Business Models for Electric Vehicles: Lessons from the Japanese EV Ecosystem

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Abstract In this paper, we explore the reasons for Japan's early success in the EV industry and the challenges it faces in sustaining its growth in the future. In-depth semi-structured interviews with major players in the Japanese EV ecosystem provide substantial data to draw lessons for EV business model innovation. Current barriers to the EV market are also discussed. We address the impact of the catastrophic tsunami and earthquake that hit Fukushima Prefecture in March 2011 on the emerging EV market. Three main business models are analysed in this paper. First, we present the strategies for the development of the EV charging network in Japan from industry and government perspectives. Second, we discuss innovative business models as drivers of the market with two cases of e-mobility services in Japan. Finally, energy service business models such as vehicle-to-home and storage that allow to capture more value from electric vehicles, are discussed as drivers of entry in the EV market.

1 Introduction

The Japanese EV market is one of the earliest and strongest ones worldwide in terms of sales and industry entry. Since 2005, a combination of factors in Japan has led to the second highest levels of EV sales globally (Fig. 1). Innovative OEMs (Nissan, Mitsubishi, Toyota), a proactive electric utility (TEPCO), and leading

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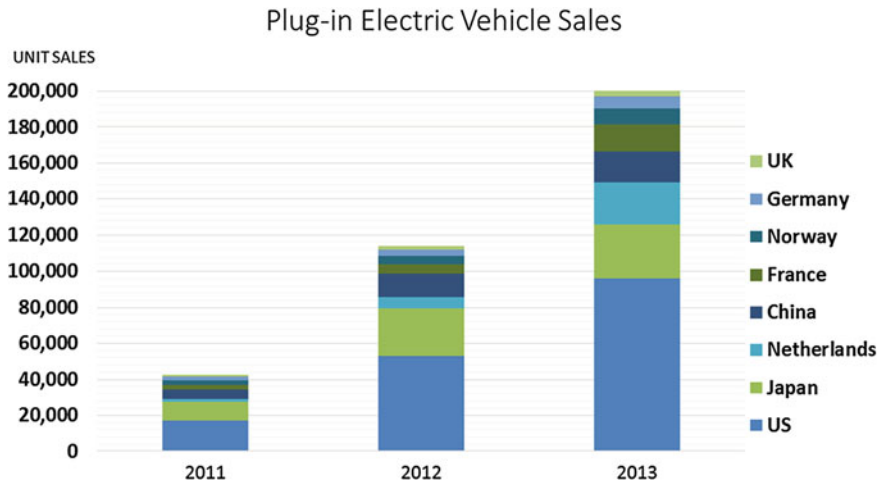

Fig. 1 Plug-in electric vehicle (PHEV & EV) sales in selected countries, 2011–2013. *Sources* Industry websites, http://ev-sales.blogspot.co.uk/

battery and energy companies (NEC, Hitachi, Mitsubishi, Sumitomo) headquartered in Japan have entered the EV market. In addition, a corporate culture that is generally supportive of collaborative R&D across organisations has made Japan a leader in the practice of "open innovation" [1] in many high-technology industries, including automotive and power electronics [2].

In this paper, we explore the reasons for Japan's early success in the EV industry and the challenges it faces in sustaining its growth in the future. In-depth semi-structured interviews with major players in the Japanese EV ecosystem provide substantial data to draw lessons for EV business model innovation. Current barriers to the EV market are also discussed. We address the impact of the catastrophic tsunami and earthquake that hit Fukushima Prefecture in March 2011 on the emerging EV market.

We analyse three main business models in this paper. First, we present the strategies for the development of the EV charging network in Japan from industry and government perspectives. Second, we discuss innovative business models as drivers of the market with two cases of e-mobility services in Japan. Finally, energy service business models such as vehicle-to-home and storage that allow to capture more value from electric vehicles, are discussed as drivers of entry in the EV market.

