European Commission

bridge

Vehicle-to-Grid to support grid stability and RES integration

Case study #2

Vehicle-to-Grid to support grid stability and RES integration

Case study #2

LEGAL NOTICE

DOCUMENT INFORMATION

Editors

- Clémentine Coujard, Dowel Innovation
- Athanase Vafeas, Dowel Innovation

Support from BRIDGE secretariat

- Shenja Ruthenberg, *CLERENS, BRIDGE Secretariat*
- Marcos Jareño, *ZABALA, BRIDGE Secretariat Coordinator*

Acknowledgements

The editors would like to acknowledge the valuable inputs from the communication managers involved in the different BRIDGE projects, who participated and contributed in the regular meetings of the taskforce and the consultation rounds as well as members of the SPRING team, all contributing to this BRIDGE Annual Report of TF Joint Communication.

European Commission

- *European Commission – Energy Directorate-General, Unit B5 "Innovation, research, digitalisation, competitiveness"*
- *European Climate, Infrastructure and Environment Executive Agency - Unit C.C2 "Horizon Europe Energy"*

INDEX

1. Electric vehicles as a potential source of grid flexibility

1.1 Context

Reaching the ambition of a Climate-neutral Europe by 2050 will rely on the further deployment of renewable energy sources (RES) and the electrification of mobility end uses, in particular through electric vehicles (eV). This transfer of end-use towards the electric system will impact it in terms of energy but mainly in terms of power.

The batteries embedded in electric vehicles represent a potential source of flexibility for the power system, that can help support the grid stability and the further integration of intermittent and still hardly predictable RES.

Smart charging (V1G) and vehicle-to-grid (V2G) are two feasible technologies to integrate electric vehicles into the power system:

- V1G allows to control the power flow from the grid to the vehicle and adapt its charging schedule and pace according to grid constraints
- V2G goes one step further and allows bidirectional charging: the electric vehicle becomes both a programmable load and a programmable generator.

1.2 Benefits

Theoretical advantages can be expected from two main perspectives:

- Network operators could use the flexibility of eVs in congestion management, frequency regulation, peak shaving or spinning reserves. Such flexibility services could help limit grid investments in the future.
- Through the remuneration of V1G and V2G services, the eV user will reduce the cost of charging.

These advantages could be interrelated when price incentives for smart charging an V2G constitute cost-cutting for the end users while simultaneously benefitting to network operator and balancing responsible parties (similarly to Time of Use or power tariffs are to peak curtailment).

1.3 Challenges addressed in this case study

The V1G and even more so V2G concepts are facing some major challenges to prove the economic viability, end user acceptance and roll out potential:

- Depending on the scenarios of ‘deep electrification’ of Europe considered, the impact of eV charging on the power networks is not yet clearly evaluated, nor the potential contribution of V1G/V2G to network management
- Both concepts have to prove their economic viability from the eV perspective: smart charging requires suitable remuneration mechanisms and a critical mass of eV users at local scales; and the V2G concept raises the question of how to account for the degradation of the eV battery system due to the provision of grid services. In both cases, end user acceptance is a critical success factor, but so far an issue.

The next pages illustrate how some of the BRIDGE projects contribute to tackling these issues.

2. Setting up the conditions of V1G / V2G technical and economic feasibility

This case study focuses on three main building blocks that are investigated by a selection of H2020 funded projects:

SMART CHARGING STRATEGIES AND THEIR IMPACTS to enable V1G and V2G services. This block includes all charging and discharging strategies as well as technical solutions and infrastructures that enable the provision of grid services by electric vehicles.

ECONOMIC ASSESSMENT TOOLS FOR V1G/V2G SERVICES to support distribution grid (operation & planning). This block explores the types of grid services that eV could provide, and the possible ways to reach the economic profitability of such eV-based services in the framework of tariffs and regulatory context.

END USER ACCEPTANCE of eV-based flexibility services to maximise V1G/V2G value. This block addresses the behaviour of eV users, and their potential for change in the perspective of providing V2G services.

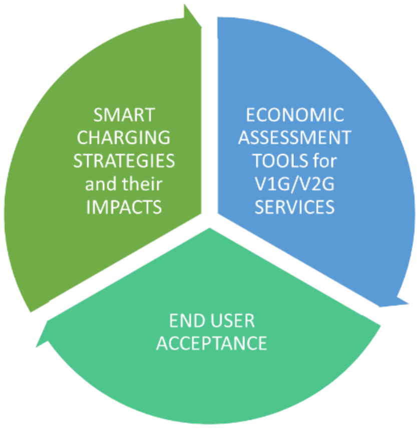


Figure 1:
The three building blocks to explore smart charging and V2G potential

This case study focuses on four H2020 projects that address those buildings blocks complementarily:

INTERFLEX investigated the use of local flexibilities to relieve distribution grid constraints. The Czech and Dutch demos address smart charging and smart energy storage.

INSULAE aims to demonstrate RES-based power systems in geographic islands. Lighthouse island Madeira is upgrading its eV charging infrastructure to study the enabling of frequency support and voltage regulation services by electric vehicles.

INVADE deals with the integration of eV and batteries to empower storage in distribution grids. The Norwegian demonstration explores eV user behaviours, while the Dutch demonstration tests different charge points (home, office, public space)[1].

