SOLAR ENERGY,
ENERGY STORAGE
AND VIRTUAL POWER PLANTS
IN JAPAN

- Potential Opportunities of Collaboration between Japanese and European Firms -

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EU-Japan Centre for Industrial Cooperation

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List of Abbreviations

Abbreviation	Meaning
AC	Alternating Current
ADR	Automated Demand Response
AI	Artificial Intelligence
AIST	National Institute of Advanced Industrial Science and Technology
ANRE	Agency of Natural Resources and Energy
ASG	Asia Super Grid
ATENA	Atomic Energy Association
BAJ	Battery Association of Japan
BEE	German Renewable Energy Federation
BEMS	Building Energy Management System
BEV	Battery Electric Vehicle
BIPV	Building-Integrated PV
BNEF	Bloomberg New Energy Finance
CATL	Contemporary Amperex Technology Limited
CAES	Compressed Air Energy Storage
CCS	Combined Charging System
CDV	Clean Diesel Vehicle
CHAdeMO	Charge de Move
COP	Conference of Parties
C&I	Commercial and Industrial
DC	Direct Current
DER	Distributed Energy Resource
DR	Demand Response
DRC	Demand Response Council
EASE	European Association for Storage of Energy
EGC	Gas Market Surveillance Commission
EMS	Energy Management System
EMSC	Electricity Market Surveillance Commission
EPC	Engineering, Procurement and Construction
EPCO	Electricity Power Companies
ERAB	Energy, Resource, Aggregation, Business Review Committee
ESS	Energy Storage System

EU	European Union
FEPC	Federation of Electric Power Companies of Japan
EV	Electric Vehicle. Also PEV (BEV + PHEV)
EVI	Electric Vehicles Initiative
FCEV	Fuel-Cell Electric Vehicles (or FCV)
FCV	Fuel-Cell Vehicles (or FCEV)
FIT	Feed-in Tariff
FY	Fiscal Year (April to March)
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GRCJ	Glass Recycling Committee of Japan
GW	Gigawatt
HEMS	House Energy Management System
HEPCO	Hokkaido Electric Power Co., Inc.
HEV	Hybrid Electric Vehicle
IAE	Institute of Applied Energy
ICO	Initial Coin Offerings
IEA	International Energy Agency
IEA-PVPS	IEA Photovoltaic Power Systems
IEEJ	The Institute of Energy Economics, Japan
INDC	Intended Nationally Determined Contribution
IoT	Internet of Things
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
ISEP	Institute for Sustainable Energy Policies
JAEC	Japan Atomic Energy Commission
JAMA	Japan Automobile Manufacturers Association
JANSI	Japan Nuclear Safety Institute
JAREA	Japan Association of Independent Appraiser
JEPX	Japan Electric Power Exchange
JET	Japan Electrical Safety & Environment Technology Laboratories
JETRO	Japan External Trade Organization
JPEA	Japan Photovoltaic Energy Association
JPV	Japan PV Recycling Model Executive Committee
JPY	Japanese Yen
KEPCO	Kansai Electric Power
kW	Kilowatt

kWh	Kilowatt Hour
LCOE	Levelized Cost of Energy
LED	Light Emitting Diode
LIBTEC	Lithium Ion Battery Technology and Evaluation Center
Li	Lithium
LNG	Liquefied Natural Gas
MAFF	Ministry of Agriculture, Forestry and Fishery
METI	Ministry of Economy, Trade and Industry
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MOE	Ministry of the Environment
MOFA	Ministry of Foreign Affairs of Japan
MoU	Memorandum of Understanding
MOX	Plutonium-Uranium Mixed Oxide
MW	Megawatt
NaS	Sodium-sulfur
NEDO	New Energy and Industrial Technology Development Organization
NESTI	National Energy and Environment Strategy for Technological Innovation
NiMH	Nickel-Metal Hybrid (NiMH)
NIMS	National Institute for Materials Science
NITE	National Institute of Technology and Evaluation
NRRC	Nuclear Risk Research Center
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
O&M	Operation and Maintenance
P2P	Peer-to-Peer
PCP	Pilot City Programme
PCS	Power Conditioning System
PEV	Plug-in Electric Vehicles (or EV)
PHEV	Plug-in Hybrid Electric Vehicles (or PHV)
PHV	Plug-in Hybrid Electric Vehicles (or PHEV)
PPA	Power Purchase Agreement
PPS	Power Producers and Supplier
PV	Photovoltaic
PVT	PV-Thermal
REC	Renewable Energy Credit
REI	Renewable Energy Institute
R&D	Research and Development
SII	Sustainable open Innovation Initiative

TEPCO	Tokyo Electric Power Company
TOCOM	Tokyo Commodity Exchange
TW	Terawatt
UK	United Kingdom
US	United States
USD	United States Dollar
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
V2G	Vehicle to Grid
W	Watt
y-o-y	Year on Year
ZEB	Zero Energy Building
ZEH	Zero Energy House

1. EXECUTIVE SUMMARY

In the COP21 held in Paris in December 2015, participating countries agreed to combat the climate change by reducing greenhouse gas (GHG) emissions by half by 2050, in order to keep the global warming under two degrees Celsius. Meeting this difficult target requires to make renewable energies the main source of power generation and move towards electric vehicles since the transport sector accounts for 23% of global GHG emissions. But it is also essential to reduce the primary energy consumption by means of increasing energy conservation and energy efficiency.

After the adoption of the Paris Agreement, Japan announced its intention to reduce GHG emissions by 26% by 2030 compared to 2013 in July 2015. Furthermore, in May 2016, the Plan for Global Warming Countermeasures established a long-term goal of an 80% reduction by 2050. The transportation sector contributed with 19% to entire CO_2 emissions in Japan in 2015, and the government target is to reduce it by 25% by 2030 increasing the popularization of the next-generation vehicles, and reaching an electric vehicles' share in the new car sales of 20%-30% by 2030.

Japan was considered one of the more energy-efficient economies in the world, but exceptional energy efficiency and conservation efforts greatly helped Japan to deal with the energy emergency resulted after the Great East Japan Earthquake, and it has achieved to maintain these improvements after that through behavior change and policy measures. However, more efforts are needed in the residential and commercial sectors (demand side), in which GHG emissions have to be reduced by 39% and 40% respectively by 2030 compared to the levels in 2013.

Since the Great East Japan Earthquake of March 2011, the government has been promoting a low-carbon society through energy efficiency measures and the development of a stable and reliable supply of renewable energy.

Despite of the progress made since the introduction of the new feed-in tariff scheme in 2012, the installation of solar photovoltaic systems in Japan continues with a downward trend in the last years. Nevertheless, it is expected that the government's solar target of 64 GW by 2030 will be achieved around 2020, and its goal of 22-24% renewable generation by 2030 seems too low.

The rapid adoption of renewable energies, especially solar energy, has brought problems affecting the stability of the power grid, including output fluctuations and surplus power generation. Energy storage is a simple way to integrate solar (and wind) power into the grid, achieving feasible flexibility, and removing the curtailment risk from photovoltaic power plants output, which has been seen as a barrier to investment in some of the more saturated grid areas in Japan.

Energy storage is also an important way to increase the self-consumption ratio in the residential and commercial sectors, and the energy efficiency through a distributed model where the energy is generated, stored, consumed and sold locally. Therefore, residential solar photovoltaic systems, energy storage batteries and energy management systems markets will greatly increase in the next years, also because of the net-zero energy house/building targets.

Through the vehicle to grid (V2G) technology, electric vehicles' batteries, larger than the residential ones, will increase in importance as new smart management tools to operate the energy system, reinforcing the grid of specific areas when the demand is higher or during an unexpected natural disaster. Their charging could also be shifted to the middle of the day, to absorb high levels of solar generation, or at night, when demand is the lowest, helping to integrate higher shares of variable renewable energy without interfering with the stability of the grid, increasing the flexibility of the electricity system, and enabling higher decarbonization ratio of both transport and power sectors. Therefore, the V2G technology will make electric vehicles part of the energy solution, reducing the cost of their ownership, and helping to increase their sales.

It is a fact that the power generation system is shifting to a more efficient and cheaper distributed model, closer to demand centers, promoting the self-consumption and a local trade between neighbours, without almost any losses during the energy transportation and distribution from large facilities, and without affecting the stability of the main grid. A virtual power plant (VPP) digitally integrates/aggregates the energy and power capabilities of large numbers of connected distributed energy resources, mainly solar plus storage systems at households and commercial businesses, but also highly efficient energy equipment (air conditioners, heat sources, generators, thermal storage tanks, etc), and electric vehicles' batteries through the V2G technology. It offers passive consumers the possibility of becoming active prosumers who can participate in the electricity trading market and get revenues.

VPP technology has become a priority for the Japanese government during the last years, and though it is still in the demonstration stage, there is high demand for it. Demand response solution has the largest share in the VPP market, and it has already been used successfully in Japan when supply and demand of electricity were tight. The negawatt or negative watt trading was opened in Japan in April 2017 and is an incentive-style demand response that conserves electricity at the timing of the peak demand.

In terms of content, this report begins by explaining the framework that caused the evolution of the energy market in Japan, mainly the Great East Japan Earthquake and the Paris Agreement. The main chapters are focused on the photovoltaic solar market, the energy storage market and the virtual power plants market in Japan, with an introduction to the current situation of each of them worldwide.

In the overview of the photovoltaic solar market, the electricity market in Japan it is also presented, and its evolution and effects during the last years. This chapter contains the businesses in the solar sector with most growth potential, including the net-zero energy houses/buildings, floating solar PV systems, solar sharing, operation and maintenance service, recycling and reuse, and the main players in each of them.

In the overview of the energy storage battery market, it is also included the current situation of the electric vehicles market in Japan, and its ability to become portable batteries through the V2G technology implementation, and the reuse as well as the recycling of batteries.

In the overview of the virtual power plants market, demonstration projects carried out by the government and the main players involved are presented. Demand response solution, which already helped Japan reducing the peak demand, is also presented, and the potential of the blockchain technology to accelerate the shift to a decentralized energy system and the deployment of virtual power plants is highlighted.