2 Case Study Data

This case study of the Japanese EV ecosystem is based on data collected from the Japanese EV ecosystem through in-depth interviews with experts from industry, academia, and policy (Table 1). Each interview lasted 1–2 h and followed a

Table 1 Case study interviews

Company or organisation type	Number of respondents	Role or function	Interview reference code
OEMs	4 (incumbents) 1 (start-up)	Firm founder; general managers, strategy planning departments; senior engineers	A1–A4, A5
Electric utilities	2	Senior researchers, R&D department	U1, U2
Battery manufacturers	2	General manager, battery department; senior researcher	B1, B2
Energy equipment and services providers	2	Assistant general manager, battery department; general manager	EQ1, EQ2
Industry experts	3	Research strategy	EXP1–EXP3
Academics	2	Firm founder; research	AC1, AC2
Energy management/software providers	1	Manager, executive, managing consultant, smarter cities department	EM1
Mobility-as-a-service provider	1	Environmental manager	MS1
Management consultancy	1	Consultants	MA1
Automotive research institute	1	Research director, senior chief researcher, FC-EV research division	R1
Engineering design and entrepreneur	1	General manager, design	D1
Governmental ministry	1	Deputy director and director, EV and advanced technology office divisions	GOV1

pre-defined protocol to gain an in-depth understanding of the opportunities and challenges for various e-mobility business models. The interviews were recorded, transcribed and coded in NVivo 10 to analyse content systematically according to the qualitative case study methodology [3].

3 The Development of a Charging Network

In the early days of the EV market in the mid-2000s, the largest public electric utility TEPCO (Tokyo Electric Power Company) started actively promoting the development of the market for EV charging. Through its research, the TEPCO R&D unit for e-mobility recognised the need for the widespread availability of fast-charging to alleviate consumers' range anxiety and to support EV adoption (EXP2).

The TEPCO team, led by expert Dr. Anegawa, initiated the first consortium to develop a common international standard for fast-charging called CHAdeMO. The CHAdeMO charger technology allows a 100-mile EV to fully recharge in less than 30 min at 50 kW (U1). Over 400 companies joined the consortium including RWE, Peugeot Citroen, ABB, and General Electric.[1] Since 2011, the CHAdeMO DC fast-charging connector and standard have been in use in 1,858 stations in Japan and 3,073 worldwide and 57,000 CHAdeMO compatible EVs are on the road as of October 2013.[2]

This success story has, however, been tainted by two major events. First, a competitive threat emerged with Combo, which is a similar standard for DC fast-charging technology developed by German and American automobile manufacturers BMW, Volkswagen and General Motors. While the Combo standard has yet to obtain ISO approval as of 2013, the EV industry largely predicts that it will win this standards battle (AC1, U1) and the European Parliament has already proposed to phase out financial support for CHAdeMO chargers in Europe as of 2018 [4]. Secondly, the activities of the e-mobility team at TEPCO have been severely affected by the nuclear accident in Fukushima. Visionary leader Dr. Anegawa was appointed to the nuclear asset management department to oversee the emergency response to the nuclear plants in Fukushima, and e-mobility research was largely put to a halt after the merger of the unit into the energy storage solutions unit following drastic reductions in TEPCO's R&D budget. The CHAdeMO standard will continue to be manufactured by fast-charging station providers (EXP2), despite the aggressive competition from the US/European Combo standard coupled with the change of focus in the Japanese electric energy industry following the Fukushima catastrophe.

Similarly as in many countries, the government in Japan at federal, prefecture and municipal levels plays an important role in supporting the development of the EV charging infrastructure network. The Japanese Ministry for Energy Trade and Industry (METI) recently announced 1 billion yen ($10 M) funding for slow and fast-chargers (MS1). While the government's role is not to pick technology "winners", it has supported the EV industry through R&D projects in the automotive, ICT and energy sector, particularly as part of smart city projects (G1).

The competitive landscape in the charging network in Japan is characterised by four major industrial consortia that entered the market in 2012: Japan Charge Network, CHAdeMO Charge Network, Nissan Leaf Zero Emissions Service, and the EVSS Network (Table 2). The first one, the Leaf Zero Emissions Support, is an EV after-sale service that integrates all customer needs in IT, maintenance, emergency response, and access to the fast-charging network for a fixed monthly subscription fee. Charge Network Development is a network of fast and slow-chargers in Japan run by the other three main OEMs, Toyota, Honda and Mitsubishi Motors,

[1] CHAdeMO Members list (04/10/2013). Available at: http://www.CHAdeMO.com/pdf/memberlist.pdf.