EU-SYSFLEX develops a flexibility roadmap to support the implementation of cost-effective solutions. Its Finnish demo includes eV among other flexibility source on low voltage grid.

[1] https://h2020invade.eu/the-project/the-netherlands/

3. Smart Charging strategies and their impacts

This section details projects results with regards to all charging and discharging strategies as well as technical solutions and infrastructures that enable the provision of grid services by electric vehicles.

3.1 The technical feasibility of flexible eV charging is demonstrated, however not yet its usability by DSOs

- **INTERFLEX** project in its Czech demo tested smart eV charging with the objective to reduce the maximum charging power of charging station in case of under-frequency or under-voltage upon DSO signal through simple one-way PLC communication. When the reduction was activated, the eV charger supplied maximally 50 % (or 0%) of the full charging power, depending on DSO signal. Compared to a base line of 90 kW charging power, the smart charging system enabled to curtail this value to 55 kW upon DSO signal (>60% load curtailment) [project deliverable D6.3, 2019].

- **INTERFLEX** Dutch demonstration deployed some smart charging eV stations to investigate eV-based flexibility for congestion management. To allow aggregators to answer flexibility request from the DSO, Charge Point Management System (CPMS) and Flexibility Aggregation Platforms (FAPs) were implemented. An Open interface protocol supports connections between Mobility Service Providers who have eV drivers as customers, and Charge Point Operators who manage charging points via the CPMS. **2200 charging sessions were recorded** and analysed in terms of eV user behaviours. Results show that, while eV connection times are long enough to enable some flexibility (minimum one hour of flexibility), the charging power is too low (5kW in average) to provide flexibility services. A key conclusion is that eV flexibility is difficult to forecast, to control, to measure, and to obtain from users [project deliverable D7.7, 2019].

- In Finland, **EU-SysFlex** project tested 8 eV charging points (22 kW max AC power each), in an office environment with the aim to provide frequency containment services (Finnish FCR-D market), but without setting up automatic activation signals or real market operations. An Energy Platform was used to send (manually) control signals to all eV chargers connected to its network. During the test with 4 vehicles charging in parallel [Deliverable D6.6, 2021]. Results show that the **accuracy of the control request is quite good**: the realised power reduction differed by 7 % - 14 % from the average requested power reduction. [Deliverable D6.6, 2021].

- In this **EU-SysFlex** demo, the **response times of the AC chargers** varied between 13 and 25 seconds (measured via log-files from the chargers). This delay corresponds to the time between the configuration change limiting the maximum current for charging and the time when the full power decrease was realized in the log files. Such response time is not compatible with the requirement of max 5 seconds delay for the Finnish frequency containment market.

- A DC fast charger control was also tested: results show that the **eV models or the charging standard have effect on reaction time,** varying from 1 to 70 seconds. On average the eVs using CCS standard had a reaction time of 1.83 seconds to power decrease command and with CHAdeMO it took 65 seconds.

Table from D6.6: DC fast charger tests

EV	Test	Reduction of charging power (kW)	Time from received control command to fulfilled control (seconds)	Sample interval (seconds)
Nissan Leaf	1	20	60	10
	2	23	70	
Audi e-tron	1	44	3	1
	2	25	1	
	3	10	1	
Volkswagen e-Golf	1	35	3	1
	2	25	2	
	3	10	1	

- The same **Eu-SysFlex** demonstration tested a different smart charging system architecture on AC chargers, targeting reduced communication delays. The systems consisted of a charge point using OCPP1.6 communication connected to a charge point administration controlled by an IoT platform. Test result showed an average communication delay between charge point administration and charge point of <150 ms and an average total delay in power change of 2.4 s as measured by an external power meter. This delay would meet the strict requirements of FCR-D market (max 5 s) [Deliverable D6.6, 2021].

- **INVADE** project in its Dutch demonstration proved the feasibility of large scale control of the speed of charging eV over 700 public charging stations (1000 charging points) located in two neighbourhoods with expected large eV concentration in the future: in Ede (Doesburgerbuurt) and in Arnhem (Schuytgraaf-Noord): out of the **160 000 charging sessions**, half were subject to slight modulation to prevent a virtual network overload [website: https://h2020invade.eu/news/algorithms-successful-in-controlling-the-charging-speed-of-electric-cars/]. Controlling smart charging algorithms ensured a **minor impact to the customer**. In addition it should be noticed that most of adjustments took place in winter season showing a seasonal effect of smart charging in a given location in the Netherlands.

3.2 eV smart charging is tested to increase RES penetration in an isolated island

- Madeira island is isolated from mainland. The **INSULAE** demonstration showed how a growing eV infrastructure combined to eV smart charging components can leverage enhanced grid control and stability and thus allow higher RES penetration levels in the island energy system with impacts for operation and planning [source of next statements: INSULAE project coordinator, September 2021]

- The grid impact analysis on the smart eV chargers integration and related control strategies in Madeira island: results show that the smart charging components as designed should be ready for replication to other remote and isolated islands which are seeking electromobility solutions for frequency support and voltage regulation[2]

- The specific demonstration in **Madeira island** on electrification of islands' transport will include the upgrade of the current charging infrastructure with four 10 kW V2G prototypes (developed by EFACEC), two 50 kW quick chargers (QC45 and QC60 models by EFACEC) and one fully SiC 50 kW fast charger (developed by CIRCE), all of them integrating new functionalities for frequency support and voltage regulation. A control system will manage all the charging infrastructure in an integrated way[3].