The document ends with the conclusions, identifying which are the main areas with potential opportunities for European SMEs, and some recommendations for both the Japanese government and the European Commission.

2. INTRODUCTION: THE FRAMEWORK OF THE PARIS AGREEMENT AND THE GREAT EAST JAPAN EARTHQUAKE

The Paris Agreement was announced in December 2015, during the Conference of Parties 21 (COP21), and enforced in November 2016. It set the objective of limiting the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. This new international fair and effective framework was adopted by all the countries and stipulates that each country shall communicate or update emission reduction targets every five years.

The greenhouse gas (GHG) emissions from the transport sector, which currently accounts for 23% of global energy-related GHG emissions, were anticipated to rise from 2016's levels to almost 20% by 2030 and close to 50% by 2050 unless major action is undertaken. Therefore, and in order to deliver significant GHG emission reductions, transport and power generation decarbonization need to go hand-in-hand.

The commitments were released through the Paris Declaration on Electro-Mobility and Climate Change & Call to Action at COP21. It specified that at least 20% of all road transport vehicles (cars, two- and three-wheelers, trucks, buses, and others) globally should be electrically driven by 2030, this is, more than 100 million cars and 400 million two and three-wheelers by 2030. To achieve this target, electric drive vehicles have to represent 35% of global sales by 2030[1]. Accordingly, the charging infrastructure will need to be developed to power these fleets.

Because of COP21, The Climate Group brought global initiatives such as EV100 and RE100 to accelerate the transformation of the global energy market. EV100 brings together companies committed to accelerating the transition to electric vehicles (EVs) and making electric transport the new normal by 2030[2]. More than 130 influential businesses from all the sectors (Apple, Microsoft, Google, Visa, Facebook, Coca-Cola, IKEA, Nike, BMW, Starbucks or Citi Bank, among others) joining RE100 set a public goal to source 100% of their global electricity consumption from renewable sources by a specified year, accelerating the transition toward a net-zero economy[3]. Apple and Google already generate all of their electricity from renewable sources.

Some Japanese companies already involved in this initiative are AEON, Fujitsu, Ricoh, Sony, Daiwa House Industry, Sekisui House, Watami and Johnan Shinkin Bank. The Ministry of

[1] United Nations Framework Convention on Climate Change, November 29, 2015: https://unfccc.int/media/521376/paris-electro-mobility-declaration.pdf.
[2] The Climate Group: https://www.theclimategroup.org/project/ev100.
[3] RE100 : http://there100.org/re100.

Environment (MOE) established the goal of having 50 Japanese companies become part of RE100 by 2020. MOE and Ministry of Foreign Affairs (MOFA) also set the target of getting 100% renewable power for their offices and embassies around the world. On national, regional and local levels, Global 100% RE is another global initiative that is committed to 100% renewable energy[4]. In September 2017, municipal leaders in Japan released the Nagano Declaration, committing to work towards 100% renewable energy for cities and regions across the country[5]. Besides, in July 2018, over 100 Japanese private companies, local governments, research institutions and non-government organizations launched the Japan Climate Initiative, an equivalent of the United States (US) “We Are Still In” initiative. It is a network focuses on strengthening communication and exchange of strategies and solutions against the climate change[6].

In 2017, the Electric Vehicles Initiative (EVI), a multi-governmental policy forum dedicated to accelerating the deployment of EV worldwide, launched the EV 30@30 campaign, setting a collective goal of an average 30% market share for EV by 2030 (passenger cars, light commercial vehicles, buses and trucks), including several implementing actions. Ten countries accounting over 60% of the global EV stock support this campaign: Canada, China, Finland, France, India, Japan, Mexico, the Netherlands, Norway and Sweden[7]. As an active member of EVI, and because of the Government Fleet Declaration announced at the Marrakech Climate Change Conference in November 2016 [1], the Japanese government is making efforts to ensure that all government vehicles will be next-generation vehicles by 2030. As an intermediate goal, approximately 40% of the government vehicle fleet, around 9.000 units, will be next-generation vehicles by 2020, which will contribute to Japan’s one million target by 2020.

As part of this initiative, EVI also launched the Global EV Pilot City Programme with the aim to build a network of 100 EV-friendly cities. According to the International Energy Agency (IEA), a total of 30 cities currently committed to participate in this programme, including the Japanese Aichi Prefecture, Kanagawa Prefecture, Kyoto Prefecture and Tokyo Metropolitan Government[8].

According to the IEA, global energy-related CO_2 emissions remained flat in 2016 for the third year in a row, in spite of the global economy grew, due to the combination of the move towards renewables and cleaner fuels and, especially, energy efficiency improvements. Because of energy efficiency, global energy use was 12% lower in 2016 [2].

Energy efficiency and conservation efforts greatly helped Japan to deal with the energy emergency resulted after the Great East Japan Earthquake, representing 39% of the original

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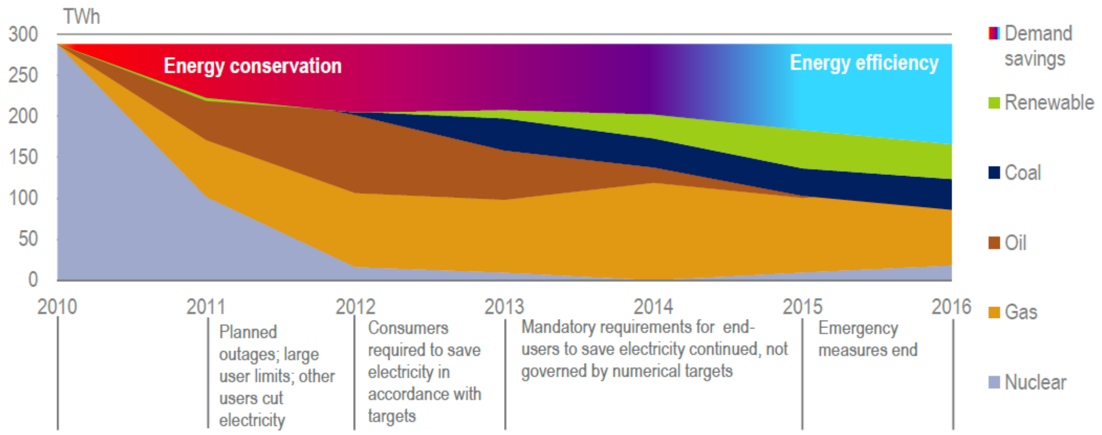
[4] 100% Renewables: http://www.go100re.net/.
[5] Local Renewables, September 8, 2017: http://local-renewables-conference.org/fileadmin/repository/LR_Nagano/LR2017-Nagano-Declaration-JP-EN.pdf.
[6] Japan Climate Initiative: https://japanclimate.org/english/.
[7] IEA, June 8, 2017: https://www.iea.org/newsroom/news/2017/june/new-cem-campaign-aims-for-goal-of-30-new-electric-vehicle-sales-by-2030.html.
[8] IEA, May 24, 2018: https://www.iea.org/newsroom/news/2018/may/global-ev-pilot-city-programme-launched-at-clean-energy-ministerial.html.

nuclear power generation in 2016. Gas (30%), renewables (13%), coal (12%) and restarted nuclear (6%) also replaced the energy generated by nuclear power in 2010 (Figure 1). This shows the huge potential of energy efficiency measures even in Japan, which was already considered one of the more energy-efficient economies in the world. It achieved to maintain the energy-saved improvements even stopping mandatory temporary measured since 2013 through behavior change and policy measures. Electricity consumption has continued to decline since 2011.

Therefore, main measures against climate change are increase energy efficiency and conservation, make renewable energies the main source of energy and move towards electric vehicles.

Figure 1: Replacement of Nuclear Electricity Generation in Japan after Shutdown



Source: IEA [2].

2.1. ENERGY SCENARIO AFTER THE GREAT EAST JAPAN EARTHQUAKE

Because of the earthquake in March 2011 and outage that followed, all 54 units were shut down in May 2012. Since then, 6 units declared decommissioning due to the accident, and 5 units declared decommissioning in March 2015. Due to this reason, Japanese imports of fossil fuels, coal, oil and liquefied natural gas (LNG), increased from around 81% in 2010 to around 89% in 2016 [3] (LNG imports were the ones that increased the most), impacting all 3E's, this is, energy security, economy and environmental conservation:

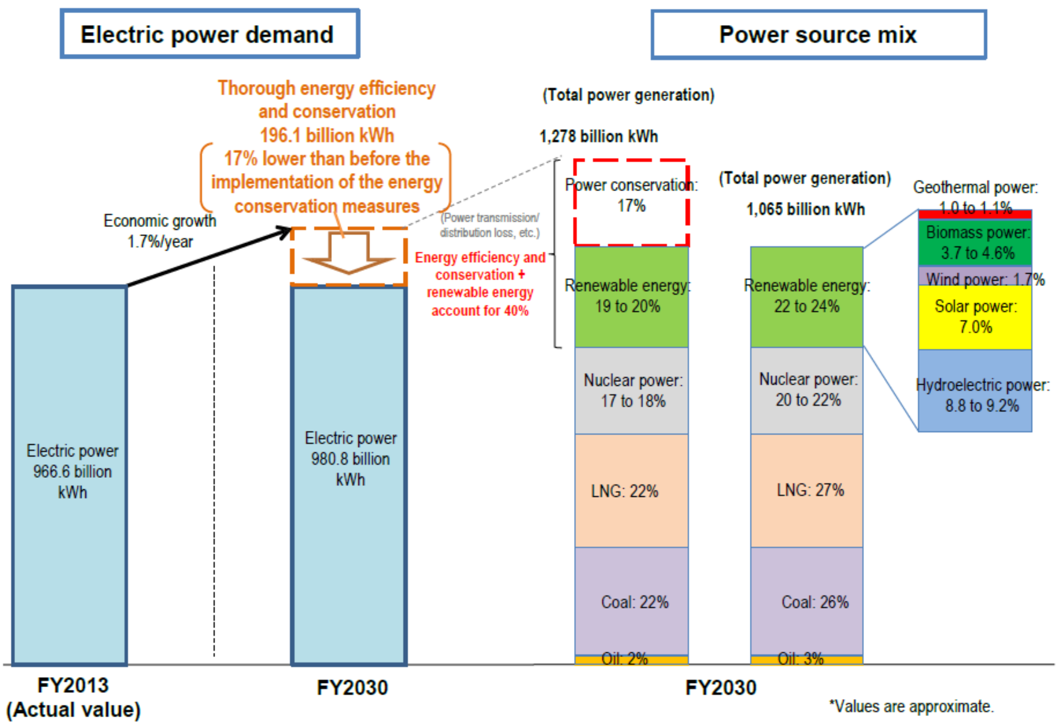
- The energy self-sufficiency ratio decreased from almost 20% in 2010 to 6.3% in 2012 (8.4% in 2016) [3]. Fiscal Year (FY) 2017 was the first time since the Great East Japan Earthquake that this ratio exceeds 10% [4].