[2] Website of CHAdeMO association, www.CHAdeMO.com.

Table 2 Industrial consortia for the EV charging network in Japan

	Leaf zero emissions support	Charge network development	Japan charge network	EVSS network
Investors	Nissan	Toyota, Honda, Mitsubishi Motors, Chubu Electric Power	Nissan, Sumitomo, NEC, Showa Shell	Idemitsu Oil, Cosmo Oil, ENEOS, Showa Shell
Background	Comprehensive customer service	Spin-off from CHAdeMO, Membership sharing service model	Nissan dealers, Nexco East Japan, Family Mart	"Next Gen Gas Station" program supported by METI
Number of fast charging stations (Fall 2012)	450	188	22	29
Operations	IT, maintenance, emergency, fast charge	Demonstration service started in Sep. 2012	Started in Oct. 2012 (interoperable with EVSS network)	Started in Oct. 2012 (interoperable with JCN)
Pricing plan	Free fast-charging at Nissan dealers and in some Japan Charge Network stations	Individual members: 1,050 yen/month ($10/month) Corporate members: 3,150 yen/month ($31/month)	Monthly plans from 500 yen ($5) to 4,500 yen ($45), plus charging	Each of the 4 gas retailers have their own pricing plans, including monthly vs. per charge

(*Source* Interview with TEPCO, 02/04/2013)

in association with Chubu Electric Power Company (the third largest electric utility). They are trialling a two-tier membership scheme for corporate vs. individual users on a monthly subscription basis (Table 2). The Japan Charge Network, developed by a collaboration between Nissan, Sumitomo, NEC and Showa Shell, are also testing various pricing schemes with membership or per-usage tariffs (EQ2).

Having a diversity of entrants and of pricing models in the EV charging business is beneficial to stimulate the growth of the market and ultimately increases consumer welfare. The "bottom-up" approach of development of the charging network seen in Japan, where industry partners jointly invest in infrastructure and network solutions and compete for bids for government funding, encourages business model experimentation and innovation with different products and services. Having a common standard for fast-charging, CHAdeMO, enables the rest of the industry to design their own business models in the emerging EV industry. This model of collaborative R&D is found at other levels of the value chain for EVs as well: for vehicle design and manufacturing (e.g. SIM-Drive Corporation), and with joint venture companies such as Automotive Energy Supply Company for batteries and Advanced Energy Company for charging services on Okinawa Island (see Case 1).

In the next two sections, we present innovative business models for EV rental services on Okinawa Island and for energy services.

4 Mobility-as-a-Service Business Models

4.1 Case 1: Okinawa Electric Vehicle Rental Service

In 2010, 200 electric vehicles (EV) were deployed by car rental companies on Okinawa Island (Japan) as part of the "Eco-Resort Island Okinawa Promotion Project". One of the first of its kind, the project included the deployment of a fast-charging network based on Japanese CHAdeMO technology. Through the project, EV rental services are offered by 3 of the islands' many car rental service providers: Nippon Rent-a-car Okinawa (100 cars), Nissan Rent-a-Car Okinawa (60 cars), and ORIX Rent-a-car Okinawa (40 cars). All 200 EVs in the project—which represent 1 % of all 200,000 rental cars on the island—are Nissan Leafs with 160 km range. The energy supply infrastructure for the EVs is provided by Advanced Energy Company (AEC), a company formed in 2010 by a consortium of 26 funding companies with 80 million Yen ($775,000) capital. The main contributing founders include local construction company Kokuba-Gumi Ltd., Nissan Okinawa, and Hitachi Software Engineering Ltd. AEC is responsible for the construction, operations, and services for fast-charging stations (Fig. 2). Alternatively, customers can use the "slow-charging" stations that are available for free on the island and take about 8 h for a complete charge.