[2] As of today, the demonstrators are in their early stages with equipments to be installed and operational soon.
[3] [Home - Insulae h2020 (insulae-h2020.eu)] (Insulae (eem.pt) Portuguese landing page for Madeira charging demonstrator).

- In Madeira the demo key objective is the use of eV charging V2G and V1G; and BESS plus BMS systems as potential flexibility sources. Following a selection process, 25 eligible users were thus selected to participate in the V1G upcoming demonstration. One of the benefits that the participants will have by letting their eV batteries available for V2G, is free energy for the charges of the vehicles[4]

- The deployed V1G Smart-charging technologies (V1G) provides the background data required to estimate the potential flexibility benefits of this technology and the potential remuneration for the 25 selected users.

- In Bornholm a DC microgrid with a novel 288kWh BESS coupled to 61kW of PV production and 2 eV fast charging stations (combined 150kW) seeks to find efficiencies compared to more traditional PV connections and maximise local independence/self-consumption, while allowing ultra-fast charging without requiring upgrades to the grid connection.

- Lessons learned from demonstrations to island planners will rely on the developed decision-making facility: the INSULAE investment planning tool.

3.3 Recommendations are made to improve interoperability

- The Open Charge Point Interface (OCPI) protocol that was chosen for the **INTERFLEX** Dutch demo mentioned above actually required some adjustments for the demo. The adjustments improved the OCPI usability, and feedback was sent to the protocol owner [project deliverable D7.6, 2019].

- This was also confirmed in the recommendations formulated by the **INVADE** project on standardisation in relation to future versions of Open Charge Point Protocol (OCPP) that will support for V2G use cases [project deliverable D4.1, 2017].

- Uniform requirements from DSOs for the power grid are a clear prerequisite. Quoting **INVADE**: "Though there are requirements for solar invertors, no specific technical requirements for V2X exist yet. In national grid codes, distribution systems are addressed as a general topic and have to deal with under/over voltage situations and anti-islanding functionality. However, current requirements are limited and should be extended or become more specific on 'mobile' distribution units. » [INVADE project deliverable 10.4 first demo results, 2019].

[4] although this is still under analysis by the National regulator.

4. Economic assessment tools for V1G/V2G services

This section explores the economic framework related to potential V1G/V2G services.

4.1 A theoretical framework of stakeholders' roles and services sets the picture for business modelling

- **INVADE** project observed that smart charging of eV and V2G can be embedded - market wise - in a wider flexibility concept including 'prosumption' features with self-consumption and demand response schemes.
  - The generic term Vehicle to Grid refers to a range of applications in which the electric vehicle's battery is used to buffer electricity. Options include 'Vehicle to Home', 'Vehicle to Office/ Building', and the actual 'Vehicle to Grid', each application having its own value proposition. Each of the variants have specific pros and cons, but V2G proved to be less mature and less implementable to the DSOs

  - The project highlighted the particular role of eV fleet operator to handle services to different actors as a result of smart charging / discharging strategies. With similar functions to an aggregator, the term of eV aggregator or eV service provider or eV VPP is also used. **Four categories of services** were **identified** with specific offers : (i) ancillary services to TSO; (ii) ancillary services to DSO; (iii) storage service to RES supplier; (iv) charging cost minimization to plug in eV owner [project deliverable D5.1, 2017]

- **Potential business models opportunities from eVs integration emerge**. The two pilots in **Madeira island** demonstration in the **Smile** project deal with eV integration and smart charging[5]. Most immediate business opportunities according to the project are related to the software to control the smart charging process and the related smart charging services to be provided to the stakeholders. Next, the collected data for eV fleet operators have a potential value for exploitation (e.g., historical charging data can be used to assess the life cycle of the eVs batteries and to provide recommendations on driving behaviours). More ambitious business models can be envisioned such as in smaller isolated electric grids with high potential for energy generation from renewables, eVs could be used as temporary BESS for supporting the gird, used as buffers to respond to short increases in the demand and/or decreases in the renewable generation [source: Deliverable-D4.1.pdf (h2020smile.eu), 2017].

4.2 Smart charging strategies present advantages but still face a series of barriers

INVADE project analysed the potential of distributed stationary storage and flexible load to support integration of RES and plug-in electrical vehicles. Pros and cons of each of the three main charging strategies (respectively uncoordinated charging, smart charging, smart charging and discharging-V2G) were assessed.

- Advantages for distribution grids take the form of new services such as congestion management, voltage support, loss minimization, redundancy, power quality. Reduced additional investment costs in distribution assets may also result from smart charging strategies in an area in which massive eV deployment is expected [adapted from INVADE project deliverable D5.1].

