Final report

The following final report is based on the report produced by Task 28 which is published on http://www.ieahev.org/tasks/home-grids-and-v2x-technologies-task-28/

1.1 Project details

Project title	Task 28 –Home grids and V2X technologies - Extension
Project identification (program abbrev. and file)	64018-0102
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	DTU Electrical Engineering Department of Electrical Engineering Ørsteds Plads Building 348 2800 Kgs. Lyngby Denmark
Project partners	None
CVR (central business register)	DK 30 06 09 46
Date for submission	31-10-2019

1.2 Short description of project objective and results

English

DTU has, with support by EUDP, participated in the workgroup Task 28 for more than four years. Most recently in a one-year extension (covered by this grant).

The possibility to integrate the electric vehicle in the power system as a resource capable of both charging and dis-charging is being researched and explored in several European countries, including the eleven countries represented in Task28. Denmark has positioned itself as a leading country within this field through a number of national projects.

The continued participation in Task 28 has played an important role in ensuring dissemination and networking regarding Danish knowhow on V2X, supporting collaboration with international partners and ensuring that experience from Denmark is included in the Tasks conclusions and final recommendations.

Danish

DTU har, med støtte fra EUDP, deltaget i dette samarbejde i over fire år. Det sidste år har været en del af en 1-årig forlængelse (dækket af denne bevilling).

Integrationen og nyttiggørelse af elbilen i elnettet, ved at benytte en elbils evne til både at optage og afgive effekt (Vehicle-To-Grid) er et område med stor relevans for arbejdsgruppens medlemslande (elve lande inkl Danmark) Danmark har bragt sig i spidsen inden for V2X forskning gennem en række nationale FoU projekter.

Deltagelse i arbejdsgruppen Task 28 har været et vigtigt instrument i varetagelsen af den nødvendige formidling af de danske aktiviteter inden for V2X, støtte samarbejde med internationale partnere og gøre de danske erfaringer gældende i arbejdsgruppens endelige konklusioner.

1.3 Executive summary

Task 28 – "Home Grids and V2X Technology" was carried out 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.

1.3.1 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. Task 28: Home Grids and V2X Technologies www.ieahev.org 4 Final Report (2014-2018)
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. Task 28: Home Grids and V2X Technologies www.ieahev.org 5 Final Report (2014-2018)
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.

1.4 Project objectives

Task 28 aimed 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 modelling.

1.5 Project results and dissemination of results

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.

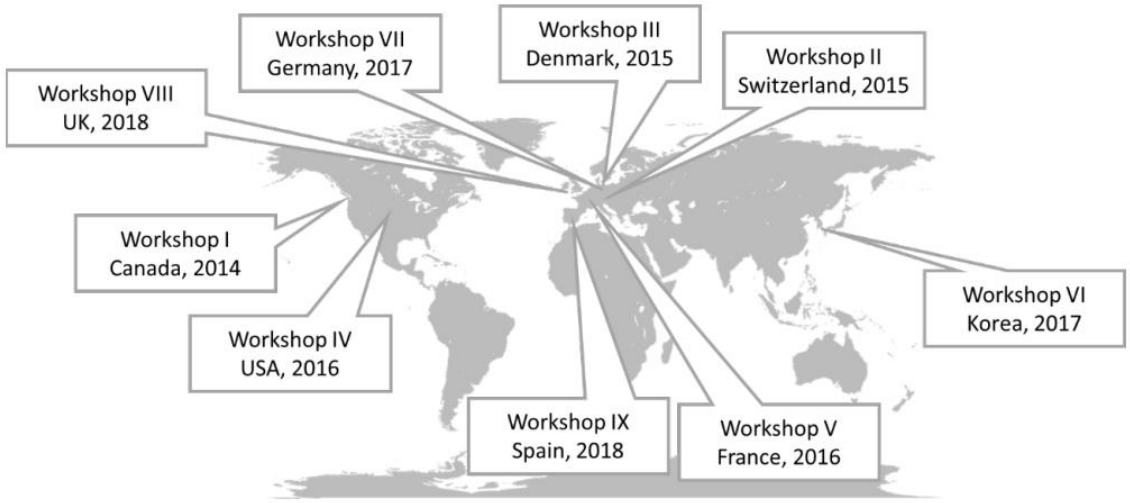

Figure 1 - Map of expert workshops 2014 – 2018

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

Workshop III: V2X Flexibility Aggregation, BEMS and Bidirectional Chargers. Workshop held in Copenhagen (Denmark) on 26 - 27 October 2015. It included panels on aggregation Task 28: Home Grids and V2X Technologies www.ieahev.org 12 Final Report (2014-2018) and regulatory framework, bidirectional chargers, grid codes and building energy management systems.

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.

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.

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.

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.

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.

<u>Other Events</u>

- 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 Task 28: Home Grids and V2X Technologies www.ieahev.org 13 Final Report (2014-2018) 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.

1.6 Utilization of project results

One of the main 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.

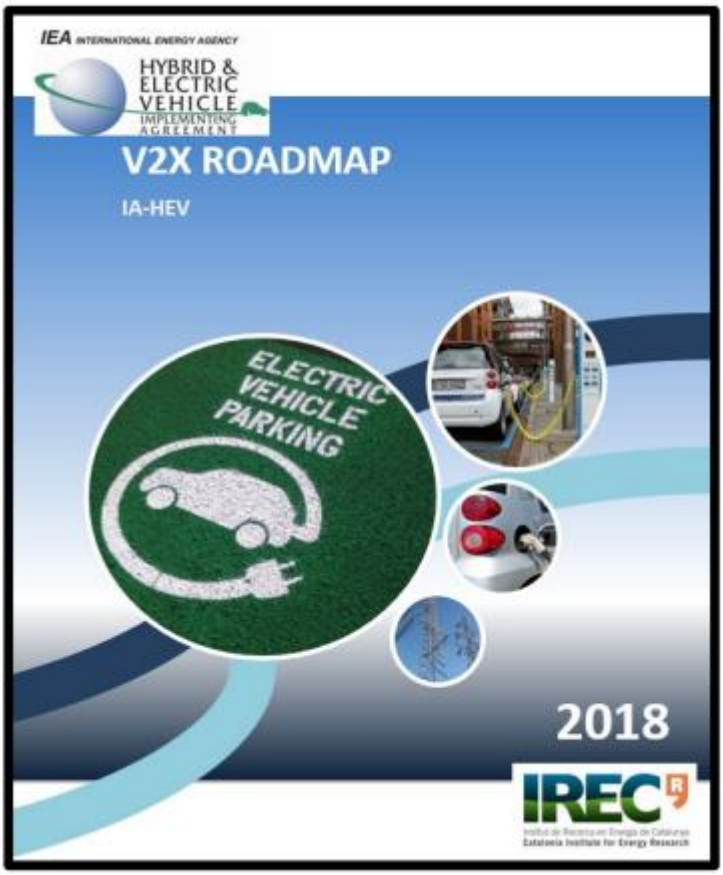

Figure 2 - V2X Roadmap

1.7 Project conclusion and perspective

The objective of Task 28 was to identify the knowledge gaps and barriers which 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 ten main findings from the project 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 electricity 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.