The island is reputed for sightseeing and attracts 5.5 million tourists per year, most of which are Japanese, Chinese or other from other Asian countries. About half of the

Fig. 2 AEC fast-charging stations (close-up, *right*; with Nissan Leaf, *left*)

visitors rent a car. Due to its geographical characteristics, the island was thought to be a prime location to introduce EVs in Japan: it spans 130 km from the North Cape Hedo to the Southern tip, and 30 km from East to West. The optimal sites for fast-charging (40–50 kW) stations were determined based on analytical simulations of typical driving routes for sightseeing. Out of 24 proposed sites, property owner and legislative approvals were obtained for 18. A total of 27 fast-charging stations were

built on these 18 sites, which can be classified in four categories: gas stations (4 sites), convenience stores, highway service stations, and scenic viewpoint commercial stations.

4.1.1 Challenges of the Okinawa EV Rental Service

High investment costs for an uncertain market In designing the project's business model, due to the high costs of EVs and of charging infrastructure, the investment risk was spread over multiple companies. The following entities participate in the value chain to deliver the EV rental service to customers:

- University of Tokyo researchers, who proposed the project to Okinawan companies and local authorities. Responsibilities include business model design, including revenue structure, long-term market analysis, and research analytics on EV performance and charging sites
- Travel agencies across Japan, who sell package tours that include car rentals from Nippon Rent-a-car and others; bundled booking is the preferred way of renting a car for tourists
- AEC, composed of 3 full-time employees, including general manager Mr. Munehisa Matsumoto (interviewee EQ1), and its 26 founding companies
- Shiraishi Group, the company that owns resorts and the island's branch of Nippon Rent-a-car. Mr. Hiroyuki Nakajima was interviewed as the representative of Nippon Rent-a-car Okinawa (interviewee MS1)
- Alternative "slow" charging service providers, including local companies and tourist sites
- Nissan Rent-a-car and ORIX Rent-a-car Okinawa, other participating car rental companies
- Nissan Motors, manufacturers and providers of the Nissan Leaf cars used in the service
- Local Okinawa authorities and the Japanese government.

Energy provision and regulation Originally, the Okinawa Electric Power Company participated in the strategic discussions concerning energy charging for the EV service. The island is powered by a 26 MW diesel plant and a 10 MW gas power plant. When AEC was created in 2010 and decided to use fast-charging technology rather than standard power infrastructure, the utility retired from the project. Because investments in EV charging stations only benefit EV users, who represent a very small fraction of the Okinawa Electric Power Company service area, regulatory authorities prevented the utility from spreading the costs of the EV infrastructure investments over all of their users, which is the usual way utilities cover their fixed costs. Therefore, the utility did not have a viable revenue model that would allow them to make up for the high capital expenditure for the fast-charging stations. Also due to regulations in Japan governing electricity sales, AEC had to position itself as an infrastructure provider rather than an electricity provider

selling kWh. This determined the flat-fee structure of its pricing: AEC charges its customers a fixed price of 2,000 Yen ($20) per rental, which was decided based on the assumption that the average rental lasts 3 days. AEC estimated their business, including investment costs of $8,000 per fast-charging station, would break even based on 10 users per day per charging station.

Customer response The main feedback from customers was that fast-charging stations were too sparse and that the service was not price-competitive with regular ICE rental. 60 % of customers said they feared there were not enough charging stations and that they were anxious about running out of fuel. The density of EV charging stations on the island is 1/10th of that of gas stations, and this is the reference EV drivers use to compare with (MS1).

The car rental companies' objective of reselling the EVs to private users after 3 years failed for lack of demand from the local population. The average income on the island is too low to create an EV market, even for used cars. Customer surveys showed that the willingness-to-pay for the used 3-year old Nissan Leafs is 1.5 MYen ($15,000) rather than the 2MYen ($20,000) the company wanted to resell for. The rental companies have therefore been operating at a loss.

4.1.2 Outcomes of the Okinawa EV Rental Service

The EV rental project was designed as the first stage of a 3-phase "Green New Deal" for Okinawa Island. The long term objective of the project was to develop a smart grid that integrates used EV batteries for electricity storage, an increased amount of wind and solar energy production, and smart home energy management systems. As of 2013, 2 MW of battery storage have been installed by AEC and 1 MW of solar plant capacity has been built at Kanucha Bay Resort as part of the project. The project is therefore well underway towards its initial objective of promoting cleaner, integrated energy systems on "Smart Island Okinawa".