- Technical challenges refer to the need for ICT and effective control strategy, potential conflicting use of batteries and their degradation especially for V2G, while challenges on the market side were tackled by

[5] Pilot 1: 'getting started with eVs and smart charging' aiming to achieve smart charging using inexpensive infrastructure; pilot2: 'eVs are our future' focusing on a smart charging solution using standard chargers by taking control of the ON/OFF status of the charge and enabling to control the charge according to pricing signals, electricity demand on the island, renewable availability and level of aggregated energy consumption in the building

widening the business concept strictly beyond the eV flexibility through a Flexibility Operator concept [INVADE project deliverable D5.1 and project coordinator, September 2021].

- The German pilot in INVADE project addressed precisely smart charging in the wider context of a combined flexibility concept. Controlling the charging power was seen in context with adjustments of other loads in a home. Each home had a two tier control, one for cost reducing peak shaving and one for DSO driven demand-response. It highlighted well what smart charging in association with other load control could do to the market and grid if sufficient volume is aggregated. But current German regulations impede significant take-ways due mainly to market and regulation inhibitors (see section 4.1).

- An important finding of INVADE was that combined with capacity related tariffs the concepts of combined flexibility (strictly beyond the smart charging) that were introduced were effective for the charge point operator (CPO), for the home and for the DSO alike.

4.3 The critical mass of eV users is difficult to be reached to test the economic feasibility of V1G/V2G in real environment

- In **INTERFLEX Dutch demo**, the share of eV charging sessions was not adequate to solve the congestion problem yet. The eV aggregator was able to deliver flexibility **only for 30% of the time**, and with a delivered flexibility much less than the ordered value. Hence, there is a significant power deficiency between the DSO order for flexibility and the settlement, which leads to high penalties for the eV aggregator. It is thus important to investigate better incentives and other approaches to improve the awareness and interest of EV drivers to take part in smart charging programs. The project analysis also observes that shifting the EV flexibility load from one to another time slot can result in higher risks for the DSO at the end [project deliverable D7.7, 2019].

- **INVADE** had to add a static battery to the testing ground of their Dutch demo to be able to test reverse power flows as if the battery (storage capacity of 100 kWh with a doubled discharging speed compared to charging speed) were V2G cars charging and discharging, enabling thus to perform tests with combinations of multiple goals, like combining local balancing and energy market services [project deliverable 10.4 First demo results, 2019].

4.4 Smart charging can be performed without discomfort for the eV driver

- The first results of the **INVADE** Dutch pilot show that, **without the eV driver noticing**, the charge process can be sufficiently influenced for balancing the grid and dealing with peak moments, hence with a limited impact for the driver [INVADE project deliverable D10.4, 2019].

4.5 Methodologies were tested to assess V1G potential impact on grid investments

- **INTERFLEX** developed a methodology to quantify the technical and economic impact of selected smart solutions on the hosting capacity of DERs and EVs on low and medium voltage grids in the future. The methodology was a applied to the Czech territory based on national governmental scenarios to 2040, to compare some nominal grid reinforcement plans with smart grid solutions involving V1G. The analysis showed great potential of smart grid solutions to increase the hosting capacity of DER and eV charging stations, resulting in reduced investment needs for distribution capacity. Results showed that the grid investments could be almost cut by half with a smart EV charging strategy, compared to a Business as Usual scenario. [publication DOI: 10.1109/SEST.2019.8849135 , 2019]

- A similar approach was followed using the measurement from **INTERFLEX Dutch demonstration**. Based on future scenarios of high RES penetration, results show that the peak load a of typical future household with eV and heat pumps could be reduced by 58% by using their flexibility potential [resulting from the 67% compared to the 158% in the table below, project deliverable D7.7, 2019]

Simulation results	Consumption	Peak Load	Reinforcement % required
Standard Household	4.000 kWh	0,95 kW	0 %
Household with EV and Heatpump	10.000 kWh	2,45 kW	158 %
With only an aggregator active on energy markets (no local congestion market)	10.000 kWh	2,73 kW	186 %
With 100% renewable variable energy	10.000 kWh	3,01 kW	217 %
Maximum peak reduction via GMS by DSO on the local congestion market	10.000 kWh	1,59 kW	67 %

Table 5 Overview of the expected peak loads for some future scenarios

GMS = Grid Management system

"A standard reference household load as used in this simulation consumes 4.000 kWh and has a peak load of 0,95 kW. The future reference household load consumes 10.000 kWh and has a peak load of 2,45 kW. In case the flexibility of the EV and Heat Pump is exploited on energy market (80% variable renewable) by an aggregator, the peak load increases to 2,73 kW. In case we take 100% renewable variable energy (from wind and PV) the peak load goes up further to 3,01 kW. In this case some curtailment needs to be considered. In case the DSO can also negotiate with the aggregators and the energy of the worst day can be made flat (enough flexibility is needed), the peak load decreases to 1,59 kW."
Source: [INTERFLEX D7.7, 2019]

4.6 Recommendations are made to enhance cooperation between value chain stakeholders

- **Data exchange for optimum coordination:** to enable Smart Charging, multiple parties in the chain must work together and share information with one another. At present, there is no shared vision of the data that must be shared to ensure optimum collaboration. Technical standards and information protocols that apply throughout the chain are still under development. This can result in coordination problems that slow down the further development of Smart Charging. [INVADE deliverable D9.3 report on legal policy implications, 2018].

