Re-charged for Success

The Third Wave of Electric Vehicle Promotion in Japan

This report describes how Japan is working to promote the development, market, infrastructure and adoption of electric vehicles – specifically policy focused on quick-charging. The report is part of Growth Analysis' policy intelligence mission in sustainable development.

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Förord

Under hösten 2011 har Fredrik Obel från Kungliga Tekniska Högskolan genomfört ett antal intervjuer, studiebesök och samlat information kring den Japanska elbilsutvecklingen som en del av sin praktik vid Tillväxtanalys Tokyokontor. Slutsatserna sammanfattas i följande rapport. Fredriks praktik har för ändamålet finansierats delvis med stipendier från Sweden-Japan Foundation och Elforsk. Målsättningen med rapporten är dels att ge en översikt över utvecklingen på den japanska elbilsmarknaden, men främst att belysa den nödvändiga samverkan som behövs mellan tillgång till elbilar och infrastruktur för laddning.

Rapporten har skrivits av Fredrik Obel med hjälp av Izumi Tanaka, analytiker vid Tillväxtanalys Tokyo. Synpunkter och korrektur har givits av Anders Karlsson, kontors-chef och teknisk vetenskaplig attaché, Tokyo, Martin Flack och Markus Bergfors, temaansvariga analytiker för hållbar utveckling vid kontoret i Stockholm. Sten Bergman vid Elforsk och Michio Mori, projektansvarig fordonsindustri vid Invest Sweden i Tokyo, har även bidragit med synpunkter under projektets gång.

För Tillväxtanalys,

Stockholm, februari 2012

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Table of contents

1 Summary

To closely follow the development of the introduction of fossil-free electric vehicles is of relevance for Sweden both from an environmental perspective as well as from a competiveness perspective. The transport sector in Sweden is the most fossil fuel dependent sector. Sweden has also large automotive industry relative to the size of the country, which has been affected by the latest development in the global automotive industry. Recently Nissan and Mitsubishi Motors released electric vehicles in Sweden aimed at larger target group than previous generations of electric vehicle. Because of the relatively short range for electric vehicles there is a need for quick charging. Japan is the country in the world with most advanced infrastructure for quick charging. In Sweden there are ongoing tests with the Japanese system for quick charging, CHAdeMO. In the report we review the recent developments of electric vehicle promotion in Japan and discuss policy implications for Sweden.

Key points*:*

- The Japanese market for electric vehicles (EVs) is perhaps the most mature market in the world as of today. Japan has the car manufacturers, infrastructure, battery manufacturers, and is the country with highest the number of EVs in Asia.
- The Japanese government has set ambitious goals in terms of number of vehicles. Besides direct subsidies to increase sales of vehicles and to improve infrastructure, the government is also supporting research to develop batteries.
- Quick charging is seen as a key factor for a larger usage of EVs. Japan has taken a lead with the CHAdeMO, a system for quick charging developed by the Tokyo Electric Power Company in collaboration with the major Japanese auto manufacturers. In Japan, there are 801 quick charging stations in use as of December 1, 2011.
- Even with subsidies and government support EVs are still judged as very expensive for ordinary people and the main early users are expected to be government and companies. The main challenges for EVs are the short driving range and the high cost of the batteries.
- The first test of battery switching was conducted in Tokyo April 2010 – December 2010, using a small number of taxis in Tokyo by the American company Better Place. Battery switching is an alternative to quick charging; the car is sold without a battery which is leased.
- The Japanese experiences with quick charging, the early users' experience, and the effectiveness of various government support measures are all relevant learning for policy makers and implementing stake-holders.

Sammanfattning

Att nära följa och ta del av utvecklingen och introduktionen av elektriska fordon är av intresse både från miljöperspektiv såväl som från ett konkurrensperspektiv. Transportsektorn i Sverige är den sektor som är mest beroende av fossila bränslen. Sverige har också en stor bilindustri relativt landets storlek, som påverkas av den senaste utvecklingen i den globala bilindustrin. Nyligen släppte Nissan och Mitsubishi varsin elbilsmodell riktade mot större målgrupp än tidigare generationer av elbilar. På grund av den relativt korta räckvidden för elbilar finns det ett behov av snabbladdning. Japan är det land i världen med den mest avancerade infrastrukturen för snabbladdning. I Sverige finns det flera pågående projekt med det Japanska systemet för snabbladdning CHAdeMO. Från en svensk synvinkel är det viktigt att bevaka utvecklingen Japan rörande fordon, infrastruktur, forskning och policys.

Viktiga slutsatser:

- Den Japanska marknaden för elbilar (EVs – från electric vehicles) är den mest mogna i världen. I Japan finns biltillverkare, infrastruktur, batteri tillverkare och Japan är till dags-dato (2012) det land i Asien med högst antal elbilar.
- Den Japanska regeringen har ambitiösa mål i termer av antal elbilar. Förutom subventioner och skattelättnader för stimulera försäljningen ges stöd åt infrastruktur och forskning för att utveckla nästa generations batterier.
- Snabbladdning ses som en nyckelfaktor för ett ökat användande av elbilar. Japan har tagit ledningen med CHAdeMO ett system för snabbladdning av elbilar utvecklat av Tokyo Electric Company i samarbete med de Japanska biltillverkarna. December 2011 fanns 801 stycken snabbladdnings stationer i drift.
- Även med stöd och subventioner bedöms elbilar som väl dyra för privatpersoner och den huvudsakliga målgruppen ses initialt i form av företag och myndigheter. Den stora utmaningen för elbilar är det korta räckvidden och den höga kostnaden för batterier.
- Det första testet av batteribyten var i Tokyo april 2010 – december 2010, ett litet antal taxibilar användes för demonstrera teknologin. Testet utfördes av Better Place och finansierades av Japanska regeringen. Batteribyten är ett alternativ till snabbladdning, bilen säljs utan batteri som man leasar separat
- De tidiga erfarenheterna från Japan kring snabbladdning, användarmönster och effektiviteten av olika offentliga stödåtgärder bör studeras med intresse av svenska policyintressenter och implementerande aktörer.

2 Introduction

Japan is a forerunner in electric vehicles (EVs) because of a large automotive industry developing next generation vehicles. There are both hopes and doubts about how large the market for EVs will be in the future Japan. Goals from the Japanese government are significant larger than predictions from independent research organizations and companies. The fact that Japan is a highly density populated country with large portion of the population living in densely populated metropolitan setting makes it suitable for an early EV introduction. The size of the average car in Japan is also small and the same with the majority of all EVs released in the near future. Additionally, in Japan people drive less than in Europe and North America. An average Japanese EV owner will hence save less money than in other parts of the world. The price of gasoline and driving distances affects potential savings compared to conventional cars (BCG 2010). Fuel cell vehicles are also a special kind of EV that uses a hydrogen fuel cell to generate electricity. An introduction of FCVs is some years in the future, but is briefly discussed in the report since Japan is forerunner also in the area of FCVs.

The introduction of EVs has been promoted twice before in Japan. The first time was in the 1970s when the Japanese government started to support research and development of EVs in an effort to solve the problems with pollution. The oil crisis also contributed to an increased interest in EVs, but as the oil price went down so did the interest for EVs. The second time occurred in 1990s when the state of California adopted a law demanding car manufacturers to participate in a zero emission vehicle program. Both times the introductions were unsuccessful due to high costs and the poor performance of the batteries (Nikkei Weekly 2007, 2008). Now, the third time EVs are promoted in Japan, Nissan and Mitsubishi Motors have recently released one EV each for a larger market and Toyota is about to release a plug-in version of its Prius. The CHAdeMO Association, a group of all the major Japanese car manufacturers together with Japans largest electric utility are trying to establish a standard for fast charging of EVs, trying to solve the problem with long charging times and short driving ranges. As of December 1st 2011, 801 quick charging stations have been installed in Japan (CHAdeMO 2011).

Fact box: Definition of acronyms used in the text:

The term electric vehicle is broad and indicates several different vehicles. The following acronyms are used throughout the report.

EV - Electric vehicle if nothing else stated battery electric vehicle, e.g. Nissan LEAF

HEV - Hybrid electric vehicle, e.g. Toyota Prius.

PHEV - Plug-in Hybrid electric vehicle

FCV – Fuel cell vehicle

ICE - Internal combustion engine, (i.e. a conventional car, no electric propulsion)

The March 11th earthquake and the energy crisis that followed affected Japan in many ways. Due to disruptions of the supply chain, the automotive industry was partially shut down for weeks and it took months before production returned to pre-quake levels.[1] In the

[1] (Growth Analysis 2011a)

small cities along the coast that were hit worst by the tsunami, there was a fuel shortage. Electric vehicles were used in the refuge work, supplied by Japanese car manufacturers Nissan and Mitsubishi Motors. Still, Japan has experienced many natural disasters and aims to be even more prepared in the future. Nissan and Mitsubishi Motors are, for example, about to release systems to use their EVs Leaf and i-MiEV as backup electricity sources for individual homes in the case of un-expected electricity cut-offs.

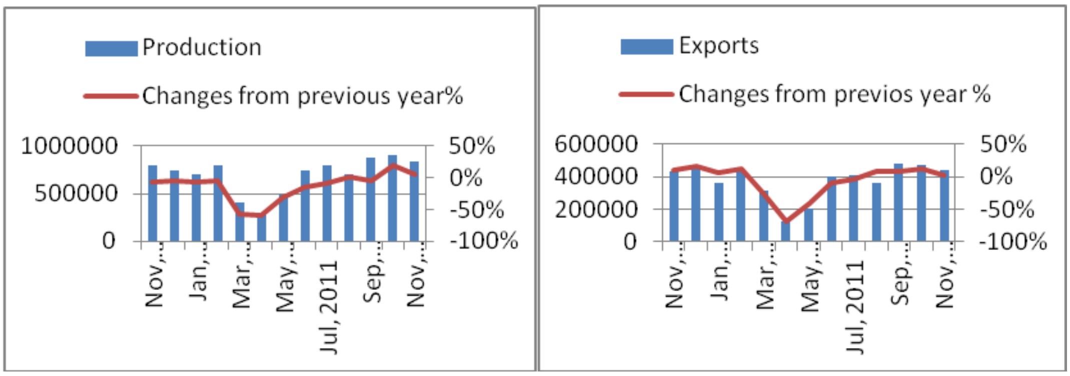
2.1 The automobile industry in Japan

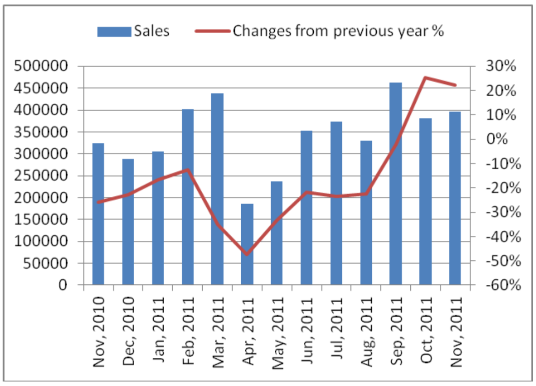
The automobile industry is one of the largest and most important industries for Japan. In 2009 automotive shipments accounted for 15.3 percent of the total value of Japan's manufacturing shipments. This number has been growing since 1970 with exceptions of a few years. As an export commodity, automobile industry plays an important role; automobile export consisted 18.7 percent of all exports in 2010. The industry makes huge investments in equipment and R&D activities; consisting of 15.6 percent and 18.5 percent, respectively, making the industry a core industry not only economically, but also as a driving-force for innovation of the country (JAMA 2011a).