In terms of market uptake, however, the EV rental service did not meet the early expectations of its founders. The "utilization rate", calculated as the proportion of time a car is rented in the year, reached only 10.6 % in 2012 and 20 % overall since the start of the project. For the project to be profitable, an 80 % utilization rate would have been necessary. Three suggestions that came out of the research and stakeholder interviews are presented in the next section. Designed to get the Okinawa EV service back on track towards its financial targets, these recommendations also provide more general considerations for other EV rental services.

4.1.3 Lessons for EV Mobility Services

In the medium term, three main strategic recommendations may help improve the uptake of EVs for rental in Okinawa.

The first solution, which is in the process of being implemented, is to improve customer experience through intelligent route planning or "smart navigation". Through smart tablets and connected devices, intelligent navigation systems could provide highly accurate predictions of energy usage and suggestions for charging stations along the journey based on the customer's driving style and the different types of roads (highways/rural/city). Customers' fear of running out of electricity or "range anxiety" was cited as the biggest barrier to adoption the service, which such planning services can contribute to alleviating.

The second recommendation is to target travel agencies, the weak link in the value chain. Travel agencies, whose services are used by a majority of the tourists in Okinawa, have no incentive to recommend EVs as rental vehicles for their customers. Concretely, during the selection of rental vehicles from the travel agencies, EVs are advertised as a "green" option that curious or environmentally-conscious travellers may use. However, the EV rental started off slightly more expensive than ICE, and even though the cost has since been equalised with ICE, few customers are willing to take the risk. We suggest that rent-a-car companies in Okinawa should identify travel agencies that are willing to include an EV as the *default* car in their holiday package. During the booking service, customers could opt out but otherwise, would be automatically assigned an EV. The default assignment, even if rejected, would at least prompt customers to consider the option in more detail, resulting in a higher probability of acceptance.

The third recommendation is to "open the data". One of the main barriers to acceptance of EVs is the lack of real data on EV usage and experience. The flow of information between the stakeholders in the EV ecosystem must be improved and become more seamless. There is a need for collaboration and information sharing to resolve the practical issues and customer concerns when deciding to rent an EV or not. Combining the data collected from the various stakeholders, from Nissan Motors, the car rental companies, AEC, the tourism industry, and academic researchers, could significantly help refine and improve the service business model. In particular, it would help address customers' questions and concerns at the time of deciding whether to rent and EV or not.

4.2 Case 2: E-Mobility Services in Smart City Projects (Kashiwa and Toyota-City Trials)

Kashiwa and Toyota-city are examples of demonstration phase trials of innovative transport solutions in Japan. Near Kashiwa campus in Chiba prefecture, a joint project between the city authorities, Chiba prefecture, and a development company Mitsui, called upon engineering design manager Ichiro Hatayama to design an optimal transportation system that responds to residents' travel needs while minimising costs and environmental pollution. Through his company Tokyo Design, Ichiro, who has 30 years of experience in automotive design including EVs, tackles

the third point of the triple agenda for the smart city: smart energy, an ageing society, and smart mobility.

The resulting vision is to develop a system of autonomous (self-driving) public electric taxis that operate throughout the city and can be called upon at any time to pick residents up at any location. This mobility-on-demand system would allow residents to make all their local trips by car, such as between the home, grocery stores, schools and other local activities, without having to purchase, maintain, and drive their own private cars. For many small and medium city dwellers, as well as an increasing ageing population in Japan, this mobility service addresses their day-to-day driving requirements without the inconvenience of relying on sporadic public transportation. As for the charging ecosystem, the idea in this project is to use wireless charging during the EV operation. The city would not need any traffic lighting as the autonomous driving system in the vehicle would replace traffic controls (D1). Electric vehicles, with their simplicity of use for driving and charging, low operating costs, and environmental advantages, are the ideal vehicle technology for such a service.