- The operation of the Smart Charging chain depends on digital data exchange (vehicle charging status, possible charging speed, time when the e-driver wants to leave, and minimum battery charge level) and it must be determined which data should be made available to market parties to optimally perform their task or to develop new services and products that maximise social welfare [INVADE deliverable D10.4 first demo results, 2019].

- **Standardization** is required on communication between all interfaces (e.g., future versions of Open Charge Point Protocol (OCPP) that will support for V2G use cases and fast charging. In particular having eV manufacturers honouring standards like ISO15118 is crucial [INVADE deliverable D10.4 first demo results, 2019].

- **Designing sustainable business models requires iterative co-design minimum viable products (MVP) by at least DSOs and aggregators, starting with local concrete situations and flexibility needs analysis:**

  - **INTERFLEX** recommends to study whether and under which conditions profit margins can be sufficient for aggregators and DSOs simultaneously. A good way to start may be do define 'minimum viable products' that can be developed and scaled up step by step. Initially business models could be developed for specific and concrete situations: like a neighbourhood, an area with a lot of heat pumps, a parking area with high number of eVs. It is therefore recommended to distinguish different type of networks situations, flexibility needs, areas with large supply from PV. This enables an approach that is neighbourhood specific.

- Typical questions include: *'Is sufficient flexibility at low voltage level available at reasonable prices, in case of congestion?'* This is so far not clear and requires further study. Alternatively, insight in the potential flexibility for resolving congestion in medium voltage networks needs to be studied and assessed [INTERFLEX deliverable D7.7, 2019].

4.7 Data privacy matters when designing user interfaces

- In **INTERFLEX Dutch demo**, the privacy law led to some limitations in the operator's user interface between the aggregator, charge point operator (CPO) and charging session (CS). An important aspect of the interface is to have a current validation of the charging request with the register of the administrator charging points network. Privacy aspects (e.g., guarantee the aggregator still has permission of the eV driver) must be taken into account by designing the operator user interface [project deliverable D7.6, 2019].

4.8 Proposals towards regulatory bodies are made to reduce bottlenecks for smart charging markets

[Source: Adapted from source D9.3 INVADE, 2018, and contribution by project coordinators, 2021]

- **More regulatory sandboxes is essential.** INVADE Norwegian pilot was designed as a regulatory sandbox to analyse the effect of capacity related tariffs and study charging cost minimization to plug in eV owners. Capacity related tariffs are now introduced on a wide scale by the Norwegian regulator [source: project coordinator, September 2021]

- **New roles and responsibilities in the smart charging market are needed.** The novelty of this market requires creating new roles and responsibilities and possibly leading to institutional bottlenecks (either due to the long lasting incorporation of these new rules into legislation and regulations or to the need to adjust existing roles). New or adapted roles and responsibilities have to be included in legislation and regulations and to ensure an optimal operation of the market with socially optimal welfare outcomes. Smart charging Market design shall thus be able to unlock flexibility potential and encourage smart charging slots based on these new/adapted roles and responsibilities.

- **Financial incentives are needed.** Existing legislation and regulations (energy tax, VAT, tariff structures, grid costs, but also electricity transmission costs) affect negatively the charging price for the eV user or other parties of the new Smart Charging Market and financial incentives would be needed to stimulate Smart Charging. Ideally a complete revision of the energy tax system is ultimately desired with incentive to reduce CO2 emissions. In the current system, grey and green energy are taxed the same, so that it does not reflect the original regulatory nature of the energy tax. Negative financial incentives for sustainable (energy) solutions should be removed and replaced where necessary with positive financial incentives. This includes the introduction of an exemption for CO2 neutral solutions or the use of a fixed tariff for low CO2 solutions or a progressive tariff as the CO2 emissions increase. A level playing field for Smart Charging can also be achieved in this way.

- **Regulatory and tax aspects.** Smart Charging of eV being highly dependent to tax and regulatory frameworks, tariffing and policies that encourage self-consumption among prosumers proved to be an important incentive for "battery on wheels". [INVADE project coordinator, September 2021].

5. eV user acceptance

This block addresses the behaviour of eV users, and their potential for change in the perspective of providing vehicle to grid services.

5.1 Low participation of eV users in some demos, but easy onboarding

The return on experience of the **INTERFLEX Dutch demo** regarding eV user participation, as presented in the project deliverable D7.7 (2019) is synthesised as follows:

- Out of the total amount of 944 unique users, only 23 (2.4%) chose to participate in the **INTERFLEX** project and provide flexibility on the eV charging, despite significant and repeated recruitment campaigns. However, once in, the onboarding of participants went well (download of the app, tutorials).

- It was quite difficult to get eV drivers to participate in the demonstration. The requirements for smart charging in the field test were that participants used the smart charging app of the involved aggregator and that they enabled smart charging for their eV. Among the possible explanations: - eV drivers preferably charge their car during the night at home, - eV drivers did not know about the InterFlex charging locations, because they were placed at new locations on the demo area.

- Recommendations on drivers' acceptance highlighted the necessity of a study to analyse circumstances under which eV drivers accept that their flexibility is being used, including different customer propositions for smart charging services (smart charging services to consumers could for example offer the eV owner a choice between low, medium and maximum flexibility).

