IEA INTERNATIONAL ENERGY AGENCY

HYBRID &

HEV-TCP

Task 28: Home Grids and V2X Technologies

Final Report (2014 – 2018)

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1 Summary

Task 28 – "Home Grids and V2X Technology" was carried out between 2014 and 2018 as part of the International Energy Agency's (IEA) Technology Collaboration Partnership on Hybrid and Electric Vehicles (HEV TCP). Activity consisted principally of biannual expert workshops for researchers, industry and policy makers to work together in order to tackle the various technical, regulatory and social challenges slowing the development of V2X technology. This report provides an overview of the work carried out through Task 28 and the lessons learnt, such as current trends, opportunities, barriers and recommendations for moving forward.

1.1 10 Key Findings

1) Technology still at the research and development stage

V2X technology is still largely at a research and development phase and the business case has yet to be proven. Over 70 pilot projects have been carried out globally, predominantly in Europe and North America, some of which have been focused on developing bidirectional charging technology, whilst others have tested how V2X can be imbedded in existing electricity grids and markets. So far few demonstration projects have explored new business models for V2X, nor the social aspects such as the value proposition of V2X to end-users.

2) Japan has developed first V2H mass market

Since 2012 Japan has become the first country in the world with a real mass market for V2X technology. Over 4000 Leaf-to-Home V2H chargers have been installed to provide back-up power supply and behind-the-meter optimization in domestic buildings. This scheme has been supported by incentives from government, along with the relaxing of battery warranty rules by Nissan to enable V2H in their Japanese vehicles.

3) V2G aggregation in fleets is the most promising opportunity

The other major area of activity is the aggregation of EV fleets to provide frequency regulation services to the TSO and behind-the-meter optimization at business premises. This business model is likely to be one of the first to reach commercial viability and already several pilot projects in Europe and the U.S. have demonstrated annual revenues in the region of $1,800/€1,400 per vehicle. Further, these projects have demonstrated that bidirectional charging is capable of generating significantly greater revenue than smart unidirectional charging, in the region of eight to ten times.

4) Lack of V2X enabled EVs and EVSE in the market

One of the biggest barriers to development is the lack of V2X capability in standard EVs, a sign that OEMs do not yet anticipate there being sufficient demand for V2X capability from EV buyers. This presents a "chicken and egg" problem when it comes to moving the technology from the research and development stage to a mass market for bidirectional EVSE and EVs. Currently, CHAdeMO DC chargers are the *de-fecto* bidirectional EVSE, used in the majority of V2X pilot projects to date, although new CCS DC charges include bidirectional protocols and several projects are testing emerging AC solutions. As for vehicles, Nissan, Mitsubishi and Renault account for over half of all V2X projects.

5) Battery aging impact from V2X is minimal

Most evidence suggests that battery degradation impacts as a result of V2X is minimal; generally less significant than the impacts of fast charging, battery temperature and aggressive driving styles. Further, the next generation of EVs with higher capacity batteries will experience even smaller impacts on battery aging, down to near negligible levels. OEM manufactures should therefore not see this as a barrier to enabling V2X in their EVs and provision should be made for V2X in battery warranties, with restrictions on daily energy throughput to mitigate risks for V2X.

6) Standards getting better but more work is still required

Standards are essential for bringing down the cost of V2X and enable actors to extract maximum value from V2X's technical characteristics, such as very fast response times and high power. Since the start of Task 28 significant progress has been made to this end, with the introduction of protocols for bidirectional power flows in CHAdeMO, ISO 15118 and OPC2.0 standards. However, more work is required to account for all types of V2X application, AC charging systems and harmonization with existing charging protocols, grid codes and energy markets.

7) Aggregation still a challenge in many countries

Aggregation of V2X chargers is required for participation in systems service and energy markets. However, many of these markets are not well suited for DERs and need redesigning in order to enable full participation remuneration of V2X. Variations in system service market design between countries presents an additional complexity challenge to aggregators operating internationally and often the size of the TSO system services markets are reduced due to mandatory frequency regulation requirements for synchronous generators. Some countries, such as Spain, do not yet permit the participation of aggregators in system services markets.

8) Levels of public awareness of V2X technology are still low

V2X technology is often seen as being too complex for the general public's interest and current awareness among the general public remains scares. In order to generate a market for V2X products it will be necessary to promote the benefits of the technology to a boarded audience, as well as manage potential concerns, such as data security, battery aging and range anxiety. Large scale demonstration projects should be utilized as a platform to promote V2X technology to a wider audience.

9) Competitively of flexibility markets risks viability of V2X

Flexibility and capacity have become very competitive in recent years and there is risk of market saturation. New types of flexible resource, such as stationary battery storage and demand response may be able to provide the services of V2X at lower cost. This remains an open question and will largely depend on each of these technologies potential to reduce capital costs though innovation and economies of scale. Synergies to combine V2X with on-site renewables, such as through shared power conversation hardware and increased self-supply, should be explored as a route to increasing financial viability.

10) Next step: test "customer centered" business models

It is widely believed that consumers are motivated by the Total Cost of Ownership (TCO) and ease of use of transport services. Therefore V2X must demonstrate potential to reduce the TCO of electric mobility whilst at the same time offering flexibility, reliability and ease of use to EV owners. Rather than just focusing on technology, future demonstration projects should test new business models for V2X and different incentive schemes for end-users, including lease agreements, free power and bundled services. A £30M fund has recently been provided to support V2X projects in the UK, which includes 8 pilot schemes to test new business models for fleets, home users and public transport providers.

