Reprinted from

KITAKYUSHU SHIRITSU DAIGAKU HOU-SEI RONSHU

Journal of Law and Political Science. Vol. XLVIII No. 1 / 2

December 2020

Sustainability and Challenges of Electrical Vehicles in Asia

Chowdhury Mahbubul Alam

KITAKYUSHU SHIRITSU DAIGAKU HOU-SEI RONSHU, Journal of Law and Political Science. Vol. XLVIII No. 1/2, December 2020

Sustainability and Challenges of Electrical Vehicles in Asia

Chowdhury Mahbubul Alam *

Abstract

The automobile industry is experiencing a technological revolution with the rise of electric drive vehicles (EDVs), which are challenging their internal combustion engine vehicles (ICEVs) counterparts. Due to the problems caused by the gasoline engine on the environment and people, the automotive industry has turned again to the electrical powered vehicle. There is growing environmental awareness, increased innovation, growing consumer acceptance, government support of infrastructure and financial subsidies, and investments by OEMs (original equipment manufacturer), and therefore an increasing demand for EDVs. But there are still many issues with EDVs that need to be resolved in the near future. In addition, EDVs have a promising future, although it's going to be a long journey to get close to ICEVs, which have existed for more than a century. This study explains how the challenges facing EDVs will be solved and how they will be made sustainable in Asia and the world. The world's largest EDV auto market is in Asia, specifically China, Japan, South

* Professor, Department of International Liberal Arts and Graduate School of Humanities and Social Sciences, Fukuoka Women's University.

Korea, India and some others southeast Asian countries and regions although the automobile industry worldwide has been providing consumers with a broad range of EDVs, Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (EVs), Fuel Cell Electric Vehicles (FCEVs) and others. This paper demonstrates some of the advantages and disadvantages of EVs and gives a brief view of the technological development of these cars.

Keywords: electric drive vehicles (EDVs), challenges, sustainability, technology, innovation

I　Introduction

At the end of the December and into the new-year of 2018-19, I visited Bangladesh. There I noticed so many battery-driven three wheelers light commercial vehicles (LCVs), on roads in the countryside. I was astonished, and wondered what was happening in the field of electrical vehicles in developing countries like Bangladesh, as well as other Asian countries. The rising personal income and wealth, as well as increasing per capita incomes have created a middle class and purchasing power has been contributing to the affordability of ICEVs as well as an electric cars. According to the IMF in 2014, China became the world's largest economy ranked on its purchasing power. America is now number two. In addition, the IMF figures also showed that three of the world's four largest economies are in Asia, with Japan at number three and India at number four (Gideon 2017, IX). Asia over the last five decades has made extraordinary economic progress that has contributed to making the region wealthy and powerful through a process called 'Easternization' (Gideon 2017, IX). The expansion of the Asian economy in recent decades, however, has also caused a negative impact on environments, with the increasing demand for oil raising concerns from both government authorities and the international community. As a result, governments initiatives and automakers have prioritized the innovation for alternatives to oil as a means of vehicle propulsion, and the Toyota Prius hybrid is an example of this prioritization. At present there are many types of EDVs including the Nissan Leaf, Tesla S model and others environmentally-friendly vehicles, next generation vehicles which are being produced worldwide. For the purposes of this paper all-electric vehicles or Battery Electric Vehicles will be noted as Electric Vehicles (EVs).

The International Energy Agency (IEA), together with Bloomberg's research by predicts that sales of EDVs will increase from 1.1 million in 2017, to 11 million in 2025 worldwide. Bloomberg calculated that EDVs will become cheaper to produce than ICEVs, resulting in a surge in sales of up to 30 million by 2030.

This article provides a comprehensive overview of EDV research and describes Battery Electric Vehicles (EVs), concepts, market share and future markets, challenges, prospects and sustainability development. This study is based on secondary and archival materials and documents. The discussion is organized as follows: Section 2, Electrical Vehicles in Asia; Section 3, Challenges of Electric Vehicles; Section 4, Sustainability of Electric Vehicles; and Section 5, Concluding Remarks.

Ⅱ　Electrical Vehicles in Asia

Since the beginning of the new century, the Fourth Industrial Revolution has been contributing to the newest technologies like robots, AI, drones, internet of things (IoT), electric drive vehicle (EDVs)[(1)], which, as stated above are Electric Vehicles (EVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicle (HEVs), Fuel-Cell Electric Vehicles (FCEVs), and others. The reason for this is that even though these innovations are breakthroughs, they still can be improved in many aspects in order to make these cars more affordable and more reliable (in automobile sectors). Nowadays, almost every automaker is investing in EVs in order to improve their models, range and others technology to make the cars more convenient and the companies more competitive. It is also important here to remember that the Kyoto Protocol of 1997, aimed at reducing greenhouse gas emissions, but the situation has not significantly changed and an explicit link between the transportation sector and fossil fuel led pollution was made (Høyer 2008, 63-71). Despite this, most automobile manufacturers continued for a number of years to demonstrate widespread reluctance to shift production towards EDVs. As an example, GM came up with the Chevrolet Volt in 2007, a vehicle that would drive on battery power; Tesla Motors produced the luxury model Tesla Roadster in 2010, and Nissan Leaf introduced the first Asian mass produced EDV. The Mitsubishi iMieV is the first EV that sold more than 10,000 units in 2011. The Prius Model through Toyota's successful innovation, totaled 3 million units sold in 2013 (Chowdhury 2019, 24). According to research by NRI, there are three reasons for the increase in the share of HEVs. The first, relates to the electric drive vehicle strategies of Japanese automakers. Toyota and Honda have placed emphasis on HEVs from the beginning of the development of EDVs. Nissan, which first company which focused only on all-electric vehicles or Battery Electric Vehicles (EVs), and later shifted to a

(1) Electric drive vehicles include battery electric vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicle (HEVs) and Fuel-Cell Electric Vehicles (FCEVs). A BEV, pure electric vehicle, only-electric vehicle or all-electric vehicle is a type of electric vehicle (EV). PHEVs are like HEVs but have a larger battery that allows them to travel on electricity alone. The battery can be charged by plugging in to an electric power source. HEVs are powered by a traditional gasoline or diesel ICE and by one or more electric motors that use energy stored in a battery. And FCEVs, the electric motor is powered by a hydrogen fuel cell. Within the fuel cell, hydrogen gas is combined with oxygen drawn from the air to create water (H_2O). All these types of vehicles, different size and model, cars, light commercial vehicles, buses, trucks, and two- and three wheelers vehicles.

strategy involving both EVs and HEVs. The second factor is related to an image building strategy. Automakers made marketing efforts to evoke an image that "HEVs are environmentally friendly." This strategy has appealed to users who wanted to have a feeling of superiority and differentiation in the sense that they drive expensive, eco-friendly cars. In particular, by launching dedicated hybrid models, Toyota was successful in making these models iconic so that everyone would recognize them as hybrid cars. The third factor concerns Japan's unique road conditions. Because there are many curves and hills in Japan, drivers must frequently accelerate or reduce speed and must often endure stop-and-go traffic jams. HEVs are efficient at dealing with such driving conditions (Kazama, *et. al.,* 2017, 4). As a result, the global EDV market is dominated by Asia and is expected to be the largest market for EDVs for the near future. Government support, in the form of subsidies and tax rebates, and the continued building of charging infrastructure will encourage the use of EDVs.