Toyota city is another example of mobility service experiments within a collaborative urban planning concept. Toyota city developed around Toyota headquarters and main factory in Aichi Prefecture, Japan. Toyota Motors, in cooperation with the Toyota City municipal government, Hitachi, local public transportation companies, and Chukyo University, developed a small-scale demonstration of a multi-modal optimised urban transport system using EV sharing (see Fig. 3). The service that began in October 2012 provides EVs for its 100 members at four locations in the city for use in conjunction with other public transportation modes. The system offers a route planner for smart phones that takes into account traffic congestion and emissions of different routes, including regional electric power mix for the EV travel. The EV sharing service is meant to fulfil the "last-mile" needs of users who take public transportation into the city and use the car to get from the station to their final destination. Toyota will use the trial to collect data on EV battery usage in an energy data management system. In the early days, the system is provided for free at four locations, two at the partner University and two at local

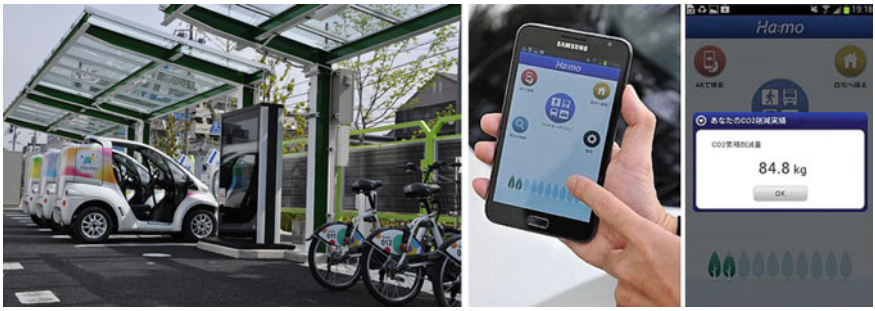

Fig. 3 The Ha:mo EV-sharing station in Toyota City (*left*) and the Ha:mo Navi smartphone application (*right*)

railway stations. Plans are to increase the number of members to 1,000 and increase the number of stations to 20. As part of the Next-Generation Energy and Social Demonstration projects sponsored by the Ministry of Economy, Trade and Industry, the tests are conducted by Toyota City's Low Carbon Verification project. The aim of this collaborative trial is to lower overall energy use from transportation in the area and improve the efficient of transport for users' needs.

The realisation of such innovative projects requires large scale investment and behavioural changes, which only collaborative efforts between the various stakeholders can enable. In the Japanese case as in other urban ecosystems in the world, the important players include businesses such as information and communication technology (ICT) solutions companies, academic and research institutes, entrepreneurial firms and investors, and government and utilities [5]. Partnerships ensure that all of the elements are provided: capital investments, human and technological resources, trial participants (e.g. University students or company employees), and longitudinal (time) resources to monitor the evolution of the project.

For entrants in the EV ecosystem, and particularly in the EV charging business, a major question of designing an e-mobility business model is how broad to extend the scope of the offering. Companies can choose between developing technical standards for the hardware and connectors, as CHAdeMO did (Sect. 1), or designing infrastructure and network services, or embedding charging services within mobility service platforms, i.e. focusing on the whole driving experience, as in the case of Okinawa Island (Case 1). Finally, even broader platforms integrate electric mobility and their charging systems as just one piece of the puzzle, such as smart home energy management systems and smart cities (Case 2).

5 Energy Service Business Models

Throughout these interviews in Japan, it became clear that many companies entered the EV industry with a longer term objective to develop "smarter", cleaner energy systems and technologies that can be re-used in the broader market for energy management services, such as battery and storage systems. As described in the case studies of Okinawa and Toyota City, the transition to mobility services with EVs is often part of a wider transition to smarter energy management systems at the level of the home, the grid or the city.