- The electric power costs increased about 38% for industries and about 25% for homes. Although the downward trend since 2014, those rates were still higher in 2016, about 14% for industries and 10% for homes [3].

- CO_2 emissions increased by about 4% because of the higher electric generation by thermal power plants [3]. In 2016, it was confirmed the downward trend from 2013 mainly because of the increased in the generation by renewable energies and the restarting program of nuclear power plants[9]. In FY 2017, the energy-related CO_2 emissions also decreased by 2.0% [4].

The Government formulated the Strategic Energy Plan of Japan in April 2014, “Fourth Energy Basic Plan”, under the Basic Act on Energy Policy, which entered into force in June 2002. The plan presented the basic direction of Japan's energy policy, based on the fundamental principles of safety, energy security, improvement of economic efficiency and environmental suitability. It was followed by the Long-term Energy Supply and Demand Outlook in July 2015, which foresees the future energy mix towards 2030, with a 22-24% ratio for the renewable generation [5]. The objectives of the government in 2030 are the following:

Figure 2: Targets for the Electric Power Supply-Demand Structure in Japan in 2030



Source: METI [5].

[9] MOE, December 11, 2017: http://www.env.go.jp/en/headline/2352.html.

- Raise the self-sufficiency rate up to nearly 25%, higher than before the earthquake.

- Reduce the dependence on fossil fuels to 56% on the basis of power source composition.

- Substitute the nuclear power by expansion of renewable energy, especially geothermal, hydroelectric and biomass powers, which can be operated stably despite weather conditions, and by improving the efficiency of thermal power generation.

- Reduce the electric power demand by 17%, even with an expected economic growth of 1.7% real Gross Domestic Product (GDP) per year. In FY 2017, the Japanese economy grew 1.4%, but the primary energy consumption slightly decreases by 0.1% due to continuous energy conservation efforts [4]. In FY 2018, it is expected a GDP growth of 1.1%, while the primary energy consumption will decline by 0.6%.

  The Japanese government is promoting an energy efficient society, with an integrated implementation of the Act on Rationalizing Energy Use (Energy Conservation Act) and support measures. Energy conservation measures in the industrial, commercial, residential and transportation sectors are expected to improve the energy efficiency by 35% by FY 2030. Several measures such as Top Runner Programme and Zero Energy House (ZEH) are carrying out by the government. Together with the maximum renewable energy penetration, the government expects to cover about 40% of electricity demand in FY 2030.

  Top Runner Programme aims to improve the energy efficiency in equipment and devices, and has already contributed to greatly enhance the energy efficiency of consumer electronics and automobiles in Japan. It covers around 70% of household energy consumption and it is mandatory for companies (manufacturers and importers), encouraging competition and innovation among them without increasing market prices.

The 2015 Outlook was prepared with Paris' climate change objectives in mind. After its adoption, Japan announced its Intended Nationally Determined Contribution (INDC) in July 2015 to reduce the GHG emissions by 26% by FY 2030 compared to FY 2013 (a 25.4% reduction compared to FY 2005). Furthermore, in May 2016, the Plan for Global Warming Countermeasures was decided by The Cabinet of Japan, establishing a long-term goal of an 80% reduction by FY 2050, and clarifying policies and measures to be implemented [6].

To support these promises, the government is working together with industry and academia to promote energy technology innovation under the Environmental Energy Technological Innovation Plan, focusing on 2030 targets, and the National Energy and Environment Strategy for Technological Innovation towards 2050 (NESTI 2050). The Plan foresees gradually stricter energy efficiency requirements for buildings, equipment and appliances, and promotes net-zero energy houses/buildings (ZEH/ZEB), house/building energy management systems

(HEMS/BEMS), high efficiency lights such as light emitting diodes (LEDs), and smart meters, among other measures.

In April 2016, the Cabinet Office also announced the Energy and Environment Innovation Strategy. The main innovative technologies are related to the efficient power generation, the reduction of the cost of renewable energies, storage energy battery technologies beyond lithium, and efficient energy carriers such as hydrogen. In July 2016, The Long-term Global Warming Countermeasures Platform, consisting of members from the government, industry and academia, was established to discuss measures for reducing GHG emissions on a long-term basis [7].

Apart from the implementation of energy conservation measures and the maximum introduction of renewable energy, the ministry aims to build a hydrogen-based society through the Basic Hydrogen Strategy, as a key for the energy security and the fight against global warming. Hydrogen and fuel cell technology will play an important role in applications such as stationary and portable power, energy storage and transportation. The government is also promoting new businesses based on smart community-related technologies such as the demand response (DR), virtual power plants (VPPs) and blockchain technology as a way to increase the energy efficiency through distributed generation, storage and trade of energy.

Keeping in mind the goals of increasing the energy self-sufficiency rate and creating a low carbon society, the deployment of renewable energy has continued to be important for the Japanese government. The installed capacity of renewables has grown by 2.5 times since the introduction of the feed-in tariff (FIT) scheme. Solar energy is the center of this revolution. The government aims to develop and utilize renewable energy as the major power source by 2030. Efforts are being made to reduce costs, overcome system constraints, and secure sufficient load following capacity. The development and deployment of high-performance low-price storage batteries are also being promoted.

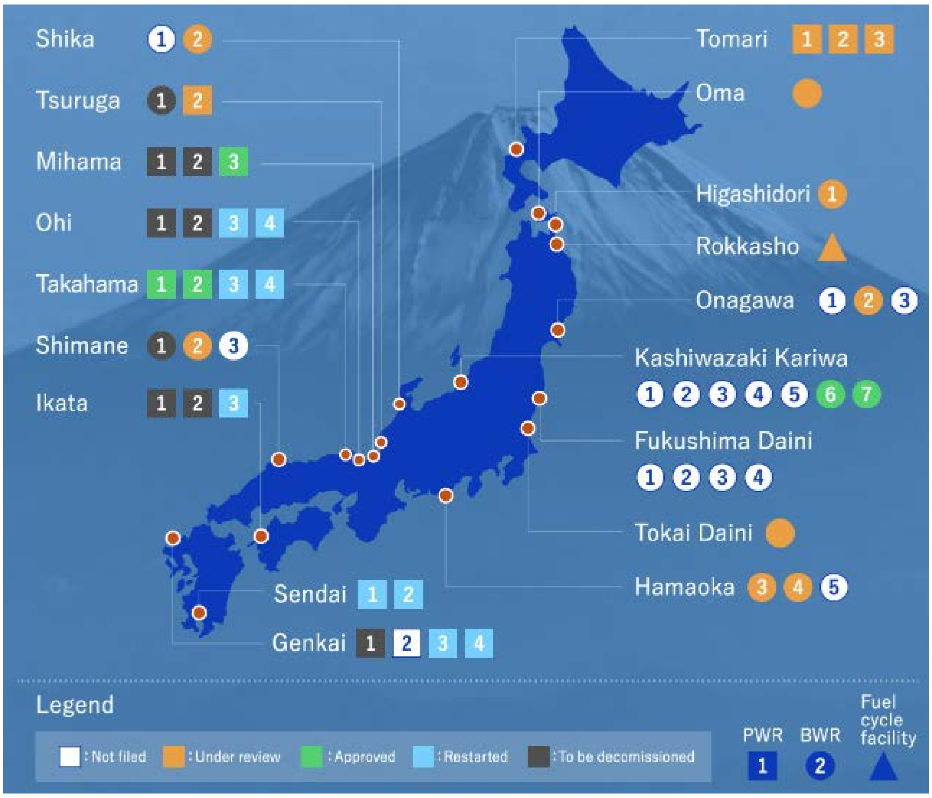
However, in order to achieve the S (Safety always comes first) and 3E's targets in 2030, a nuclear power generation ratio between 20 and 22% was established by the government (Figure 2). One of the biggest issues of the Japanese energy market is that it depends on foreign fossil-fuel supply, becoming easy to be affected by international situations. This, securing a stable supply, is one of the reasons because the nuclear power generation is indispensable nowadays in Japan. The others reasons are that its use reduces the CO_2 emissions and the electric power costs, even taking into account the costs of the accident risk response. And it is an important baseload power supply that contributes to the stability of the supply and demand structure of energy.

Therefore, the restarting of the nuclear power plants that have conformed to new regulatory requirements evaluated by the Nuclear Regulation Authority is promoted. As examples, in May 2018, Kyushu Electric Power restarted the No. 3 reactor at the Genkai nuclear power plant, in Saga Prefecture[10], and Kansai Electric Power restarted the No. 4 reactor at the Oi nuclear plant

[10] Kyushu Electric Power, May 16, 2018: http://www.kyuden.co.jp/var/rev0/0134/2575/0gh3we57.pdf.

in central Japan, joining three other nearby units already online[11]. The licensing status of the Japanese nuclear facilities in August 2018 is shown in Figure 3, and it can be checked in the website of the Japan Nuclear Safety Institute[12].

Figure 3: Licensing Status of the Japanese Nuclear Facilities



Source: Japan Nuclear Safety Institute.