１．Brief Historical Background of EDV

In the earliest days of the automobile in the late nineteenth century, many kinds of cars competed with each other; steam, battery, and ICE. In 1896, Morris and Salom were the first to start a horseless vehicle scheme which has had encourage, the Electric Carriage and Wagon Company started with capital of $10,000 in January of the same year. Among the founders was George Herbert Condict, a leading battery engineer who later played a crucial role in the expansion of the New York electric EDV system (David, 2000, 36).

However, battery powered cars were already in existence as early as the 1890s and by 1897 electric taxis had been deployed in London, New York, and Paris (Høyer, 2008, 63-71). According to Duke *et al.* (2009, 3455-3462) by 1898 the very first vehicle to achieve a speed of 100 km/hour was an electric car known as 'La Jamais Contente'. Table 1 following gives a brief historical background on EVs. The unfortunate decline in use and production of the EV occurred in the 1920s due to the reduced price of gasoline precipitated by the discovery of Texas crude oil, the invention of the electric starter, the mass production of ICEVs, better road systems and the high purchase price of EVs (Bellis, 2006, 1). Also, according to Bellis in the *History of Electric Vehicles*, "In 1912, an electric roadster sold for $1,750, while a gasoline car sold for $650" (Bellis, 2006, 1). The development of the ICEVs production process and gasoline service stations led to cheaper prices and quicker and easier refueling times of ICEVs, and as such, EVs gradually became obsolete.

ICEVs won the competition with EVs with the success of the Model T, which first rolled off the assembly line in 1908. However, a century later EVs were on the road again, because of the technology and innovation which contributed to its development. Interest in EVs has resurfaced due to concern for the environment and the damage inflicted on it by ICEVs. EVs are once again on the market, however, a mass transition to such vehicles from their gas-powered equivalents seems unlikely to happen just yet.

According to the IEA (2015), Japan and the US were the biggest consumers of EVs however in 2017 China became the biggest market. Although consolidated rankings on the production of these vehicles are not yet available, industry experts agree that the Asian countries Japan, South Korea, and China have shown the most significant technological advances and innovated EV related components, and parts. Batteries are an important component of EVs. The world top ten leaders of battery development and production are in Asian countries. Five are Japanese companies: AESC, Mitsubishi / GS Yuasa, Hitachi, Panasonic and Toshiba. Two are South Korean: LG Chem and Samsung SDI. There is also one joint venture company between Germany and South Korea: SK Continental E-Motion. BYD is the Chinese automaker rounding out the top 10 in the world ranking (Chowdhury, 2019, 39-40).

Table 1: Historical Development of Electric Drive Vehicle

- 1832 – Robert Anderson develops First Crude Electric Vehicle.
- 1890 – William Morrison develops first successful electric vehicle in the USA.
- 1899 – Electric Cars gain popularity
- 1900 – Electric Cars are the trend
- 1901 – The World First Hybrid Electric Car, the "Lohner – Porsche Mixed" is created by Ferdinand Porsche.
- 1908 – The Ford Model T is introduced by Henry Ford.
- 1912 – The Electric Starter is introduced.
- 1920 – 1935 – Decline in electric vehicles due to use of crude Texas Oil as fuel
- 1960s – Interest in electric vehicles regain as Fuel prices soar
- 1971 – First Manned Electric Vehicle for the moon, NASA's Lunar Rover is developed.
- 1973 – Many Automakers explore alternative options to fuel
- 1974 – Sebring Vanguard introduces the 'Citi Car'.
- 1979 – Interest in Electric Cars fade due to drawbacks
- 1990 – Clean Air Amendment Act is passed.
- 1992 – Energy Policy Act is passed.
- 1996 – General Motors launch EV1.
- 1997 – Toyota produces the first mass produced hybrid, the 'Prius'.
- 2006 – TESLA announces production of luxury electric cars
- 2008 – TESLA produces its first electric vehicle, the Roadster with range of 244 miles per charge.
- 2009 – US Energy Department invests in nation-wide charging infrastructure.
- 2010 – General Motors introduce first Plug In Hybrid, the Chevy Volt.
- Nissan introduces LEAF, an EV, zero emission cars.
- 2012 – TESLA introduces Model S with battery range of 270 miles per charge.
- 2013 – Cost of Electric Vehicle Batteries drop by 50%.
- 2014 – TESLA announces plan to build 'Gigafactory' and double worlds 2014 battery production figures.
- 2016 – BMW Group, Daimler AG, Volkswagen Group with Audi and Porsche along with Ford Motor Company (European Division) agree to build ultra fast charging sites across Europe by 2020.
- 2017 – Toyota announces sales of 10 million hybrids since production of 'Prius'.
- 2019 – Expected date by which Swedish Automaker Volvo announces to produce only electric and hybrid cars.
- 2020 – China's expectation of 10% of auto imports and production will be only electric vehicles.
- 2025 – Expected date by which Norway and Netherlands plan to ban sales of petrol and diesel cars.
- 2030 – Expected date by which India plans to promote an all-electric car fleet. Also, China expects to limit its carbon emissions, hence affecting sales of petroleum-based cars.
- 2040 – Expected date by which Britain and France announce plans to ban sales of all new petroleum based vehicles.

Source: Mohamed M, G Tamil Arasan and G Sivakumar (2018)

2．Current Status of EDV Technology

EDVs are a promising technology for drastically reducing the environmental burden of road transport. More than a decade ago EDVs were advocated by various actors as an important element in reducing emissions of CO_2, air pollutants and noise in particular. An EDV operates differently from a vehicle with an ICE (Table 2). In terms of structure, ICEVs and EDVs share similar basic structural parts, such as the chassis and the body. On the other hand, EVs neither need a fuel tank, exhaust system or catalyst and the five or six speed gearbox is normally replaced by a single speed with torque flow (turning force) which is briefly interrupted when the driver changes gears. In small size EVs with low maximum speeds, a gearbox is neither needed nor optimal. Some EVs, like the Tesla for example, do have 2 gears though.

An EV is powered by electricity with a large, rechargeable battery, an electric motor, and a controller that sends electricity to the motor from the driver’s accelerator pedal, and a charging system. Vehicle to grid (V2G) is an important technology which allows vehicles to feed electricity back into the grid, it is a reverse charge system.