2 Acronyms

BEV	**B**attery **E**lectric Vehicle
BRP	**B**alancing **R**esponsible **P**arty
DER	**D**istributed **E**nergy **R**esource
DOD	**D**epth **Of** **D**ischarge
DSO	**D**istribution **S**ystem **O**perator
EMS	**E**nergy **M**anagement **S**ystem
EV	**E**lectric **V**ehicle (**P**lug-in **E**lectric **V**ehicle and **P**lug-in **H**ybrid **E**lectric **V**ehicle)
EVSE	**E**lectric **V**ehicle **S**upply **E**quipment
LOM	**L**oss **Of** **M**ains
LoLP	**L**oss **of** **L**oad **P**robability
OCPP	**O**pen **C**harge **P**oint **P**rotocol
OEM	**O**riginal **E**quipment **M**anufacturer
PEV	**P**lug-in **E**lectric **V**ehicle
PHEV	**P**lug-in **H**ybrid **E**lectric **V**ehicle
SOC	**S**tate **of** **C**harge
TCO	**T**otal **C**ost of **O**wnership
TLS	**T**ransport **L**ayer **S**ecurity
TSO	**T**ransmission **S**ystem **O**perator
V2G	**V**ehicle to **G**rid
V2H	**V**ehicle to **H**ome
V2B	**V**ehicle to **B**uilding
V2L	**V**ehicle to **L**oad
V2V	**V**ehicle to **V**ehicle
V2X	**V**ehicle to **E**verything

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4 Introduction

4.1 Background

The IA-HEV Executive Committee (ExCo) unanimously approved this task at the Executive Committee meeting in May 2014 held in Copenhagen. It was expected to continue until December 2016 but it was extended until the end of 2018.

This task explores the technologies and accompanying issues associated with the use of electric storage from plug-in electric vehicles (PEVs) for uses other than powering the vehicles. Customers may use their PEV electric storage capabilities for other applications such as vehicle-to-grid (V2G), vehicle-to-home (V2H), vehicle-to-load (V2L) or vehicle-to-vehicle (V2V). The main characteristics of these applications include the following:

- **V2G**: Electric utility may be willing to purchase energy from customer during periods of peak demand, and/or use the EV battery capacity for providing ancillary services.
- **V2H**: Use of the PEV as a home generator during periods of electrical service outage and for increasing self-generated renewable energy usage.
- **V2L**: Use of the PEV storage to provide power to a remote site or load that does not otherwise have electrical service. Examples include construction sites or camp sites.
- **V2V**: Use of the PEV storage to transfer electrical energy to other PEVs in case of emergency.

These electric vehicle applications are known as Vehicle to Everything (V2X), a term that represents the strategic technology for ensuring sustainable, secure, and cost-effective deployment of electro mobility. Note that although the possibilities are multiple, most of the research and the demonstration projects are focused on V2G and V2H applications which have shown further grid benefits and higher revenue potential.

4.2 Objectives

Task 28 aims to address the technical and economic knowledge gaps including regulatory issues preventing V2X technology to fully deploy.

The initial task objectives were the following:

1. Analyze the technical and economic viability of V2X technology, specifically, give responses to a number of identified questions.

    - When will V2X be available as a consumer application?
    - Which are the potential synergies with self-generated electricity in households?
    - Which is the value provided by V2X in terms of security of supply?
    - Which impact is to be expected on tax revenues?
    - Which are the roles of the different industry players?
    - Which is the impact of the different regulatory frameworks in different countries?

2. Develop a set of best practices by connecting and synchronizing the existing V2X research and demonstration projects.

3. Develop a policy-making toolbox and a technology roadmap definition in order to serve decision makers seeking to introduce V2X technology in their respective countries.
4. Establish a worldwide technical information exchange platform enabling information sharing among scientific institutions and industrial representatives working in V2X issues.
5. Promotion of new V2X technology demonstration projects.

The gained knowledge and results of such analysis can be used by policy-makers and industrial partners in the promotion of V2X technology as well as by different players on the EV market within their market research and business modeling.

4.3 Working Method

Utilizing the existing HEV framework, Task 28 provides the opportunity to bring together the key actors in the EV industry including research and industry players and energy policymakers in order to discuss the requirements for the development and the use of V2X technology. Biannual meetings are programmed on different strategic topics. By leveraging the technical skills and different experiences of the participants, it will be possible to improve the currently available market analyses of V2X technology.

In addition to expert workshops, a close relation and coordination major V2X technology players is planned in order to connect existing V2X research and demonstration projects. The promotion of new V2X technology demonstration projects will be done by collaborating with international organizations and call for proposals.

5 Activity

5.1 Participants

The Task started with four member countries in 2014 but since has grown to comprise eleven member countries and three private companies, summarized in Table 1 below.

Country	Organization	Description
Spain	IREC Institut de Recerca en Energia de Catalunya Catalonia Institute for Energy Research	Operation Agent for Task 28 and Catalan Energy Research Institute working in building energy management and smart grids, including several V2X projects.
Canada	Natural Resources Canada	Government agency responsible for management of Canada's natural resources. Main contributions on battery degradation of V2X.
United States	U.S. Department of Energy Energy Efficiency & Renewable Energy	Government agency responsible for energy and involved in promotion of EVs and V2X in the U.S.
France	CentraleSupélec	Research institute focused on innovation and applied science.
Switzerland	Bern University of Applied Sciences	University with active energy research departments including solar PV lab.
Ireland	ESB Energy for generations	Republic of Ireland's national TSO and owner of generation infrastructure and EV charging infrastructure in UK and Ireland.
Denmark	DTU	Technical university and smart grid lab developing V2X technologies and standards. Involved in several V2X pilot projects in Denmark doing V2X aggregation.
Netherlands	Amsterdam University of Applied Sciences	Technical university involved in V2X technology projects and business model development.
Germany	Fraunhofer ISI	Research organization focused on developing of application-oriented technology.
United Kingdom	Innovate UK	Government agency responsible for facilitate innovation and growth in UK business and industry. Currently leading on UK national funded for V2X demonstration projects.
South Korea	울산대학교 UNIVERSITY OF ULSAN	University involved in research projects to develop V2X technologies and test standards.
Nissan (Japan)	NISSAN	Vehicle manufactures and one of the leading companies developing EV and V2X technology.
Endesa (Spain)	endesa	Energy company working internationally on electrity generation, supply and distribution.
Vedecom (France)	INSTITUT VEDECOM DU VÉHICULE DÉCARBONÉ ET COMMUNICANT ET DE SA MOBILITÉ	Research institute with goal of developing disruptive mobility technologies. Working on development of new V2X technologies and standards.

