation system. The cooperation among stakeholders

[27] http://event.seev4-city.eu/. Also, the SEEV4-City webinar on the 20th of May 2020 on “Policy learning from SEEV4-City pilots: what policies do we need for the future?” addressed this.

through a decision-making process is expected to bring overall societal benefits in future smart energy systems. The strategies proposed by MOTTEO optimise the utilisation of distributed energy resources (RES) and EVs, and would therefore improve sustainability of future energy.

Finally, in addition to (and often independent from) the benefits of Smart Charging and/or V2X, it is important to consider other means of energy saving, e.g. energy losses. In several OPs considered in this project, energy losses were considered within systems boundaries and this resulted in energy efficiency savings measures which can also reduce costs and make environmental benefits ($CO_2$ emissions reductions). Evolving technological capabilities need to be monitored and experimented with for learning and gains over time, including for RoI. These technical innovations need to be harnessed and underpinned by organisational and social innovations in order to be adopted and making a significant impact.

## *5.2. Recommendations*

Organisations, whether for-profit nature or not, should carefully consider what their overall motivation and strategy is and how this intersect with a number of sectors, which are beginning to interact and integrate more and more: Electric Vehicles (cars, vans, e-bikes in this case), RES and distributed RES (here in particular solar). They should consider the – often parallel or even partly interacting - co-presence of competitive and collaborative relationships with other key players / organisations.

At least internally, respective organisations and partners should develop a good understanding and monitoring of technical, logistical, organisational, and financial performances.

These organisations should consider what kinds of players they intend to be, and what kinds of resources, capabilities and key activities and partnerships they need to put in place (and develop) in order to be able to develop and sustain a business model, which can deliver on a RoI over a reasonable time or meet other strategic (policy) objectives (if the motivation is not net financial).

Close and important stakeholders should consider adopting, pursuing, negotiating for co-benefits and sharing of costs (until there are shared net benefits), aided through a multi-criteria optimization decision-making framework such as the one proposed by [93].

Externally facing, they should be able to give credible representation of their endeavours of developing a business model, with some degree of (at least organisational, and perhaps to a degree financial without damaging commercial or other sensitivity) transparency which fosters trust by other stakeholders.

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# Appendix (A) Advancing from the State-of-the-Art report

## *A1. Industries in transition and in search of (new) business models*

[1] make clear that at least for the UK, with similar studies on a range of other countries also, that even with an accelerated EV uptake program which is needed for a number of strategic reasons, due the slow vehicle stock turnover, even with higher sales of EV than currently the case only a limited impact of reductions in $CO_2$ emissions will be seen before 2030. EV uptake will help with the UK's 2050 $CO_2$ emissions targets, but with embedded $CO_2$ production, in order to meet the 2050 targets the UK will need an intense grid decarbonization. [2] state and calculate that the $CO_2$ emissions reduction of EVs when substituting ICEs is often underestimated. It is important to also explore expert perceptions on decarbonisation though different low carbon technology application fields [3], as these may shape and inform a transition to some degree.

Charging of EVs from distributed local (renewable) energy is on the rise in the discussion and piloting (as part of an electric energy autonomy agenda [4] [5], either by supplying EV charging stations with local renewable energy (beyond just supplying the energy to maintain the installation itself, or the lighting thereof) – e.g. (even virtual but certainly physical) solar car ports – or via an Energy Storage Device (stationary battery [6] that is powered locally by renewable energy, or sources only renewable energy from the central grid (at low prices of electricity) [7].

One of the remaining issues is the Total Cost of Ownership or Total Cost of Use of EVs. For instance, [8] concluded from empirical field work in south-west Germany that whilst e-mobility product service systems (i.e. plug-in electric vehicles, interconnected charging infrastructure as well as charging platforms and additional services) are supportive to plug-in electric vehicle adoption in professional environments, the results of their user oriented techno-economic analysis of costs and benefits based on empirical data originating from a large number of organizational fleets participating in a field trial with a large number of plug-in electric vehicles and charging points show that organizations indicated a high willingness to pay for e-mobility product service systems.

Organizations were found to encounter non-monetary benefits, which on average overcompensate for the current higher total cost of ownership of plug-in electric vehicles compared to internal combustion engine vehicles. However, the willingness to pay for e-mobility charging infrastructure and services alone was found not to be currently sufficient to cover corresponding actual costs. It is important to have data rich trials which are realistic, over a sustained period of time and good level of analysis with both empirical road data and grounded simulations beyond first feasibility studies. For instance, an Edinburgh-based fleet trial, [9] conducted analysis of real operational data from the electric vehicle fleet both in proprietary data logging and reading, and also investigating data coming from 50 BEVs' own electronic control unit data for a four-year test period. Key characteristics of the EV's operations, such as journeys, speeds, distances, routes, and EV energy consumption, were evaluated. It was found that driving cycle patterns have significant impact on EV's energy intensity. Furthermore, different operational modes, such as acceleration, deceleration, cruise, ascent, and descent, were analysed and validated using operational data to determine the regenerative braking efficiency of the EV fleet.

With the movement from the current transportation technology mix to a more electric driven one, EVs will play an increasingly important role in this system. However, whether EVs are going to provide a significant contribution to the Smart Grid or make a detrimental impact depends on the financial assessments and the regulatory framework [10]. The former can be addressed with optimised business models whilst the latter refers to supportive national, regional and local policies to favour EV integration, in the context of a high share of renewables in the grid electricity mix [11] [14].

A classification of Business Models for Electric Vehicle Integration depends to a considerable degree on the category of EVs, including the degree of electrification (i.e. the relative importance and sizing of the EV battery, how it is recharged, how the EV is integrated into a smart grid via ICT as well as smart mobility via Intelligent Transport Solutions (ITS), and also Vehicle-to-Grid enabled capability.

One way to think about this is using the following dimensions:

- Product / service: This describes the area of business and the value proposition a company offers to the market;
- Customer interface: This explains which kind / groups of customers are targeted, how a company delivers the product or services and how the customer relationship is maintained;
- Infrastructure management: This defines a company's logistical approach and network that the company needs to deliver created value;
- Financial aspects: address the revenue model and the cost analysis (in the start-up phase also the investments, and the proposition for the recouping and then a RoI.

A significant amount of literature has been focussing on the automotive Original Equipment Manufacturers and their strategies in relation to the ongoing transition, partly enforced by regulatory environmental OEM fleet aggregate emissions emission caps, to electro-mobility (as well as other Ultra-Low-Carbon-Vehicle technologies). Some new market players as significant or niche start-ups (BetterPlace - with the development of extensive battery swapping stations in Denmark and Israel and an EV leasing model, but with limited buy-in by other than one OEM; Streetscooter – the German postal services self-produced logistics vehicle) have as individual business failed for a range of reasons discussed in the literature due to significant liquidity (and buy-in and uptake) and losses – in the countries and perhaps in part due to the countries they were operating in, whether their full business model type has failed, or indeed whether Tesla's – as innovation and market leader – will prevail and become profitable remains to be seen.