The EV is propelled by an electric motor, powered by rechargeable battery packs, unlike ICEVs (Figure 1). There are other types of vehicles, like fuel cell electric vehicles, which are powered by hydrogen fuel cells, essentially a battery fed by an external source of hydrogen. Electric motors are smaller, more

Table 2: The EV Excluded Parts

Engine Related Parts	Drive Related Parts
engine block, engine head, piston, incidental parts, fuel injection device, crankshaft, camshaft lubricator, cooling means, air intake and exhaust tube carburetor, manifold, supercharger, turbocharger, muffler, ignition, starter, spark plugs	Manual Transmission (MT) Automatic Transmission (AT) parts for transmissions clutch, fuel tank

Source*: sōgō kenkyūjo (2011), Nippon kōko sōken repōto*

Figure 1: Common factors of Electric Drive Vehicles

<table>
<tr><td colspan="3">Common factor</td><td rowspan="2">Four Type of EDV</td></tr>
<tr><td rowspan="5">Battery

Motor

Inverter
</td><td colspan="2"></td></tr>
<tr><td rowspan="4">＋</td><td>＋ Charger</td><td>Battery Electric Vehicle (EV) or Electric Vehicles (EVs)</td></tr>
<tr><td>Engine ＋ Charger</td><td>Plugin Hybrid Electric Vehicle (PHEV)</td></tr>
<tr><td>Engine</td><td>Hybrid Electric Vehicle (HEV)</td></tr>
<tr><td>Fuel cell + Hydrogen tank</td><td>Fuel Cell Electric Vehicle (FCEV)</td></tr>
</table>

Source: Ministry of the Environment (MOE, 2016) *Jisedai jidōsha gaidobukku, Website.*

compact, and more efficient than existing motors even those presently used in ICEVs, and the batteries used in EVs are getting better year by year.

In spite of the differences, ICEVs or hybrid vehicles are dominating car markets in Asia. The primary reason behind that is the low driving range of EDVs. Among various possible improvements to extend EDV range, regenerative braking is one unique advantage EVs have over ICEVs.

However, continuing advances in EDV technology has meant improvements in batteries, chassis, regenerative braking, as well as in other areas. At present the maximum speed of the EV is limited to 150 km/h and a range of up to 300 km on a single charge. This includes highway capable EVs such as the Nissan LEAF, Ford Focus Electric, and Mitsubishi i-MiEV. PHEVs have the capacity to operate as 100 percent electric and include an auxiliary ICE that operates after battery depletion. Small, segment EVs with short operating ranges, usually have a range of under 100 km.

3．EDVs in Some Asian Countries

After the Second World War, Asia was a region with a ‘poor’, ‘low-income’ image. Over the last couple of decades a number of Asian countries have achieved miracle economic growth and social development. Economic growth has driven prosperity and helped to shift them from low-income countries to middle income and middle to high income countries [(2)]. Vis-a-vis household income categories have moved from low income to middle income, middle to high income and high income classes are growing (Chowdhury 2018, 28-29).

Rising income levels and increasing prosperity in Asian countries and different regions throughout Asia, means more and more people are able to afford personal cars. According to Bloomberg (2018), approximately 900 million vehicles are on the roads today worldwide. About 96 percent of the fuel used for propulsion purposes is produced energy from fossil fuels. There are estimates for the year 2020 that the number of vehicles will increase to approximately 1.1 billion worldwide, due, in particular, to the economic growth and industrial development of Asian countries especially India and China. In 2016, automobiles including EDVs sold in 18 Asian countries, totaled 42.64 million which was the first time the total sales number exceeded 40 million units. China was the highest at 28.03 million units, Japan 4.97 million units and India 3.71 million units (Fourin, 2017a, 270-275).

Relatively affordable personal cars mean significant increases in vehicle travel, more often and for long distances, and developing tracts of suburban housing, shopping centers and workplaces bring about an increasing demand for

---

(2) According to the World Bank Report, the world’s Middle Income Countries (MICs), which are defined as having a per capita gross national income of US$1,026 to $12,475 (2011) are a diverse group by size, population, and income level. Middle income countries are home to five of the world’s seven billion people and 73 percent of the world’s poor people. At the same time, middle income countries represent about one third of global GDP and are major engines of global growth. (Loayza, N., *et. al.*, 2012, World Bank, website, Chowdhury, 2018, 58).

cars. In terms of the development of its EV industry, Asia has a leadership position, with Japan, South Korea and China at the forefront, with growing industrialization in India, Thailand, Indonesia, Malaysia and several other countries contributing to the growth of vehicular demand. In addition, automobile manufacturers in China, India and ASEAN [(3)] are also is takeoff periods from the development stage.

However, the EDV market, which has been growing since the late 20th century in some developed nations, has sparked a movement for mass adoption in some Asian countries. The EDV market in Asia is dominated by China, Japan and followed by South Korea, India and Thailand. Rising environmental awareness and government support are expected to assist in the expansion of the EDV~~s~~ market in these Asian regions (Table 3). India, China, and other Asian countries are reducing their dependence on costly fossil fuel by promoting EDVs.

According to the China Automotive Technology and Research Center (CATARC), China's new energy vehicle (NEV) market has been growing rapidly since around 2014 – 2015. In 2015, about 390,000 NEVs (of which, about 220,000 units are passenger cars and about 120,000 units are buses) were produced (Kazama, *et. al.,* 2017, 2). Both central and local governments provided a maximum of about 110,000 yuan per vehicle in financial subsidies in the large and medium sized cities, which has been contributing to the expansion of the NEV~~s~~ market in China. Other NEV purchase incentives include ~~a~~ free license plates and vehicle purchase tax exemptions. The cost of obtaining a license plate varies from city to city. The fee is most expensive in Beijing at

(3) Among the ASEAN-10, seven countries have exceeded the per capita income of UD$2000-3000, which has contributed to the motorization in the majority of ASEAN countries (Fourin, 2017b, 2-9). In this perspective, Asian cars have the potential to grow and there is a very good possibility of ASEAN countries becoming the world market leader of the EV industry.

around 100,000 yuan and it is also high in Shanghai at about 80,000 yuan. Given such high costs, the incentive of a free license plate has an extremely large impact on the purchase of NEVs (Kazama, *et. al.,* 2017, 2).

Although China's EDV market has seen expansion with government support and financial subsidies, it will only be continued until 2020 and it is noted by some that the market will decline after 2020. The Nomura Research Institute (NRI) however believes that the NEV market in China will not decline, due to others government support which will continue (Kazama, *et. al.*, 2017, 2).