The Japan Nuclear Safety Institute (JANSI) was established in November 2012 aiming to become Japan's version of the international Institute of Nuclear Power Operations, under the determination to "never again let the Fukushima Daiichi accident occur". Additionally, a new safety regulation was established in 2013 to include the Fukushima Daiichi nuclear power plant accident lessons learned and opinions/proposals from inside and outside of Japan. This includes the enhancement of protective measures against extreme natural hazards, such as earthquakes and tsunamis, as well as improved resistance to fires, internal flooding, blackouts and other risks. The Nuclear Risk Research Center (NRRC) was established in October 2014 as the base for research and development necessary for the voluntary improvement of safety of nuclear power generation. In this sense, operators have to reflect the results in their safety improvement

[11] KEPCO, May 9, 2018:
http://www.kepco.co.jp/english/corporate/pr/2018/__icsFiles/afieldfile/2018/05/11/2018_may11_2.pdf.
[12] Japan Nuclear Safety Institute: http://www.genanshin.jp/english/index.html.

activities. Finally, in July 2018, the Atomic Energy Association (ATENA) was established, in which the nuclear industry (nuclear operators, manufacturers, and other nuclear organizations) will participate, in an effort to strengthen initiatives for the autonomous and continuous improvement of safety[13].

On the other hand, Japan has built up a large plutonium stockpile of about 47 tons at the end of 2017, though only about 10.5 tons are kept within the country, while the rest is stored overseas, about 21 tons in the United Kingdom (UK) and about 15.5 tons in France[14]. The Japan Atomic Energy Commission (JAEC) has addressed this problem planning to use this stockpile by the plutonium-thermal power generation method. Spent fuel from nuclear reactors is reprocessed to extract uranium and plutonium, which is then recycled into a fuel called plutonium-uranium mixed oxide (MOX), which can be burned at normal reactors, though currently, only four nuclear reactors in Japan can burn it. Plutonium will be recycled at the Rokkasho nuclear fuel reprocessing plant, which is still under construction in Aomori Prefecture, and it will be completed in the first half of the fiscal year 2021[15]. It is designed to extract about 8 tons of plutonium per year through the reprocessing of up to 800 tons of spent fuel[16]. Because of the international concern, Japan decided to reduce its plutonium stockpile to only the amount necessary for peaceful use in July 2018, and JAEC said that the plutonium production at Rokkasho plant should be limited to the amount required to the country's nuclear reactors.

[13] FEPC, June 15, 2018: http://www.fepc.or.jp/english/news/message/1258072_1653.html.
[14] JapanTimes, July 31, 2018: https://www.japantimes.co.jp/news/2018/07/31/national/science-health/japan-cut-plutonium-stockpile-amid-international-concerns/#.W2EIfdIzbIV
[15] Recycling International, July 6, 2018: https://recyclinginternational.com/editors-top-picks/plutonium-fuel-recycling-venture-the-only-realistic-method-for-japan/.
[16] JapanTimes, July 31, 2018: https://www.japantimes.co.jp/news/2018/07/31/national/science-health/japan-cut-plutonium-stockpile-amid-international-concerns/#.W2EIfdIzbIV.

3. SOLAR ENERGY MARKET IN JAPAN

Renewable accounted for 70% of the new power generation capacity added globally in 2017, essentially from wind and solar projects. The total capacity installed was 178 gigawatts (GW) according to REN21 [8] and about 167 GW according to the International Renewable Energy Agency (IRENA) [9]. According to IEA, renewables now account for 25% of global electricity generation, second only to coal. Despite the strong increases in wind and solar photovoltaic (PV) electricity generation, hydropower remains the largest renewable source by far, with a share of about 65% in overall renewables output. At the end of June 2018, Bloomberg New Energy Finance (BNEF) announced that the total combined capacity of wind and solar energy surpassed the historic 1 terawatts (TW) milestone, with the former accounting for 54% and the latter accounting for 46%[17].

Wind power was increased by 52 GW worldwide in 2017, about 11% more than in 2016, for a total installed capacity to around 539 GW, and an increase about 30% for offshore wind capacity [8]. These data are slightly differenced from IRENA [10], with an increase of 46.7 GW in 2017 and a cumulative installed capacity of around 514 GW.

Solar PV capacity was increased by 98 GW in 2017, about 33% more than in 2016, reaching a new record. This is, it added to the global electricity system more than the coal, natural gas and nuclear power plants combined. Therefore, about 402 GW of solar PV was in operation at the end of 2017 [8], 386 GW according to IRENA [10] (Figure 4). Regarding the cumulative capacity, the top countries were China, United Stated, Japan, Germany and Italy, with India not far behind and growing fast (Figure 5).

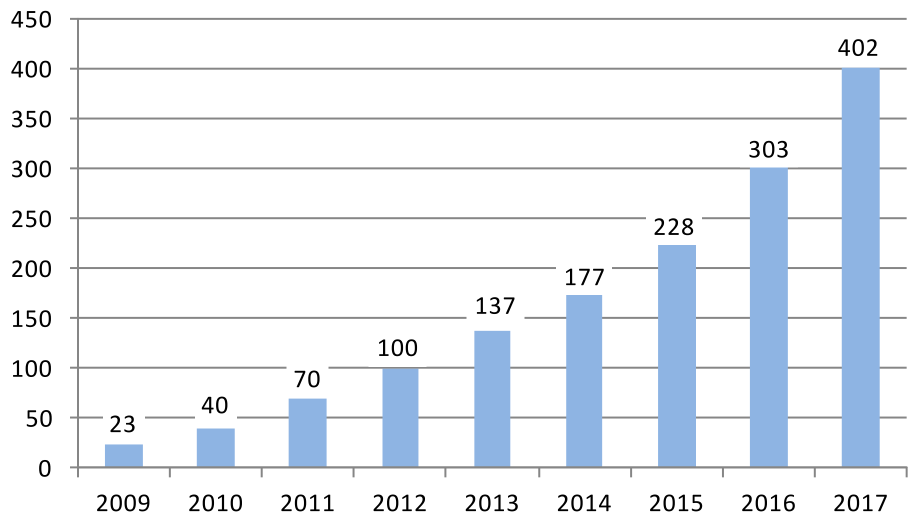
Solar PV new installations will reach 105 GW in 2018 according to IHS Markit forecast, 11% more than in 2017, despite the expected reduction in the Chinese market due to the new government policies (utility-scale abolished and FIT subsidy stopped, among others). That curtailment in China will bring an intense competition among suppliers because of the overproduction, with a price reduction that will make the solar energy even more competitive[18]. Main Chinese panel manufacturers such as Canadian Solar Inc, JinkoSolar Holding Co Ltd and Yingli Green Energy Holding Co Ltd have been already affected by this announcement, as well as other American panel makers such as SunPower Corp and First Solar Inc. However, it looks that the Chinese government will approve 300-500 MW of distributed PV in each of the 34 administrative regions without subsidies but with a reduction in “non-technical costs” such as

[17] RenewEconomy, August 6, 2018: https://reneweconomy.com.au/global-wind-solar-capacity-surpasses-1-terawatt-91295/.

[18] PVTech, June 8, 2018: https://www.pv-tech.org/news/ihs-markit-forecasts-global-solar-demand-to-increase-11-in-2018-despite-chi.

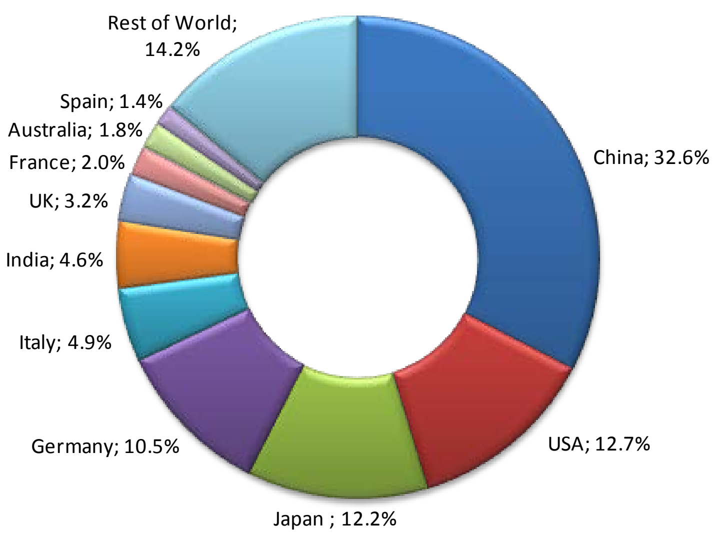
land prices, taxes, fees and grid connection charges. It would suppose 8 to 10 GW of new solar installations, and the bidding would start in October 2018[19].

Figure 4: Global Cumulative Solar PV Capacity



Source: Author, with data from REN21 [8].

Figure 5: Global TOP 10 Solar PV Markets



Source: Author, with data from REN21 [8].

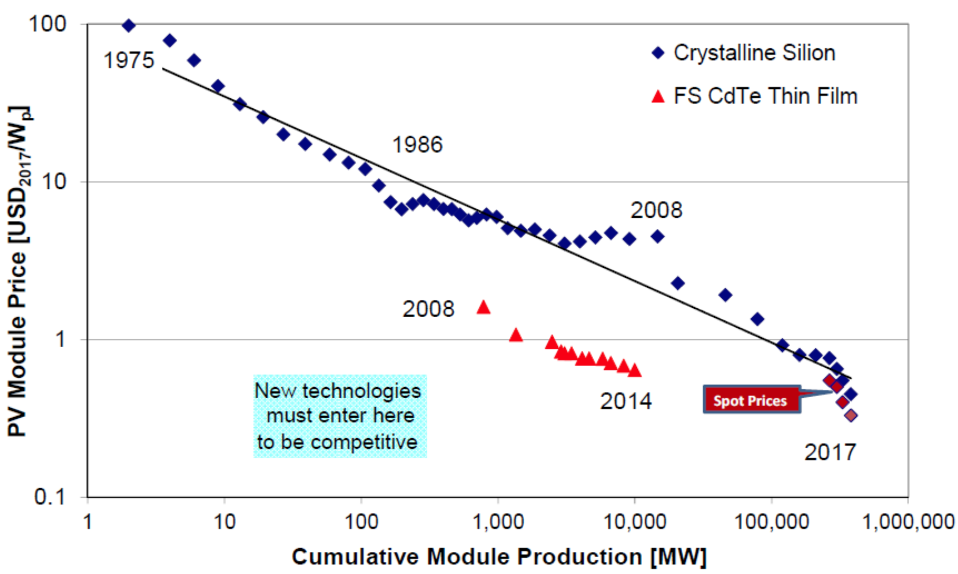
[19] PV Magazine, August 27, 2018: https://www.pv-magazine.com/2018/08/27/is-china-about-to-add-10-gw-of-unsubsidized-solar/.