The year 2011 was a tough year for the Japanese automotive manufacturers with the Great East Japan Earthquake and the flooding in Thailand which affected their supply chain and production, and on top of that a very strong yen. Domestic sales, production and exports decreased all sharply after the earthquake due to the supply-chain disturbances. It took months before the car production returned back to pre-earthquake levels. There are electronics used in cars that only produced in Japan, and the disruption in their production affected car manufacturers all around the world. The graphs below illustrate the severe effect of the earthquake and the time it took before the production, sales and exports were back to pre-quake levels (Economist 2011).

Toyota, the largest car manufacturers in the world in term of vehicles 2010, dropped to third place in 2011 surpassed by Volkswagen and General Motors mainly due to decrease in production after the earthquake.

Figure 2-1 Production, Exports and Sales of all automobile vehicles (passenger, trucks and buses) in Japan Nov 2010 – Nov 2011





Source: JAMA 2012

The Japanese car manufacturers are well positioned for the future and will release several environmental-friendly models in the next couple of years. There are different strategies and focuses among the car manufacturers. Compared to the situation in Sweden with many ethanol and biogas cars, bio-fuels have attracted less interest in Japan. The Japanese car manufacturers are mainly focusing on EVs PHEVs, HVs and FCVs when it comes to environmental-friendly cars. The major Japanese car manufactures have diverse strategies and are planning release cars featuring different environmentally-friendly technologies.

HEVs have been on the market for several years. EVs and PHEVs are being released right now while FCVs are a couple of more years in the future. FCVs are a special kind of electric vehicles that use a fuel cell to convert the energy in the hydrogen to electricity leaving only water as end-product. The technology has existed for a relatively long time but both the car and the needed infrastructure is still very expensive. The first commercial FCVs are scheduled for release in 2015 in Japan. Three Japanese auto manufacturers Toyota, Honda and Nissan and ten energy companies announced jointly in a statement on January 13 2011, 2015 is the target year for an early commercialization of fuel cell vehicles in Japan. Hydrogen fuel suppliers have a goal to construct about 100 hydrogen fueling stations by 2015 (Hara 2011).

Toyota, by far the biggest of Japanese car manufactures, has stated that they see more potential for PHEVs than pure EVs in the near future due to the short driving range of EVs (Toyota 2011). Toyota is also the company that invests most on R&D in FCVs, which they see it as the ultimate environmentally friendly car. Nissan is the most aggressive when comes to EVs with release of the Nissan Leaf in December 2010. Nissan, also, stands alone in the strategy of EV being the “first car,” while other manufactures consider EV as a secondary car for a limited and specified use for short-distance driving. This is evident in the size of Nissan Leaf being the five-person passenger car, and Mitsubishi Motors introducing PHV concept car PX-MiEV to be used for long-distance driving while i-MiEV is to be used for shorter trips and daily commuting. The biggest technological challenge in EVs is the performance of the batteries. Japan not only has car manufacturers but also has several EV-battery manufactures. Car manufactures and battery manufactures collaborate closely in the development of EVs.

Fact box: Tokyo Motor Show 2011 goes electric

The bi-annual Tokyo Motor Show, the 42nd one, took place December 2-11 2011. The theme was "*Smart mobility"*, with emphasis on next generation vehicles role in a smart communities. There was a special section showing cars and technologies relating to Smart mobility together with scenarios on how we live and transport ourselves in the future.

As an example of smart-community and smart-grids with connection to EVs, Hitachi Ltd., had a presentation of smart grid projects in Japan and also a joint project with the USA. It is a demonstration of smart grid on an isolated island on Maui, Hawaii, which is one of a series of smart grid national projects run by NEDO (New Energy and Industrial Technology Development Organization), Japan. The project is to test the effectiveness of EV management system to stabilize voltage and or frequency fluctuation produced by "green electricity," such as solar and wind power generation, and also by charging EVs at the same time on an isolated island. The system controls EV charging schedule, and uses EV and other batteries as power storage.

The earlier focus on safety in the car industry has now shifted to environmental concerns. Several battery electric vehicles, hybrids, plug-in hybrids, hydrogen vehicles especially from the Japanese car manufacturers were showcased at the Tokyo Motor Show. In the commercial vehicle section electric and hybrid vehicles were displayed, the same green trend as for passenger vehicles.

The Tokyo motor show has received increasing competition from the motor shows in Shanghai, Beijing and New Delhi during the last couple of years. There was a hope from the organizers, *Japan Auto Manufacturers Association* JAMA that the more central location and longer opening times would attract more attention and visitors. In total 842,600 people visited the show compared to 614,400 in 2009 and 1,425,800 in 2007. The show in 2007 was held seven days longer than the Tokyo Motor Show 2011.

2.2 EV market maturity

There were approximately 9030 EVs in use in Japan March 31st 2011, the end of March being the last day of a fiscal year. Out of those 9030 vehicles, the majority is normal passenger cars and the rest are trucks, buses or other special vehicles. The large increase in EVs during fiscal year 2009 and fiscal year 2010, as seen from Table 2-1, can be explained with launch of Mitsubishi i-MiEV in July and Nissan Leaf in December 2010. In Japan, the majority the electric vehicles are either Mitsubishi i-MiEV or Nissan Leaf. Before market introduction of those two, electric vehicles in Japan were conventional vehicles that had been converted to run on electricity. In the middle of November 2011 more than 5,000 i-MiEVs and 8,500 Leafs had been sold in Japan, combined more than 12,500 EVs (Berman 2011, Mitsubishi Motors 2011).

The number of hybrid vehicles are considerable larger in Japan than other markets, mainly due to the success of the Toyota Prius, which is one of most sold cars in Japan. Besides the Toyota Prius, Honda has also sold hybrid vehicles. Among the hybrid vehicles there are a small number of buses, trucks and other special vehicles included. The small numbers of plug-in hybrids are pre-production cars, Toyota started to lease pre-production version of its upcoming 2012 Toyota Plug-in Hybrid in end of fiscal year 2009 to the national government, local governments, and corporations such, as electric power companies, and other entities. (Toyota 2009) When the 2012 Toyota Plug-in Hybrid is released on the market, the number of PHEVs is expected to increase considerably.

Table 2-1 Electric Vehicles in traffic estimation end of fiscal year

Type	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010
Electric vehicles	505	421	389	1941	9030
Hybrid vehicles	343,223	428,771	535,964	983,401	1,417,995
Plug-in hybrids	0	0	0	165	379

Source: Created by the author based on [Next-Generation Vehicle Promotion Center 2012]

Table 2-2 Comparison EVs and PHEVs on the market and coming

Electric Vehicles	Range*	Battery	Charging time	Price**
Mitsubishi i-MiEV	150 km	16 kWh	Quick charging (50kW) 80% 30 min 8 hours 230 volt 10A	363 000 SEK
Nissan Leaf	150 km	24 kWh	Quick charging (50kW) 80% 30 min 8 hours 230 volt 16A	370 000 SEK
Plug in-hybrids				
Opel Ampera / Chevrolet Volt	40 -80 km in EV mode	16 kWh***	3 hours 230 volt 16A	439 000 SEK
Toyota Prius Plug-in Hybrid	20 km in EV mode	4.4 kWh	1.5 hours 230 volt 16A	Less than 360 000 SEK
Volvo V60 Plug-in Hybrid	up to 50 km in EV mode	11.2 kWh	3.5 hours 16A 4.5 hours 10A 7.5 hours 6A 230 volt	560 000 SEK

**According to the car manufacturers **List prices in Sweden without subsidies ***10.4kWh useable*
Source: Official Swedish websites of the car manufacturers

The table shows the major drawbacks with EVs, the high price and the short driving range. PHEVs eliminate range issue but at a high cost, PHEVs have a conventional ICE-engine that is used when the battery is depleted giving a combined driving range comparable to a conventional car. All of the cars listed above use lithium-ion batteries in different sizes. The charging time depends on the size of the battery and the output from the socket. The exceptions are the two pure EVs Mitsubishi i-MiEV and Nissan Leaf which support quick charging through the CHAdeMO protocol, (see part 4).

Even with quick charging, 30 minutes is a long time compared to time it takes to refuel a conventional car with gasoline. The range of an EV is difficult to estimate since it differs depending on how the car driven and used. City traffic and usage of air-conditioner will considerable lower the driving range. In Sweden a cold climate will also have a negative effect on the batteries' performance. The driving range at optimal conditions can be double compared to more demanding driving conditions. (Muller 2010)

To overcome the issues with charging time and short driving range, EVs have a need for charging infrastructure, which today is much less developed than the fueling infrastructure for conventional ICE vehicles. The success of EVs will depend on many aspects, including technology innovation on batteries, cost reductions, direct subsidies to support early demand and development of charging infrastructure. In the next chapters these issues will be discussed in more detail.

The Japanese government is placing high priority on the introduction of next generation vehicles, as a tool to realize a low emission society, as well as to strengthen the competitiveness of the Japanese automobile industry. The Japanese government uses the terminology "next generation vehicles", which includes hybrid vehicles, electric vehicles. plug-in hybrids, fuel cell vehicles and clean diesel vehicles. There is a significant difference between EVs, HEVs, PHEVs and FCVs in terms of potential carbon dioxide reduction. The largest reductions can be made with PHEVs EVs and FCVs. HEVs can be compared with highly efficient conventional cars. According to all sources, in the near future EVs and PHEVs will have the most important roles.

2.3 Market potential

A strong public purchasing by national and local governments, in addition to demand for commercial use, has been seen to be the driving force for the increase in market share of EVs. The Japanese government has set several long term targets for the future development of the EV market (see charts below). The Ministry of the Environment (MoE) and the Ministry of Economy, Trade and Industry (METI) have set up goals for EVs; MoE in absolute numbers and METI in percentage of total sales. Both of their goals are very optimistic compare to other predictions. MoE goal can, perhaps in some respect, be seen as more idealistic compared to the more powerful and business focused METI.

Challenges in the development of battery technology and the establishment of infrastructure are expected to limit the penetration of EVs into the market to 40,000 units in 2015, 140,000 units in 2020, and 1,000,000 units as late as 30 years from now, according to a study conducted by the think-tank Fuji-Keizai (Fuji Keizai 2010). Another comparison can be made to JD power's report from 2010 which predicts that the sales of pure EVs in Japan only will be 67,000 in 2020, in comparison to 510,000 goal set by MoE.

Table 2-3 Diffusion targets with private sector efforts and government targets (proportion of new vehicle sales), according to METI.