Table 1 - Task 28 participants

In addition to the organizations officially involved in Task 28, a number of other organizations have participated in the workshops and contributed with presentations and panel session.

5.2 Expert Workshops

Work has been carried out by means of bi-annual international expert Workshops that provide the opportunity to bring together the key actors in the EV industry, including research and industry players and energy policymakers in order to discuss the requirements for the development and the use of V2X technology. A summary of these workshops is provided in Figure 1 below.

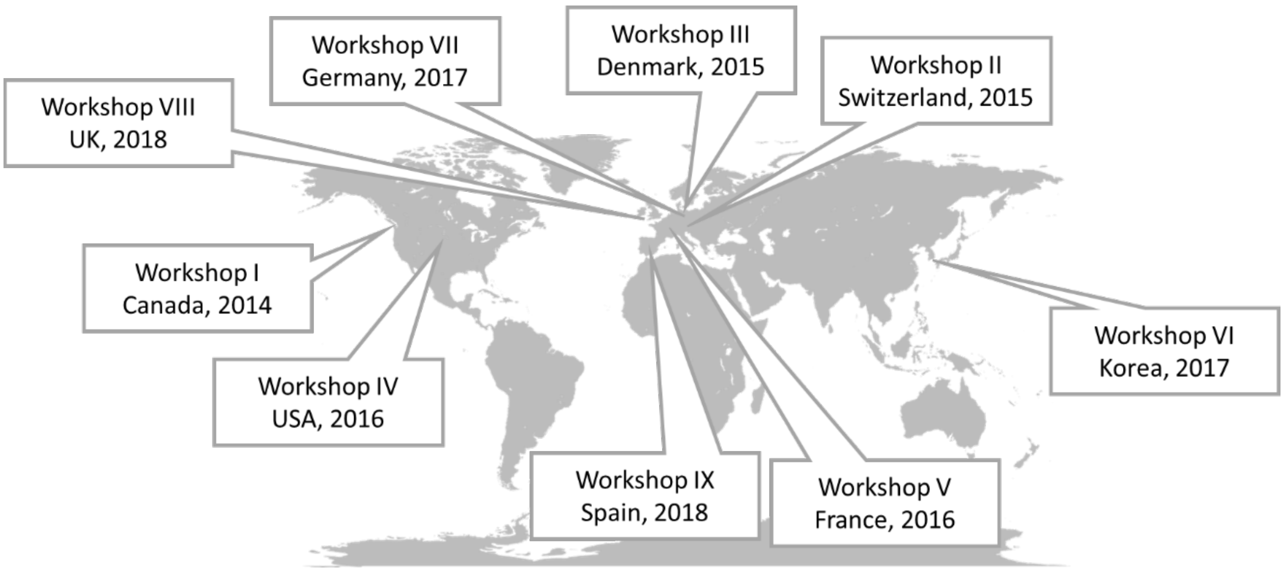

Figure 1 - Map of expert workshops 2014 – 2018

1. **Workshop I: User requirements, business models and regulatory framework of V2X technology.** Task 28 held a half day workshop on in Vancouver **(Canada)** on October 27, 2014, immediately prior to the EVI V2X Workshop. There were about 16 international attendees, mainly from Canada, US and Europe. They were a good mix of research centers, universities, industry representatives and decision makers active in V2X activities. The intended outcomes of this session included: user requirements, current and future business models and the existing regulatory framework of V2X technology. The workshop attendees addressed these questions through a combination of technical presentations that were concluded by a round table on identified V2X regulatory challenges. Main results from this workshop were shared afterwards with a wider international audience attending the EVI V2X Workshop.

2. ***Workshop II: V2X Technologies and the Power System.*** Workshop held in Burgdorf (**Switzerland**) on 15-16 April 2015. It included panels on home grids, communication and protocols and on opportunities of V2X integration into power and energy markets

3. ***Workshop III: V2X Flexibility Aggregation, BEMS and Bidirectional Chargers.*** Workshop held in Copenhagen (**Denmark**) on 26 - 27 October 2015. It included panels on aggregation

and regulatory framework, bidirectional chargers, grid codes and building energy management systems.

4. ***Workshop IV: V2X enabled EVs.*** This Workshop was held in Denver (**United States**) during the 18 - 19 May, 2016. It included panels on interoperability standards, V2G participation in US demand response market, battery degradation models and market potential as a function of mobility patterns.

5. ***Workshop V: V2X User's perception, business models and regulatory framework***. The Workshop took place in Paris (**France**) during the 26 and 27 October, 2016. The topics of discussion included business models, V2X challenges for field implementation, V2G experiments and internal diffusion and user's engagement.

6. ***Workshop VI: V2X Business models, recent developments and international pilot projects overview.*** This Workshop was held in Jeju Island (**South Korea**) during the 21 and 22 March 2017. The workshop had a specific focus on V2X business models, recent developments and international projects review. Korean electric vehicle (EV) market and V2X development in Korea were also addressed with input from local partners. A V2X international pilot projects session reviewed experiences in US, Denmark, UK and Switzerland including a review of EV market in Thailand. Other relevant topics addressed were Distribution System Operator (DSO) perspectives for V2X development, standards and potential of plug-in hybrids for V2X. A technical visit to e-Bus battery swapping facility was organized in addition to a visit to the Korean Renewable Energy Center in Jeju island.