5.2 Valuable insights on pilot users' involvement constitute the ground for future demonstrations

- The demo in **INVADE** project showed that the there was **no uniform response from the user**, although proposed smart charging was achieved in different ways (in the Netherlands state driven charging went unnoticed by multiple eV users) and it was not possible to draw a general conclusion on user acceptance in that domain, most likely due to the mutual interaction between Business Model design and end user acceptance.

- More generally it was found that **INVADE pilot users** turned out to be playful and practical when involved in the project. This is a resource that can be generally exploited by involving the playful and practical end users in the innovation process. The results also indicate that **smart charging is making end users grid sensitive** as it is oriented towards a practical issue. But pilot users do not necessarily represent the full spectrum of users. Again, it became clear that fine market differentiation and a higher resolution segmentation that was done in INVADE is important **to hit the different users with the right incentives**.

- **To increase responsiveness of end users** to different kinds of energy related measures, the qualitative review performed in **INVADE**, concludes that **social learning** is the most important aspect of such intervention. Thus, direct feedback, individually targeted, with some interactive elements have to be preferred. When designing such interventions, one should pay attention to the vulnerability of reward systems to fall back effects, to possible side effects of hourly pricing leading to shifts in consumption but without necessarily reduction in electricity use, or to the effectiveness of peer-comparative feedback. Last, community feedback proved its value by cementing identify feeling among members (of a group, community, district, city, etc.) [INVADE project deliverable D9.2, 2018].

5.3 Key motivational drivers are identified among early adopters of V1G & V2G

- **SMILE publication:** The case study in the Madeira Autonomous Region helps understanding the challenges behind eV usage by drivers. It is shown that drivers' preference to charge the vehicles at their household and that users are satisfied with the vehicle's technology and that users' battery range anxiety did not seem to have a significant impact.

- **INVADE** project compiled scientific literature on eV smart charging, V2G and user acceptance and highlighted findings from two studies which were challenged by demonstrations. **First,** Will and Schuller (2016) report from a German analysis of 237 early adopters revealing reveal a high acceptance of the concept of smart charging, and confirming the importance of communication of benefits to end users. This first study also revealed that money was not an important influential factor and authors suggested that the tariff design itself needs to communicate public benefits, which users can leverage by restricting their mobility and flexibility. In the **second** identified study by Schmalfuß et al. (2015) a five-month field trial was undertaken with 10 eV drivers comparing conventional charging with smart charging: study concluded that Controlled Charging (CC) was feasible for users if they were able to plan the charging process and configure settings, and since the system rewarded setting limits to charge state, many end users willingly offered up their flexibility in favour of mobility and spontaneity. This trade-off was characterized as a learning process. On the opposite, many participants did not feel like they needed to be curtailed however, and this was explained as a lack in transparency of the system design.

- **However**, some of the finding from this state-of-the-art such as the **lack of importance of financial incentives as motivation drivers were not confirmed** by the INVADE demonstrations. The project concluded differently on the importance of self-consumption to **save costs as an attractor for prosumers**. Project also claims that all pilots relate strongly to pivotal ideas related to end-users and market design, with business models fully relevant to the concepts of citizen energy communities. Self-consumption has transpired in several pilots as the most essential thing for many end-users since creating a strong incentive for building the sourcing for flexibility trade. Essential aspects developed in EC working document 'Best practices on Renewable Energy Self-consumption (SWD(2015) 141 final) have been embraced by **INVADE**.

- On V2G findings **INVADE** referred to the limited number of available studies which suggest high acceptance among users for smart charging and that engagement mainly found to originate with concern for society's benefit (e.g., grid stability) rather than own personal gains. If acceptance was negative due to desire for high flexibility in mobility, even programming capabilities for charging was not found to improve acceptance. While users expect some **remuneration for smart charging, 20% of total charging expenses** were often considered to be enough [INVADE project deliverable D9.2, 2018].

5.4 Recommendations are formulated for setting up future eV demonstrations

- **Lessons for replication are formulated to recruit committed end users in future demonstration pilots:** Reaching a critical mass or at least a significant amount of end users appears to be challenging. Lessons learned from projects include the active involvement and promotion by local partners, online user engagement campaigns having by-design the perspective the scaling-up and enhanced with incentives in eV charging (subject to national regulator authorization). The community engagement activities in Madeira Island constitutes thus a success story that should help future replication [Insulae, September 2021].

- **Demonstrations shall take into consideration some findings** on possible blockers for V2G demonstration. For example few vehicles are supporting V2G in current eV fleet and V2G chargers still remain too expensive to compete with Smart Charging with direct impacts on end users recruitment [INVADE project coordinator, Dutch demonstration, 2021].

- **Demonstration of wider scale and functional scope including V2G are needed :** large scale demonstration involving a high number of eV users are needed to reach a critical mass of local actors and enable the testing of associated grid services in real conditions[6]. Such demonstrators should be backed by social studies and marketing tools addressing user acceptance. **Such large scale demonstrations shall also be articulated with techno-economic simulations** for increased efficiency in the exploration of the viability of flexibility products beyond minimum viable products (MVP). In addition to demonstrations, valuable to learn and gain experience with respect to the practical implementation of flexibility solutions, it is recommended to perform technical simulations which include new business models with expected future situations (including large number of eVs, heat pumps and RES). These can provide insights for the technical system and business model viability in the future, while avoiding the complexity of building a future situation in a demonstration [INTERFLEX deliverable D7.7, 2019].