Table 3:Trend of New Electric Car (EV and PHEV) in Some Asian Countries

(Units: 1,000)

Country	Type	2010	2011	2012	2013	2014	2015	2016	2017
China	Stock	1.91	6.98	16.88	32.22	105.39	312.77	648.77	1227.77
	Sales	1.43	5.07	9.90	15.34	73.17	207.38	336.00	579.00
	Market Share (%)	0.01	0.04	0.1	0.1	0.4	1.00	1.4	2.2
America	Stock	3.77	21.50	74.74	171.44	290.22	404.09	563.71	762.06
	Sales	1.19	17.73	53.24	96.70	118.78	113.87	159.62	198.35
	Market Share (%)	0.01	0.2	0.4	0.7	0.8	0.7	1.00	1.2
Japan	Stock	3.52	16.14	40.58	69.46	101.74	126.40	151.25	205.35
	Sales	2.44	12.62	24.44	28.88	32.29	24.65	24.85	54.10
	Market Share (%)	0.1	0.3	0.5	0.6	0.7	0.6	0.5	1.0
South Korea	Stock	0.06	0.34	0.85	1.45	2.76	5.95	11.21	25.92
	Sales	0.06	0.27	0.51	0.60	1.31	3.19	5.26	14.71
	Market Share (%)	-	0.02	0.04	0.1	0.1	0.3	0.5	1.3
India	Stock	0.88	1.33	2.76	2.95	3.35	4.35	4.80	6.80
	Sales	0.35	0.45	1.43	0.19	0.41	1.00	0.45	2.00
	Market Share (%)	0.1	0.3	0.05	0.01	0.02	0.04	0.02	0.06
Thailand	Stock	0.01	0.01	0.02	0.03	0.10	0.37	0.38	0.40
	Sales	0.01	0.01	0.01	0.01	0.07	0.27	-	0.03
	Market Share (%)	-	-	-	-	0.01	0.03	-	-
World	Stock	14.26	61.33	179.03	381.30	703.65	1239.45	1982.04	3209.05
	Sales	7.49	47.24	117.84	202.80	322.70	540.72	744.22	1148.70
	Market Share (%)	0.01	0.10	0.23	0.38	0.54	0.85	1.10	

Source: IEA, 2018, website, - (data are not available)

The high oil prices(4) in 2008 urged some consumers to shift from ICEVs to energy efficient EDVs and an example of this shift is in India which plans to replace all cars with electric ones by 2030. China plans to replace all gasoline vehicles by 2050, and as a first step the country has been offering considerable subsidies on EDVs depending upon battery size. Government subsidies are seen as a positive move for the industry, which would encourage consumers to purchase vehicles and promote the idea that the government is being supportive.

That EDVs are becoming more popular is unquestionable, especially considering that only a decade ago this type of transportation seemed a distant and perhaps unrealistic dream (5). The introduction of EDVs into the global market has massively influenced consumers who consider buying a new vehicle. According to Accenture, survey of over 7000 people in 13 countries, found that about 60 percent of those respondents who intend to purchase a car within the next decade, say that they will probably or certainly consider EDVs. This includes both plug-in hybrid electric vehicles and EDVs models (Accenture, 2011, website).

The number of EDVs sold in 2017 was; in China 1.23 million, America 0.76 million, EU 0.82 million and others 0.30 million, with more than half of global sales in China. The total number of EDVs sold has grown from 45,000 units in 2011 to 300,000 units in 2014 and 3 million worldwide in 2017, an expansion of over 50 percent from 2016 (IEA, 2018, website). Table 4 below shows, the number of EDVs sold by different automakers like; Nissan 119,195 vehicles, BYD 113,949 vehicles, Tesla 103,122 vehicles, BMW 103,080 vehicles, and

---

(4) In 2015 the price for a barrel of crude oil was less than $50 compared to approximately $115 per barrel in June 2014, (http://www.vox.com/2014/12/16/7401705/oil-prices-falling).

(5) The 2006 American documentary "Who Killed the Electric Car" (Sony Pictures) gave a troubling account of how despite developing and test marketing its first electric car (the EV1) and even though this model was well received by many, GM was a key protagonist in terminating the program demonstrating that the major players in the motor industry were not yet ready to move away from the status quo.

Toyota 50,883 vehicles which have been leading the worldwide markets and BYD, BAIC (Beijing Automotive Industry Holding Co., Ltd.) and Geely have dominated the Chinese domestic market.

Table 4: EDV Sales Ranking in the World in 2017

Rank	Company	Vehicle units
1	Renault-Nissan-Mitsubishi(Japan)	119,195
2	BYD Group (China)	113,949
3	BAIC Group (China)	104,536
4	Geely Group (China)	103,194
5	Tesla (America)	103,122
6	BMW Group(Germany)	103,080
7	Volkswagen Group(Germany)	70,314
8	SAIC group (China)	56,149
9	GM (America)	55,188
10	Toyota（Japan）	50,883

Source：Inside EDVs "Plug-In Electric Car Sales Ranked By OEM for 2017"

Ⅲ Challenges of Electric Vehicles (EVs)

A wide range of research documentation, international institutions, international organizations, and literature reviews covers a variety of EV issues including; high prices, the lack of charging infrastructure, the weight and size of batteries, and also some technological issues related to the development of EVs. One of the main challenges is that the purchase price is still higher than that of ICEVs. Due to the high cost of some important components in particular, motors, inverters, controllers and batteries.

The EVs that are being developed are not yet competitive with ICEV technology. One of the main issues is batteries. The battery capacity of EVs is limited, thus it is necessary to charge and re-charge when doing long distant runs. Table 5 below shows, the Nissan Leaf X models' ranges is a maximum of

400 kilometers. Recently, there some automakers producing high range~~s~~ EVs which run over 500 km, Tesla Motors X model range~~s~~ maximum is 565 km, but the price is very high at more than 13 million yen, as shown in Table 5. The small size EVs have a range of less than 200 km and need to be recharged. The Mitsubishi’s Minicab range is only 150 km. Small size EVs can be used as a second car or as a substitute for a bicycle or 50cc motor cycle, which are not normally used for longer trips or long distance driving. Most of these smaller EVs are only available as two-seaters and are not permitted on highways or freeways. A survey by Kempton and Tomi (2005) points out that drivers of these smaller vehicles prefer to maintain a minimum range of 30 km (Kempton and Tomi, 2005, 144).

According to a personal survey done by e-mail, telephone and direct interview in the Japanese cities- of Nagoya, Fukuoka and Kitakyushu City in 2018 by the author, many residents, it turned out, are owners of EVs. The object of the survey was simply to establish “the advantages and disadvantages of driving an EV”. The surveyed population were retired men, salary-men, ‘office ladies’ and housewives. The survey showed that, the interviewees usually drove on a daily average less than 100 km. It is reasonable to assume that the power

Table 5: Price of New EV in Japan in 2018

Maker	Car model	Main grade	Price (tax-included Japanese yen)	Maximum range (km)
Nissan	Leaf	X	3,513,240	400
	e-NV	G　Seven-passenger	4,762,800	300
Mitsubishi	i-MiEV	X	2,948,400	164
	Minicab	CD 16.0 ｋ Wh	2,150,280	150
BMW	i3	Lodge	5,800,000	390
Volkswagen	e-Golf	Premium	5,349,000	301
Tesla Motors	Model S	100D	12,506,000	594
	Model X	100D	13,541,200	565

Source: Renewable Energy Institution, 2018, *EV Fukyu no Doki to tenbou.*

equivalent of about half of this distance would be available at charger stations in these cities.

The above survey population mentioned the following advantages are, fuel cost savings, lower emissions, low maintenance costs, fewer maintenance cycles, tax incentives are mainly. These advantages should encourage EV customers. However, the literal survey and some document also shows the following disadvantages associated with EVs.