7. ***Workshop VII: V2X insights and applications.*** This was a session that took place within the 30th International Electric Vehicle Symposium & Exhibition (EVS 30) in Stuttgart (**Germany**) on the 11 October 2017. The topics presented where "V2X protocols" by CHAdeMO, "Fiscal barriers" by ElaadNL and "V2G as and economic gamer" by INSERO.

8. ***Workshop VIII: V2X market potential and business models*. **This session took place on the 20 March 2018 in Newcastle (**UK)**, with support from Newcastle University. The session was scheduled to coincide with the UK Energy Storage Conference and covered the topics of technology development, market potential and business models.

9. ***Workshop IX: V2X Technology.*** This final session of Task was focused on scientific research and lessons learnt from industry and was held in Barcelona **(Spain)** on the 6 and 7 June 2018. The session included presentation and panel sessions, coving topics including battery derogation, new standards and optimization for markets and building integration. There were significant contributions made from Canada, the EU and Korea.

5.3 Other Events

As well as expert workshops, Task 28 has participated in several other events relating to V2X technology:

- Talk on **"Vehicles to buildings: electric cars as storage systems" at** WSED'17 (World Sustainable Energy Days) in Wels **(Austria)** on the 2 and 3 March 2017.

- **EEVC Round Table: Challenges and opportunities for V2G applications as part of the EV massive roll out.** Round table at the European Battery, Hybrid & Fuel Cell Electric Vehicle

Congress held in Geneva (**Switzerland**) on the 14 and 16 March 2017. The participants where representing car OEMs, distribution system operator (DSO), protocol developers and demo projects.

- Talk on **"V2X insights and applications"** at 2nd V2G Conference in Amsterdam **(Netherlands)** on the 11 and 12 May 2017
- 31th International Electric Vehicle Symposium & Exhibition (EVS 30) in Kobe (**Japan**)
- IEEE Smart Grids for Smart Cities Forum in Genk (**Belgium**)
- **Presentation on Task 28** at Vehicle Grid Integration Summit, **Denmark,** 21-22 November, 2018.

5.4 V2X Roadmap

One of the outputs from Task 28 is a "V2X Roadmap", which may be used by policy makers and industrial partners in the promotion of V2X technology. In it, an overview is given on V2X applications and routes to generate value. A description of the current state of the technology and pilot projects is also provided. Finally, key barriers slowing the development of V2X technology are identified, along with goals and actions required to support and accelerate development.

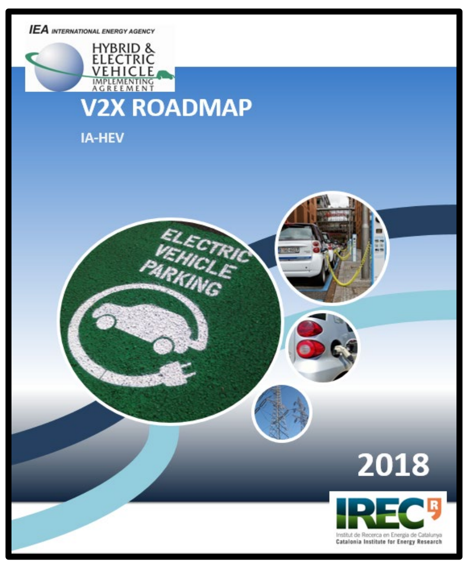

Figure 2 - V2X Roadmap

6 Lessons Learnt from Expert Workshops

In this section of report the lessons learnt from each year of the project have been summarized, based on text submitted for the annual HEV-TCP book publications. These comprise a synthesis of presentations and panel discussions that took place at each of the workshop(s).

6.1 2014 – Canada

EV user requirements

Users will be driven by the total cost of ownership (TCO) of a transport mode. V2X technologies can bring down TCO by a number of added value services that EVs can deliver (e.g. TOU rate arbitrage, emergency power, demand charge avoidance, etc.) only if proper regulation is put in place.

The ease of use for different technologies is an essential requirement for EV users. They need education and engagement programs to understand the impact of their driving behavior in battery performance as well as the opportunities to maximize their benefits via V2X activities. Warranty implications of V2X activities is an essential factor for EV users as it will directly impact their TCO.

In addition to the technical and economic factors, EV users might be concerned about privacy issues and cyber-security.

Business Models

The viability of different business models and use cases for V2X technologies are directly dependent on country regulatory framework and local specificities. A number of cases are presented to exemplify it:

- US driving patterns do no match use of EV for renewable energy self-consumption (charging with excess PV generation during the day and discharging during the evening). Net metering policies do not support the development.
- Strong Government incentives in Japan for V2H systems for emergency backup power. From May 2012, NISSAN launched LEAF to home in Japan and developed a charge/discharge bidirectional inverter.
- V2G opportunities benefits from a better environment than other V2X activities in US regulation. Power availability benefits ($/MW) are higher than utilization benefits ($/MWh).

For a business to take advantage of value streams associated with V2X, the standardization of the different concepts included in V2X technology is required (e.g. communications, interoperability, etc.).

European grid codes are moving in the right direction for V2X business model to become viable. It was concluded that mandatory services to balance the grid (e.g. not remunerated automatic primary regulation provision), existing in a number of countries for synchronous power generating modules, should be avoided for V2X business to become viable.

Regulatory framework

A number of barriers were identified for V2X business to deploy:

Limited payback for V2H applications in US (for a rate arbitrage application, most US customers lease vehicles and would need paybacks lower than 3 years; for a backup power application it does exist cheaper generators alternatives).