One of several such studies over the past decade [15] evaluated the approximate NPV, with many assumptions, of the options for strategic decision-making as well as business models (mainly vehicle-focused) of the main automotive OEMs based on the market projections concerning the development of electro-mobility. They stated that the difference between the expected income for the OEMs and their costs including investment must be discounted fully over time (in their calculations, over an 8-year period (for an EV coming to market in 2017). They considered four national markets (Germany, France, Japan and the USA, as well as an aggregated national one; and one reference vehicle in the superior segment used either as a business vehicle or as a private vehicle such as used by financially well-off early adopters, and also looked evaluatively into the other market segments of the 'middle-class' vehicle, the smaller vehicles, and the compact car. In their view at the time, and then projected forwards to about 2019 with conservative accounting (that is, creating a buffer by cutting the calculated NPV by 30%), only a 'technology-follower' in automotive electro-mobility reached positive NPV. And according to their findings with those assumptions, only an EV in the superior vehicle segment would bring profits (always in the overall scenarios assuming that no discounts would be given by OEMs for EVs).

This was all based on 8 derived investment options as adaptation pathways of OEMs into electro-mobility, as in the (translated) options below [15, p. 138; p. 141], as well as a fixed cost distinctions between existing or entirely new production facilities in OEM self-owned or external sites, 'conversion' (adaptation an existing variant of a volume-produced vehicle) and 'purpose' design (an entirely new vehicle concept, with significant research & development expenditure required for this), and use value of the new technology to establish new services (such as rental/fleet/car2go/parking services, dedicated driving lanes etc.):

- Investment Option 1: Technology follower with a strategy of cost leader and/or differentiation, limited investments into value creation and limited investments only into services in the field of electro-mobility and the product offer of PHEV or vehicles with range extenders;
- Investment Option 2: Technology follower with a strategy of cost leader and/or differentiation, limited investments into value creation but high investments into mobility services and the product offer of PHEV or vehicles with range extender;

- Investment Option 3: Technology follower with a strategy of cost leader and/or differentiation, high investments into value creation but low investment into mobility services and the product offer of PHEV or vehicles with range extender;
- Investment Option 4: Technology follower with a strategy of cost leader and/or differentiation, high investments into value creation as well as into mobility services and the product offer of a PHEV or a vehicle with a range extender;
- Investment Option 5: Technology leader with a strategy of product innovation, low investments into value creation but high investments into mobility services and the product offer of a BEVs;
- Investment Option 6: Technology leader with a strategy of product innovation, low investments into value creation but high investments into mobility services and the product offer of a BEV
- Investment Option 7: Technology leader with a strategy of product innovation, high investments into value creation but low investments into mobility services and the product offer of a BEV;
- Investment Option 8: Technology leader with a strategy of product innovation, high investments into value creation and high investments into mobility services and the product offer of BEVs.

(translated from [15, p. 141])

Arguably, Toyota (with the Prius, and some other PHEV and energy/ household related research and innovation), Renault (in the compact car market segment in particular) and also Nissan (particularly with full battery electric vehicles, and also V2G) have been technology-leaders, taking risk and developing brand positioning and trying to establish value stream propositions, regularly also in conjunction with home charging technology, static batteries. They are also trying to move into second-life battery value streams in some fashion. Volvo, BMW, Daimler/Mercedes-Benz/Smart, and VW have more recently arguably played a catch-up game, in different market segments (including the compact to smaller sized car one). Tesla is a major product innovation disruptor also with their own exclusive EV charging network, in addition to being able to connect to some public charging infrastructure without difficulty.

One of the criteria which, [15] in line with other commercial consultancy research, regularly looks at is the assessment of market trends and – at least before long eventual and significant – profitability of companies, OEMs and beyond, especially those that are publicly listed on stock markets. This interest has increased which, for instance for Tesla, can at time bring volatility, and may be based on longer-term brand image and capital market (for investments) effects. Also, companies, including OEMs, may pursue more the strategic role of an integrator or that of a specialist for their value creation, and may or may not change – for the time being – their business model radically, partly because the use value of the technologies is still evolving with significant uncertainties attached. Suppliers may or may not cooperate more in the future to offer more integrated technologies, and derived service propositions, in electro-mobility. Qualified staff in the technology and innovation areas, as well as the derived services, are needed in the domain of electro-mobility, with the requisite investments in training required [15].

According to [16, p. 3], "business model innovation is needed because new technologies and engineering innovations are currently far ahead of the energy system's ability to accommodate them". They claim that, "to date the focus has been on public policy and subsidy as opposed to independent business models which link city transport systems with the energy system and automotive industry. While national level subsidy policies have claimed to be successful, research by the RAMSES Cities project has found that in the UK, city level policies to increase EV uptake have not been effective". Accordingly, they conducted a range of semi structured interviews across the automotive industry, energy utilities, city governments, and EV charging infrastructure providers (but not with users) to identify the respective business model innovation needs. From this, they shortlisted ten business model archetypes, two representing current business models, and representing new business model archetypes which are technically possible but require further investigation and comparison. Furthermore, they used two business model innovation workshops to investigate the implications of each of these business models and to analyse how well each archetype fulfilled the innovation needs of each sector, and how well it catalysed the identified Innovation Interface.

In response to [16]'s first research question, "what are the business model innovation needs of different stakeholders?", they found nine business model innovation needs for the respective types of sectors:

*The Automotive industry innovation needs:*

1. A coherent and accessible charge network, giving buyers certainty and reducing range anxiety;
2. New routes to market/use models for e-mobility;
3. Clarity on energy infrastructure capabilities to better design the next generation of charge capacity and management.

*The Energy System innovation needs:*

4. Better optimisation of intermittent generation and EV Charging;
5. Tariffs to reward flexibility and response and new aggregator businesses/functions;
6. The ability to anticipate and respond to network stress.

*The City Government innovation needs:*

7. Coherent and accessible charge network;
8. Better partnerships with energy system stakeholders;
9. Integrated service approaches to mobility.

The second research question for their study was: 'what are the business model archetypes that meet these needs'? They investigated ten different business models, drawn primarily from participant suggestions in the interview phase of their study. The ten Business models [16] identified were:

1. "The Current Archetype: In the current archetype, private individuals and companies purchase electric vehicles and buy electricity from a utility with (at best) a static time of use tariff (ToUT). This archetype represents the current system and locks out many smart services, energy and transport benefits;
2. The Smart Utility: This archetype is similar to the Current Archetype but uses smart meters to aggregate electric vehicles to better serve energy markets and help consumers avoid peak power prices. Here, little is done to find new routes to market for auto makers, but energy innovation is enabled;
3. The EV White Label: In this archetype a partnership is forged between the auto industry and energy utilities which creates a specially branded EV tariff. Private and commercial customers buy both the vehicle and the electricity from the same company. This means the vehicle manufacturer can take responsibility for both battery warranty and energy service provision, but little is done to encourage smarter transport choices;
4. The Mobility Utility: In this archetype consumers buy mobility as a service from utility companies, bundling energy and transport services. The need to buy an electric vehicle is replaced by a regular energy and mobility bill. This means the vehicles can be used as an energy system resource;
5. The Municipal Mobility Utility: In this archetype the city sets up a utility to both provide energy and mobility as a service. Here local renewable energy optimisation is possible. The model is similar to the national Mobility Utility, but much more local optimisation of energy is possible;
6. Public Charge - Current Archetype: This is the current way provide public charge points are provided. It is often grant dependent and has led to patchy coverage and inconsistent standards of service and technology;

7. Public Charge - Municipal Lead Utility: Here the city owned utility takes control of the charge infrastructure provision across a city. EV charging can be linked with local energy priorities and local infrastructure can be better managed;
8. Car Share Compound: In this archetype the electric vehicles are stored in a car share compound. The compound can serve high use locations such as transit stations and, when not in use, the compound vehicles can provide energy services;
9. Rapid Charge Hubs: This archetype looks and feels like a 'petrol station of the future' where drivers can charge cars in less than 20 minutes while accessing other services such as retail options;
10. E-Mobility Service: Here the city's transport body rolls electric vehicle hire into the wider integrated mobility package of the city."