Safety problems: High levels of awareness of EVs drivers, and the need for more re-charging to run longer distances means an increase in rage anxiety or road rage. There are concerns expressed that EV's are very quiet at low speeds compared to ICEVs, which is, or can be, a safety hazard for cyclists, runners, small children, and other pedestrians. The problem can be especially acute at intersections with loud noise and where blind pedestrians make decisions about crossing streets, however quite and can lead to accidents in some cases. Therefore, many people are not confident when choosing an EV over another car for performing trip.

Over heating problems: EVs with thermal management systems make use of coolants, ICEV have easy access to airflow from the front of the vehicle but electric motors tend to be axle-mounted which makes them significantly more complicated to cool. EVs can only run at top speed for a very short time because of overheating issues. EV use because of its high energy density to overheat possibly leading to fires or explosions, especially when damaged in a crash.

Maintenance problems: EVs will not bring any easy fixes for their owners. EDVs have fewer moving parts than ICEVs. At the same time, there was a lack of available resources for quickly solving technical issues with EDVs (Pelletier *et al,* 2014). Ninh *et al*. (2014) stated, there are "only some garages where they know technical specifications of EDVs in order to fix them". As EDVs are still relatively new product, limited technical parts, limited of skilled servicemen to repair. Therefore, repair time is very long – sometimes up to several months

(Ninh *et al*., 2014).

High price: EVs are predicated to cost significantly more than their ICEV counterparts so the high prices of EVs is a big challenge. To overcome this challenge automakers have been making an effort to introduce cost reduction strategies through technology development. There are some other important EV component related challenges, which are as follows.

1. Battery Related Challenges

Batteries are one of the most important parts of an EV as they store electric energy, which in turn powers a motor. Range, charging speed, durability, availability and environmental impacts of materials depend on batteries. Recently, several types of battery have shown great potential for use in EVs including lead-acid (LA) batteries, nickel-metal hydride (NiMH), Technology batteries, and lithium-ion (Li-ion)[(6)] batteries (Bleischwitz, 2010, 227-244; Wang, *et al.*, 2010, 362-366; Wadia, *et al.*, 2011, 1593-1598). Lead acid batteries are not only low in weight, but have a low power density and have a smaller range. They are also very cheap when compared to Li-ion batteries.

There are various alternative battery technologies for EVs including metal air and sodium batteries (Wanger, 2011, 202-206), but these technologies are still being developed and are not yet competitive. Lithium-ion (Li-ion) cells enjoy the bulk of investment, and remain the preferred technology for some

(6) Lithium, the lightest solid element, is an excellent conductor of electricity and heat. In the Lithium-ion battery, lithium is not the only rare material used in their production. Dysprosium, lanthanum, neodymium, praseodymium and cobalt are also used. According to a 2015 US Geological Survey, Australia is the world's biggest supplier of lithium, followed by Chile, Argentina, China, and Zimbabwe roughly 90 percent of global resources. Sony commercialized the lithium-ion battery and the battery industry is dependent on this element; a smart phone battery contains 1 gram of lithium and 8 grams of cobalt. An EV requires 10kg of cobalt. Most of the world's cobalt comes from mineral-rich regions in Zambia and the Democratic Republic of Congo (DRC) (USDOE, 2011, website).

companies, like LG Chem, Panasonic, and Samsung, the three largest producers.

Over the past several years, battery costs have fallen significantly from around $1,000 per kWh in 2010 to $250 per kWh in 2018. Battery costs are commonly expressed in kilowatt hours (kWh). Recent reports indicate that Li-ion batteries cost about $500/kWh, which would mean the 16kWh Volt battery would cost $8,000 and the 24kWh Leaf battery would cost about $12,000. (National Research Council, 2013, 26). The Nissan Leaf powertrain grew from 24 kWh to 30 kWh in the first generation, then to 40 kWh in the second generation, while Tesla's Model S base model has grown from offering 60 kWh, to 70 kWh, with a 100 kWh model released in 2016. The total cost of an EV battery pack has declined more slowly than the cost per kilowatt-hour (kWh). As a result, installed battery costs continue to be a barrier to widespread consumer acceptance (Lee, and Clark, 2018, 1-5). Lithium-ion batteries dominate the EDV market, due to their excellent energy-to-weight ratio and increasingly attractive prices (Arrobas, Hund, McCormick, Ningthoujam, & Drexhage, 2017)[7].

２．Charging Related Challenges

Battery charges are limited, and drivers need the infrastructure to be made available for recharging batteries. Presently, there are three re-charging systems: household connections, fast charging and battery swap systems. Worldwide, only three standard-connectors are recognized, the American SAE, the International Electro-technical Commission (IEC) in the EU and CHAdeMO in Japan. Even though all players insist that they support a uniform standard, allowing any vehicle to charge at any station, and are increasing the total

⑺ Specifically, lithium cobalt oxide batteries lead the EV market, but other compositions include lithium nickel manganese cobalt oxide, lithium nickel cobalt aluminum oxide, lithium iron phosphate, lithium titanite, and lithium manganese oxides (Levin Sources, 2017; Synergy Files, 2016).

number of charging stations, there are not enough to cover the need. The other components of interest include the AC/DC converter for 14 Volt supply for the lights and ignitions (in PHEVs), high voltage wiring harness, the special heating ventilator. EVs and PHEVs carry an on-board inverter with limited capacity, to convert AC power to direct current (DC), which is required to charge the battery. There is otherwise no relevant difference in the AC and DC charging process. Charging stations can be divided into two types: fast charging and slow charging. A fast refueling station can quickly recharge an EV in less than five minutes (Wang, Y.; Wang, C. 2010, 791-810), but this kind of charging can significantly shorten the life of the batteries. Conversely, a slow refueling station needs a longer time to recharge an EV. At slow recharging stations of 110 volts 240 volts, EDVs need from two to eight hours to be fully charged. At recharge stations of 480 volts, charging a battery fully takes about 20–40 minutes.

３．Range Challenges

The driving range of EVs is also another challenge. Range anxiety reflects a concern about batteries in EVs losing power before reaching a destination or charging point. There are some European automakers who plan to focus on the deployment of PHEVs because EVs have a limited travel distance and many European countries provide incentives for PHEVs. On the other hand, the Chinese financial subsidy incentive program is provided to drivers of NEVs with a pure electric driving range of no less than 50 km. Recent progress in technology and innovation, in relation to range of EVs might increase significantly within a short time. Comparatively, the mechanical systems of EVs are not as complex as those of ICEVs. The producers of EVs will eventually overcome the disadvantages of range limitation and long charging times, and customers will shift from PHEVs to EVs. Recently there are many governments which support the expansion of the EV market including; Germany’s approval of a resolution calling for a ban on internal combustion engine vehicles, in

China, there are NEV regulations, zero emission vehicle (ZEV) regulations in America, in India there will be a ban on ICEVs and Japan is also emphasizing an increase on the number of EDVs. With all of these points being under consideration, there is a strong possibility that EVs will be in the mainstream by 2030.