The European Union (EU) renewable energy target for 2030 was increased from 27% to 32% in June 2018, which will bring more jobs in this sector, lower energy bills for consumers, fewer fuel imports, and will help to meet the Paris Agreement goals of EU. Particularly, solar energy is going to a subsidy-free stage where the industry stakeholders would prefer regulatory framework than financial help. Besides, the new policies will promote and protect consumers to generate, consume, store and sell their own power without excessive paperwork or charges[20], helping to create the business of the future closer to the final customers.

In September 2018, the EU stopped the minimum import prices for solar PV cells and modules from China, Taiwan and Malaysia. In Europe, as a consequence, IHS Markit expect a decline in module prices by up to 30%, leading a reduction in the total project system costs, and a growing of 40% in PV demand in 2019[21].

The costs of solar PV and wind power continued to fall due to massive deployment, technological innovations, effective policies and new business models. According to BNFE, the prices of solar modules fell by 80% between 2010 and 2017 because of the growing supply pushed down expenses, the increase in the efficiency of the modules, and a massive installation globally, caused in turn by this continued decline in prices.

Figure 6: Average Selling Price for Solar Module



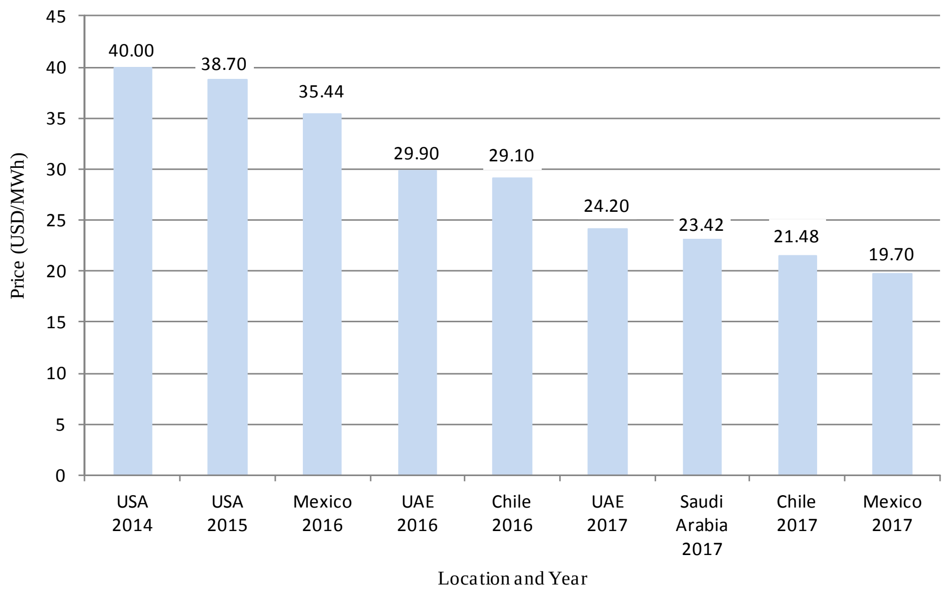
Source: BNFE and PV news, compiled in [11].

[20] PVTech, June 14, 2018: https://www.pv-tech.org/news/boost-for-european-solar-as-eu-raises-2030-renewables-target.
[21] PV Magazine, September 3, 2018: https://www.pv-magazine.com/2018/09/03/mip-impact-eu-module-prices-to-decline-up-to-30-2019-pv-demand-up-40/.

At the end of 2017, the solar module spot price was 0.3 USD/W[22]. BNEF's forecast expects a decline in the global average selling price of solar modules by 35% in 2018. PV system prices have followed the lowering of module prices, but at a slower pace.

According to IRENA [10], between 2010 and 2017, the US saw utility-scale total installed costs reduce by 52%, while Italy experiencing the largest reduction of 79%. According to SolarPower Europe [12], in 2016, power supply contracts were awarded for 0.0291 USD/kWh in Chile (about 3.2 JPY/kWh) and 0.0242 USD/kWh in the United Arab Emirates (about 2.7 JPY/kWh). In February 2018, a 300 MW tender in Saudi Arabia was won by the local company ACWA Power at a new world record low price of 0.0234 USD/kWh (about 2.6 JPY/kWh).

Figure 7: Global Solar Price Deflation (USD/MWh)



Source: Author, with estimation data from the Institute for Energy Economics and Financial Analysis [13].

Levelized Cost of Energy (LCOE) for solar technology has been reduced by 77% between 2009 and 2018. LCOE of utility-scale PV plants is estimated to have fallen from around 0.36 USD/kWh in 2010 to 0.10 USD/kWh in 2017 [10]. According to the US Investment Bank Lazard, solar utility scale was cheaper than nuclear, coal and newly combined cycle gas turbines.

According to BNEF's report "The New Energy Outlook 2018", about USD 11.5 trillion will be invested in new power generation capacity between 2018 and 2050, with USD 8.4 trillion going to wind and solar, and a further USD 1.5 trillion to other zero-carbon technologies such as hydro and nuclear. This investment will produce that solar capacity increases 17-fold by 2050,

[22] Bloomberg, June 5, 2018: https://www.bloomberg.com/view/articles/2018-06-05/chinese-burn-only-makes-the-solar-industry-stronger.

while wind power will grow six-fold. BNEF expects the LCOE for new solar and wind plants to drop 71% and 58% by 2050 respectively[23]. However, solar investments decline 19% to USD 71.6 billion during the first half of 2018 because China slows the development of utility-scale plants and because they are cheaper to build, so they require lower investments[24].

With regard to the investments in power generation, more than two-thirds of the investments in 2017 were for renewables. Of this investment, 75% was concentrated in China, Europe and the US, being Japan the third country that more invested in renewable. Business investment and technology development efforts in the clean energy sector around the world have been focused mostly on renewable energy development, distributed power generation, power storage and new generation vehicles, among others, creating huge business markets.

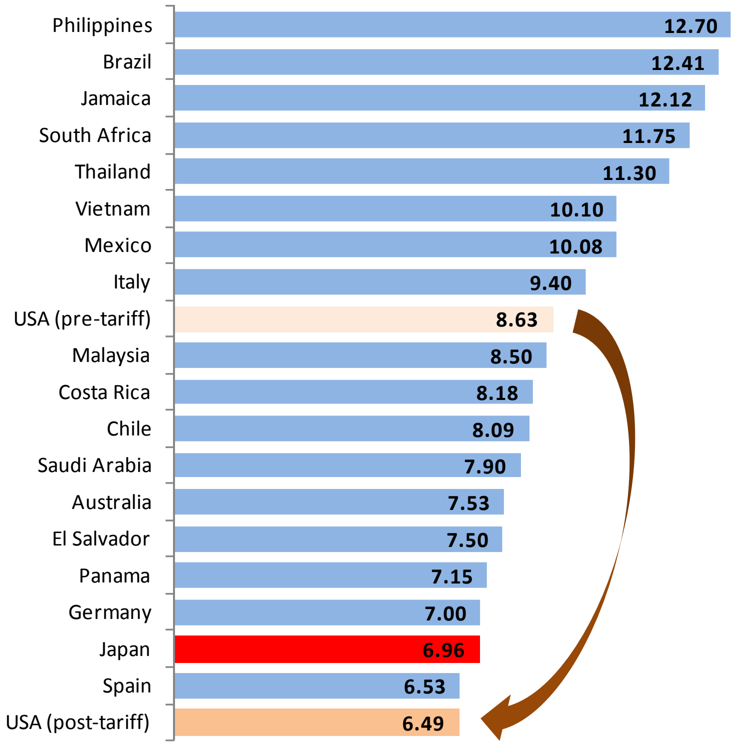
Mercatus Inc., a maker of software for energy companies and investors, established a ranking of world's best solar markets in June 2018, which is shown in Figure 8. The Philippines is the most profitable solar market, delivering 12.7% returns, followed by Brazil, with 12.4% (Figure 8). The tariffs up to 30% for imported panels that President Donald Trump imposed in 2018 could increase costs enough to reduce 2.1% from returns on projects larger than 50 MW[25].

Residential PV system total installed costs have also declined sharply in a wide range of countries since 2010. BNEF estimates that installations of solar projects less than 1 MW grew by 15% globally, to USD 49.4 billion in 2017, and that the cumulative global installations for residential plus commercial & industrial (C&I) was 173 GW at the end of 2017. In 2018, with module prices expected to fall an additional 15%, more markets will see rooftop solar pricing go below the grid parity.

With an also rapid decline in stationary storage devices, the use of distributed solar PV generation with storage is expanding rapidly in some countries, particularly in Australia, Germany and Japan, and the digitalization is helping to convert consumers to smart consumers or prosumers, who also storage and sell the solar energy that they produce, playing an active role in the demand-side management. According to REN21, peer-to-peer (P2P) micro-trading through virtual marketplaces has started to occur in Australia, Denmark, France, Japan, South Korea and the US [8].

[23] BloombergNEF, June 19, 2018: https://about.bnef.com/blog/batteries-boom-enables-world-get-half-electricity-wind-solar-2050/.
[24] Bloomberg, July 9, 2018: https://www.bloomberg.com/news/articles/2018-07-09/it-s-been-a-bumper-year-for-wind-investments-less-so-for-solar.
[25] Bloomberg, June 14, 2018: https://www.bloomberg.com/news/articles/2018-06-13/u-s-sinks-in-ranking-of-best-solar-markets-as-tariffs-take-hold.

Figure 8: Estimated Average Solar Project Internal Rate of Return



Source: Author, with data from Mercatus Inc.

Solar modules and inverters manufacturers

The list of the global largest module suppliers (by shipment volume) in 2017 is again dominated by Chinese firms, with a combination of costs, technology and very large economies of scale. Only South Korean Hanwha Q CELLS and American First Solar offered some competition, though the last one is out of the list in favor of the Chinese Shunfeng International Clean Energy Limited and Suzhou Talesun Solar Technologies CO., Ltd., depending on the consulted source. Jinko Solar and Trina Solar have been leading the industry since the last years. It is remarkable that Japanese companies that led the market in the past, such as Sharp or Kyocera, disappeared from the top 12 list for the last years, in part due to their relatively higher prices.