	Projections (private-sector efforts)		**Government Targets**	
	2020	**2030**	**2020**	**2030**
Conventional vehicles	80% or more	60-70%	50-80%	30-50%
Next-generation vehicles	less than 20%	30-40%	20-50%	50-70%
Hybrid vehicles	10-15%	20-30%	20-30%	30-40%
Electric vehicles, Plug-in hybrids	5-10%	10-20%	15-20%	20-30%
Fuel-cell vehicles	Miniscule	1%	1%	3%
Clean diesel vehicles	Miniscule	5%	5%	5-10%

Source: METI 2010b

Table 2-4 Target for EV introduction from MoE

2020		2030		2050	
Sales	Stock	Sales	Stock	Sales	Stock
510,000	2,070,000	730,000	5,900,000	700,000	8,800,000

Source: MoEb 2009 (translated by the author)

Most potential private consumers will most likely check for economic advantage of an EV compared to a conventional ICE-car. The economic advantage of buying an EV over conventional car differs throughout the world due to differences in driving range, cost of gasoline and electricity and incentives provided. The Boston Consulting Group compared the pay-back time for buying an EV instead of a conventional car in 2020 in Europe, North America, China and Japan taking account expected technological developments that would decrease the costs for an EV and assuming an EV owner drives the same distance as an owner of a conventional ICE-car (BCG 2010).

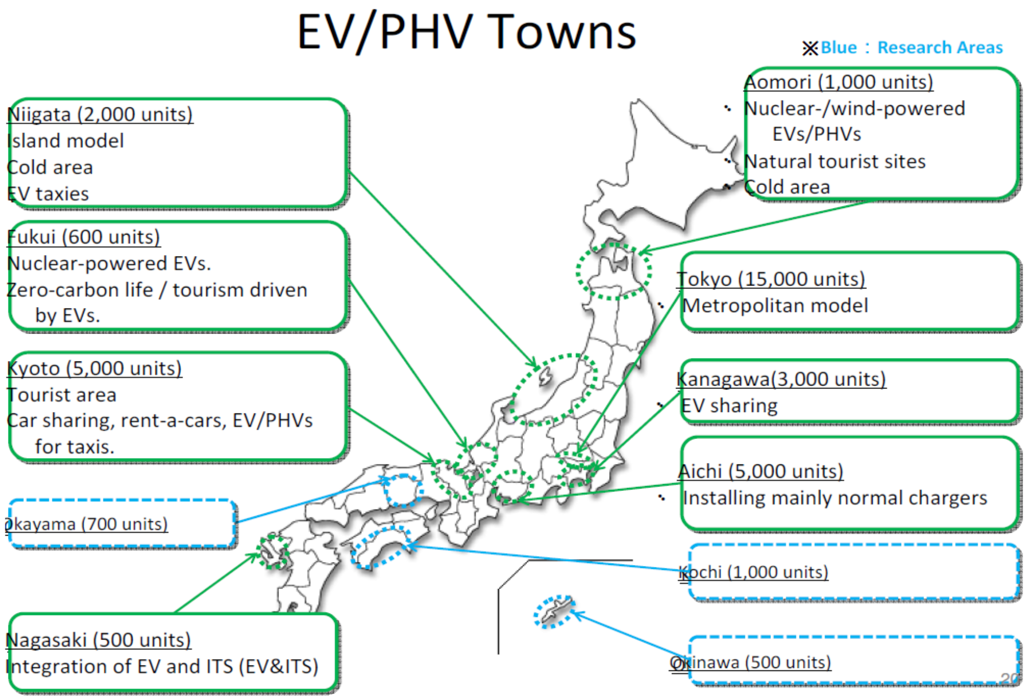
The study showed the time to break even was, by far, the longest in Japan. This is because in Japan people drive less on the average and the gasoline prices are not high enough to compensate it. The study expected that pay-back time for EV bought in Japan in 2020 would be 25 years without any incentives. The more one drives the more money saved since recharging an EV is considerable cheaper than filling up a normal car with gas. In the United States, gasoline prices are low but the driving distance is much longer than in any other part of the world. The high gasoline price in combination with a relatively long driving distance makes the time to break even shortest in Europe. (BCG 2010)

2.4 Strategies and measures to promote EVs

2.4.1 EV/PHEV Towns

There are governmental initiatives in Japan to accelerate the introduction of charging infrastructures. “EV/PHEV Town” initiative is a model project to implement the demonstration of full-fledged diffusion of EV’s and PHEV’s, which is stipulated in the “Action Agenda for a Low Carbon Society” of METI. Model regions have been chosen for the introduction of EV’s and PHEV’s. In cooperation with municipalities and local enterprise, intensive development of infrastructure is pursued. Secondly, case models of the selected towns are shared nationwide to promote dissimilation to other regions (METI 2010a).

Figure 2-2 Map of EV/PHEV Towns



Source: METI 2011

In December 2010, a second round of municipalities qualifying for EV/PHEV towns was announced, making the number 18 municipalities in total. Knowledge gained from the experiences in introduction of EV, issues such as capable driving distance at single charge, battery weight and time needed for charging of the battery appeared to be the limiting factors.

In this third attempt to penetrate EVs into the market, the technological strategy as identified by some of the manufacturers of EV and charging stations is stated as follows (CHAdeMO 2010):

1. Use advanced lithium-ion battery for comfortable acceleration, enough max speed and provide accurate power meters.
2. Target commuter vehicle for daily short trips to reduce necessary battery capacity amount and cost in the early stage of market penetration.
3. Locate adequate public quick chargers to compensate limited driving range.

From the past experiences, the suitable EV usage models maximizing the current performance level are furthermore identified as follows (METI 2010a):

1. Vehicles used by public sector and business sector
2. Police cars, short-distance taxi, postal service cars
3. Car sharing
4. EV park-and-ride in dedicated areas

2.4.2 Financial incentives for acquisition of EVs

To stimulate domestic demand, the Japanese government furthermore introduced temporary tax reduction/exemptions for fuel-efficient vehicles with good environmental performance for three years, for acquisition between April 1 2009 and March 31 2012. The fulfillment of the Kyoto Protocol and the new government mid-term target of 25 per cent carbon dioxide reduction by 2020 (announced but has not passed the diet) were big motivations for the introduction of the measures. Considering the normal phase of model changes in the automobile industry, there are only two model changes foreseen before 2020 and urgent actions are needed. (METI 2010a)

Tax exemption

For next-generation vehicles, including EVs, Acquisition and Tonnage taxes are exempted. The incentives below are in effect from April 1, 2009 through March 31, 2012 for the Acquisition Tax (imposed once only, at the time of vehicle purchase) and from April 1, 2009 through April 30, 2012 for the Tonnage Tax (with reductions applicable once only, upon first payment of the tax at the time of first mandatory inspection, three years after vehicle purchase) (JAMA2009).

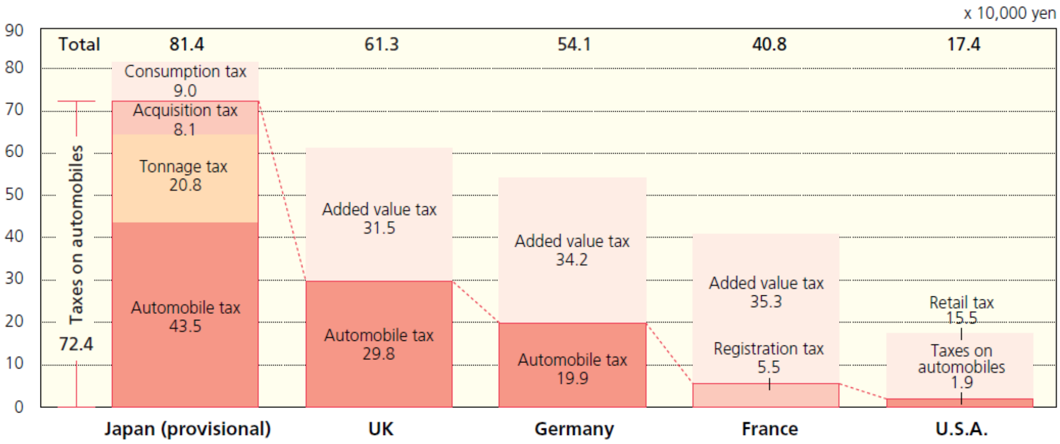
Figure 2-7 Tax incentives

Vehicle Type	Requirements		Reductions/Exemptions	
		Certification Stickers	Acquisition Tax	Tonnage Tax
Next-Generation Vehicles	Electric (including fuel cell) vehicles Plug-in hybrid vehicles Clean diesel vehicles (1) Hybrid vehicles (2) Natural gas vehicles (3)		Exempt	Exempt
Fuel-Efficient and Low-Emission Vehicles (4) (Passenger cars and mini-vehicles)	Compliant +25% compared to 2010 fuel efficiency standards and emissions down by 75% from 2005 standards		75% reduction	75% reduction
	Compliant +15% compared to 2010 fuel efficiency standards and emissions down by 75% from 2005 standards		50% reduction	50% reduction

Source: METI 2010a

The proportion of these taxes is approximately 40 percent of the entire amount of tax and the reduction of these taxes are playing an important role in stimulating the market of next generation vehicles, including EVs.

Figure 2-8 International comparisons of automobile-related taxes



Source: JAMA 2009

Subsidies eco-car tax reduction

In late 2011, the government announced plans to offer subsidies of up to 100,000 yen (approx. 8,500 SEK) on purchases of eco-friendly cars through January 2013. The subsidies will be offered on cars meeting 2015 fuel efficiency standards, and also on some models meeting current standards, this, of course, includes EVs and PHEVs. The government predicts about 3.4 million cars will be eligible for the subsidies and will allocate a total of 300 billion yen (approx 25.5 billion SEK) for the purpose in the planned Fourth Supplementary Budget for fiscal year 2011 (April 2011 to March 2012).

Though this supplementary budget is expected to pass the Diet early 2012, the government plans to apply the subsidies retroactively to the date of Cabinet approval, in order to prevent consumers from delaying vehicle purchases until the subsidies to go into effect.

A similar subsidy system, for the purchase of eco-friendly cars, 100,000 yen for an ordinary passenger car and 50,000 yen for a smaller sized car classified as “kei” in the Japanese system, was introduced in April 2009 as part of the government's emergency economic stimulus package. It ended in September 2010. At the time, cars that met fuel efficiency standards for 2010 were covered by the subsidies (Yomiuri, 2011).

Subsidy for promotion of clean-energy vehicle

Since 1998 and continuing through fiscal year 2011, there is the “Subsidy for promotion of clean-energy vehicle (tentative translation)” for purchases of EV, Plug-in-hybrid car, clean diesel car and charging equipment. The subsidy is available for local government/public organizations, private companies and individuals. The limit of subsidy for vehicles is half of the difference between the cost of EV and similar type of conventional vehicle with the upper limit of 1 million yen (approx. 85,000 SEK) 400,000 yen (approx. 34,000 SEK) for EV/PHEV and clean diesel cars, respectively and half of the cost for chargers. There are minimum years of ownership demanded to utilize the subsidy, four and eight years for vehicles and chargers, respectively. Additionally, starting in 2010, Ministry of Economy, Trade and Industry started subsidies targeting normal charging (as opposed to fast charging) scheme, for example in single-unit and multi-unit housing. (Next Generation Vehicle Promotion Center 2010)

Scrapping scheme

Additionally, to further stimulate the domestic vehicle market and economy in general, subsidies in the format of scrapping scheme and incentives for purchasing a new environmentally-friendly vehicle were introduced for the duration of April 10, 2009 to March 31, 2010.