- In V2G applications, it operates in wholesale markets which are fluid and paybacks are uncertain.
- Energy storage in 2014 is very competitive and may rend V2X opportunities non-financially interesting.
- Need to characterize the impact to the battery of different applications and understand warranty implications.
- Split incentive problem: power system could benefit from V2G technologies while OEMs may face the liabilities.
- Vehicles need to meet utility and the aggregators' interconnection requirements.
- EV has not been defined yet as a storage energy resource.

There are broad variations in V2G regulations (different building, electric and residential codes and standards, different procedures for permitting), utility services and policy structure within different regions in the US, rendering V2G deployment difficult. Non homogenous permit fees are bringing uncertainty to the business modelling and representing a market barrier. It was evidenced the importance of working towards common practices and nationally approved standards.

Regarding international and regional technical standards for V2X technology, it is worth to note that they should take into account the power electronic features that ancillary services will require (e.g. time of response, utilization, etc.). Additionally, in order to move towards a regulatory framework allowing VX2 technology to fully deploy, market players and demonstration projects should be exempted of certain technical regulations to encourage trial and error.

A new stakeholder appearing in the V2X market is the so-called EV aggregator. The aggregators will have the fundamental role of presenting an EV fleet as a unique entity to the TSO when participating in V2G applications. The paper of an EV aggregator for V2G applications is necessary because of a number of reasons: a unique EV does not have sufficient power capacity to contribute to frequency regulation services, the TSO need to ensure the reliability of their reserves and a unique EV cannot assure its full time connection and finally, TSOs do not have sufficient connection means to connect to individual EVs .

6.2 2015 – Switzerland and Denmark

PEVs and Home Grids

Regarding V2H, Japan has become the first real market in 2015 for V2H technologies as a backup emergency power. A number of prefectures incentivize its usage in order to reduce peak power demand and increase power supply reliability after the shutdown of a number of nuclear power plants in 2011. Degradation effects on the EV battery for V2H applications have been proved to be similar as the effects from fast charging operation.

V2G could help to smooth peaks in demand; reducing electricity cost and increasing energy reliability. Denmark and Germany represent an attractive market for V2G due to the high share of renewable energy sources in their electricity mix. Distribution system operators (DSO) are interested in analyzing the potential for different V2G applications. It is already recognized in countries such as Switzerland the relevancy and opportunities of distributed energy resources and smart grid solutions to tackle distribution congestion issues; a centralized control (demand side management) by the distribution system operator (DSO) is carried out; in the future, demand response (DR) strategies are to emerge.

Communication and Protocols in V2X

Standards are needed to harvest V2X properties such as the fast response time, high power load, possibility of V2X support and high degree of flexibility.

Regarding standards from EV to EVSE, ISO 15118 includes a F5 sub-case on V2G but, in 2015, further developments are needed. CHAdeMO has become the de facto protocol for V2X projects and has been used in over 3000 bidirectional chargers in Japan. Currently available communication protocols can be used for V2X applications, but real time control (i.e. those controls required by TSO/DSO services) are not so well supported (e.g. ISO 15118 delay between seconds-minutes).

Between EVSE and back office system, the enabling protocol is the OCPP 2.0. Some new features of OCPP 2.0 compared to OCPP 1.2/1.5 have been introduced, such as pricing, smart charging and monitoring.

In accordance to the general view of the experts attending the workshop, standardization should be in place by 2017 when the business model for V2X will be clearer. It was agreed that might be useful to focus on guidelines and use cases instead of full standards. Standardization bodies have the risk to be too slow while product development cycles are too fast.

Aggregation and Regulatory Framework

In 2015, aggregation of V2X applications are mainly focused on V2G services for transport system operators (TSOs). A regional transmission organization in US is currently operating and providing ancillary services regulation (in October 2015, 300 kW tested, registered from EVs). In Denmark, aggregated EV with V2G capabilities operating experimentally are providing frequency-controlled disturbance reserves (pre-commercial, not yet registered, but following rules and providing reserves). Results so far show that V2X technology (bidirectional charging) is eight times the value of unidirectional (controlled charging) although more complex.

Regarding the regulatory framework, TSO rules were historically designed for large thermal power plants and that poses a challenge to qualify distributed storage. Markets designed for slow thermal do not allocate full value to very fast-responding resources.

A potential third-party aggregator will be in charge of gathering small flexibility providers (V2X enabled EVs together with other flexibility sources) in order to sell their services in the electricity markets. This scheme has possibilities in the electricity markets, however regulatory schemes need to be clarified (e.g. currently flexibility activation is blocked by intermediary players).

So far V2X applications for DSOs have been only tested at research level. However, there is a huge potential for these services (voltage control & congestion management in the short, medium and long term). Combination of TSO/DSO V2X market applications should be considered to maximize the value of V2X. Its optimal combination and potential saturation should be further investigated. Further coordination between DSO/TSO is essential for ensuring the creation of a common marketplace and regulatory framework which guarantees a transparent, secure and cost-effective flexibility services provision.

Bidirectional Chargers

In 2015, there is not a real mass market for bidirectional chargers. Subsidies could help the uptake of this technology, but proper cost-benefit analyses including positive externalities would be required in advance. In Europe there is an existing market development, but it could always be faster. A key limiting factor is the fact that no two markets are alike: different legal markets, bound of difficulties when entering the public grid.

Synergies among V2X bidirectional chargers, EV fast chargers, local DERs and local energy storage systems can improve the business models and therefore empower the market uptake for V2X technology.

Still, there are plenty of open questions to be addressed regarding bidirectional chargers:

- Should the structure be placed on or off-board?
- How to integrate customer requirements?
- How to respect electricity standards from DSO/TSO on EV side?
- How to respect charge point operators requirements?
- How to prepare an electricity market environment?