EV charging infrastructure solutions providers are increasingly making a case for their specific types of systems solutions not only around utility and degrees of inter-operability and convenience for end users, but also for commercial or other owners and operators of EV charging infrastructure. [17, p. 2] for instance, commissioned an academic consultancy study from Aalto University, conducted at the end of 2015 by interviewing EV infrastructure companies owning or controlling numerous assets in Austria, Finland, Norway, Sweden and the UK, offering both commercial and free EV charging to their customers. They summarise the findings as follows:

> According to a study, up to 80% of an EV charger's lifetime costs are related to OPEX, not CAPEX. The cost is highest with poor quality EV chargers in public use. This is too large a proportion of the total cost to overlook in terms of business case and vendor selection. The study includes OPEX cost for electricity connection, maintenance and data connection, but not the costs associated with commercial back end systems and help desks. Help desk costs increase in correlation with poor quality EV infrastructure, and this has a brutal impact on the service provider's brand and user experience.

Consultancy E&Y [18, p. 4] issued a consultancy report on business models in EV charging infrastructure. Here they distilled "five business strategies (which) will evolve to maturity following different timetables as they face different barriers to entry, by segmenting 143 (global companies') business strategies to make several findings". These five business strategies were characterised as 'the builder' (i.e. a supplier of charging infrastructure hardware), 'the maintenance-installer' (i.e. installation and maintenance services to charging network owners), 'the broker-operator' (i.e. a manager of the charging infrastructure of behalf of potential charging network owners), 'the grid-master' (i.e. an agent that integrates smart grid solutions for utilities with charging infrastructure management), and 'the guardian' (i.e. a provider of services ranging from charging infrastructure management to supporting EV manufacturers as well as customers, both fleets and individuals).

Generally, the E&Y report [18, p. 5] observes that:

- "Most companies advertise that they offer solutions for a wide range of customers — from utilities to car rentals, to hotels and home users – but lack a differentiated package and convincing revenue model.
- Several players have not considered the role OEMs and energy utilities will play in this emerging ecosystem, and until these two central stakeholders decide where they want to sit a stable value chain is unlikely to emerge.
- Charging station companies in the upper end of the value chain propose services that could be claimed by other, more natural players.
- To be a fast-mover is critical but does not necessarily secure a market share. Manufacturing charging hardware will rapidly become a high-volume, low-margin business.
- Other segments of the EV charging value chain are likely to invest on services that can be offered by leveraging the growing network of charging stations. Overall, the biggest revenue opportunities will probably go to large-scale players or nimble start-ups who can reach scale rapidly.

- The emergence of the EV charging infrastructure will likely force OEMs to take a different look at managing the customer relationship. Some OEMs already recognize the challenge and are turning it into an opportunity."

A PWC report [19] on business models from the CPO perspective identifies four different types of market player by overall strategy and business model: 'Portfolio' players (across the board of the different EV charging marker segments), 'Specialist' Players, 'Network Optimiser' Players, and 'Energy Supplier' Players. In turn, they are characterised in this report in the following way:

> The 'Portfolio' player: This type of company operates across multiple charging segments, such as home, work and destination charging. Typically, this player extracts revenue from several charging segments. This approach is more diversified and hence mitigates risk and allows the operator to bundle offerings to generate alternative revenue streams, above and beyond charging tariffs.
>
> The 'Specialist' player: Companies in this category tend to focus on one charging segment, leveraging their technical capabilities and relationships with key stakeholders to generate revenue from that business. Some rapid charging operators are a good example of this.
>
> The 'Network Optimiser' player: Companies in this group focus on building a future market position across multiple charging segments to capture alternative revenues on the back of traditional EV charging. These secondary revenues could be from helping manage the grid by exporting power from clusters of stationary EVs or by using smart technology to 'load shift' (facilitating the charging of EVs at periods of low demand).
>
> The 'Energy Supplier' player: For these types of companies, typically an electricity supplier, EV charging is currently not a core part of the business. However, they are keen to build a position in EV charging, given increased adoption of EVs will boost national demand for electricity, which in turn will benefit the power companies. Future opportunities around managing power demand profiles, via smart charging for example, will increasingly appeal to energy suppliers. [19]

[19] summarise the implications of this as follows:

> From the customer perspective, it's about developing a holistic value proposition that meets the needs of the user and delivers an experience that encourages EV drivers to come back. From the perspective of the charging operator, it's about building a business with optionality and potential to scale up. So, whether you are an aspiring CPO, an investor looking to fund an operator or a business looking to partner with a charging company, here are a few key questions to consider: Is there an optimal business model in place for long term success in the chosen charging segments? What revenue streams are planned for now and in the future? What capabilities are needed in-house and what other partners are needed to deliver revenue growth? How will technology and data analytics enable the business to provide 'smart' solutions? What are the funding plans for growth now and in the future? Getting answers to these questions will be critical to making sense of the options. With so many business models in the market, it can be difficult to figure out which ones are the likely winners. However, choosing the right strategy, capabilities and partnerships are essential.

[20] focuses on the reuse of second life EV batteries, i.e. those that reach a State of Health (SoH) of 80%, analyses economically and in terms of ageing performance the possibility of providing a second life for these EV batteries in buildings. Their study presents several scenarios depending on the battery use, considering independent buildings as well as demand response services within the context of existing European secondary electricity markets by means of an energy aggregator. Their results show whilst the reuse of batteries for residential purposes might not be the most effective economic option even though their lifespan is enlarged for a number of years; if these second life automotive batteries are able to participate in secondary electricity markets in addition to their normal use in buildings this becomes a significant net gain due to the relatively low impact on ageing. [20] also note that the promotion of EV battery reuse is necessary since there are now a large amount of them with a useful potential in stationary applications the nearby future from EVs sold over the last few years. Car manufacturers should consider eco-designing in order to facilitate this battery repurposing and lifespan enlargement. [21] explores a practical business model example with second life EV batteries.

A range of companies, expanding in and across Europe focusing on large stationary electric batteries - whether second-life automotive or not - have been developing service provisions and are targeting battery-for-energy services, such as for instance Eaton [22]. Eaton's 'White Paper' on stadia and arenas' peak shaving of February 2018 concludes that:

> Energy storage systems designed for the primary function of peak shaving need to be sized according to key criteria such as demand and consumption requirements. This means the batteries are sized to address the maximum demand (MW) and also sufficient storage capacity (MWh). Owners and operators of stadiums and arenas should also consider future energy requirements as well as any potential opportunities for revenue generation. Batteries are modular, and a system that is supplied to be scalable to meet future demand and energy needs should be considered, taking advantage of lower cost lithium ion batteries. [22, p. 5]

Eaton cautions that "selecting the right energy storage partner provider is key. Stadiums and arena owners and operators should work with a company that provides turnkey energy storage systems and engineering support, through the design, installation, commissioning and operational phases of the system", and further advocates to recognise a distinction in the commercial services market around (modular) static batteries between 'energy specialist only' who are said to "lack the deeper knowledge and experience that comes with supplying and installing power distribution, UPS and back-up equipment", and those who are more rounded and agile whilst still having the requisite depth of knowledge or experience (perhaps also in partnership with another firm) as:

> This degree of capability and knowledge is crucial for understanding how the BESS integrates and operates within existing power distribution infrastructure, ensures the system will provide energy resiliency in any event, protecting the bottom line. Choosing the right energy storage partner will ensure an energy storage system that is capable of selecting the right power sources according to the load, the grid constraints, and the availability of renewable energy, whilst optimising use of power to participate in programmes such as demand response and selling energy back to the grid. [22, p. 5]