[6] It should be mentioned the EVVE project supported by the small scale Innovation Fund instrument (July 2021) and coordinated by EDF and DREEV (France) shall bridge this gap since it aims to to demonstrate the innovative vehicle-to-grid (V2G) technology based on the implementation of a hundreds chargers virtual power plant (VPP), wich makes it a first-of-a-kind, large-scale demonstration in Europe.

6. KEY TAKE AWAYS: facts & figures

Regarding **SMART CHARGING strategies and their impacts,** the INSULAE, Interflex, INVADE and Eu-SysFlex projects brought the following:

- The technical feasibility of flexible eV charging is demonstrated, however not yet its usability by DSOs
- eV smart charging is tested to increase RES penetration in an isolated island
- V2G and ultra-fast charging demonstrations are under preparation to explore the potential of bidirectional and ultra-fast charging of eV
- Recommendations are made to improve interoperability.

SMART CHARGING strategies and their impacts	
60%	Level of Load curtailment on eV charging reached by smart charging system in INTERFLEX Czech demonstration [Project deliverable D6.3, 2019].
42%	The time flexibility of eVs was estimated to 42% of their connection time in the INTERFLEX Dutch demo [Project deliverable D7.7, 2019]
1h	The minimum connection time of eV that could be used for flexibility in the INTERFLEX Dutch demo was estimated to 1 hour [D7.7, 2019]
7-14%	EU-SysFlex demo showed a good accuracy of the control requests to reduce charging power: the realised power reduction differed by 7 % - 14 % from the average requested power reduction. [Deliverable D6.6, 2021].
13-25s	The response times of the AC chargers in the EU-SysFlex Finnish demo set-up varied between 13 and 25 seconds [6.9]
≈50%	Simulations in INTERFLEX show that smart charging strategies could reduce grid reinforcement cost by 46-58% in long term scenarios of RES and EV deployment [D7.7, 2019]
☑	Proven feasibility of large-scale control of the speed of charging eV over 700 public charging stations in the Netherlands preventing a virtual network overload with minor impact to end users [INVADE, Dutch demo, project news 20 Dec 2019]

*See section **¡Error! No se encuentra el origen de la referencia.** for context and references of the above facts and figures.*

Regarding **Economic assessment tools for V1G/V2G services,** the INSULAE, Interflex, INVADE and Eu-SysFlex projects brought the following:

- A theoretical framework of stakeholders' roles and services sets the picture for business modelling
- Smart charging strategies present advantages but still face a series of barriers
- The critical mass of eV users is difficult to be reached to test the economic feasibility of V1G/V2G in real environment
- Smart charging can be performed without discomfort for the eV driver
- Methodologies were tested to assess V1G potential impact on grid investments
- Recommendations are made to enhance cooperation between value chain stakeholders
- Data privacy matters when designing user interfaces
- Proposal towards regulatory bodies are made to reduce bottlenecks for smart charging markets.

Economic assessment tools for V1G/V2G services	
	The critical mass of eV users could not be reached in recent demonstrators to test the economic feasibility of V1G/V2G in real environment, due to the lack of participating EV drivers [Results from INTERFLEX, INVADE, 2019]. In INSULAE project 72 eV users, residents in Madeira, submitted their interest to participate in the demonstration. This was due to an online user engagement campaign by local partners carried out between 13th May and 15th June 2021. Of the 72 respondents, 25 were selected for the demonstrators based on technical characteristics and order of application. The good response shows the impact and value of effective engagement by the Madeira Island partners. Here depending on usage of the chargers more users on a waiting list can be added to allow full utilisation. In the more technically restricted V2G demonstrators (only Nissan leaf and e-NV200 vehicle considered, 16 applications were received with 4 retained).
30%	In INTERFLEX Dutch demo, the eV aggregator was able to deliver flexibility for 30% of the time requested. However, not at the power level requested. [Project deliverable D7.7, 2019].
46%	INTERFLEX showed that grid investments could be almost cut by half with a smart EV charging strategy, compared to a Business as Usual scenario 2040.

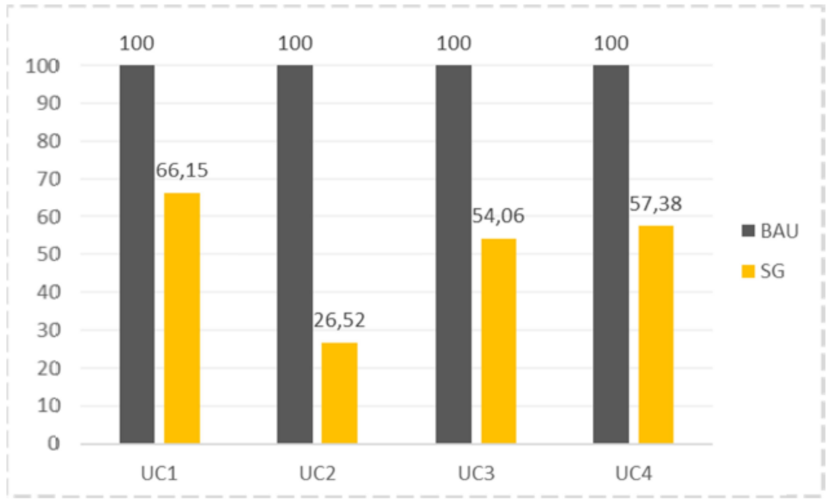
<table>
<tr>
<td></td>
<td>

Fig. 11. BAU and SG grid investment costs comparison in year 2040

BAU: Business As Usual Scenario.