For battery manufacturers and energy equipment providers, such as NEC, Hitachi, and Sumitomo in Japan, the development of lithium-ion batteries for EVs offers multiple sources of value: first, the opportunity to enter a new growth market (EVs), and second, the opportunity to re-use the knowledge and technology developed for the EV market in other markets and in broader applications. For some firms, the EV market clearly represented the starting point to new business in other energy markets: the "energy storage business, such as home energy storage or residential storage and community storage" (B1). This can be called the technology "spill-over" effects. Sumitomo, a trading company involved for over 15 years in

trading raw materials in the value chain of EV batteries including lithium, nickel, and cobalt, is conducting research in EVs and energy storage markets in view to broaden the battery market and open new markets for these raw materials.

One concrete example is the formation of a joint venture company between Sumitomo (49 % share) and Nissan (51 %), 4R Energy, for the development of batteries for home energy management services. Given the capabilities and stock accumulated by Nissan of batteries for the Leaf, 4R Energy was set up as a joint venture company in 2010 to develop a new market for the used batteries (EQ2). The batteries come from the same manufacturing facilities as the 24 kWh batteries made for the Leaf by Advanced Energy Service Company (AESC), another joint venture between Nissan and NEC (EQ2). After their life in the vehicle, the batteries are recycled into two 12 kWh batteries and sold on the retail market for use as electricity storage systems in households (A1, EQ2). In Japan, the market for domestic battery solutions has gained traction after the shutdown of the Fukushima nuclear plants which cut off power supply for hours and raised concern for energy independence from the grid among the population. 100 units of the 4R battery have been sold in the first year of operation (EQ2). The price of the service package including the battery, maintenance, installation and all customer service is 3 million yen. While this is still very high, the price is expected to decrease as the product diffuses in the market (EQ2).

Moving into the domestic energy storage market through 4R Energy and into the business for EV charging through its partnership in Japan Charge Network, Sumitomo entered the EV business to open new market opportunities and be at the forefront of any growth market in the battery value chain from raw materials to end-user services.

4R Energy is not the only company of its kind. A competitor, ORIX Corporation, recently established a company that provide battery services for residential houses. For 3,000 Yen per month, the company offers 6 kWh batteries and the ICT management system to optimise its use (EXP3). NEC also sells 6 kWh residential use batteries and other 1–2 kWh smaller ones are available on the market (EQ2). While the initial goal is the introduction of residential batteries, the ultimate vision is to control the power from 1,000 to 2,000 batteries at once through cloud services (EXP3). ORIX is a financial trading company and it would like to see a market take shape to trade electricity between power companies with the home batteries' energy (EXP3).

This vision of aggregating EV battery resources to exchange power with utilities and grid-level players is often discussed in the literature on EVs as the "vehicle-to-grid" (V2G) concept [6, 7]. Through the interviews in this research, we found that V2G will require a more complex ICT infrastructure to be deployed between home energy management systems and grid controllers, which is currently not justified by the low penetration of EV batteries. We expect V2G to be on the commercial horizon in the long term (10–15 years) [8].

As the lithium-ion battery technology improves, larger grid-scale energy storage systems are expected to be released on the market in Japan as well. Such grid mega-storage systems of 1.5 MWh are currently in demonstration and testing phases with utilities (EQ2).

Fig. 4 Nissan Leaf-2-Home (*top*) and MiEV Power Box (*down*): two vehicle-to-home devices in the Japanese market

Automotive manufacturers have also started to take an interest in the energy services associated with the electrification of vehicles and have been seen to move into the business of energy solutions in Japan. Mitsubishi's MiEV Power Box and Nissan's Leaf-2-Home system are examples of devices that enable the transmission of electricity from EVs to the home (Fig. 4). Nissan Leaf buyers can currently purchase the Leaf-2-Home for about €4,000 (U21) to use the car's 24 kWh battery as a source of energy for their homes. The MiEV Power Box, which is also on sale in Japan, offers 16 kWh energy capacity for home use (A24). The Leaf system could potentially provide up to 2 days of electricity for an average Japanese household (R1, A1). These systems of home energy supply from EVs were tested and deployed following power disruptions after the earthquake and tsunami in 2011. Gasoline supply was interrupted for a month in the region, whereas electricity infrastructure was quicker to recover (A4). Mitsubishi delivered 90 iMiEVs to the Prefecture at that time for use as home batteries. Customer feedback was positive and proved the value of such vehicle-to-home systems.