According to PV-Tech & Solar Media Ltd, almost two-thirds of all PV modules shipments in 2017 came from the above 12 module suppliers, and three-quarters if we only take into account the utility-scale[26]. Removing China market supply channels, also 12 major global suppliers are likely to account for about two-thirds of global PV module installation capacity in 2018,

[26] PVTech, August 9, 2018: https://www.pv-tech.org/editors-blog/pv-moduletech-to-showcase-top-10-global-module-suppliers-for-2019.

deleting the last Chinese manufactures from the global list in favor of REC Solar (Norway), SunPower (US) and LG Electronics (South Korea)[27].

Table 1: Top 10 PV Modules Globally Manufactures in 2017

Rank	Company	Mayor manufacturing sites	Shipment (GW)
1	Jinko Solar	China / Malaysia	9.8
2	Trina Solar	China / Thailand	9.0
3	JA Solar	China / Malaysia	7.1
4	Canadian Solar	Canada / China / Vietnam	6.8
5	Hanwha Q CELLS	South Korea / China / Malaysia	5.4
6	GCL System Integration Technology	China / Vietnam	4.8
7	LONGi Green Energy Technology	China	3.5
8	Yingli Green Energy	China	3.0
9	Risen Energy	China	2.8
10	First Solar	USA / Malaysia	2.7

Source: Author, with data from RTS [14].

The use of bifacial solar cells, where power can be produced from both sides of the cell, increasing total energy generation, is a growing trend among most of the main manufactures, including models from Panasonic, LG, LONGI, Trina Solar, JA Solar or Yingli Solar.

Regarding with the power conditioning system (PCS) market, and according to GTM Research firm, the global solar PV inverter shipment reached a record of 98.5 GWac in 2017, 23% higher than in 2016, on the back of the strong growth of the Chinese solar market. This country, the US and Japan were the three largest markets for this component, though the last two saw a decline in 2017. India is growing fast, and shipments in Europe, except Turkey, grew by 34%. GTM expects a growth of just 2% in 2018, until 100.5 GWac, a similar number predicted by IHS Markit, 104 GWac[28]. The three-phase string inverter shipments continue to gain share and exceeded those of central inverters for the first time in 2017. Inverters of 1,500 volts continue to become more popular.

Like in 2016, Huawei, Sungrow, SMA, ABB and Sineng kept leading the inverter market in 2017, increasing their share since the last year from 59% to 62%. Table 2 shows the main vendors by shipments, though HIS Markit includes Kstar (Taiwan), Goodwe (China) and Growatt New Energy Technology Co., Ltd. (China) companies in this top ten.

[27] PVTech, July 23, 2018: https://www.pv-tech.org/editors-blog/leading-gw-plus-module-suppliers-to-non-china-pv-global-markets.
[28] PV Magazine, April 10, 2018: https://www.pv-magazine-australia.com/2018/04/10/global-inverter-shipments-to-grow-just-2-in-2018/.

Table 2: Top 10 Solar Inverter Manufactures in 2017

Rank	Company	Headquarter	Notes
1	Huawei Technologies	China	Led the Chinese market with a 30% share.
2	Sungrow Power Supply	China	Largest central inverter supplier for the fifth year in a row.
3	SMA Solar Technology	Germany	Largest supplier in the United States for the sixth year in a row.
4	ABB	Switzerland	Largest supplier in India for the fifth year in a row.
5	Sineng Electric	China	
6	TBEA SunOasis	China	
7	Power Electronics	Spain	Largest supplier in Americas region for the first time.
8	TMEIC (Toshiba Mitsubishi-Electric Industrial Systems Corporation)	Japan	Largest supplier in Japan for the fourth year in a row.
9	Scheneider Electric	France	
10	SolarEdge Technologies	Israel	Largest single-phase supplier for the second year in a row.

Source: Author, with data from GTM Research and IHS Markit.

3.1. CURRENT STATUS IN JAPAN

Despite the progress made in recent years, the level of implementation of renewable energy in Japan is still low compared to the European average, even more excluding hydroelectric power (Figure 9).

Wind power cumulative installed capacity at the end of December 2017 was 3.4 GW, with an increase of 169 MW during 2017. This new installed capacity decreased from 192 MW in 2016 due to the delay of many projects because of the environmental impact assessment procedure[29]. According to the statistics released by the New Energy and Industrial Technology Development Organization (NEDO), the cumulative capacity was 3.5 GW at the end of March 2018, with 2,253 power facilities in operation. Of this total, 68.6% (1,546 facilities) are equipped with foreign generators. Aomori, Akita and Hokkaido Prefectures, all in the north of Japan, have the largest capacities, followed by Kagoshima Prefecture, in the south west of the country[30].

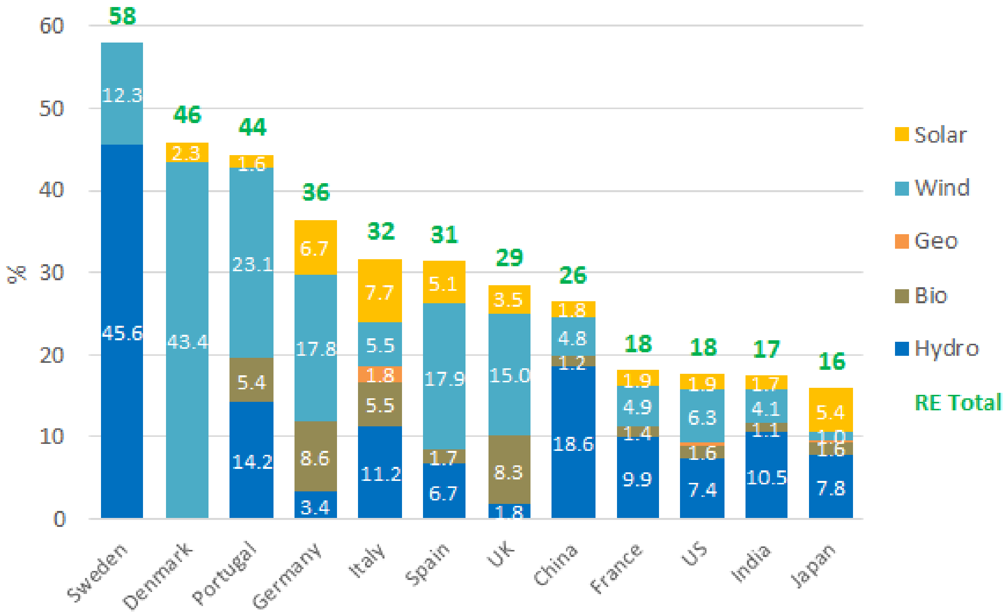
According to IRENA [9], Japan installed and connected to the grid 7 GW solar PV more in 2017, for a total capacity installed of 49 GW, the third largest in the world after China and the US (Figure 10). However, it continues with a downward trend respect to the previous years for the second year running, due to grid constraints, such as limited grid capacity and curtailment risks, and a reduction in the FIT’s purchase prices inside a race to reduce costs. These prices have fallen from 42 JPY/kWh in 2012 to 26 JPY/kWh in 2018 for residential systems, less than 10 kW, and from 40 JPY/kWh in 2012 to 18 JPY/kWh in 2018 for non-residential systems. The

[29] Japan Wind Power Association, January 17, 2018: http://jwpa.jp/page_256_englishsite/jwpa/detail_e.html.

[30] NEDO, June 28, 2018: http://www.nedo.go.jp/news/press/AA5_100984.html (only in Japanese).

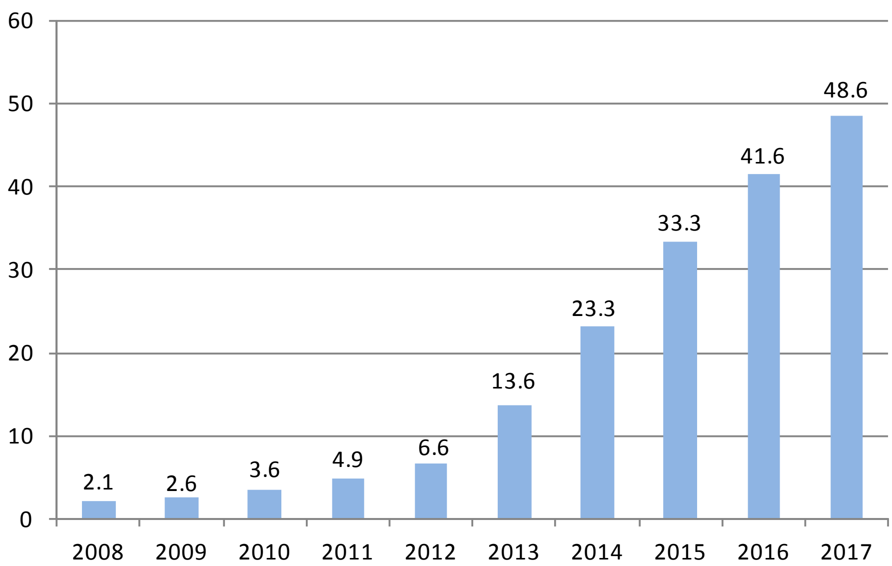
fall in the demand for large-scale projects is because Japan established an auction system for projects over 2 MW since 2017 that is not being successful.

Figure 9: Renewable Energy Share in Electricity Consumption in 2017



Source: Renewable Energy Institute (REI)[31].