Eaton's White Paper also, by way of example, reviews the relevance of static battery within different national energy services markets, with some regional differentials within that (DNO's time definitions of 'red band' periods of peak demand, for instance), for Germany, France, The Netherlands and the UK. In terms of future outlook, Eaton's 'white paper) also references that:

> Commercial premises and venues with carparks, such as shopping centres, supermarkets, leisure centres, stations, airports, not to mention stadiums and arenas, have an opportunity to provide charging infrastructure for their customers. As well as providing stadiums with a new revenue opportunity, installing EV charging infrastructure also improves the fan experience. In future carparks could also be fitted with smart charging equipment, to encourage local residents to park their cars overnight or for longer periods to take advantage of off-peak times. [22, p. 4]

## *A2. Justification of the SEEV4-City generic business model*

The key components of an EV Business Model are often seen as the power source (partly fossil fuelled in Hybrid Electric Vehicles, or entirely renewables - which can include nuclear-derived depending on the definition adopted), all of which makes a difference to a Life Cycle Assessment [23], distribution system (grid and local distribution networks) and charging station (which can have its own powering renewable resources, can have the capacity for Smart Charging and also Vehicle to Grid (V2G) [24] [29].

The EV business models must provide value for both service provider and service user [30] [25] [31] [26] [32]. There is arguably currently no fully proven working business model for EVs; however, [32] states that a home-charging based model will be the most common until the number of EVs rises significantly [31] [33]. That may change with increased workplace charging provision and a higher number of fleets EVs, as major cities are already finding that a comparatively low proportion of households have their own dedicated parking – and hence viable house-connected EV charging possibilities and provisions. Workplace charging could also utilise solar car ports [34].

Vehicle-to-Grid also has to be considered as a socio-technical transition [35] [36], which means that user take-up does not just depend on technical or just economic dimensions, and also goes beyond electric-mobility into energy prosumer behaviours. Another important transition to consider, for instance in The Netherlands or Norway, is that from hybrid (PHEVs) electric vehicles to full battery electric vehicles (BEVs), with different charging needs and impacts on local electricity grids [37].

[38] are considering, based on a substantial survey across the Nordic countries, that adding V2G capability to electric mobility can foster EV adoption further, though policy frameworks, for this currently weakly supported proposition, in some Nordic countries. EV adoption, as found in many surveys (both stated and via revealed preferences) studies, is found in [38] to be correlated with fuel economy, financial savings and environmental motivations, and also certain socio-demographic groups (in this case, younger males, with higher income, more children, and experience with EVs). Socio-technical transitions concerning energy and mobility, such as for instance V2G, should not forget to consider energy injustice and social access to both new forms of using electricity and mobility [39].

Businesses would typically attempt to identify suitable target market and consumer segments, based on a range of behaviours, preferences, lifestyle, socio-economic and geographical bases [40] [45]. This would need to include understanding EV users' mobility behaviour [46], as well as broader attitudes when considering V2G [36] [47]. For instance, according to [48]:

> "One of the biggest challenges limiting the wide-spread adoption of Vehicle-to-Grid (V2G) is the availability of clear data on the costs and opportunities for V2G, as required to build an effective business case. Cenex has performed work within the Innovate UK funded projects V2G-Britain, Sciurus and EV-elocity to tackle this gap by defining and assessing potential customer archetypes for V2G, along with possible V2G revenue streams. Every customer is different, and each customer's behaviour will impact their ability to access certain value streams. While it is not practical is to profile every potential customer, it is possible to group customers into 'archetypes' which more generally define their behaviour. Cenex has identified a list of sixteen domestic customer archetypes and eighteen commercial archetypes which are believed to be representative of current and future customers for V2G. Each archetype was assessed for their applicability for V2G, resulting in the following shortened list of archetypes that provide high applicability to V2G and significant potential scale in the UK:
>
> - Council fleet-Pool cars;
> - EV Car clubs;
> - Company car park;
> - The Retired Professional;
> - The Eco-Professional;
> - The Run-around (EV as 2nd Car)." [48, p. 6]

Feasibility studies, especially for large projects, are also a wide-spread approach being used. However, the range of factors being considered are not always comprehensive or fully realistic. [49] undertook a detailed techno-analysis of the EV-based energy storage and V2G, using the Manchester Science Park in the UK as a case study, but with minimal consideration of battery degradation, which would reduce the very substantial vehicle savings achievable. In many or even most other studies, aggregator costs are also often ignored to emphasise possible monetary returns.

[50] propose a three-layer business model framework, where the stakeholders and their commercial partners are depicted in the 'business layer', and the 'management layer' includes the necessary information flow between the stakeholders. Finally, the required infrastructure with the necessary physical connection is shown in the 'physical layer'. Unlike the work in [27], which includes the physical elements such as PV and energy storage, [50] only considers the EV and its charging unit in the end customer situation. For the existing power network, with associated physical elements connection, the final customer settles its transaction with the retailer who purchases electricity from the generators via the energy market, and the ancillary services market is the medium through which generators sell ancillary services to the TSO to ensure system security. Based on this framework, the proposed business model

introduces new commercial connections that are brought in by the EV/EV charging point, via contracts with the retailer for service provision as well as energy use due to vehicle charging. With the collected energy from the EV/EV charging point, retailers could then enter the ancillary service market for value creation, which is then settled with the service provider, i.e. EV/EV charging point. A similar three-layer structure has also been proposed in [51], and the function of the various stakeholders is discussed.

The energy flow between various physical elements relating to the final customer as well as the connection with the mobility and infrastructure providers, as presented in [27], and the commercial relationships between EV/EV charger and the energy provider/management agent, and associated ICT on top of the physical layer, as presented in [50], are combined in the SEEV4-City generic business model to provide a broad coverage of the position of the stakeholders involved in a EV business model. The physical entities consist of the base load, PV, energy storage, EV charger and EV, all of which are then connected to the higher-level network including distribution and transmission grid, and these are illustrated in a 'black box' with directed energy flow. The contracts signed between the final customer and retailer which then link with the energy market, are denoted by green colour. Those introduced by the new component of the EV/EV charger are coloured in red, with solid and dashed blocks indicating the commercial relationship and associated ICT connections, respectively. Detailed commercial connections with ICT have been discussed in [50].

In [50] the contractor/coordinator is the energy retailer, which may be replaced by a dedicated aggregator, and the energy retailer may then only be responsible for settling the transaction with the final customer for the base load. The mobility and infrastructure supplier has been introduced insofar as is relevant in [27]. The OEM of an EV is also usefully included in a consideration of the value chain. Last but not least, policies of energy, transportation and environment could have direct or indirect impact on the EV energy scheduling scenarios.

It should also be pointed out that the services provided by different stakeholders could be combined or partially combined to achieve certain objectives of these stakeholders. For example, 'The EV White Label' business model archetype discussed in [52] proposes a partnership between the automobile industry and energy suppliers to provide both the vehicles and the electricity to the final customers, via a special branded EV tariff. In this case, the EV OEM is responsible for both battery warranty and energy service provision.