SG: smart grid strategies:
- UC1 – smart PV inverter with Q (V) and P (V) functions, increased DER hosting capacity in LV grids
- UC2 – volt-var control algorithm in local DER control system, increased DER hosting capacity in MV grids
- UC3 - smart EV charging station, reduction of peak loads in distribution grids
- UC4 – smart PV inverter with residential battery, increased DER hosting capacity in LV grids

Source: publication DOI: 10.1109/SEST.2019.8849135, 2019</td>
</tr>
<tr>
<td>20%</td>
<td>The impact of smart charging on the eV driver experience in INVADE Dutch demo was very limited, most of the time unnoticed. To minimize the actual impact of throttling, a reduction of about 20% of charging power is considered (charging at 12 A instead of 15A). Source: Invade D10.4, results from pilots, page 41 (2019)</td>
</tr>
</table>

See section 4 for context and references of the above facts and figures.

Regarding **eV user acceptance,** the INSULAE, Interflex, INVADE and Eu-SysFlex projects brought the following

- Low participation of eV users in some demos, but easy onboarding
- Valuable insights on pilot users' involvement constitute the ground for future demonstrations
- Key motivational drivers identified among early adopters of V1G & V2G
- Recommendations are formulated for setting up future eV demonstrations.

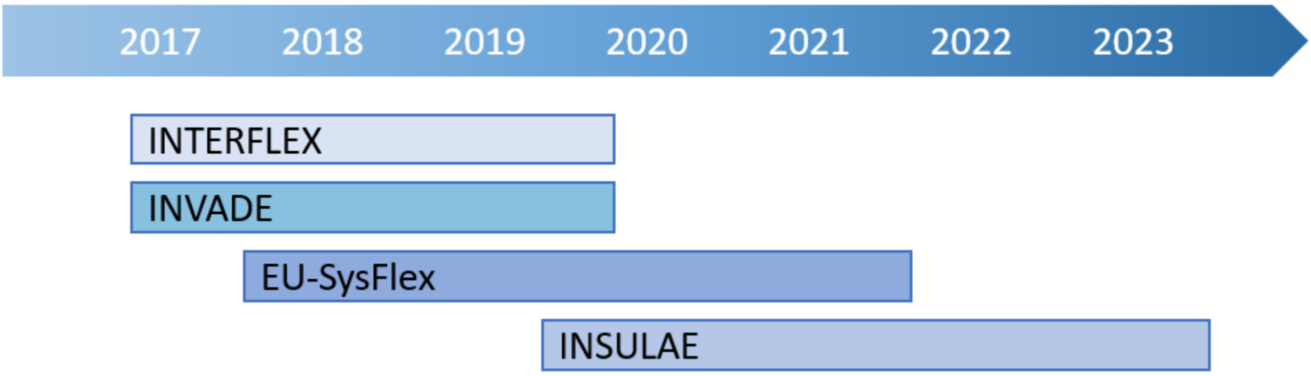
eV user acceptance

2.4%	Percentage of users of eV charging points of **Interflex Dutch demo** who accepted to participate to the projet and provide flexibility services [deliverable D7.7, 2019]
5c€/kWh	Flexibility incentive (per kWh shifted) proposed to eV drivers in the **Interflex demo in the Netherlands** [deliverable D7.7, 2019]
20%	eV users consider that a remuneration for smart charging is enough at an amount of 20% of total charging expenses [**INVADE** literature review on eV user acceptance - deliverable D9.2 section 4.4 'findings on vehicle to grid']

See section 5 for context and references of the above facts and figures.

7. References

Timeline of the projects studied:



Projects information

Bridge project	Call	Goal	Website	Coordinator / Contact
INSULAE	LC-SC3-ES-4-2018-2020 - Decarbonising energy systems of geographical Islands	Maximising the impact of Innovative energy approaches in the EU Islands	http://www.insulae-h2020.eu/	Fundacion Circe (Spain)
Interflex	Call: LCE-02-2016 - Demonstration of smart grid, storage and system integration technologies with increasing share of renewables: distribution system,	Interactions between automated energy systems and Flexibilities brought by energy market players	http://interflex-h2020.com/	Enedis (France)
INVADE	LCE-02-2016 - Demonstration of smart grid, storage and system integration technologies with increasing share of renewables: distribution system	Smart system of renewable energy storage based on integrated EVs and batteries to empower mobile, distributed and centralised energy storage in the distribution grid.	https://www.invadeh2020.eu/	Smart Innovation Norway As (Norway)
Eu-Sysflex	LCE-04-2017 - Demonstration of system integration with smart transmission grid and storage technologies with increasing share of renewables	New types of services that will meet the needs of the system with more than 50% of RES.	https://eu-sysflex.com/	Eirgrid PLC (Ireland)

Credits:
This brochure is financed by the European Commission and developed by DOWEL Innovation

bridge