Figure 10: Cumulative Solar PV Capacity in Japan (GW)



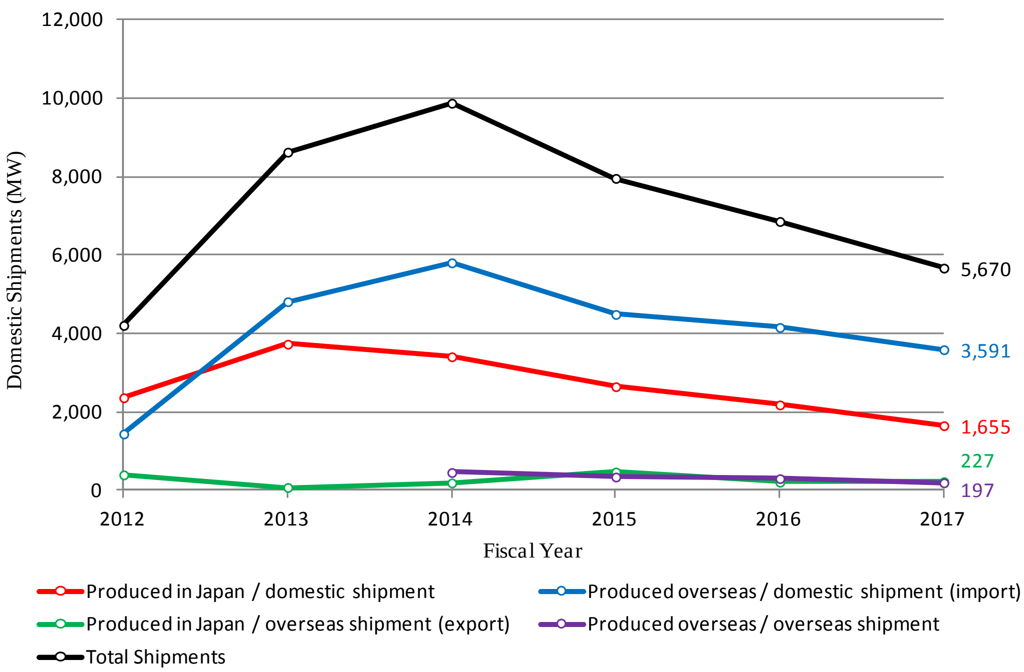
Source: Author, with data from IRENA [10].

[31] REI: https://www.renewable-ei.org/en/statistics/international/.

About 10% fewer exhibitors were in the PV Japan 2018 event, one of the country's largest solar trade shows, held in Yokohama in June 2018, and global main players such as Jinko Solar, Huawei and Tesla stopped taking part in it because of the decreasing market[32].

The Japan Photovoltaic Energy Association (JPEA) reported that PV module total shipments fell 17% year on year (y-o-y) to 5.67 GW in FY 2017. Regarding the domestic shipment, for residential application decreased by 11% y-o-y to 1,079 MW of new installations, for commercial application decrease by 13% y-o-y to 1,438 MW, and for utility-scale application decreased by 22% y-o-y to 2,719 MW. Therefore, domestic shipment dropped for the third straight year (Figure 11 and Figure 12).

Figure 11: Japan’s Total Shipments of PV Modules by Fiscal Year

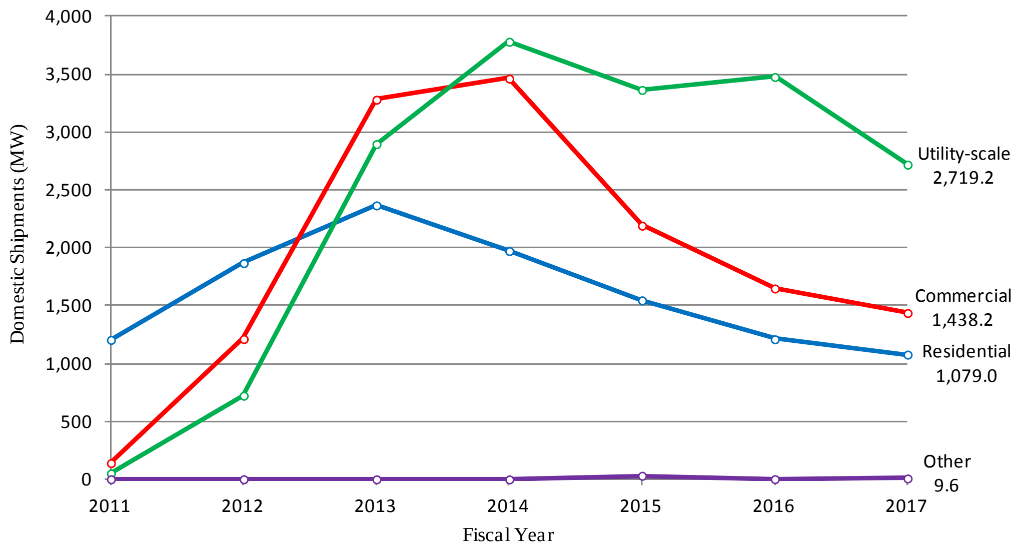


Source: Author, with data from JPEA.

Regarding the domestic shipment, utility-scale accounted for almost 52% in FY 2017, while residential and commercial shipments were, respectively, about 21% and 27%. Prior to 2012, around 84% of the total capacity installed was for residential purposes [15]. The new FIT scheme introduced in July 2012 changed that trend and boosted the non-residential market, accounted for about 75% of the total shipments PV modules until the end of FY 2017, and about 79% of the total capacity installed in FY 2017.

[32] Asia Nikkei, July 3, 2018: https://asia.nikkei.com/Business/Business-Trends/Japan-s-solar-panel-makers-suffer-as-power-plant-demand-fades.

Figure 12: Japan's Domestic Shipments of PV Modules by Application and Fiscal Year



Source: Author, with data from JPEA.

Teikoku Databank announced that 50 solar-related companies went bankrupt during the first half of 2017, most of them small companies with less than 50 million yen in capital, compared with 23 during the same period in 2016[33]. At the end of 2017, there were 88 cases, and another 44 more during the first half of 2018[34]. But also the largest Japanese companies such as Kyocera, Panasonic and Solar Frontier faced losses in FY 2017 due to the decrease of sales in Japan. The reason is the slowdown in the solar deployment during the last years because of the reduction in the FIT and the difficulty to find suitable land and grid connection for large solar plants. But also because South Korean and Chinese competitors with cheaper products forced some domestic manufacturers out of production.

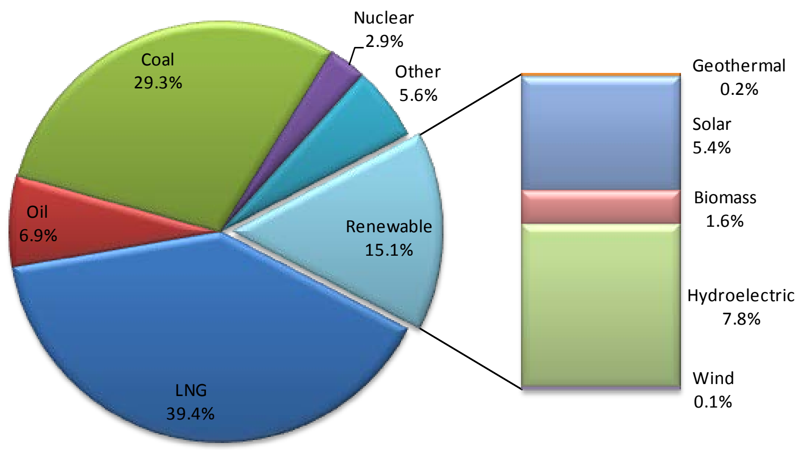
According to the Electricity Business Act, the PV investment plan has to be submitted to the Ministry of Economy, Trade and Industry (METI) at least 30 days in advance, and the project is also subject to the Forest Act or some local regulations. However, PV solar power plants are not subject to the restrictions of the Environment Impact Assessment Act, which covers other renewable sources and nuclear power. Because of the large land expropriation and felling of trees, MOE plans to include utility-scale PV solar plants under Act from autumn 2019, without knowing yet which sizes will be subjected. According to The Forestry Agency, under the Ministry of Agriculture, Forestry, and Fisheries (MAFF), 2,600 hectares of forest were permitted to be used for PV solar plants in 2016, 12 times higher than in 2012. MOE also revised the Natural Parks Act in order investor must apply with the local authority to set PV

[33] PVTech, July 18, 2018: https://www.pv-tech.org/news/up-to-100-japanese-solar-pv-firms-could-go-bust-this-year-report-finds.
[34] Kankyo Business, July 9, 2018: https://www.kankyo-business.jp/news/020742.php?utm_source=mail&utm_medium=mail180710_d&utm_campaign=mail.

solar power plants inside national parks. On the other hand, market players are concerned about the possible increase in costs and the slowdown in the deployment of utility-scale projects that this new regulation could bring[35].

The ratio of renewable energy generation was about 15% in 2017, with a 5.4% of the total from the solar power generation, up from 4.8% in 2016.

Figure 13: Energy Mix in FY 2017



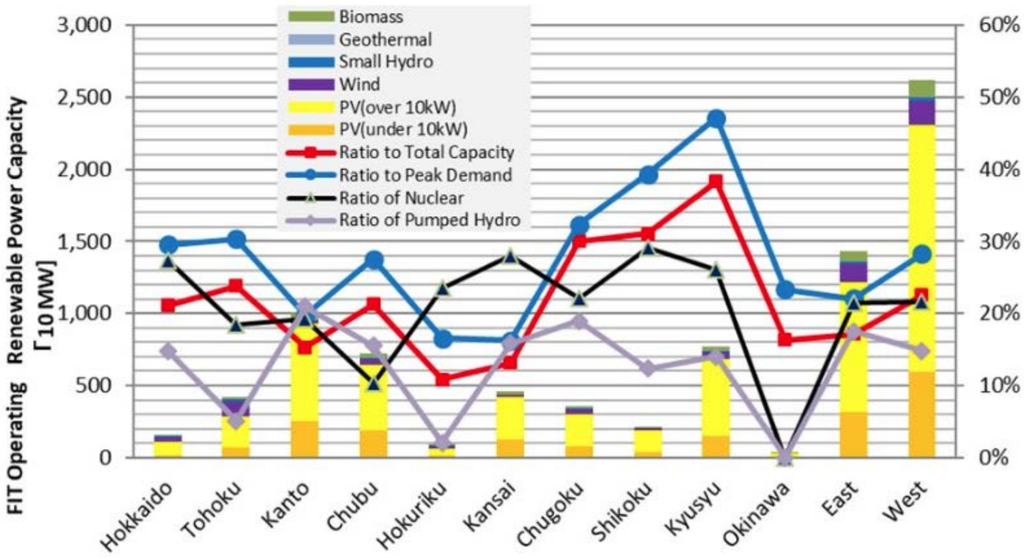
Source: Author, with data from METI/REI[36]. “Others” includes pumped storage and non-renewable waste.