Table 2-5 Subsidies

◆Scrapping scheme ※Duration 10th Apr 2009 – 31st March 2010

<Passenger Cars> (Registered vehicles, light vehicles)

Requirement	Registered vehicles	Light vehicles
Vehicle 13 yrs or older to vehicles meeting 2010 fuel efficiency standards	250,000 yen	125,000 yen

<Heavy-duty vehicles> (buses, trucks, etc.)

Requirement	Small (GVW3.5t class)	Middle (GVW8t class)	Large (GVW12t class)
Vehicles aged over 13 yrs or more to vehicles meeting new long-term emissions regulations	400,000 yen	800,000 yen	1,800,000 yen

Source: METI 2010a (edited by the author)

3 One for the road – quick charging as a main technology push

At home an EV can be charged overnight or at work during the day but in public spaces, there is a need for quick charging or battery switching. People are in general not willing to wait for much longer time than it would take to fill up gasoline at a gas station (Aoki 2011, and others). Because of the limited driving range of EVs, there is a need for public fast charging stations. With battery technology that is used today, mainly lithium ion batteries, it is unlikely that range of an EV will be the same as conventional car in the near future. A breakthrough in battery technology would be needed for the range of EVs to increase substantially.

3.1 CHAdeMO – EV quick charging in Japan

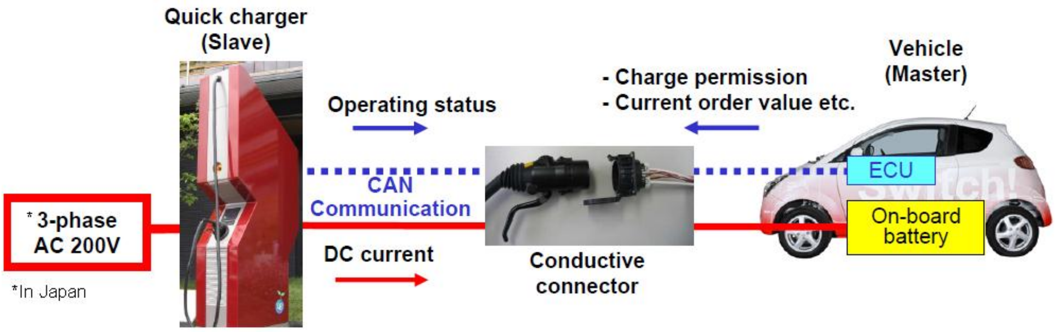
CHAdeMO is a Japanese method for quick charging electric vehicles. CHAdeMO is Japanese a pun for *O cha demo igaka desuka*, “let’s have tea while charging” or abbreviation for *CHArge DE MOve*. For EVs to be successful, a standardized infrastructure for charging is necessary. Japan’s goal is that CHAdeMO will be the de-facto world standard for quick charging EVs. The CHAdeMO association was founded by Japan’s largest electric utility, TEPCO (Tokyo Electric Power Company) and four Japanese car manufacturers, , Nissan, Mitsubishi Motors, Fuji Heavy Industries and Toyota. CHAdeMO was developed by TEPCO in collaboration with the Japanese car manufacturers. TEPCO as an electric utility has an interest to accommodate a large number of EVs charging from the grid in the format of electricity sales. At the moment there are 170 regular members, as of January 23, 2012 in CHAdeMO Association, mainly consists of car manufacturers, electric companies and manufacturers associated with charging equipment. About half of the member companies are Japanese companies and the other half is consisted of companies from other countries. Other types of membership are supporting members and observers; in the observers, local municipalities, public organizations and industrial associations are included.

3.2 CHAdeMO technology

CHAdeMO is a DC quick charging method in which the car and charging station are using the CHAdeMO connector and protocol to assure that battery is charged with optimal current. The car’s battery management system decides the current from the CHAdeMO charger and the battery is charged as fast as possible without putting any damage on the battery. For communication CHAdeMO uses a combination of digital (a so called CAN-bus) and analog communication to increase the safety. According to the CHAdeMO association, using a can bus is much safer than power-line communication which the competing SAE standard will use (the SAE standard is discussed below).

All rechargeable batteries lose little a bit of their performance every time they are depleted and recharged. The difference in performance between the latest EV batteries of different battery manufacturers is relatively small. All batteries used in new EVs are lithium-ion batteries and the chemical reaction does not differ. For batteries, especially heat is the damaging factor so the battery management system monitors the temperature of the battery and several other factors and determines how “fast” the batteries should be charged.

Figure 3-1 Illustration of CHAdeMO charging



Source: CHAdeMO 2011a

The battery management system is developed by the car manufacturers and differs among them. The EV Nissan Leaf allows the car to be charged faster than the Mitsubishi i-MiEV and Subaru Plug in HV Stella. It takes the same time (approx. 30 min) to charge the Leaf battery to 80 percent as in the i-MiEV and Plug in Stella even though the Leaf battery is larger. Car manufacturers' claim that the damage from quick charging is very small compared to normal slow charging. Mitsubishi claims that there newly released i-MiEV can be quick charged every day without any problems. Since the i-MiEV and LEAF have been introduced on the public market, Nissan and Mitsubishi's confidence regarding the performance of the EV batteries, including the risk of damaging them during quick charging, has rose. The car manufacturers i.e. Nissan and Mitsubishi are, according to the CHAdeMO association, expected to publish reports in 2012 with proof that there batteries are not damaged by repeated use of quick charging. (Aoki 2011).

Fact box: The main competitor - SAE standard for DC fast charging

There is one major competing potential standard for DC fast charging to CHAdeMO. Seven car manufacturers Audi, BMW, Daimler, Ford, General Motors, Porsche and Volkswagen jointly released a press release October 12, 2011 that they intend to support upcoming standard that will be released by SAE International, an organization for standardization. The SAE standard for DC fast charging is expected to be released in late 2011 or early 2012. Most likely it will not be in any consumer vehicle until 2013 (Business Fleet 2011).

Technically it is possible to rebuild an existing CHAdeMO station to have two connectors and information systems, one for the CHAdeMO standard and one for the SAE standard. The main part of the CHAdeMO charger is a conversion of AC- to DC-current. The charger basically delivers a specific current on demand from the cars battery management system. The plug connecting and how the information in transferred can be doubled (Tanaka 2011).

Josef Krammer, team leader for charging systems at BMW, believes two standards cannot exist in parallel in the same region and that the majority of car manufacturer will support the SAE standard, forcing the market away from CHAdeMO. According to John Gartner from Pikes Research, two competing standards for quick charging will have a small effect on penetration of EVs on the market since the average consumer cannot even distinguish between hybrids and battery electric vehicles (Chambers 2011).

3.3 CHAdeMO chargers

Figure 3-2 ABB CHAdeMO charger

Source: CHAdeMO 2011a

To develop and sell a CHAdeMO charger one need to be a regular member of the CHAdeMO association. Only regular members have access to the CHAdeMO protocol. In the market there are CHAdeMO chargers from 30 different companies. The Swiss-Swedish company ABB is selling a CHAdeMO charger and has with its knowledge in power electrics growing market opportunities within the infrastructure needed for EVs.

Because of the standardization of the CHAdeMO protocol chargers from different companies are relatively similar, one exception is JFE Engineering's solution with a storage battery inside the charger to "boost" charging capacity. This allows the JFE charger to use a lower capacity 20 kW grid power compared to the 50 kW recommended for CHAdeMO. See chapter 4.4 for more details. The market is competitive and prices for chargers are decreasing. Takaoko Electric's CHAdeMO charger cost 3.5 million yen (approx.300, 000 SEK) two years ago and now 2.5 million yen (approx. 210,000 SEK). Takaoka electric is one of several companies contracted by TEPCO for development of the CHAdeMO standard.

Nissan has in collaboration with Sumitomo developed their own CHAdeMO charger and is selling it at a very low price only 9900 US Dollars, (approx. 70,000 SEK) in order to quickly increase the number of CHAdeMO charger stations. There have been questions raised if the charger is sold at a price subsidized by Nissan. Nissan states that it is not subsidized but is manufactured at a lower price. As a car manufacturer, Nissan strategy is to make money selling cars, the charging infrastructure is just a tool for promoting and selling the cars. The low cost of the Nissan charger is a problem for the other electrical companies selling chargers. It has been argued that if the Nissan charger is sold at a subsidized price the number of other companies selling chargers would decrease and this might affect the whole CHAdeMO association negatively.

A major cost is the installation cost of the charger, if the grid needs to be strengthened or if a new transformer is needed. Additionally, there is a big difference between the basic electricity tariffs for a 20kW and 50kW electricity supply contract in Japan. This has led to installation of chargers with lower power than the recommended 50 kW. The chargers with lower power can be installed in more places.

3.4 JFE engineering - fast chargers with internal storage batteries

CHAdeMO charger – JFE Rapidas

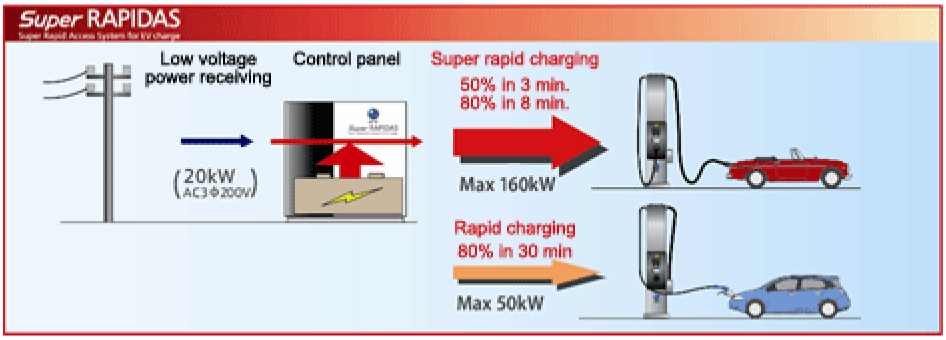
JFE Engineering's CHAdeMO charger differs from others in that it has an internal storage battery. The storage battery allows the charger to receive electricity from a low voltage supply. When fast-charging, the internal storage battery adds to the charging of the car battery, hence allowing both of a boost in charging power, as well as the use of a lower grid power. Recall there is a big difference between the basic electricity tariffs for a 20kW and 50kW electricity supply contract. The storage battery also makes it possible to receive electricity during the night when prices are lower compared to daytime and store in the battery. The storage battery in the charger is 24kWh allowing the charger to charge three cars in a row before the storage battery has to be recharged. The charger needs a 20kW power supply and when the storage battery is depleted the charger can charge with maximum power of 20kW. In the future if more EVs are introduced and EV charging becomes more frequent, it is of course possible to increase the internal storage battery making it possible to charge more cars in a row than three with the maximum power of 50kW. The storage battery, after 4,000-6,000 cycles from completely discharged to full charge, have 80 percent of its capacity left. JFE Engineering is working together with Toshiba for battery supply. The charger takes up more space than a normal CHAdeMO charger because of the storage battery inside the charger. (Ishikawa, Kajitani 2011)

The target groups for the charger are convenience stores and gasoline stations that have low voltage supply where a normal 50kW CHAdeMO charger cannot be installed. Instead of installing a charger with a lower power (20kW-30kW) JFE Engineering's solution can be used. The complete initial cost, according to JFE, is comparable to a conventional CHAdeMO charger when installed at gasoline station around 6 million yen (approx.510, 000 SEK). The cost of electricity and the basic tariff will be lower for JFE's charger. The customer can save up to 600,000 yen (approx. 51,000 SEK) per year just on lower basic tariff cost for 20kW contract according to JFE. As of December 2011, JFE has sold a few chargers and has orders on 20-30 more. (Ishikawa, Kajitani 2011)

Super-fast charging - JFE Super Rapidas

JFE Engineering has developed their own system for super-fast charging named Super Rapidas. The basic concept is the same as their normal fast charging system with a storage battery and utilization of a low power supply. The major difference is the charging power, the rated output; Super Rapidas' output is 160 kW instead of 50kW allowing it to charge an EV to 50 percent in 3 minutes or 80 percent in 5 minutes. At the moment there are no EVs supporting 160 kW quick charging. According to JFE, increasing the charging power is not a problem for the batteries in the charger or in the car.