Grid Codes and Building Energy Management Systems

In 2015, there are no clear standards for bidirectional chargers connection to distribution networks. As a first step photovoltaic generation modules standards can be extrapolated together with other more general micro-generation connection rules. So far, standards outside Europe and US are lagging behind with less or no focus on grid support mechanisms; there are lower levels of penetration, so fewer issues are experienced.

Existing network design rules and congestion management mechanisms should be adapted and an active role of the DSO on V2X chargers operation should be required.

Energy management systems are key tools for V2X chargers and interaction with DSO. They are also required for V2H applications such as peak shaving, renewable energy sources integration and energy arbitrage applications.

The available communication protocols in 2015 should be adapted in order to increase the number of parameters to be included (charging time, amount of energy, V2X authorization, tariff, power limits, etc.). The EMS – EVSE architecture should also be reviewed, currently there are too many gateways that difficult real-time applications realization.

6.3 2016 – United States and France

V2X Grid services standards

One main conclusion is that standards for ease the participation of PEVs in grid services through V2X face different challenges around the world. Experts from Europe and the United States analyze the difference in V2X standards:

Challenges on V2X Standards in US: the main challenge is the lack of standards versus the need of them. On one hand, the SAE (Society of Automotive Engineers) has its recommended practices but not standards. On the other hand, regulatory bodies and utilities do not accept recommended practices. Specifically, utilities need to certify equipment sending power to the grid and require that the equipment comply with Underwriter Labs (UL) standards. Additionally, utilities have traditionally dealt with stationary hardware but PEVs could plug-in anywhere and pose a challenge on the portion of interconnected equipment that should be approved.

Challenges on V2X Standards in EU: in EU there are some already defined and used standards; EVs are providing grid services using IEC61851 and CHAdeMO, although security aspects are still weak. IEC15118 is the only standard used from the EV to the EVSE (Electric Vehicle Supply Equipment), including TLS (Transport Layer Security) encryption, however this ISO (International Organization for Standardization) has a slow response time (i.e. order of magnitude of 60 s). From the EVSE to the back-end, the standard used is IEC61850 which only includes technical parameters (missing identification, billing, etc.); OCPP version 1.6 does not include V2G features although it is expected that version 2.0 will do (with some further details included such as SOC (State of Charge), identification and higher security requirements). Standards developments run behind pilot projects.

V2X Business Models

Since the beginning of the task, an important issue to be analyzed has been the V2X business models. V2X economics depend on the integration with other components: the payback time can be considerably reduced when increasing the penetration of solar panels (strongest market) and optimized charge/discharge cycles. According some US experiences, revenues for the end-user are quantified as 1,800 USD for grid services; 600 USD for peak shifting and 0 USD for emergency backup a year. Nevertheless current models are not sustainable since compensations have been estimated at 20 times expected aggregator revenue.

The participation of a PEV aggregation in day ahead and reserve electricity markets needs to quantify the amount of energy that could be call. Also, other approaches for massive PEV's management could be the PEVs fleet clustering based on departure time or maximum power.

Business model innovation/value proposition reconfiguration can help to compensate for technological inferiorities and create a more attractive value proposition (discharge technologies) to enhance customer engagement. V2X technologies have the potential to reshape the EV value proposition: EVs have points of superiority to exploit V2X technology better than the incumbent ICE technology. Besides, there are actually opportunities to expand the V2G value proposition to other vehicle fleets such school buses.

All markets are trying to adapt themselves to enable distributed energy sources to participate. Until 2016, there is no country using distributed resources to deliver large regulation reserves.

Effects of usage profile on battery lifespan and battery degradation models for V2X

Some interesting conclusions on battery lifespan and battery degradation have been presented during 2016 workshops.

One important novelty from the analysis presented is that calendar fade represents the most significant factor for battery degradation; physical reality cannot be ignored. Previously identified important factors such as time, temperature and SOC at which battery sits have been proven to be high significant factors in battery degradation. Actually, maintaining the SOC close to 50% is crucial for battery degradation mitigation.

Therefore, the impact of V2G services on PEV battery life depends mainly on how the PEV is used in regular driving and recharging and not in V2G services. An extreme case of daily discharging the full PEV battery for V2G purposes results in 3 or 4 years lifespan reduction. Moreover, if we take into account pros and cons of V2G services in terms of battery degradation, frequency regulation market results to be the most interesting market given that it requires lower energy transfers.

Battery degradation is a real concern among the potential EV consumers and it poses a challenge for the roll out of EVs and more specifically for V2G services development. It is therefore convenient to keep devoting resources to continue the research around this topic.

V2X Experiments

By 2014, 3.15 billion EUR had been invested in European on smart grid projects. Several world-wide projects have been presented during the workshops whose main goal is to demonstrate the potential and benefits of the EV integration into energy systems. The IEA expects a further 600 billion EUR of smart grid investment in Europe from 2014 to 2035.

Following one of its objective, this task is building a catalogue on V2X experiments and projects around the world. **Error! Reference source not found.** represents a summary of the first version of the catalogue.

Some of the conclusions presented in the experts' workshops as result of world-wide demonstration projects investigating topics related to V2X technologies are the following:

When practice is applied, complexity regarding sub-metering and charge-based metering requirements, physical production of suitable chargers and aggregation testing has been observed.

Revenue potential of bidirectional chargers has been proven to be more than 10 times higher than for unidirectional ones.

In general, pilot projects have shown that technical barriers are less important than social and regulatory issues.

User's engagement

How to motivate people to participate in the market? The decision to plug-in is dependent of different factors: inconvenience, benefits regarding using gasoline, battery space, environmental issues, etc. In order to encourage people to plug-in some actions could be taken such as increasing battery size, decreasing transaction costs or increasing the gasoline cost. Incentivizing users per plug-in event would also certainly stimulate the willingness to plug-in.