Battery degradation is included in the SEEV4-City generic business model as a cost/asset stakeholder, since the battery is clearly an important and valuable component of an EV. Even given the existence of a battery warranty, the OEM or lease provider or car rental / shared vehicle provider has to consider the degradation of the SoH of a battery. This also applies to stationary battery energy storage. Issues around the impact of Smart Charging [53] and especially V2G are considered in the academic and policy literature [54-58]; it is therefore possible to conclude from a Texas-based modelling study of V2G with dynamic programming and unit commitment that the economic rewards for EV owners, being based on electricity prices, without financial compensation for reduced battery life were insufficient.

However, these EV batteries can potentially be sold as 'second life batteries' (typically considered to be a battery whose SoH is reduced to 80%) [20] [59], to continue their useful life as stationary storage; this could be considered as an extra benefit to improve the returns from the EV.

A current major barrier to EV take-up is the battery cost, albeit declining in price both for OEMs and end consumers. Since the EV battery is currently – and likely to stay (albeit reducing in production cost) – the most expensive part of an EV, there has been much investment (both public sector funded and support for, as well as private sector, by OEMs or indeed very prominently specialised large Tier 1 Suppliers - and indeed often in combination as Public Private Partnerships) into battery technology [60], largely Lithium-ion, as well as nickel-metal-hydride and other future technologies, and combinations with different types of (for instance hydrogen) fuel cells and range extenders.

From the owner's point of view there may be some concerns about battery degradation (since this is a very significant, and in fact the highest, component part price of an BEV) and the relatively short (though expanding, and quite large with a Tesla) range of electric cars: BEVs have a lower range compared to conventional ICE cars, which is mainly due to the higher energy density of fossil fuels and the volume occupied by batteries. Regarding this issue, the remarkable progress in battery technology, specifically with regard to the predominantly used Li-ion batteries, is continuously increasing battery efficiency and therefore reducing their volume for the same energy [61].

With reference to business models for Vehicle-to-Grid (V2G), as well as the cost of the necessary V2G bidirectional charger, there will be further costs in order to enable V2G. One will need to provide a bidirectional communication channel with the TSO or Aggregator as the case may be, and an additional energy meter so that the financial impacts of V2G may be measured. Further opportunities for value creation could be realized by applying business models; however, EV business models must provide value for both service providers and service users [62]. Positive drivers for V2G could include market-oriented regulations/tariffs, for example dynamic pricing of energy and grid usage [63].

Information and Communication Technology and other services that can aid fleet managers, EV drivers through various apps that may be pre-supplied by automotive OEMs or free-standing (e.g. routing, charging locations and charge station reservation, preferences of charging) are increasingly being complemented with energy services, not least aggregators for V2G solutions and virtual power plants.

Purchasing of private vehicles purchased via Personal Contract Purchase (PCP), i.e. leasing/ renting, has been gaining popularity in recent years, including prominently also for business vehicles/ fleets (which may come with a fleet manager service also). Personal leasing involves an upfront payment followed by payments in regular (monthly) payments over a specified length of time. Leasing agreements are typically based on a specified term and mileage, with charges accruing if the mileage is exceeded. There may be an option to buy the vehicle outright at the end of the lease, though as the vehicle belongs the financing company ones hands the vehicle back to them ordinarily.

The issues of higher price and shorter driving range compared to conventional ICE vehicles, plus the uncertainty of battery life, create more uncertainty for private ownership of EVs. Also, from a behavioural economics' point of view, a high initial price with low future operating cost is often perceived as less attractive than a lower initial cost but higher operating cost, even when the total economic impact is exactly the same [64].

Taking these points into account, Renault sells BEVs without the EV battery and instead the EV buyer signs contracts for a monthly lease to change the temporal distribution of financing; in other words, the risk of curtailed battery life is taken by OEMs under a car leasing service by shifting the battery ownership. A similar level of EV ownership is proposed as 'the EV White Label' in [52], where the OEM takes responsibility for both battery warranty and energy service provision by setting up a partnership with the energy utilities and creating a specially branded EV tariff. Under this proposal, private and commercial customers purchase both the vehicle and the electricity from the same company.

Two main changes to the business model of private transport have been put forward by [65]. The first is the shift of ownership from the end-users to the service provision company. Secondly, the revenue and cost has been restructured in such a way that the end-users pay a subscription fee covering the aforementioned ancillary costs and thus bearing all of the upstream and downstream risks. The ease of use of an EV based car sharing service would bring a new driving experience for the users [66], and the more efficient use of the shared vehicles in comparison to the privately-owned ones helps to reduce the car density and traffic congestion. The air pollution issue is also addressed due to the use of all-electric cars. From the investor's point of view, however, the drawback of such service is the business risk involved in the significant initial investment. Hundreds of vehicles are required at launch given a reasonable car density within a reasonable designation area. Also, the current battery warranty condition for EVs might be another financial constraint. In addition, the use of a single car model limits innovation and competition-driven improvements in design and technology which could promote further use and success of the service, though it is the most efficient economic solution for a specific car sharing system [65].

The technique of 'battery swap' has not been successful so far for cars (though there are perhaps a range of reasons why Better Place, one of the first companies in the field failed, including the markets tested (Denmark and Israel and the organizational model offered) [67] [68] [69]; and are perhaps in the running for taxis - or vans or buses [65] [31] [33], with considerable interest in China especially.

By car-sharing, vehicle ownership is completely given up, which is supported by the general trend where the interest in owning a car is decreasing [70]. A car sharing service provides personal mobility in as flexible and as private a way as a personal vehicle, for both private and business use, but with more convenience and less inconvenience than incurred by private car ownership in a city [64]. The idea is that of going by taxi, but you are the driver, and the service could be charged either by minute of use or through a subscription, which often involves monthly fee at a contracted level. The payment covers the electricity bill, maintenance, and road tolls, etc. This service could be accessed online or through smart phones or tablets, and service vehicles should be accessible at any public parking spot within a designated city zone. Free parking is suggested by [64] for all electric cars in the car sharing service due to their contribution to air pollution prevention and car density reduction; according to [64] privately owned cars are replaced by one shared car.

With ICT and smart grid infrastructure are in place, the aggregator is responsible for collecting information as to the available power from the EVs that are involved in smart charging/V2G activities, providing network services such as frequency regulation or spinning reserves provision, and settling the transactions with EVs based on the energy provision and the capacity provision for some of the available schemes. An aggregator is an intermediary between EV users, the electricity market, the DSO and the transmission system operator (TSO). The role of the aggregator is that of an agent that acts in behalf of many EV users to establish business relationships that otherwise would not have been possible, given the small size of an EV battery, compared to the grid requirements.

[71] showed for Sweden and Germany that PHEVs can be used, when suitably aggregated, for regulating grid power.

The fact that it is important to distinguish between TSO and DSO, in countries where that distinction is provided for in legislation is illustrated by [72] for the Danish context, which evaluated the utilization of EVs to support the central grid with ancillary services, especially frequency regulation. The Danish electricity grid has two different networks, namely DK1 (Western Denmark) and DK2 (Eastern Denmark), which are both coordinated by the same TSO (Energinet.dk). These two networks have quite different characteristics, including the capacity, supply composition, and grid connections. With the capacity of DK2 network being significantly smaller than DK1 and having relatively high share of renewable energy, this results in several problems, including frequency fluctuation. With regard to primary frequency regulation, DK2 adopts a symmetrical regulation for both up and down regulation. DK1, on the other hand, opts for an independent price for both up and down regulations. [72] find through analysing revenue obtainable from frequency regulation service through passenger EVs that about 7,000-11,000 DKK can be earned per year for each car in both DK1 and DK2. However, conducting primary frequency regulation by EVs leads to higher revenue in DK2 compared to one conducted in DK1, as the symmetric primary frequency regulation in DK2 leads to higher revenue in total, including up (discharging) and down (charging) regulations. However, since the frequency and its fluctuation of both up and down services are higher in DK2, a faster battery degradation of EVs in DK2 is predicted, negating some of the higher revenues otherwise obtainable.