Driver behavior has a direct and significant influence on vehicle range. A variety of accessories are used in cars; radios, tape recorders, air conditioning systems, wipers, window defrosters and lights, which are also used extensively, and the power needed for these accessories comes from the battery which makes driving ranges shorter. At low speeds it is recommended to circulate the air by opening windows rather than by using the air conditioner. This is just one way of avoiding power loss. Despite the auxiliary systems reducing the EV range, the main factor that contributes to the vehicle driving range, with a full battery, is driving style.

Drivers of EVs influence environmental impact through their driving styles and charging behaviors. An aggressive driving style leads to higher energy consumption whereas a more conscious and safe driving style results in an efficient use of energy. The use of heating and cooling to achieve desired temperatures also has a significant influence on energy consumption.

Therefore, batteries, chargers and range can significantly disadvantage EVs. Unlike EVs, which failed to inspire consumer confidence due to negative perceptions regarding limited range and refueling opportunities, not to mention high purchase costs (in the interview) this doesn’t fit here..., hybrids emerged as a popular option since the drivers of such vehicles are always able to fall back on gasoline power once the car has used up its battery power (Skerlos, and Winebrake, 2010). EV purchase costs are higher than average purchase costs for ICEVs, but the annualized effect of this incremental purchase cost is outweighed by significant fuel cost savings, as well as savings in scheduled maintenance costs. Over the last 20 years the price of gasolines has increased by 90 percent, while electricity prices have increased 43 to 45 percent. According to Skerlos, and Winebrake (2010), the sales numbers of hybrid vehicles such as the Toyota Prius and the Honda Insight has been growing since the late 1990s with more concerns about the rising cost of fuel than with concerns about the environment.

Fatih Birol, the Executive Director of the IEA stated, “EDVs today are not the end of global oil demand growth, nor are they the key solution to reducing carbon emissions... [that] five million EDVs globally is nothing compared to 1 billion ICE vehicles [and that] this year we expect global oil demand to increase by 1.3 million barrels per day. The effect of five million EDVs is 50,000 barrels per day. Which are large amount of oil 1.3 million” using in ICE (IEA, website). The demand for oil and environmental concerns still continue. As EDVs do not simply run on free energy, the energy that would have been provided by petroleum would need to be provided by electric power, coal-fired power, and/or nuclear, hydro, wind, or solar power sources. As a consequence, for sustainably scaling EV customer is the cost-effective, efficient deployment of the chassis is expected to be significantly lighter, battery, charging infrastructure and range have been identified as the technological challenge as follow that should be overcome in the successful development of the EDV for future markets.

Continuous technological developments, growing environmental awareness, and increased focus on sustainable energy are major driving factors in the global EDV market. NRIs research predicted that, HEV sales would peak around 2013 – 2014, but the market is heading for a (negative) turn-around due to the cost-consciousness of prospective buyers. HEVs are still expensive, even with tax incentives and subsidies, thus customers have started to lose interest (Kazama, *et. al.*, 2017, 4).

According to the Japan Automobile Dealers Association, in November 2016, sales of the ‘Nissan Note’, which has gained popularity by featuring a new electric-motor powertrain “e-Power,” beat the best-selling Prius (fourth generation) and ranked first in the Japanese market. The popularity of the ʻNissan Noteʼ, has occurred because the new model was launched offering two major marketing elements, freshness and reasonable price. As a result, Nissanʼs HEVs dominating the market might bring about a shift towards one in which EDVs and PHEVs take the majority share. NRIʼs research also estimated the size of the EDV market to be about 18 million units per year, about 17 percent of the overall car market. The average annual growth rate between 2016 and 2025 is estimated to be 26.6 percent (Kazama, *et. al*., 2017, 4).

Ⅳ　Sustainability of Electric Vehicles

“Sustainable Development” is a universally accepted solution to the economic development of humankind for present and future generations. Sustainable development is however a complex concept that is subject to numerous interpretations since it involves several disciplines and possible interconnections. There is still no single definition of sustainable EDVs. But what is clear is that in producing a sustainable EDV, effects on economy, environment, and society can only be positive. EDVs will be sustainable, because of the decreased burden on petroleum reserves, through EDVs new technology can be introduced, the use of IoT-enabled services can be increased and the introduction of AI can help decrease the number of road fatalities and injuries, and the negative impacts of petroleum-based emissions on air quality that can overcome. The problems related to noise pollution, structural damage due to vibration from ICE, pollution attributable to runoff from streets and highways, the loss of wetlands, open spaces, historic facilities, and ocean pollution due to oil spills and others problems can also be overcome. Ultimately, EDVs can contribute most positively to sustainability.

The sustainability of EDVs will have environmental and economic as well as social benefits. The expectation is that in the future, technological innovation in

EDVs will be more a sustainability driver than it was in the past. Despite the improvements in battery technology, EDVs at the moment are still unable to reach the range of ICEDVs. According to Lee and Clark, EDV deployment have become more tractable in recent years to overcome their challenges, however, there are still considerable challenges and sustainability is constantly under debate. IEA predicted that energy sources of EVs, that is, some charging stations, may not be regarded as "sustainable," however, in terms of direct emissions, EDVs do have advantages. The 'total life cost' of EDVs has fallen substantially and further declines in installed battery prices below per kwh may lead to genuine parity with ICEDVs in the next several years (Lee, and Clark, 2018, 1-5).

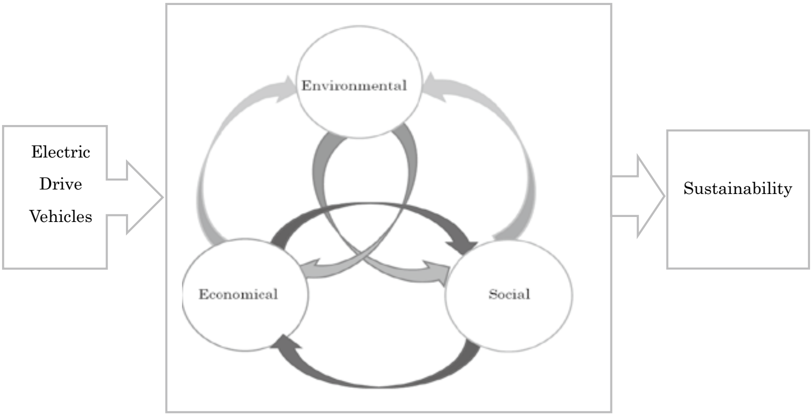
It can assumption but there are not statistics data here. EDVs have also been generating economic growth and social development opportunities by (indirectly) improving quality of life and health, reducing energy spending, and decreasing reliance on gasoline imports. Recently, EDVs have been advocated by various actors, for playing an important role in reducing emissions of CO_2, air pollutants and noise.

Figure 2 illustrates the three dimensions of sustainable development: "Environmental", "Economical" and "Social". Sustainable development applied to innovation of EDVs requires linkages between environmental protection, economic efficiency and social progress. The overall impact of the EDVs ultimately benefits people. These three dimensions are equally important in implementing sustainable development as indicated in Figure 2.