PEVs with small capacity batteries can only ever generate small financial returns and plugging in tend to fade away over time. They require additional incentives. End users prioritize upfront discounts or a pay-as-you-go contract (rather no obligations).

In one workshop, an interesting analysis from Germany was presented. In the case of Germany there is not yet a real electro-mobility take off. This has been attributed to politico-economic reasons, path dependencies and behavioral inertia. Another possible further reason could be a weak offer from car manufacturers. The project carried out in Germany wanted to encourage people to plug-in their vehicles when arriving at home enabling smart charging showed that they trusted the system and agreed on the suitability and effectiveness. Reliability, flexibility, smarter systems and financial incentives emerged as key elements in user behavior.

Final remarks

During 2016 expert workshops, there have been detected challenges on the V2X market for all stakeholders: the low EV sales volume does not seem to justify investment in technology for utilities and battery degradation costs. Equipped EVS with bidirectional capabilities are not obvious for OEMs (Original Equipment Manufacturer) and there is a need to clearly identify compensation for grid services to the owners. The development of these technologies has been also slowed down due to the scarcity of politico-economic support.

6.4 2017 – Korea and Germany

Insights on Korean EV market and demonstration projects

The VI workshop was dedicated to Korean and Asian markets, with special focus on demonstration projects review, business models and recent technology developments. The 2017 EV market in Korea is as follows: an estimated 12,000 EVs are on the road, a total of 9,300 charging points are available and 1,300 fast chargers are installed (considering both public available and private ones belonging to KEPCO). The 2020 targets are: 250,000 EVs, 50,000 PHEV and 3,000 fast chargers.

Korean policy does not only address incentives but also technology development (such as increased range, reliability and efficiency) and infrastructure policy and deployment as key elements for EV massive penetration. As an example, incentives are slowly decreasing in time but special promotion campaigns for residential apartment buildings charging infrastructure have been launched with a target of installing 30,000 charging points.

From the point of view of the Korean DSO, KEPCO, the key elements for EV integration in the Korean energy system are the integrated EVSE platform development. In the Jeju island pilot project (2016-2030), they are developing an AC/AC V2G charger including V2G service demonstration (2015-2017), building security infrastructure for Smart Grid vulnerability test & analysis (2015-2017) and developing a 6.6 kW wireless power transfer EV charger (with special focus on luxury class EV's and autonomous EV). The services planned to be introduced are demand response (peak reduction and load levelling) at distribution level. At present, V2H is limited due to regulation but can be performed as a demand response (DR) service through a EVSE or V2G provider.

The Korea Automotive Technology Institute presented the evolution of the automotive industry in Korea which after 60 years of evolution enters into the globalized advanced country in the world unprecedently: total of 900 Tier-1, 3,000 Tier-2 & 5,000 Tier-3 parts companies are collaborating with 14 assembly sites of 7 OEMs in Korea. Internationally, Hyundai-Kia motors are producing 2.5million vehicles in 10 plants abroad. The Eco-car in Korea (supported by government's law) focuses on eCar (PEV, HEV/PHEV, and fuel cell-FCEV) and clean and efficient ICE. In parallel, the government is promoting EV charging and fast charging infrastructure in Korea. Hyundai has launch its first full electric vehicle Ioniq EV and Kia is planning its first own electric version of Kia Niro. Both companies are commercializing HEV and PHEV since 2016.

EV status in Thailand

HEV and PHEV demand is increasing (80,000 cumulative sales through 2016) while BEV decreasing. National Reform Council (NRC) proposed an action e-Mobility plan to the government (in 2015) based on promoting Thailand as an Association of Southeast Asian Nations (ASEAN) Electric Vehicle Hub, promoting Electric Vehicle usage on Thai roads, promoting Electric Vehicle production in Thailand, supporting local EV companies, supporting R&D of EVs parts and charging infrastructure and supporting investments on EVs.

The main demonstration project, EVAT, is a 100 EV charging station project supported by EPPO (Thailand Ministry of Energy). It includes fast and normal charging points for hotels, offices, condominium, etc., together with the launch of a communication platform and scheme with shareholders, namely EV users, charger owners, and service providers. Special attention is placed on standardization of protocols and connectors for charging systems and services. A registration database is proposed for 4 categories of EV's (with the 4 categories being electric motorcycle, electric 3-wheelers, electric 4-wheelers, and tractors). The other relevant demonstration project is the eTuk Tuk with the scope of replacing 22,000 Tuk Tuk motors with electrical motors by 2021.

Fiscal barriers for smart charging

ElaadNL presented during the EVS30 an interesting analysis on the fiscal barriers that the smart charge and V2G have to face. The main important regulatory questions that arise during the talk have been analyzed also previously in other expert workshops:

- Does the smart charging qualify as energy supply?
- Between what parties is this supply effected?
- How does smart charge relate to netting?
- How does smart charge relate to self-generated power exemption?

Different case studies were presented where these questions try to be answered in different countries and demonstration projects. Lomboxnet project (Utrecht, Netherlands) has installed a number of solar PV systems are directly linked to charging points in the area, bi-directional charging points allow generated solar energy to be stored temporarily in EVs and to be re-delivered at later time, increasing own use and allowing storage to be used to balance the local grid.

Another interesting project presented is a set of fast charging points installed in a highway, each installation consists on a solar PV system, a charging station for four EVs and a battery system.

The power consumption from the grid is lower due to storing of solar energy in the battery allowing the grid operator to avoid grid reinforcement.

One of the highlighted fiscal barriers is the absence of financial stimulation to EV owners that also have solar panels, that will allow optimization of own consumption and an enhance usage of the self-generated electricity. Moreover, when adding V2G technology there is the possibility of suffering double taxing, one when the vehicle is charged and one when it is discharged.