Overall, the net gains from V2G do not automatically guarantee that all stakeholders derive a net benefit from it, and certainly not an equally fair share without a proper system design of benefit sharing. [73] demonstrated this for the City of Shanghai through a cost-benefit analysis comprising EV users, power grid companies and power plants when four brands of EVs participated in V2G peak shaving service in Shanghai, with a sensitivity analysis to determine the key parameters affecting costs and benefits of both EV users and power grid companies. Their results show that a total net profit of V2G services can be obtained given an appropriate set of parameters. The net incomes of EV users is positive with V2G peak shaving services when the peak price of electricity fed into the grid is more than three times higher than the valley price, and the lower the cost the EV, the higher the net income of a single user. However, the net incomes of power grid companies are always very negative and the higher the peak shaving load, the greater are their net losses. The benefits of power plants are the biggest among the three types of participants, being far greater than those of the EV users. [73] conclude that a fair market distribution mechanism of V2G profits should be constructed between the three types of stakeholders in order to promote a healthy development of V2G applications.

The uncertainty in social acceptance of V2G, together with the associated inconclusive net value creation capability of the current business models, urge investigations into EV business model structures with feasible scenarios that could potentially be applied to the various scales, such as household level, street level, neighbourhood level, and city level. Some available examples of smart charging and V2G schemes are presented in Section 2.3, Section 4 and Section 7 of the SEEV4-City Full State-of-the-Art report.

To achieve more established commercialising setups beyond trials, pilots and government created early markets through interventions of a subsidising or enabling dis-incentivising of alternatives, one requires a substantial systems change of not only a technological but also regulatory nature with transformative change of social / behavioural modes from organisational to individual levels, enabled by smart controlling that is adaptive and supportive to different ownership and user models in order to result in acceptance and wider uptake. If this is to occur at a more extensive and larger scale, as needed for declared decarbonisation strategies of the energy infrastructures of the future as well as of road transport at the same time, it does need further system-building networks as well as coopetition (that is, the simultaneous presence of both cooperation and competition at network level, across the boundaries of companies in the automotive [74] [75] and the smart grid industry [76], the energy value chain, the EV value chain as well as different charging and dis-charging propositions, coupled with compatible stationary where beneficial storage, with ICT integration across service platforms.

One of the main topics for discussion, pilot exploration and more recently actual commercial testing, has been the integration of electric vehicles (with a high degree of electrification amongst hybrid models, towards full battery electric vehicles) with the central electricity grid [77-81] which increasingly has a higher share of renewable energy as its source with intermittent features and thus requiring new functionalities as part of a so-called smart grid.

The smart integration of EVs into the grid should always consider the synergy from social, technical, economic and environmental aspects. Taking these points into account, the dimensions for successful V4ES implementation are identified and illustrated in Figure 6 in the main section of this report, where the core model in the centre represents the coordination between EVs and the relevant participants, including the grid, local demand, storage and renewable energy sources. Outside the core model, other economic factors (such as infrastructure investment) that contribute to the business models for the house, or higher-level developers/investors are also considered. Possible opportunities for EV owners/users to procure revenue benefits are identified through network services provision and interaction with renewable generation and storage. Environmental incentives and battery life optimization can be understood as economic gains to offset purchasing or depreciation use costs of EVs.

In previous work in relation to smart charging and V2G, different network services such as peak power provision, frequency regulation and spinning reserve have been explored. The revenues for V2G depend on the payment structure for the different services: for Regulation services it usually consists of a fixed payment to reflect the power which the EV can provide in support of the Grid (usually limited by the charger capacity ('capacity payment') and an energy payment for the actual energy supplied in up regulation and absorbed in down regulation.

The revenues for V2G depend on the payment structure for the different services: for Regulation services it usually consists of a fixed payment to reflect the power which the EV can provide in support of the Grid (usually limited by the charger capacity ('capacity payment') and an energy payment for the actual energy supplied in up regulation and absorbed in down regulation. Different network service provision available in the NSR countries has been discussed in detail in Section 4.3 of the Full State-of-the Art SEEV4-City report.

Costs induced by smart charging and V2G include (dis)charging infrastructure cost, energy payment and battery degradation cost due to additional wear of the EV, in particular when V2G is involved. Energy payment depends on the EV-driven kilometres and – in some cases at least – an additional price tariff involved. The cost reduction of the charging device relies on the grants and subsidies available. In most V2G scenarios, aggregators are needful to combine EVs into economically viable blocks with enough capacity to enter the market for ancillary services. The aggregators will charge for their services, part of the calculation of profitability involves determining how profit would be shared between aggregator and EV owner, where optimisation can increase profits on balance but not automatically equitably between the two [82].

Various economic results for smart charging and V2G have been achieved from previous projects, simulations, calculations and trials, ranging from net negative results to negligible net incomes but also those studies arguing that substantial annual net revenue can be obtained, all depending on types of markets, services, systems boundaries considered as well as policies applying (at the time or for simulations).

The study in [55] considers energy arbitrage and performs a cost minimization for three different charging approaches: as fast as possible (AFAP), Smart Charging and V2G. The battery degradation model considers two different costs, related to energy throughput and the charging power. 4 types of user profiles are considered but mainly costs for the employees and retired are compared. Smart charging and V2G show significant cost reduction compared to the AFAP approach, but the difference between the two accounts only for 10 percentage points. For retired, the cost reduction is higher because the low mileage driven and the consequent higher EV availability. This interesting finding highlights the effect of the different driving profiles in the benefits.

Frequency regulation is carried out in [83] and a system that involves an EV fleet of 50,000 vehicles with Solar and Wind generation is considered. The costs include capital investment, degradation of the battery (arising from Depth-of-Discharge cycling) and electricity used for driving. The revenues consist of the regulation price obtained from the energy supplied from the EVs and the price of the electricity provided by the RES. Cost of the electricity and the regulation price are kept constant and with a difference of 2 cents between them; this will not be the case always. The net profit varies in the year going from a minimum of 1$/EV/day to 5$/EV/day according to the RES production. The resulting profits are always positive because it is held that the revenues obtained from the RES production compensate the costs related to battery degradation, capital and the electricity for driving.

The Net Present Value approach, considering a 10 years cash flow, is considered in [84] where the minimization of the ownership costs is attempted. These costs include: capital costs, infrastructure costs and operating costs and these are compared against the revenues coming from the frequency regulation. It is worth mentioning that the investment costs for the fleet of 250 trucks is the initial purchasing cost which has been set equal for the three types: ICE, PHEV and EV (BEV). Besides, PHEVs and EVs enjoy different subsidies that were available in the US context. The revenues consist of capacity payment and energy payment. Two scenarios have been adopted: ramp down and ramp up and down. Although it has been proven that EVs and PHEVs reduce the ownership costs of the vehicle compared to a comparable ICE one in both the scenarios, the revenues are not able to exceed the ownership costs, mainly because the initial investment costs are too large. The sensitivity analysis shows that the capacity of the battery affects the revenues because it determines the energy that can be absorbed and provided, but it is the charger rating that has the most significant effect; in fact, variations of the charger rate are reflected in nearly proportional variations in profit.

It has been argued V2G may be most cost effective for EV owners who participate in the short-duration, high-value power market of ancillary services, preferably with both capacity payment and energy payment [85], but according to [48] and other research projections these values will shrink in the long-term as the market (for instance in the UK) becomes more saturated.