In the case of Okinawa Island's EV rental service, the EV business was only the first phase of a longer term strategic transition to "green" the island's energy sources with smart grid technologies, renewable energy generation, and efficient

buildings (EQ1). EV batteries were intended to be recycled after their life in the EVs and reused in buildings and homes for energy management and storage services. These batteries were seen as an important component of the system to balance the grid at times of excess or undersupply of energy. EVs themselves, of course, also provide a solution to improve the environmental sustainability of the island.

In summary, three pathways for value creation and capture in energy services business models with EVs have been found in Japan: the technology spill-over effect of EV battery technology into other markets and applications, the secondary life value of EV batteries, and the direct use of EV batteries in the vehicle for energy management in the home.

At the moment, OEMs are bearing the largest share of the investments and costs in EV technology (EQ2, A1). The results in this paper suggest that risk-sharing participation from companies in other sectors such as electricity supply and equipment can enhance the viability of the market and create business opportunities in the emerging EV ecosystem.

6 Conclusions

The case of the Japanese EV ecosystem contributes strategic perspectives from multiple points in the value chain for EVs, from battery and car manufacturers to mobility-as-a-service providers (Fig. 5). Examining the business models that led Japanese companies to have a global presence in the EV market has provided three significant insights as to how to create and capture value in early EV commercialisation.

Firstly, the provision of a seamless charging network is an essential part of the value proposition for EV customers. In Japan, a combination of government investment and corporate investments have led to the formation of consortia of companies developing the charging network with both fast- and regular chargers. The first standard for fast-charging connectors was developed by the CHAdeMO association initiated by TEPCO to address the problem of recharging wait times. Defining a financially profitable business model in the early stages of the EV market, where sales are still low, is still a challenge. The consortia in Japan operate on a shared risk model (joint investments) and on an experimental basis where different membership schemes are available and charging stations are trialled in

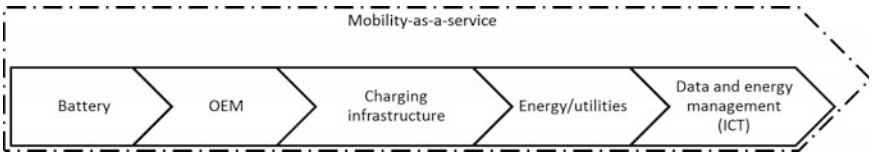

Fig. 5 A basic representation of the EV value chain

preferred locations such as tourist sights, participating shops and gas stations. The deployment of a charging network as a competitive, innovation-driven process is beneficial to the growth of the industry.

Secondly, a competitive advantage for firms in the EV market can be obtained by investing in technologies and competencies. However, a strategic recommendation from this paper is to have a "smart" business model that uses digital technology to address end-user needs. Innovating a business model can be just as powerful as acquiring technological advantages to compete in the EV ecosystem [9]. The cases of the EV rental service and of e-mobility in smart cities in Japan highlight the importance of overcoming the barriers to EV adoption by formulating business models around the *end-user driving experience*. Firms in the EV ecosystem must take a customer-centric view to design the right end-user experience.

Finally, the business model for EVs must give customers more value from their car. In Japan, the potential for mobility services is limited, but energy services business models such as integration in smart home systems, smart cities, and the reuse of batteries for grid management applications, are new sources of value that the industry stakeholders are already starting to tap into.

The Fukushima nuclear reactor crisis following the earthquake and tsunami that hit Tohoku area in March 2011 caused a significant shift in customer perceptions of the electricity industry, making them less accepting of any related innovations such as electric vehicles. It also readjusted the priorities of energy infrastructure and supply companies towards stabilizing mechanisms such as storage batteries, renewable energy and smart grid integration, and away from shorter-term/secondary priorities such as electric mobility. However, the EV is widely seen in Japan as one element of a greater structural transition to a sustainable and efficient "new energy society" (EQ1). One of the drivers of the EV market in Japan are the long-term strategic and financial value creation opportunities discussed in this paper. Such opportunities may inspire new business models and entry in other markets globally to stimulate competition and create a viable EV ecosystem [10, 11].

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