6.5 2018 – United Kingdom and Barcelona

Markets and Regulation

Demonstration projects in Europe have highlighted a number of challenges when it comes to connecting to grids and participating in energy markets. Since most DSOs are not use to qualifying EVs or EVSE as generators, V2G projects have regularly experienced slow and costly network connections.

Further, TSO frequency regulation markets are challenging for aggregators to enter, since there is significant variation between countries, pre-qualification process are complex and market design is often ill-suited for V2G aggregation. Denmark is home to the first commercial V2G scheme, where TSO frequency response is provided by an aggregator in return for annual revenue of around €1,400 per EV. A study from Canada also showed the potential for V2X to generate energy cost savings of around 20% through peak shaving and frequency regulation. However, in many counties flexibility markets have been very competitive in recent years and the risk of market saturation could threaten the business case for V2G.

In Spain, regulations have proven to be prohibitively expensive for V2X and the priority in this region is to change regulation to permit the entry of aggregators into electricity markets. Other countries in Europe have reported other bottlenecks to development, such as taxes for energy storage and interoperability.

Technology Development

A number of projects are underway in Europe and Korea to test and develop bidirectional AC charging system, comprising onboard DC/AC converters. This type of V2X charger is less developed than the DC equivalent and more work is required to upgrade hardware and software for these system. There is also a need for grid code modification to connect AC V2X chargers and the development of performance indicators to maintain service quality.

Several standards have been updated to include provision for V2X, although more work is required to harmonize these with existing charging protocols and grid codes. Current standards for V2X include: IEC/IOS, CHAdeMO, OCPP, OSCP, and OpenADR. There are three requirements of standards in order to unlock grid connection and energy market participation: (1) controllability, (2) observability and (3) performance measurement. Several projects in are underway in Europe and Korea to test new V2X standards for reliability and controllability. This includes the implementation of the ISO 15118 protocol in new bidirectional DC and AC chargers in Korea. France is also carrying out tests on new protocols, including speed tests which have shown reaction times of AC charges to be within a few seconds, sufficient for grid services such as voltage control.

Customer Engagement and Business Models

Demonstration projects to date have focused on the development of technology, whilst customer engagement and business models remain largely unexplored. The next generation of V2X demonstration projects will need to test what motivates EV users to adopt V2X technology and develop novel business models to share benefits between stakeholders. Amsterdam University has recently carried out research on possible incentive schemes, including gamification, air miles, free power and bundled services. Other factors, such as environmental responsibility and energy autonomy may also influence the V2X value proposition to end users.

In the UK a £30M fund has been made available for 8 V2X demonstration projects to develop and test customer centered business models. These project will focus a range of user groups, including commercial fleets, public transport providers and domestic users. Several of these projects will also offer services to the DSO, thus developing new value streams for V2X based on local grid support.

Battery Aging Impacts

Three presentations from Canada were given on battery aging. The first explored how the battery aging impacts of V2X may change with the 2nd generation EVs, which will have larger battery capacities than their predecessors. V2X impacts were simulated to be significantly reduced in 2nd generation EVs, down to near negligible levels. This was due to large batteries extending the battery End of Life (EoL), such that additional aging caused by V2X did not result in a short lifespan for the EV or trigger the need for battery replacement.

Another study looked at battery aging impacts under non ideal isothermal conditions. Pervious battery aging models have assumed that the temperature of the battery has been in an idea state, which is not the case under real driving conditions. The simulation and lab results indicated that battery life could be reduced by 1 to 2 years compared with ideal conditions, depending on the battery cooling system uses. These impacts are much more significant than V2X impacts.

The final study explored the business case for V2X in Canada, taking into account the cost of battery aging. Results indicated for most applications of V2X in most provinces of Canada the benefits for providing V2X services are not sufficient to offset battery aging impacts. The two applications that seem to be net positive were V2H back-up generation, since this elevated the capital cost of a generator, and TSO spinning reserve, which experiences few calls and low volumes of energy throughput.

7 Conclusion and Next Steps

The objective of Task 28 was to identify the knowledge gaps and barriers prevents V2X technology from fully deploying. This has been achieved through nine expert workshops to bring together researchers, industry and government to discuss the key technical, regulatory and social issues which influence V2X. Further, Task 28 has participated in a range of other events and collaborated with related HEV Tasks, as well as producing a V2X Roadmap to support stakeholder planning.

The headlines from the project, presented at the beginning of this report, are:

1- Technology still at the research and development stage
2- Japan has developed first V2H mass markets
3- V2G aggregation in fleets is the most promising opportunity
4- Lack of V2X enables EVs and EVSE in the market
5- Battery aging impact of V2X is minimal
6- Standards getting better but more work still required
7- Aggregation still a challenge in many countries
8- Levels of public awareness of V2X technology are still low
9- Competitively of flexibility markets risks viability of V2X
10- Next step: test “customer centered” business models

Moving forward, a range of activities need to be undertaken by stakeholders relating to technology development, markets and regulation and social acceptance of V2X technology. This includes making changes to regulation to overcome barrier to grid interconnection and power injection, as well as changes to electrity market designs to enable entry of new actors, such as aggregators. Industry players will also need to show commitment to embed V2X capability in EVs and follow global standards to ensure interoperability, replicability and harmonization with existing systems. Large scale demonstration projects which test different forms of customer engagements and new business models is the most important next step.

Specific goals and activities required to meet these aims are laid out in the V2X Roadmap.

Following on from Task 28, Task 43 on “Vehicle-grid Integration” is planned to commence in 2019. This task will build on the outcomes from Task 28, focusing more on the potential for EVs to support grids and participate in electricity markets.