Figure 3-3 System overview, JFE Super Rapides



Source: JFE Engineering 2011

The car manufacturers which JFE have been in contact with have showed a small interest in their super-fast charging technology. The car manufacturers are mainly focusing on 50kW CHAdeMO fast charging technology already available. JFE engineering lists EV buses and EV trucks that travel the same routes everyday as the main target for the applications today. Buses and trucks also carry larger batteries that need to be charged faster. Buses drive short routes but are used the whole day. The super-fast charging technology makes it possible to charge the bus while it is standing still at a station waiting for passengers to get on and off. Keio University has developed an EV bus and next year JFE's super-fast charging technology will be tested in project by Kanagawa prefecture, JFE and Keio University. The price of the Super Rapidas fast charging system, not including installation cost, has a target price of 15 million yen (approx. 1.3 million SEK) with an internal storage battery of 40 kWh. The price is subject to change as the system is under development (Ishikawa, Kajitani 2011).

Outside of their headquarters in Yokohama, JFE Engineering has a demonstration charger with two connector one normal CHAdeMO connector and one Super Rapidas connector. Super Rapidas fast charging system is using a special connector and an extra thick cable because of the high current. The connector and cable are relatively heavy compared to a normal CHAdeMO connector and has to be improved if the system is to be used by private drivers. The information between the car and the charger is transferred using a modified version of the CHAdeMO protocol. For demonstration JFE has built their own EV that uses batteries from Toshiba based on a Nissan Fairlady, a sports car from the 60s. During the interview and demonstration, the head Engineer Ishikawa of the Rapidas project demonstrated how the car is fast charged plugging in the thick connector and charging the car. When the car is being charged the voltage and current is displayed on the display on the charger. Except for the heavy connector and cable, there is no difference when charging a car with JFEs super-fast charging system compared to CHAdeMO chargers. JFE Engineering does not disclose more details about the batteries in their Super Rapidas charger and Nissan Fairlady EV other than that they are from Toshiba. JFE has expressed some complains on the batteries and say that they are little bit heavy but are satisfied with their fast charging capabilities. (Ishikawa, Kajitani 2011)

Figure 3-4 JFE Super Rapidas quick charging

Source JFE Engineering 2011

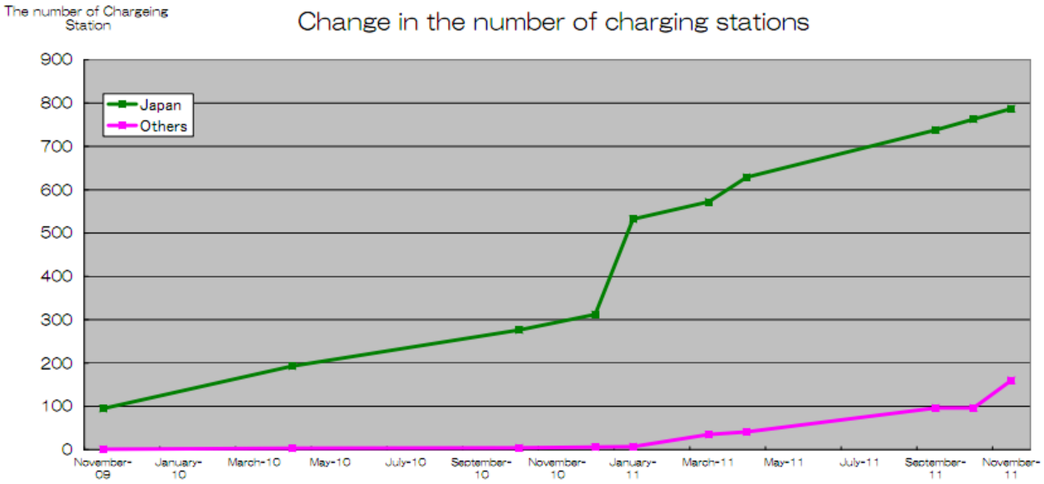
3.5 CHAdeMO compatible vehicles

At the market right now in Japan there are basically only two CHAdeMO compatible models that will be sold in any significant number: Mitsubishi i-MiEV and Nissan Leaf. In Europe Mitsubishi i-MiEV is sold as Peugeot Ion and Citroën c-zero. Mitsubishi is just about to release a light commercial EV that support CHAdeMO aimed at the Japanese market because Japan has a tax regime with lower taxes on light vehicles. Toyota will, in 2012, release its model Toyota IQ, a compact car EV which is their first EV to support CHAdeMO fast charging. Toyota is also planning release an EV version of its SUV Toyota Rav4 that will not support CHAdeMO fast charging. This is might be an indication that Toyota does not believes in CHAdeMO to the fullest. The Toyota Rav4 EV is currently under development and if the number of CHAdeMO station increases fast it may be included. For Toyota it would have been easy to let the Rav4 EV support the CHAdeMO fast charging. It would have been a small additional cost. The Toyota Rav4 EV is developed in collaboration with Tesla Motors which is not member of the CHAdeMO Association. Honda will release Honda Fit EV that will be sold worldwide but only the Japanese version will have support for CHAdeMO. According to CHAdeMO Association, car manufacturers try to minimize their risks and have CHAdeMO as one part of their R&D strategy (Aoki 2011). If the CHAdeMO system gains popularity in world it will be easy to release EVs supporting it for other car manufacturers than the Japanese.

3.6 Experience from CHAdeMO in Japan

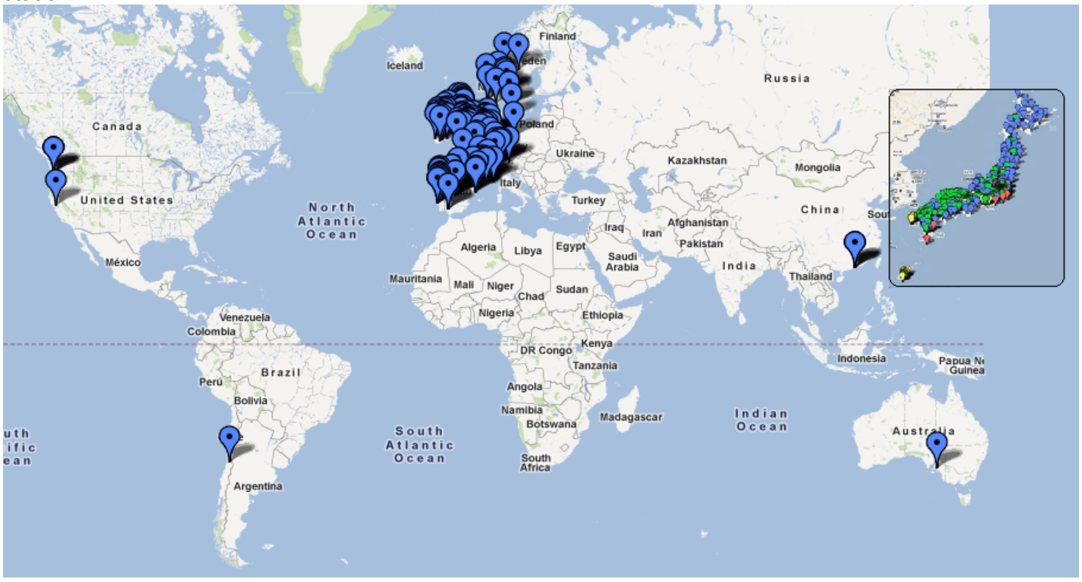
The number of CHAdeMO stations is increasing fast in Japan from just above 100 in November 2009 to more than 800 in December 2011. In the rest of the world the progress is slower and there is less than 170 charging stations as of December 2011. Available data and statistics from usage of fast charging (CHAdeMO) are limited in Japan. There are as of December 1st 801 charger stations in Japan but many of them have been installed very recently and the number of EVs is small compared to the number of charging stations. Companies that have installed and run charger stations keep their data and there are no studies that include data from all chargers stations. The user data has value since it can be used for business purposes, where to locate chargers, optimum payment offers etc.

Figure 3-5 Number of CHADeMO charging stations in Japan and the rest of the world



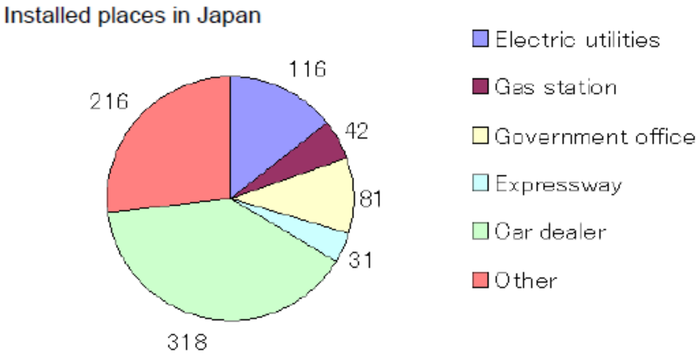
Source: CHAdeMO 2011a

Figure 3-6 Location of CHAdeMO charging station



Source: CHAdeMO 2011

Figure 3-7 Installed places of CHAdeMO charging stations in Japan



Source: CHAdeMO 2011a

3.6.1 CHAdeMO user satisfaction study made by TEPCO

The Tokyo Electric Power Company - TEPCO has around 70 charging stations but the majority of them are located at their branch offices. The charger stations next to the branches are mainly for the TEPCO corporate fleet of EVs. Mr. Hiroyuki Aoki Senior Manager, Mobility Technology Group, TEPCO, shared some information about a small recent study conducted by TEPCO on the usage behavior of 10 of their public CHAdeMO stations. The 10 chargers were installed during 2008-2010, and the study was carried out in 2011. Since the sample of the study was very small conclusions are limited. The usage pattern of each charger was unique and differed based on location. A significant increase in charging time was observed after the Nissan Leaf was released. As the study was carried charging out charging time increased due to the sale of Nissan Leaf.

Table 3-1 Dissatisfaction with lower output chargers (questionnaire)

Power	Dissatisfaction rate
30 kW	10%
20 kW	19%
10 kW	50%

Table 3-2 Length of time that quick chargers were used by output (observed spread)

Power	Time
50 kW	15-23 minutes
30 kW	21-30 minutes
20 kW	20-31 minutes

Source: Aoki 2011

The power output of the CHAdeMO chargers ranges from 10-50 kW this because chargers with lower power can be installed in more locations. A 50 kW charger needs to be installed on a stronger grid to minimize the effect on grid. The user satisfaction is increases with power output of the charger, i.e. a larger output implying a faster charging time. Among other complaints in the study were that the charger connector is too heavy and located to high up.