Three business cases are evaluated in [86]: profitability evaluation of different ancillary services in the PJM context in the United States, economic benefits from loss reduction due to V2G and economic benefits given by different parameters, such as: location of the fleet, capacity injected and load distribution in the feeder. The ancillary services that have been considered are: baseload power provision, peak provision, frequency regulation and spinning reserve. The costs and the prices that shape the revenue structure have been carried out from Kempton's work and the analysis show that peak provision and frequency regulation are the most profitable. This can be partly caused by the values used for the different payments for the services. V2G provision on the spot allows a lower feeder loading which gives loss reduction. The higher the loss reduction the higher are the economic benefits deriving from it (as this is a saving of money). According to the capacity and the load distribution, there is an ideal location in terms of optimal profit. The more distributed the feeder load the lower are the losses. Generally, it has been found that the optimal situation is when the feeder load is low and there is high injected capacity. [86] concluded that under current cost structures, batteries that provide only one ancillary service generally do not provide a net economic benefit. However, they argued that in most of the cases, the economics can be turned in favour of EV battery storage by providing multiple services, given that the primary service is delivered by using only 1-50% of the battery's lifetime capacity. This done through four cost-benefit analysis studies where different services were provided. Of course, the characteristics of the energy storage system has to comply with the requirements of the different services.

The role of energy distribution and services companies (DNOs/ DSOs) is predicted to change, partly induced towards the move toward 'smart grids' that are heavily digitalized, incorporate more distributed (renewable) energy and also allow for more consumer and local producers interactions (and these may increasingly, at least fractionally) overlap as 'prosumers'. For DNOs/ DSOs, it is predicted that an exclusive business model on retailing electricity will not be sufficient for them in the future, so they will need to develop new (additional) business models, also in interaction with the central grid (transmission) and energy producers (both on a larger and smaller scale) [87]. This may for instance include one-to-many business models. There are from a central provider, but with many services around energy management - including on efficiency, and / or different forms of dynamic pricing - including ToUTs, Critical Peak Pricing (CPP), Real Time Pricing (which is data-richer and more customised than quickly varying spot-market-prices and may include some options of cost reductions with appliances or energy storage in different forms), (commercial) project participation business models, 'gamification' business models (aimed at inducing behavioural change over time). But they may also include many-to-many business models. These may include peer-to-peer models (bilaterally between different, but equally treated, transaction partners), and community models (local or regional). They may also include smart multiple domains business models, that is coupling different forms of retailed energy (such as electricity and natural gas) with multi-utility metering and/or sub-metering), and platform-driven models for combination offers (essentially transaction-based platforms-as-a-service, with different offers that can be packaged together. Platform hosts can either be offering products or services themselves, facilitate (as white label) offers by others, or for a fee simply the use of the platform for transactions. There are also energy self-production business models, where decentralised renewable energy production (solar/PV, wind, or biomass) are in the centre of attention. This may be also based on not self-owned but a leased basis for the installation (say, PV panel, cabling, inverters, sensors) and may be based on a regular fixed leasing and servicing fee. This in contrast to sales of installations model (perhaps with a financing = credit rate also). Direct (that is from the producer of the electricity over a particular size which would nationally vary in a legally mandated way) marketing models (for instance, in connection with community electricity) are also possible here (either subsidised by law or not). If not state-publicised, then an intermediate actor can be involved to the electricity installation provider to the end customers. There is also the variation of a purchasing model, where the direct marketing agent buys the electricity from the electricity generator/ large installation and sells it on to one or several customers as their supplier. Another variation is the service provision model, where the direct marketing agent takes over tasks of the electricity generator in connection with the electricity provision of the end user based on a contract which may comprise procurement, operations and interactions. If all of the latter are handled in this way together, the electricity generation operator becomes the electricity provider (under a power purchasing agreement).

If the electricity generation operator and the end customer are geographically congruent, and no external distribution network is needed, fees and service charges connected with the use of this may be obsolete. Direct marketing of electricity on the basis of a market premium means that a direct marketing agent takes over as a mediator in all tasks for a client of their (say, prosumer), of self-produced electricity for a fee. This role could be played for several parties, as an aggregator. In order to reduce costs (computation, IT) technologies along the value chain can be used. Similarly, scaling up of the model to share fixed costs amongst more users or customers may be an option. One of those is virtual power plant, essentially a digital platform which connects independent electricity producers with electricity markets and DNOs/ DSOs.

A Virtual Power Plant undertakes direct marketing of the electricity produced that is connected with it, for instance to spot markets or regulation services markets. A Virtual Power Plant covers the aggregation, networking between and the financial integration of different power generation installations in a pool of generated electricity as well as the operative trade with this pooled electricity. For this, diagnostic, trade, portfolio management as well as steering systems of the installations are needed, and an as accurate as possible forecast of the electricity provided to the grid at different trading points in time to maximise market opportunities. Hence data on generation, weather or conditions of the installation, as well as market communications systems with the DNO/ DSO are required, from good analytical data banks as well as self-learning algorithms.

Finally, there are energy self-consumption business models, again connected also to prosumers (unless there is a 100% self-consumption, and energy autonomy from the grid). In principle, this can occur in the context of one-to-one, one-to-many, or many-to-many business models. An example of a one-to-one model would be PV-generated solar electricity self-consumption. A one-to-many example would be to provide several end consumers with one electricity-generation installation (say PV or district heating), for instance in the context of providing renting parties (flats, apartments, houses or commercial/industrial quarters). Such models for quarters (mostly urban) increasingly occur in the context of micro-grid projects, where electricity producers, prosumers and consumers are connected through peer-to-peer transactions (typically via blockchain solutions. The 'local' electricity may be cheaper for the connected end user parties, though not necessary the residual electricity needed from the grid [87, pp. 111-140].

Finally, there may well be a (perhaps prominent) return of municipal energy companies (both generation and distributing energy/electricity to locally bounded users, including households and businesses, as opposed to international(ly) owned electricity producers and distributors. Commercial energy management and services companies, as one form of the digital economy, are experiencing fluctuating individual fortunes (start-up, expansion and at times insolvency and closure, including enforced ones due to unpaid renewables obligations to central (state, regulatory) actors.

Different stakeholders (such as the network operator, energy market operator, mobility provider etc.) exist in all forms of business models, which are developed based on the various revenue streams from network service provision (for instance Frequency Control [88], Demand Side Management (DSM), price arbitrage, etc., or a combination (stacking) of these. EV ownership clarification [89] provides the basis for the commercial relationship definition of the business models, i.e. under a certain form of EV ownership, which stakeholders are more directly related to what energy scenarios, and with whom the contract are signed with. There are three main types of business model structures, depending on ownership, as listed in Table 1:

**Table 1: Ownership based business model structures**

| Type | Definition |
|---|---|
| EV Private ownership | ▪ The vehicle user is also the vehicle owner;<br>▪ The energy provider introduces time-of-use energy prices and FiT to the customer, and settles the transactions through an intermediate energy management agent;<br>▪ The customer must purchase the vehicle and the battery from the mobility provider and the infrastructure provider is responsible for the charging device. |
| EV Car leasing | ▪ Private vehicle purchased via a PCP, i.e. leasing/renting;<br>▪ A personal lease consists of an upfront payment followed by regular monthly payments over a fixed period of time;<br>▪ It is usually cheaper than financing a vehicle outright as the individual is effectively renting the vehicle, but they do not own it;<br>▪ The risk of battery life curtailment is taken on by OEMs under a typical leasing agreement. |
| EV Car sharing | ▪ By sharing vehicle, individual vehicle ownership is given up, which may be supported by a general trend where the interest in owning a car may be decreasing;<br>▪ Advantages: shift of vehicle ownership together with associated upstream and downstream risks to the service provision company;<br>▪ Disadvantages: high initial investment for purchasing the vehicles. |

The output from the business model should cover the economic and environmental savings, as well as performance related rewards, in the TCO and/or TCU, the environmental benefits in terms of $CO_2$ emission reduction, clean kilometres achieved, and improvement in local energy autonomy.