1. Environmental

Various efforts are on to find alternative energy sources for vehicles, and battery-operated vehicles are the cleanest 'zero emission' vehicles contributing to the environment. EDVs are a promising technology for drastically reducing the environmental burden of road transport as they are less polluting because

Figure 2: Sustainability of EVs



Source: Complied by author

they produce zero exhaust emissions. It is widely accepted that the main EDV ‘sustainability benefits’ are the reduction of; local emissions of CO_2, global warming, smog and air pollution and of noise in particular. In the the case of CO_2 emissions, electricity is used to charge EDV batteries so emissions are decreased. This reduction of harmful emissions will lead to better air quality, which is good for health.

Under this environmental dimension, achieving its objective depends on understanding the reciprocal influences of the physical environment, the practices of the automobile industry and that environmental issues need to be addressed by all aspects of the electro-mobility industry. The global EDV markets were discussed to identify the motivating dimension for EDV acceptance. This helped raise an important notion that EDVs have become a necessity to mitigate the rising global carbon emissions and through a strong, well established global market sustainable EVs will become a reality.

２．Economically

Under the economic dimension, the objective consists of orienting progress in the sense of economic efficiency is EDV innovation and technology helps grow an economy. An economy can be identified as a subset of society; the production and exchange of goods and developments in industry, business and technology are all in part based on social interactions. Transport must be cost-effective and capable of adapting to changing demands. EDV is an economy in itself. By buying an EDV, purchasers (may) receive government subsidies for being environmentally conscious. EDVs have a high initial cost due to the high price of batteries. This large initial cost can be returned from gasoline. EDVs also have less moving parts than those had by ICEVs (Table 6) and require less maintenance, which further reduces the cost and brings further financial return on the initial cost.

The automotive industry is a global technology and capital-intensive industry, with large product development and investment in fixed assets and significant economies of scale. The activities of global automakers, such as Renault-Nissan, Honda, Toyota, Ford, GM, Tesla, Volkswagen and others as well as domestic Chinese automakers, have announced their commitment to launch EVs. Volkswagen and other European automakers announced plans to put large numbers of new model EVs and PHEVs on the market. In 2016, Toyota announced its plan to start mass production of EVs by 2020. With the full-scale participation of the world's top two automakers, i.e., Toyota and Volkswagen, the EV market seems certain to grow (Kazama, *et. al*., 2017, 5).

Recently, the EV is an innovative concept in the world automotive industry. This innovation refers to the development of new products, new methods, new types of raw materials, new markets and new organizations. Innovation is therefore the component of an evolutionary view of the economic process. However, billions of dollars are needed to construct infrastructure like charging stations and increased grid capacity. Good government policies are needed to

Table 6: Comparison of Energy Costs of EDVs and ICEVs (Yen)

Types of Vehicle	Power/gasoline	1km	100 km	10,000 km
EDV	Daytime :25.19 /kWh	4	400	40,000
	Nighttime: 25.19 /kWh	2	200	20,000
ICEV	Gasoline 10km/L	16.5	1650	165,000
	Gasoline 20km/L	8.2	820	82,000
	Gasoline 30km/L	5.5	550	55,000

Note: 24kWhEV can run 150km, price of gasoline 160/L yen in 2011.
Source: Sōgō kenkyūjo (2011), Nippon kōko sōken repōto

further the development of EDV industries and technologies thereby creating opportunities for more employment. EDVs are perceived as technology in the automotive industry which contribute to sustainable development with lower greenhouse gas emissions, less air pollution and employment with positive social impacts. EDV adoption promises substantial environmental and economic benefits for society. It will also have substantial impacts on many other major industries, including the electric utility industry. Electric utilities will then be required to purchase electricity from the respective power producers.

EDV technology is more expensive compared with ICEV technology, mainly due to the cost of batteries but with new technology and mass production it is expected that EDVs will create a variety of potent economic development challenges and opportunities. However, due to incentives offered such as tax reductions and ~~a~~ municipal charging infrastructure, EDVs have been positively adopted in some Asian countries. While the EDV market is still at a relatively early stage of development, it is poised to reshape industries and communities the world over.

For this technology to realize widespread implementation, it requires policy makers, utility companies, and automobile manufacturers to come together and install vast amounts of infrastructure. Moreover, a transition to EDVs would mean that the industry needs to develop an entirely new set of suppliers, technicians, and assembly processes. Naturally, there will be resistance to this transition that will leave about a million automobile-technician jobs at stake, jobs that will ultimately contribute to economic sustainability.

３．Socially

Under the social dimension, the objective consists in upgrading standards of living and quality of life. Introducing a large number of EDVs will eliminate the unhealthy emissions of hydrocarbons, nitrogen oxides, and carbon monoxides (CO_2) from automobiles which are the causes of increasing risks of both cancer and lung diseases. Embracing this EDV revolution will not only help reduce our environmental problems, but also benefit~~s~~ public health. Fuel technological innovation could also have a large social benefit, due to improved air quality and thus reduced costs in health sectors.

The potential benefits of EVs are; reduced air pollution, reduced GHG emissions, and a reduction of the dependence on foreign oil. EVs were not only created to be economically and environmentally friendly but also creates specialist employment facilities, so scientists and engineers are encouraged to find solutions to any and all problems associated with them. Whether that solution is effective recycling, creating new types of batteries or something new, the existence of EDVs pushes for progress and societal improvement.

There are some beneficial services offered by Nissan and other EV makers, which are IoT, and GPS which are included in EDV~~s~~ bodies. By installing an IoT or GPS app on a smartphone, a driver can check on a real-time basis such things as battery capacity, time needed to complete charging and drivable distance. The use of IoT-enabled services is predicted to further increase the number of transport vehicles such as passenger cars and even motorcycles and buses. In 2016, PS Solutions, a member of the SoftBank Group, launched an electric scooter rental service using IoT. The use of IoT could solve all three challenges, environmental, economic and social, simultaneously. During the time drivers are charging their cars, IoT could be used to collect and analyze data regarding the use of a car, driving and charging. These data could be used to create new value, which will benefit stakeholders such as battery manufacturers, electric vehicle manufacturers, dealers and users (Kazama, *et. al.,* 2017, 3-4).

A service called “ChargeNow,” indicates the locations of partner charging stations throughout the country on a map by using an onboard navigation system or the free smartphone app, “ChargeNow”. The service also provides details of each charging station and real-time, full/empty information of each charger, and helps drivers check on the availability of a charger at the nearest charging station (Kazama, *et. al*., 2017, 4).

Conclusion

EDVs are a promising technology for drastically reducing the environmental burden caused by road transport. Driving range, battery technology, and competitive pricing are still very important issues. In the long term, EDVs might overcome these problems. Economically, as the electric sector evolves, it will become possible to sustain EDVs while reducing air and noise pollution. Moreover, from the consumer’s standpoint, EVs will contribute financially, decreasing drivers costs in the long term by reducing the amount they pay for gasoline. However, this analysis excludes the high price of the EV itself. Governments can implement policies to introduce policies to decrease the overall retail costs of EDVs, thus shifting the utility-maximizing agent’s consumption choice towards EDVs. Some governments in Asia, such as those of Japan, South Korea and China, cover the cost of subsidizing across consumers.