Mr. Hiroyuki Aoki gave some examples in detail how the charging behavior could differ from charger to charger. The chargers that were used the longest were often used by EV taxis and car sharing EVs. Overall, most quick charges occurred during the day with a peak around lunchtime. The number of times a charger was used per day was mainly affected by the number of EV owners living close to it. TEPCO chargers were on an average used a few times a day. In comparison, Nissan mentioned that their charger outside their headquarters is used 5-10 times a day.

Another noticeable behavior was that EVs drivers tended to charge shorter if they noticed that there was another car waiting to recharge. Some of the CHAdeMO chargers are located in normal parking spaces while others are located in more designated parking spaces. If the charger was located in a normal parking space and if it happened that a non-EVs parked there, it will prevent an EV to charge. It might be a need to clearly identify the charger locations from normal parking spaces with more than just a sign. The more charging space differed from a normal parking space the less risk that a normal car would park there.

One charger was located in a parking garage with 30 minute free parking had consequence the charger was rarely used more than 30 minutes at a time to avoid paying for the parking. A charger located just before a road into Tokyo that often had traffic congestions was used longer each time because EV drivers wanted to have a fully charged car to prepare for anticipated traffic congestion. In a traffic congestion situation, an EV would consume a lot of electricity from AC-usage / heater, radio etc. During the time of the study the Nissan Leaf was introduced, it could also be noticed that the amount of energy charged during each charge also increased. The battery in the Nissan Leaf is 24 kWh compared to 16 kWh and 9.9 kWh respectively for the Mitsubishi i-MiEV and the Subaru plug-in Stella, meaning that user tried to charge it up more, knowing that the battery capacity was higher. The battery management system in the Leaf also allows the battery to be charged with a higher power.

From a previous TEPCO study from 2008, the most important experience from use of quick charging is that people tend to use their electric vehicles more and drive longer distances between each recharge and further away from the homes if they know there is the possibility of quick re-charging. Owners of electric cars felt more comfortable knowing that the risk that they get stranded is smaller. Just a few charging stations can make noticeable difference in driving behavior. Based on the usage of newly released Nissan Leaf, people tend to recharge when battery level is around 50 percent. Seichi Tanaka from Takaoka Electric, a producer of fast chargers, mentioned a slightly lower figure 30-40 percent (Tanaka 2011).

3.6.2 Kyoto – Tokyo only using quick charging 504km

EV-owners have to plan their traveling more than conventional car owners, which is obvious given the limited driving range before the need of re-charging. Present EV models with short ranges are not designed for traveling long distances. Even with presence of fast charging traveling longer distances is not convenient. A test was conducted driving a Nissan Leaf from Kyoto to Tokyo only using CHAdeMO fast charging (Aoki 2011). The interesting part in the test was to see how much time is spent charging in comparison to driving. In total 2 hours and 23 minutes was spent charging that only counts the time the car actually was charging and not including the extra driving time to reach a charger. The driver of the car recharged every time the amount of energy left in the battery was a little bit less than half. A conventional ICE-car could drive the whole distance without refueling but most people would probably refuel once to make sure there is some gasoline left.

Table 3-3 Kyoto - Tokyo by only using quick charging

Stint	Length km	Time (h:m)	Charging time (m:s)	Amount energy charged kWh*
1	96	1:38	19:25	10.52
2	70	0:58	18:45	10.49
3	60	0:48	15:29	8.46
4	55	0:38	17:10	11.14
5	69	0:56	19:03	10.98
6	48	0:36	25:32	10.21
7	51	0:46	27:24	7.37
8	55	1:29		

**note Nissan Leaf's battery has capacity of 24 kWh*

Source: Aoki 2011

3.7 Moveable road-side charger

Nissan, together with JAF (Japan Automobile Federation) is furthermore testing a moveable roadside CHAdeMO charger. The truck can recharge EVs that have been stranded and it can also tow away vehicles. Nissan believes that an addition of a roadside charger for emergencies will make customers more comfortable driving EVs. The combined truck and charger is being tested in the Kanagawa prefecture since June 7, 2011 (Nissan 2011).

The AAA (American Automobile Association) announced in June 2011 that they will offer roadside charging of EVs to its members. The AAA will have trucks with several different charging modes both DC fast charging and AC slow charging.

The technology with a moveable fast charger has been presented before. Realpower demonstrated a similar solution at the Los Angele’s motor show in 2010 also with a CHAdeMO charger. At that time a Mitsubishi i-MiEV was used for the demonstration. This is first time it is being used in practice in Japan (Realpower 2011).

Figure 3-8 Moveable roadside chargers

Source: Realpower 2011, Nissan 2011

3.8 Infrastructural goals

The CHAdeMO chargers are installed by mainly local municipalities, car manufacturers and companies operating highways in Japan. The government has a target that 5,000 CHAdeMO chargers should be installed by 2020. In Japan one charger should serve approximately 200 cars. A previous government goal is to have 1 million EVs in Japan by 2020. That seems at the moment quite unrealistic. Mr. Aoki from the CHAdeMO association estimated that if there were 1 million EVs in Japan there might be need for more than 5,000 fast chargers but not more than 10,000 chargers. Furthermore Mr. Aoki estimates the need for fast chargers per car would be higher in other countries and gave the USA as an example due to longer distances. (Aoki 2011)

In comparison, the goal for public slow charging outlets is set to 2 million in Japan. Sweden has advantage when it comes to slow charging because of over 600,000 outlets for pre-heating vehicle engines during wintertime, i.e. these being of possible use also for slow charging of EVs. (Vinnova 2010)

3.9 Government subsidies for installations of charging stations

There are government subsidies available for installation of 300-400 CHAdeMO chargers per year in Japan. (Tanaka 2011). The national subsidies for chargers depend on the output of the charger. However, the upper limit is 50 per cent of the purchasing price. (Aoki 2011) The upper limit in terms of yen is 1.5 million yen but Nissan's new 50 kW charger costs less than 1 million yen which means it is entitled to less than 0.5 million yen.

Table 3-4 Subsidies for quick chargers

Output	Subsidy	
50 kW	1,500,000 yen	(127,500 SEK)
40-50 kW	1,250,000 yen	(106,250 SEK)
30-40 kW	1,000,000 yen	(85,000 SEK)
10-30 kW	750,000 yen	(63,750 SEK)

Source: (Aoki 2011)

3.10 Business models for CHAdeMO

At the moment basically all of the CHAdeMO chargers are free to use for the general public in Japan. Charging stations are installed as a service, for example at a parking lot free of use for all parked cars. In Japan, there are toll highways and some of the highway companies have also installed chargers at their service stations along the highway. Shopping centers and convenience stores install chargers to attract customers. There are also examples of private business owners having installed CHAdeMO chargers, for example, a doctor that owns a clinic bought an EV and installed charger outside the clinic to attract customers (Tsuji 2011).

The year 2012 is expected to be the start of a more widespread commercialization. The Charging Network Development organization, LLC was founded by nine Japanese companies from the CHAdeMO association to work with further commercialization of chargers. The lack of effective method to recover the cost of charging has become a significant obstacle to widespread installation of chargers. The organization will cooperate with local government and companies trying to increase the interest for installing chargers to establish a better infrastructure for charging. (CHAdeMO 2011b)

In Okinawa, the most southern tropical island group of Japan which attracts many tourists, there is ongoing project with EV-rental cars that includes a payment per charge. A new company established by local businesses, rental car companies and travel agencies called Advanced Energy Company (AEC) have installed 27 quick chargers in 18 locations. 220 EV cars are rented out to the large number of tourists that are visiting the island every year. The goal is that there will be 100 quick chargers and 6,000 EV-rental cars on Okinawa by 2020. Everyone who wants to use the quick chargers needs a smartcard that is used for paying at the kiosk terminals. Several chargers are located outside of the stores but the kiosk terminal is inside the store to attract customers. The price for one quick charge is 500 yen (approx. 43 SEK) which is a relatively high price but Okinawa is mainly a tourist spot which explain the high price. Tourists renting an EV are probably less price sensitive than normal EV owners; they don't have the opportunity to slow charge outside their private homes. In comparison, Hitachi has delivered a few chargers to other parts of Japan where a charge only costs 100 yen (approx. 8, 5 SEK). AEC is using Hitachi's charger management system that sends information about every quick charge and alerts if there are any technical problems. The charger management system is form of cloud computing and handles payment, power use, statistics, and charger statuses. Hitachi has delivered similar system to be used in the Yokohama smart city program. (TMSb 2011) Four gasoline companies will in the beginning of 2012 launch a smart card and charge 3,000 yen (approx. 255 SEK) per month for unlimited quick charging at their stations. They will also have plan where you pay a lower monthly fee and per charge. (Mainichi Daily 2012)

4 Some specific trends 2011 and research projects

4.1 Impact from the Great East Japan Earthquake

On March 11, 2011 the world's 5th most powerful earthquake ever measured occurred outside the coast of Japan causing a disaster which included a tsunami, the Fukushima nuclear plant accident, and due to many halted nuclear reactors and thermal power plant, also a significant electricity shortage. Immediately after the earthquake there was an even worse shortage of gasoline and other fuels in the tsunami stricken regions. Mitsubishi sent out 89 Mitsubishi i-MiEVs and Nissan sent out 66 Nissan Leafs to be used in the rescue work afterwards. Not only automakers sent EVs to the damaged regions also other cities in unaffected regions sent their EVs to be used in disaster relief work. (Belson 2011)

As it turned out, the usage of electric cars had a couple advantages. They were not affected by fuel shortage of gasoline and could be used immediately in the event of fuel shortage. The loss of electricity generation capacity forced Japanese people to reduce electricity consumption. However the main problem was lack of generation capacity during peak hours not the overall supply. There were no problems charging the EVs as long as it was off peak hour. In the areas that initially lost both electricity supply and had fuel shortages, the electricity supply in some cases came back faster, and given charging possibilities, the use of EVs became a viable supplementary alternative to conventional vehicles.

Figure 4-1 EVs in use during rescue work

Source: New York Times 2011, Mainichi Daily 2011

Electric vehicles were used for many small tasks such as transporting supplies to refugee centers, schools, hospitals and taking doctors and city workers around in the damaged cities. Several of cities that were damaged were not so large so the limited range of the EVs did not cause complications. The need for vehicles that could function without gas was unexpected, both car manufacturers and local governments were surprised. The local governments were very satisfied with the usage of the electric vehicles that were supplied by the car manufacturers. They played an important role especially in the places with no access to gasoline. From a disaster preparedness perspective it proved useful to have access to vehicles powered by different energy sources (Belson 2011).

4.2 EVs as emergency backup and part of smart homes

The 3/11 disaster and the energy crisis that followed affected how the Japanese people think of and use energy. Japan temporary lost a significant amount of generation capacity from both halted nuclear power and conventional thermal power. This forced the Japanese people to reduce electricity consumption during peak load hours. Japan is aiming to shift their whole energy system away from nuclear power towards a more decentralized with a larger share of renewable energy. For example, Japan promotes photovoltaic power and it's getting increasingly popular for Japanese house owners to put solar cells on the roof.