There are then also considerations derived from the ownership archetypes, their expected recharging and use profile behaviour, and the role of assets such as Electric Vehicle Charging Infrastructure. This also needs a consideration in terms of integration with the real estate/ housing markets [90].

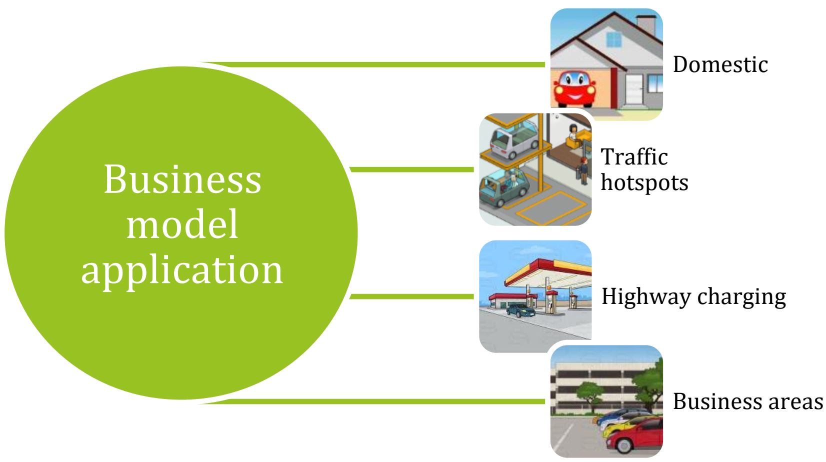


**Figure 1: intersection between EV use and re-charging behaviors archetype and EV charging point provisions and utilization**

The vehicle recharging context archetypes will differ to a degree both by country and also by city/region and locations of domestic/home, neighbourhood on-street and public more general, fleet/business. Smart charging (SC) and V2G are potentially beneficial for domestic EV charging through DSM and Network Service /Grid services and provision, and these services could have business opportunities for traffic hotspots such as shopping centres or car parks. Fleet operation and car rental/leasing allows the optimal EV scheduling in terms of vehicle usage and revenue capture. Highway charging, however, is not necessarily suitable for smart charging or especially V2G provision due to its nature in travel pattern, but explorations of DC fast charging (both in cities but especially along transport corridors [91] [92]) and High-Performance Charging (HPC) will no doubt be undertaken as well. Taxis are a special segment where 'time is money' in providing Mobility-as-a-Service (MaaS), but again perhaps at relative off-peaks for MaaS this could be explored.

In the still relatively early days of modern EV and EVES markets (for many countries, at least, and in terms of advanced models with advanced capabilities, such as V2G), it is essential to have policy as a driver of EV markets, either directly subsidising pilot projects that will lead the market by example, or incentivizing future behaviours in the market from the aspects of transport, energy and environment, as well as reinforcing regulations to enable interoperability. The regulation (see Section 5 of the Summary State-of-the-Art SEEV4-City report and the Full State-of-the-Art SEEV4City report) needs to be tailored to support EVs: the owners should be given a market to trade energy (at least through aggregators) and an appropriate taxing should be adopted. Low user acceptance may well hinder V2G adoption, not just technical or purely economic considerations.

However, it is worth noting that the SEEV4-City projects cover both Smart Charging (SC, sometimes also called V1G) and V2G, and with different prevalence of that in the different OPs of SEEV4-City. Similarly, this applies to stationary battery energy storage (ESS).

SEEV4-City aimed to comparatively explore and evaluate the respective benefits of different forms of Smart Charging and – typically but not necessarily conceived in sequence – V2G application and implementation.

The energy exchange between the EV and the power grid gives rise to various energy services to the power grid. One of the benefits for the EV owners participating in V2G, is revenue. V2G technology can further be categorised into uni-directional and bi-directional.

***Unidirectional G2V (or V1G):***

Uni-directional EV charging engages the communication between power grid operator and EV to control the charging rate of each EV. This is quite often employed to prevent system instability; voltage drops and grid overloading.

***Bidirectional V2G:***

Bidirectional energy exchange occurs between EV batteries and the power grid for EV charging and grid support. Bidirectional V2G provides more flexibility for the power grid utility to control the EV batteries to further improve sustainability and reliability of the power system.

A comparison between the two modes is provided in Table 2, which is based on, and modified from [93] [94] [95]:

**Table 2: Characteristics of uni-directional (G2V, or V1G) and bi-directional (V2G) set-ups**

| Power flow | Uni-directional (grid to EV, or V1G) | Bi-directional (V2G) |
|---|---|---|
| **Infrastructure/ hardware** | EV battery, communication system | EV battery and bi-directional battery charger, Communication system |
| **Power levels** | Level 1, 2 and 3 | Level 1 and 2 |
| **Services** | Spinning reserve, power gird power regulation | Active power support, spinning reserve, Reactive power support, Power factor correction, Improve power system stability, Harmonic filter, Frequency regulation<br>Energy backup |
| **Cost** | (Comparatively) Low | (At least currently still) Expensive |
| **Advantages/benefits** | Prevent overloading of power grid, minimise emissions and maximise revenue | Further improved grid stability and load profile, maintain voltage levels, reduce renewable energy intermittency, prevent power grid overloading, failure recovery, minimise emissions and maximise revenue |
| **Disadvantages** | Limited services | Battery degradation, investment cost, complex setup, and social barriers |

The SEEV4-City Full State-of-the-Art reports concluded that:

- There are three concepts of grid-connected EV technologies: V2V, V2H and V2G;
- To a degree, SC and V2G technology has not yet matured; the biggest disadvantages include battery degradation and social barriers;
- V2G becomes complex as large number of EVs (non-linear variables) are integrated into the power grid (grid constrains and limitations). This is at least in principle a complicated unit-commitment problem, with a large number of constraints and conflicting objectives;
- SC and V2G technologies can be successfully achieved by optimisation techniques – important techniques are genetic algorithm and particle swarm optimisation;
- Proper SC and V2G management systems along with appropriate policies (incentive-based) are important for successful implementation of SC and V2G technologies;
- SC and V2G do come with some technical issues, mostly related to the stability (transient and dynamic) of the grid:
    - While modelling SC and V2G, it is essential to consider detailed and practical models (characteristics of real EV batteries) for steady-state and stability analysis;
    - Precise forecasting of V2G capacity is paramount in both system and V2G operations. Improper forecasting, including for solar SC [28] [26] [29] will have negative consequences for both EV users, fleet managers and grid operators.
- Electricity price and economic benefits of EVs owners may be the most motivating factors to obtain load levelling, though perhaps other environmental considerations may help in terms of attitudes. However, if environmental costs were fully incorporated into the models and regulation/ policy for the sectors in questions, then they become a core explicit motivation also;
- Policy-makers should explore pursuing an ecological innovation policy, as distinct from a pure industrial policy, and embed this into both innovation policy and environmental policy at large [96].

# References for Appendix A


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