Auto makers who produce affordable EDVs by reducing the cost does not necessarily mean they are simply stripping off features. To be truly meaningful in the customer context, EDVs have to be redesigned innovatively while keeping in mind customer requirements. For successful consumer adoption, EDV developers have to step up to consumers, to identify their needs and, to realize in depth the infrastructure and associated constraints.

For innovation, it is essential to dive deeper to understand the constraints which may not always be articulated by customers. The constraints could be associated with the society, environmental constraints, and/or economical backgrounds. Innovation should be adopted and utilized to identify customer needs and requirements by observing their social, environmental and economical situations.

Finally, it can concluded that, the automakers, utility companies, IT providers, technology and government support need to contribute to an integrated system. All of these sectors will require new ways of competing and co-operating with each other. The public sector will have to play an important role and put forward funding to enable the innovation of EDVs – through R&D, consumer subsidies, and support for the development of infrastructure to overcome the above problems associated with EVs. It is my belief that, if EDV designs its system from the experiences of ‘frugal innovation’[8] a favorable situation will emerge in the long run which will help it avoid above problems which faced EDV at its early stage of development. There may be that some questions about (frugal innovation) this study, and that will be the focus of next research.

References:

Accenture: Plug-in electric vehicles: Changing perceptions, hedging bets, 2011.

Arrobas, D. L., Hund, K. L., McCormick, M. S., Ningthoujam, J., & Drexhage, J. R. (2017). *The growing role of minerals and metals for a low carbon future*. Washington, D.C.: World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/207371500386458722/The-Growing-Role-of-Minerals-and-Metals-for-a-Low-Carbon-Future

---

(8) Chowdhury (2019) “Frugal Innovation Strategies of Electric Vehicles: A New Era” presented at the 18th International Conference of the Japan Economic Policy Association held in November 16th – 17th 2019, at Tama Campus of Chuo University, Tokyo.

Bellis, M (2006) *History of electric vehicles: The early years, electric cars from 1830 to 1930*, http://inventors.about.com/library/weekly/aacarselectrica.htm.

Bloomberg's (2018) "Electric Vehicle Outlook 2018" https://about.bnef.com/

Brundland Commission established by the UN General Assembly in 1983, "US Energy Consumption," www.un.org/sustainabledevelopment/sustainable-development-goals/

Chowdhury Mahbubul Alam, (2018), "Innovation Strategies of Automobile Industry—An Assessment of the Middle Class in Asia—", *Journal of Law and Political Science*, Vol. XLVI No. 1/2, The University of Kitakyushu.

Chowdhury Mahbubul Alam, (2019), "An Analysis on Competitive Strategies of Electric Vehicles in Japan and China", *Journal of Law and Political Science*, Vol. XLVI No. 3/4, The University of Kitakyushu.

David A. Kirsch (2000), *The Electric Vehicle and the Burden of History*, Rutgers University Press, USA.

Dijk, M., Orsato, R.J., and Kemp, R. (2013). "The emergence of an electric mobility trajectory." *Energy Policy*, 52: 135-145.

Duke, M., Andrews D., and Anderson, T. (2009), "The feasibility of long range battery electric cars in New Zealand." *Energy Policy,* 37: 3455-3462.

Fagerberg, J. (2005), Innovation: A Guide to the Literature, in Fagerberg, J., Mowery, Fourin, (2017a), *Seikai Jidousha toukei nenkan* Fourin.

Fourin, (2017b), *ASEAN Jidousha Sangyou,* Fourin.

Future Electric Cars. (2007) Retrieved January 29, 2010 from http://www.future-car.ghnet/future-electric-cars.html.

Gideon Rachman (2017), *Easternisation War and Peace in the Asian Century*, Vintage, London.

Høyer, K.G. (2008), "The history of alternative fuels in transportation: the case of electric and hybrid cars." *Utilities Policy*, 16: 63-71.

IEA (International Energy Agency), website, www.iea.org/etp.

JAMA (2009). "Reducing CO_2 emissions in the road transport sector", *News from JAMA: Asia-Pacific Edition*, vol. 34. (March 2009). Tokyo.

JAMA (2008). "Reducing CO_2 emissions in the global road transport sector". Tokyo

Kazama Tomohide, Suzuki Kazunori, Cho Teiki and Yoshihashi Shotaro (2017) "Electric Drive Vehicle Market Outlook toward 2030 and Impact on Relevant Industries" NRIs Papers No. 217, Nomura Research Institute, Ltd (NRIs).

Kempton, W. and J. Tomic,(2005) "Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy" *Journal of Power Sources* Vol.144, Issues 1, 280-294 268.

Lee Henry, Clark Alex (2018) "Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption", Faculty Research Working Paper Series, RWP18-026, the John F. Kennedy School of Government of Harvard University. https://www.hks.harvard.edu/research-insights/publications?f%5B0%5D=publication_types%3A121

Mohamed M, G Tamil Arasan and G Sivakumar (2018) "Study on Electric Vehicles in India Opportunities and Challenges" *International Journal of Scientific Research in Environmental Science and Toxicology.*

Ninh, P., K. Bentzen, M.S. Laugesen (2014), Why should transportation companies join Public Private Partnership (PPP) proposed by the public sector to support the implementation process of Freight Electric Vehicles (FEVs) in Copenhagen Municipality, NSR, Activity 7.4.4. report, September 2014.

Pelletier, S., O. Jabali and G. Laporte (2014), Battery electric vehicles for goods distribution: a survey of vehicle technology, market penetration, incentives and practices, CIRRELT 2014-43, September 2014.

Scrosati, Bruno, and Jürgen Garche (2010), "Lithium Batteries: Status, Prospects and Future," *Journal of Power Sources*, 195:9, 2419-2430.

Sōgō kenkyūjo (2011), *Nippon kōko sōken repōto*

Skerlos, S.J. and Winebrake, J.J. (2010). "Targeting plug-in hybrid electric vehicle policies to increase social benefits." *Energy Policy*, 38: 705-708.

USDOE (U.S. Department of Energy) (2010) "Critical Materials Strategy," http://energy.gov/sites/prod/files/edg/ news/documents/criticalmaterialsstrategy.pdf (cited January 2012).

USDOE,(2011) "Critical Materials Strategy," http://energy.gov/sites/prod/files/ DOE_CMS2011_FINAL_Full.pdf (cited May, 2012).

Wadia, Cyrus, Paul Albertus, and Venkat Srinivasan, (2011), "Resource Constraints on the Battery Energy Storage Potential for Grid and Transportation Applications," *Journal of Power Sources, 196*:3, 1593-1598.

Wang, Haiming, Haifeng Xu, Alex K. Jones, (2010) "Crucial Issues in Logistic Planning for Electric Vehicle Battery Application Service," *International Conference on Optoelectronics and Image Processing, 1* , 362-366.

Wang, Y.; Wang, C. (2010) Locating passenger vehicle refueling stations. Transp. Res. E, 46,791–801

Wanger, Thomas Cherico, (2011), "The Lithium Future-Resources, Recycling, and the Environment," *Conservation Letters, 4*: 3, 202-206.