In Japan several major Japanese companies are planning to release or have released new systems for smart grids, smart energy metering and smart home energy management system. In October 2011 many of these systems were on display at Ceatec the largest technology fair in Japan. Focus on the Ceatec fair 2011 shifted from TVs and robots to "smart energy" due to the energy crisis. Electric vehicles will play an important role for smarter energy usage in the future and the energy crisis in Japan will speed up applications of EVs in Japan (Ceatec 2011).

Electric vehicles have a large battery that can store a substantial amount of energy. The battery can be used for more than just storing energy for purpose of powering the car. In Japan there is a demand for solutions that makes it possible to use the car as a backup energy source and shifting away electricity use from peak demand hours. Nissan recently presented its system *Leaf to home*. The car battery is connected to the house energy management system and can be used for storage of energy for future use. The battery can be charged during the night when electricity prices are low and then supply electricity to the house during peak hours of the day. The Nissan Leaf battery can store 24 kWh, if fully charged enough to supply electricity to average Japanese house for two days. An average Swedish house consumes more electricity and it is not clear when or if the *Leaf to home system* will be released outside of Japan. To be able to transfer electricity with high power the Nissan *Leaf to home* system uses the CHAdeMO connector and protocol. The system will be available to Japanese customers April 2012 (Nissan 2011).

Mitsubishi has a simpler solution. Mitsubishi system allows to the use of the Mitsubishi i-MiEV as an emergency source of electricity. Mitsubishis solution is a normal AC outlet from the car while Nissan system is supplying electricity to the house grid itself. The total available output power is also lower 1.5 kW for the i-MiEV compared to 6 kW for the Leaf. The i-MiEV battery is smaller than the Leaf 16 kWh compared to 24 kWh which means that the i-MiEV battery can store electricity for about one and half day. Mitsubishi i-Miev is supporting future solution vehicle-to-home (V2H) through its CHAdeMO port (Mitsubishi 2011).

The 2012 model of the Toyota Prius will have a normal AC outlet and may deliver electricity from the battery and when the battery is depleted the car's engine will start and generate electricity to the battery. Toyota will also release system they call home-to-vehicle (H2V) in 2012. The H2V allows user to control when the charging should begin to avoid peak load. (Toyota 2011)

4.3 Better Place's battery switching project in Tokyo

Better Place is an American Israeli company focusing on "EV services" that has ran an EV–taxi battery switching project together with Tokyo's largest taxi company Nihon Kotsu for six months. The background of the project was demonstration of battery switching in 2009 in Yokohama. Both the small demonstration in 2009 in Yokohama and the Taxi Project was completely financed by the Japanese government, the demonstration in 2009 by the Ministry of the Environment and the taxi project by the Ministry of Economy, Trade and Industry. The Tokyo The project cost around 5 million US dollars. (Isaji 2012)

In Tokyo 2% of all cars are taxis but they account for 20% of all emissions due to the high usage rate. The majority of all taxi cars in Tokyo now use LPG (liquid petroleum gas). (2009 Roadrunnerautogas) There would be a significant effect if the taxis were more eco-friendly. Taxis are basically used the whole day and if electric they need to be either quick charged or use battery switching. This makes battery switching systems especially suitable for taxis. The present technologies for quick charging will according to the critics shorten the life of batteries if used too often and it takes longer time than switching a battery. (Isaji 2012)

The project started April 2010 and was supposed last for three months but was extended another three months and ended December 2010 with break in between. It consisted of three taxi cars and a battery switching station located in central Tokyo. Batteries were switched in less than 60 seconds in the battery switching station faster than filling a tank at a normal gas station. Better Place basically converted the car to become electric. The batteries used were provided by A 123 Systems an American company specialized in Lithium-ion batteries used for transportation, grid services etc. The taxis used in the project were Nissan Quashqais that had been converted to run on electricity. The driving ranges of the taxis were 80-100 kilometers. The battery had a capacity of 17 kWh which is 7 kWh less than battery in the recently released Nissan Leaf. (O'dell 2010)

Experiences from the project

The project was successful since it proved that battery switching works according to Better Place. There were few technical problems, in the beginning two batteries malfunctioned.

The price for taxi ride was the same as a normal taxi 710 yen (approx. 60 SEK) for the first two kilometer, the standard fare in Tokyo. Normally a Taxi had to do 3-4 battery switches per day. The average time measured for a battery switch was 59 seconds. The taxi drivers learnt to deal with limited range of the taxis. Some customers had to be turned down due to long distances from the battery switching station. One of the taxi drivers driving the battery switching taxis answered the following when asked about the battery switching and driving the taxis.

> *Yes you have to re-charge frequently, but it goes very fast, so I've found it hasn't really affected my business," "Compared to the other taxis I've driven it's a very good ride, and easy to drive. There's not much lurching around, and customer reaction is quite good"*

Taxi driver Yasuhiro Kobayashi (O'dell 2011)

In the future if Battery Switching for taxis would be launched in a larger scale in Tokyo. Better Place estimates that Tokyo would need 100 battery switching stations if all taxis were battery switching. Cities especially suited for battery switching taxis are densely populated cities where many taxi trips are relatively short for example New York, Shanghai, Beijing, London, Paris and Singapore. A Better Place representative confirms that they have negotiations about larger taxi project with a major city in Asia (Isaji 2012).

Opinions about better project and taxi project in Tokyo

The general opinion is that it is very expensive to build an infrastructure of battery switching stations and that there is a big problem with standardizing the batteries. Mr. Wataru Sato from Renault Motors in Japan believed that the largest potential is for vehicles that travel the same route every day since the need for switching would be limited. (Sato 2011) Taxis drive different ways all the time so a large number of battery switching stations are needed if a taxi should be able to go everywhere in a city. If battery switching stations are installed in multiple locations basically all taxis have to use them to make the investments profitable. The CHAdeMO Association compares in their presentations the cost of infrastructure between a quick charging network and network battery switching stations. According to the CHAdeMO Association the cost of battery switching infrastructure are several times higher. Mr. Naohiro Tsuji from Mitsubishi Motors believes that in Japan if used large scale aimed at the general public there would be logistics problems since driving / traveling is concentrated to certain vacation/holiday seasons of the year in Japan. (Tsuji 2011)

Commercial launching Denmark and Israel

Better Place will enter the commercial market in Denmark and Israel in the end of 2011. In Denmark 20 battery switching stations will be built to start with. The first battery switching station in Denmark opened up in 2011.Customers will first have to buy the EV Renault Fluence Z.E and then sign up for contract which costs depends on how much you drive. Denmark has an advantage with high prices for gas low prices electricity and substantial subsidies for EVs. Israel is a little bit of a home market for Better Place since founder and CEO Shai Agassi is from Israel. In Israel 40 battery switching stations are planned in near term and 1,000 charging stations are already built. The only battery switching compatible car on the market today is the Renault Fluence Z.E, according to Shai Agassi, Renault is flexible with production and can produce anything from 40,000 to 400, 000 cars or what is needed. Renault Fluence Z.E is electric version of normal Renault Fluence it's relatively big compared to most EVs. It has 70 kW engine and a 22 kWh battery. Battery switching compatible models sold in Denmark and Israel are slightly modified. According to Renault the range is up to 185 km. (Better place 2012)

The main advantages with Better Place business model, in their own opinion, are that they own the battery and the short time for switching batteries compared to charging. Because Better Place owns the battery the risk is smaller for owner of the car. Batteries are substantial cost of an EV. One of the main challenges for Better Place is the limited number of cars supporting battery switching. Only Renault has released a car and is planning to release two more EVs supporting battery switching. A major challenge for Better Place is that they need collaborations with more auto manufacturers. (Isaji 2012)

Figure 4-2 EV battery switch

Source: Better Place 2011

Better Place offers 5 different subscription packages in Denmark all including free battery switching and free usage of Better place's public charger stations. The price differs depending on how much you driving from 1,495 DKK (approx. 1800 SEK) per month for 15,000 km of driving per year to 2,995 DKK (approx. 3560 SEK) per year for unlimited driving. Everyone that signs up also has to pay one-time 9,995 DKK (approx. 11,900 SEK) for an installation of a private home-charging station. All electricity consumed for charging is included in the subscription. The better-place charging stations in Denmark is either one phase 230 volt 16 A or three phase 400 volt 16 A. The launch on the Danish and Israeli market will very important for Better Places since it will show the actual interest from customers to pay for these kinds of services. Founder and CEO of Better Place, Shai Agassi compares Better Place's business idea to phone operator. Better Place doesn't provide cars but the services needed to use the car.

4.4 Examples of research and technology

As with other next generation vehicles, there are many technological, as well as economical, challenges to overcome in EV. The Japanese Automotive Association is classifying the challenges in the table below. The more triangles the greater challenge and a circle represents that there is no challenge at all.

Figure 4-3 Challenges for next generation vehicles

Vehicle type	Impact on CO_2 reduction	CHALLENGES			
		Cost	Battery performance	Travel range per charge	Infra-structure
Natural gas	Small	△△	–	△△△	△△△
Clean diesel	Small	△△	–	◎	–
Flex-fuel	Small	△	–	○	△△
Hybrid	Medium	△△	△	◎	–
Plug-in hybrid	Med-Large	△△	△△△	◎	△
Electric	Large	△△△	△△△△	△△△△	△△
Fuel cell	Large	△△△△	△	△△	△△△△
Hydrogen	Large	△△	–	△△△	△△△△

Source: JAMA 2010

4.4.1 Batteries

In EV, battery plays a central role in overcoming the challenges and there is no doubt that the battery is the key technology which would nurture not only the EVs market but also HVs, fuel cell vehicles. It is a necessity to develop batteries at lower costs and higher performance; the combustion engine technology which was at the center of technological development in conventional cars is replaced by battery technology in the next generation cars. Although the policy measures introduced during 1997 to 2007 did not have good results in terms of market introduction, however, they played a role in acceleration of R&D which has lead current Japanese strength in battery technology. (METI 2010a)

Statistics show that currently Japanese battery manufacturers are world leading, including capability of production, the increasing number of enterprises entering the EV and the lithium-ion market globally, Japan and Japanese auto makers are not at ease. Additionally, although Japan is world-leading in the number of patents Japan holds on materials of lithium-ion batteries, other countries, especially China, is significantly increasing its number of patents registered and academic papers presented. Japan has seen its leading position over-taken by other countries in electronics as the market matured in this past ten years and manufactures are concerned that the same may happen for batteries in Japan. (METI 2010b)

Especially with a social system of Japan yet to nurture venture businesses like Tesla or Fisker abroad and with the decrease in revenues for large auto manufactures, the industry-government-academia collaboration is becoming more important than ever before. The following R&D projects are in progress by industry-government-academia collaboration funded by Ministry of Economy, Trade and Industry (METI) through research funding and managing organization, New Energy and Industrial Technology Development Organization (NEDO):

(1) Development of advanced lithium-ion batteries (FY 2007-2011)

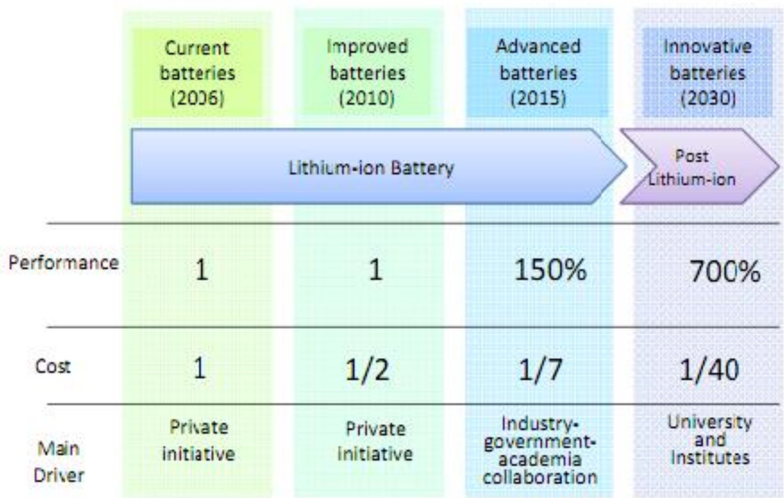
- Aim to improve the performance, and reduce the cost, of lithium-ion storage batteries as the power source of hybrid and electric vehicles.
- FY 2011 budget: ¥2.48 billion (approx. 210 million SEK)

(2) Development of innovative batteries (post-lithium-ion batteries) (FY 2009-2015)

- Aim to elucidate the reaction mechanism of the storage battery through comprehensive joint studies by government, industry and academia, and become the front-runner in post-lithium-ion battery development.
- FY 2011 budget: ¥3 billion (approx. 255 million SEK)

(METI 2011)

Figure 4-4 Battery Technology Roadmap



Source: METI 2011

The action plan proposed in the “Statement towards the future of battery used in next-generation vehicles (tentative translation)” compiled in 2006, the target is to increase battery performance by 1.5-, 3- and 7-fold, while decreasing the cost to by 1/7 , 1/10 and 1/40 (in comparison to 2006) in 2015, 2020 and 2030, respectively. (METI 2010a) To conclude the goals from the Japanese Government regarding battery technology are very optimistic and can be difficult to achieve. It is very difficult to predict how fast the development of batteries will be in future. Cutting the costs and improving the performances of batteries are challenges that the industry has to overcome if EVs should be more widespread in the future.

4.4.2 In-wheel motors

Professor Hiroshi Shimizu is head of EV-laboratory at Keio University. The EV-laboratory has carried out several successful research projects. The laboratory has developed a special concept for EVs that consists of three different technologies in-wheel motor, component built in frame, and tandem wheel suspension. The in-wheels motors make the EV more efficient because of less transmissions losses. The frame is flat which allows for better space inside the car. (SIM Drive 2011) The most famous car developed is Eliica or electric Lithium-Ion Car, this vehicle, runs on lithium-ion batteries, and currently is capable of running at 370 kilometers per hour. The team's goal is to exceed 400 kilometers per hour kilometers per hour, breaking the record set by today's gasoline-powered vehicles. The projected was funded and operated in collaboration of approximately 40 private companies. (Keio University 2010). The latest from the EV-laboratory at Keio University is an EV-bus, Sakura. It uses the same technology as the Elica car. The bus has been tested in normal traffic and the bus will 2012 be tested together with JFE Engineering’s super-fast charging technology (160kW) in a project together with Kanagawa prefecture. (Keio University 2011)

Figure 4-5 Eliica

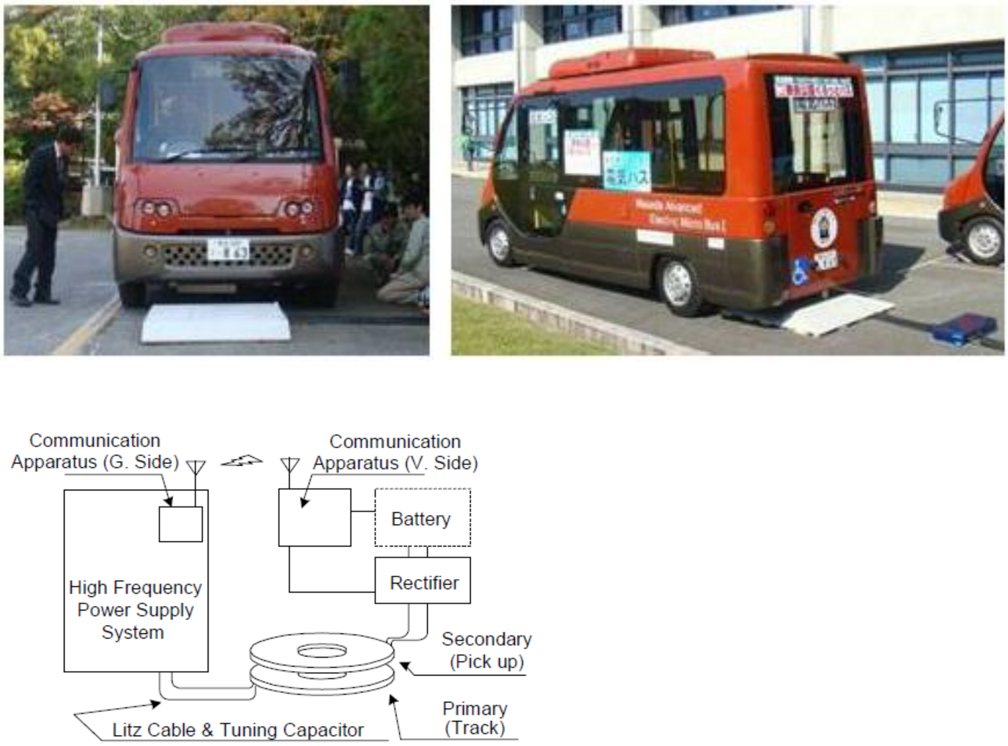
Source: Keio University 2010

4.4.3 Wireless charging

Wireless charging or inductive charging is a way to transfer electricity by using magnet field between two coils. One of the coils is in the car and the other one is on the ground. The main advantage of wireless charging is the convenience for the users as there is no need to think about plugging in a connector to the car all the time. The technology can be used in the future for charging not only EVs but also mobile phones, laptops and more. Several Japanese auto manufacturers are developing wireless charging solutions. The first products are expected to be on the market relatively soon. Nissan has announced that they will release a wireless charging solution in 2013. Both Toyota and Mitsubishi displayed prototypes at the Tokyo Motor Show 2011. Mitsubishi and Toyota is working together with American company Witricity. (Witricity 2011) The exact price for wireless charging technology in the car and infrastructure on the ground is unknown. A representative from Mitsubishi thought that wireless charging solutions first will be installed in Smart community projects, such as Hammarby Sjöstad due to high costs and then in the future outside private persons houses. The prototype from Mitsubishi had an efficiency of over 90 percent and could charge with power of 3 kW. The distance between the “transmitter” in the ground and “receiver” in the car was 20 cm. (TMSa 2011)

Waseda University in Tokyo is collaborating with Showa Aircraft Industries in a research project about inductive charging. They have developed a bus that can be charged wireless. They call their system rapid charging inductive power supply (IPS) system. Their IPS system is capable of transferring 30kW ten times as much as the prototype from Mitsubishi. The weight of “receiver” in the bus is 35kg and weight of “transmitter” in the ground is 30 kg. The distance in between is 10 cm and efficiency is 92 per cent. (Kobayashi, Pontefract, Kamiya, Daisho 2011)

Figure 4-6 Wireless Charging Waseda University



Source: (Kobayashi, Pontefract, Kamiya, Daisho 2011)

5 Conclusion

The major difference with the on-going introduction of EVs in Japan this time compared to previous ones is that there are many indicators that this time the EVs are here to stay. The major Japanese car manufacturers are releasing several EVs models now and the sales volumes are considerably higher than before but still at very low level compared to conventional cars. Japan is also building up a network of quick chargers (CHAdeMO) to be used by the EVs. On the other side, the still relatively short driving range makes the pure EVs only suitable for short-distance driving. The high prices even with subsidies are resulting in that the major customers are expected to be governments and companies. These two factors, the driving range and the price combined are causing EVs, initially to be a niche product, and a breakthrough in battery technology is needed to reach a larger market. To solve this, the Japanese government is supporting battery development through various research projects. Japan has several large battery manufacturers but manufacturers of other countries, notably Korea and China, are increasing their market share. However, the Japanese manufactures still remain to be important players in the game and technology advancement from those manufactures should be necessary to follow, not only for vehicle manufacturers.

The main challenges for EVs are the same throughout the world. Compared to Japan Sweden has an advantage with a large number of outlets used for pre-heating vehicle engines during wintertime that can be used for slow charging but a disadvantage with a cold climate and longer driving distances. For Sweden it is relevant to monitor the development in Japan and transfer possible good practices. With respect to the EVs itself, this mainly, in our opinion is a question of having knowledge of the technological frontline and commercial introduction. However, the charging infrastructure issues including the experiences from being the fore-runner we feel should be followed more closely. The development of the Japanese system for quick charging is especially interesting to follow. Furthermore, in 2012 a competing standard supported by major German and American manufacturers is expected to be released. The outcome, which will be the winning standard, is unclear. On top of that pure EVs might not be the vehicles of the future, to overcome the short driving range, car manufactures are diversifying their strategies and releasing PHEVs which eliminates the range issue. Additionally, in 2015 the first FCVs are planned to be commercially released in Japan but a high cost for both the FCVs and the infrastructure for hydrogen distribution is expected.

The Great East Japan Earthquake made people more aware of energy usage and started a green trend in the society which improved the image of EVs in Japan. In Japan there are special EV/PHV towns with special incentives and subsidies to support the introduction of vehicles at a municipal level, often offering additionally subsidies for acquisition in addition to financial incentives offered nationally. Among other factors that might increase the number of EVs are solutions such as battery switching, wireless charging and possibility to use the battery as storage for backup, solar energy and peak demand shifting.

To conclude, this report has illustrated some of the preconditions that need to be in place for a technology shift to take place towards a greater usage of EVs. Some of these aspects obviously would be more specific relevance in a pure Japanese context, while others would have relevance also for Sweden:

1. Market maturity – the cost to buy an EV or PHEV has to decrease, the Japanese car manufacturers are among the leading ones. Changes in the cost structure may affect the consumer adaption. In this respect the Swedish “miljöbilspremie” serves a good initial purpose. A question is if this incentive is enough.
2. Tech maturity – It is desirable that the performance of batteries has to improve; the Japanese Government is supporting various research efforts.
3. Infrastructure - Quick charging in the public space and access to slow charging at home. Japan has an advantage when it comes quick charging through the CHAdeMO association. Support from the governmental level to establish a charging infrastructure could be a possible way forward for a faster introduction.
4. External events to push things along, the Great East Japan Earthquake started a green trend in Japan, where EVs may be seen to find a use also as a back-up system for electricity.

Sweden has ambitions to realize sustainable urban development and to decrease fossil fuel dependency in the transport sector. EV is not the sole solution to realize these ambitions but is and will be playing an important role in both endeavors. Also, as it came to more realistic terms with the shortage of electricity and increased awareness on renewable energy in Japan, the possibility of EV as part of smart grid is to be considered. There should be something for Sweden to take from the “experiences” from Japan surrounding EV, not just the technologies, but the issues infrastructures, policies to increase and accelerate market penetration and use (of EV) as part of the grid system.

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