Nevertheless, the contribution of renewable sources in the power generation is better in some areas, such us in Kyushu, the one with the largest growth of solar PV deployment in Japan. Kyushu Electric Power announced that solar power output at 1:00 pm on April 23rd, 2017, covered 76% of demand in its service area[37], and 80% of demand on April 29th, 2018[38]. Shikoku Electric Power Company also announced that solar power covered 80% of local electricity demand on May 5th, 2018[39]. As a consequence of a surplus of power because of the rapid increase of renewable market, some utilities had to use their right to order solar power operators stop production temporarily in the past, and Kyushu Electric Power is considering do it again after restarting four nuclear reactors on the main island of Kyushu.

Nuclear, hydraulic and geothermal energies are the last sources to be subjected to output control under the government rule since they were designated as baseload power sources because their output is stable and they are relatively inexpensive, while the other renewables sources such as solar and wind are the first.

[35] EnergyTrend, September 4, 2018: https://pv.energytrend.com/news/20180904-12448.html.
[36] REI: https://www.renewable-ei.org/en/statistics/international/.
[37] REI, July 4, 2017: https://www.renewable-ei.org/en/activities/column/20170704.html.
[38] Asahi Shimbun, August 29, 2018: http://www.asahi.com/ajw/articles/AJ201808290050.html.
[39] Yonden, May 21, 2018: http://www.yonden.co.jp/press/re1805/data/pr009.pdf (only in Japanese).

Figure 14: Operating Renewable Power Capacity in each Utility as of March 2017



Source: METI, prepared by Institute for Sustainable Energy Policies (ISEP)[40].

According to a new report of RTS consulting firm, Japan will likely install between 6 GW to 7.5 GW in 2018, despite METI canceled approvals for 260,000 solar projects that were registered under the formerly tariffs of the FIT program, with a total capacity of 14.6 GW[41]. Fuji Keizai Co Ltd firm published a slightly higher number in July 2018, until 7.8 GW and JPY 546 billion in FY 2018, and it considers that the scale of the Japanese market will fluctuate between 6 to 7 GW after FY 2018 depending on the promotion of self-consumption model[42].

The Long-term Energy Demand and Supply Outlook published in July 2015 established a cumulative installed solar PV capacity target of 64 GW by 2030 [5]. However, both JPEA and RTS Corporation forecast that this target will be achieved as early as 2020. In its "PV Outlook 2050" report, JPEA expects that the cumulative solar PV capacity will reach 100 GW by 2030 and 200 GW by 2050.

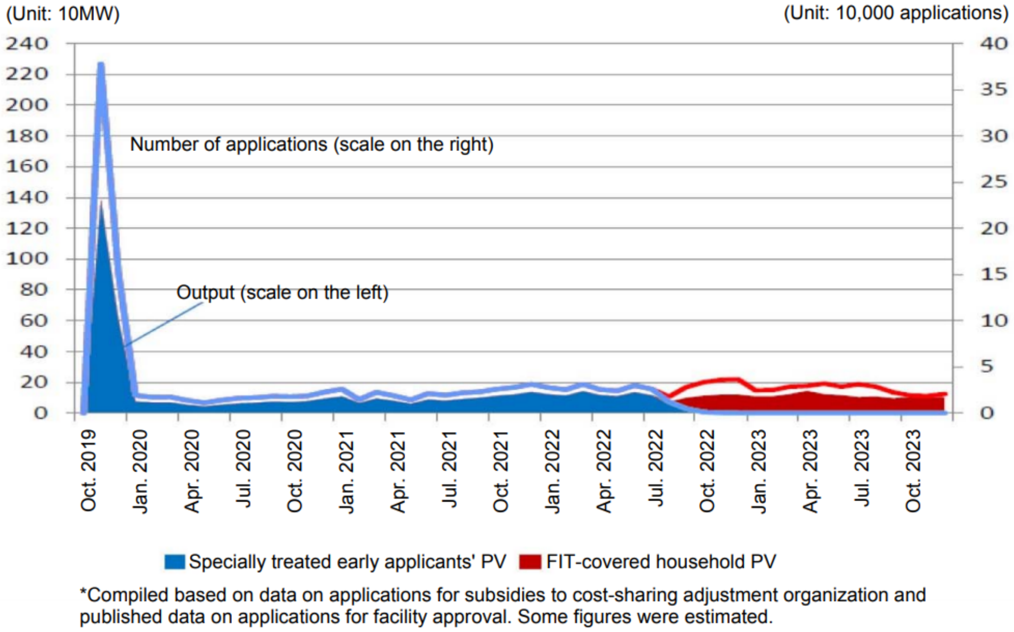
RTS Corporation estimates that residential installations rather than commercial and utility-scale markets will push 2018 PV installations in Japan to as high as 7.5 GW[43], largely on the back of rising storage battery deployment and the growing importance of ZEH. The government's target is to achieve net-zero energy on half of the new houses built by 2020. It also supports the use of HEMSs as a way to improve building energy efficiency, and it set the target of about 10,000

[40] ISEP: https://www.isep.or.jp/en/statistics.
[41] PV Magazine, February 15, 2018: https://www.pv-magazine.com/2018/02/15/japan-to-install-up-to-7-gw-in-2018-despite-cancellation-of-14-6-gw-of-approved-capacity-report/.
[42] Solar Power Plant Business, July 21, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/072102243/?ST=msbe.
[43] PVTech, July 25, 2018: https://www.pv-tech.org/news/hanwha-q-cells-touts-solar-module-supplier-leadership-in-japan-for-2017.

HEMSs installed in households by 2024 [16]. In 2017, about 25,000 new residential solar-plus-storage systems were installed.

Prior to 2012, a FIT scheme for solar PV residential rooftop was introduced in Japan in November 2009 for 10 years, which supported a remarkable growth of this market. It will start to expire in November 2019, and according to SolarPower Europe [12], about 700,000 users will need to maximize the value of their PV systems (Figure 15). Increase their self-consumption ratio through energy storage batteries, keep selling the surplus power to a lower price or become prosumers are options that will provide business opportunities for solution providers in the residential market. For example, Chubu Electric Power Co. announced that will continue to purchase solar electricity from its customers after the end of this original FIT period[44]. A gradual phase-out of the new FIT subsidy for residential PV systems will start also in 2019.

Figure 15: Timing of Excess Power Purchase Agreement (PPA) Termination and Output of PV Systems covered by the Previous and Current FIT Programmes



Source: Agency of Natural Resources and Energy (ANRE), compiled in [17].

The number of community solar PV projects also increased during 2017, with a total capacity of 86 MW, almost double than in 2016 [8]. The government set a target of up to 100 million

[44] Solar Power Plant Business, July 28, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/072802260/?ST=msbe.

buildings and households connected by 2020[45]. The Energy and Environment Council set an 85% nationwide target for smart electrical meter adoption by 2020. The number of smart meters introduced to Japan was 3.66 million units in FY 2014 and 7.5 million units in FY 2015. In the three years from FY 2016, more than 12 million units were planned to be installed each year. According to the METI Smart Meter System Study Group, completion of smart meter installation for hig-voltage users, such as factories, was completed in FY 2016. For low-voltage users, such as households, Tokyo Electric Power Company (TEPCO) expects to complete smart meter installation for all of its users by 2020. Finally, smart meter installation across all Japan is scheduled to be completed by FY 2024. The Swiss firm Landis+Gyr is providing smart meters to TEPCO in its grid modernization project. When completed, it will include more than 27 million meters and millions of other devices transmitting 1.3 billion interval data packets daily[46]. Therefore, the smart metering deployment in Japan is happening much faster than in other countries and is a market to watch for European companies involved in this sector.

Therefore, Japan's PV solar market is moving towards the residential and commercial rooftops sector, increasing the more efficiency distributed (and local) generation, self-consumption and trade energy model. The author visited the PVJapan2018 exhibition event in June 2018 and could check that the major Japanese manufacturers such as Panasonic, Kyocera, Solar Frontier, Kaneka, XSOL or Toshiba Mitsubishi are focusing on that model, with services that include higher performance and long-term reliability solar modules, storage batteries and HEMS.

The rapid adoption of renewable energies in Japan, especially solar energy, has brought problems affecting the stability of the power grid, including output fluctuations and surplus power generation. There is an ongoing debate around whether it's possible to have an electric grid running on 100% renewable power. But the key point is that many countries and regions already got it, or are close to doing it, mainly with hydropower, wind, solar and geothermal energies[47]. According to the U.S. Energy Information Administration, Iceland, Paraguay and Costa Rica have a grid 100% renewable. Norway 98.5%, Austria 80% and Brazil 75%. Other countries such as Denmark, Uruguay, Germany and Ireland also have great and successfully penetration of VRE into their electricity systems.

Strategies for system integration of renewables are crucial to minimize negative impacts, maximize benefits and improve the cost-effectiveness of the power system. Storage is a simple way to integrate wind and solar power into the grid, achieving feasible flexibility when the wind does not blow or the sun does not shine, and when the demand is lower. Batteries could also remove the curtailment risk from PV power plants output, which has been seen as a barrier to investment in some of the more saturated grid areas in Japan, as it was said before.

[45] Altair, May 22, 2017: https://altair-semi.com/japan-using-cellular-iot-lead-way-mass-smart-metering-deployment/.
[46] Enterprise IOT Insights, May 2, 2017: https://enterpriseiotinsights.com/20170502/internet-of-things/20170502internet-of-things20170502internet-of-things-japan-tepco-smart-meters-grid-modernization-project-tag23.
[47] ThinkProgress, May 22, 2018: https://thinkprogress.org/a-100-percent-renewable-grid-isnt-just-feasible-its-already-happening-28ed233c76e5/.

Energy storage is also the way to increase the self-consumption ratio in the residential and commercial sectors, and the energy efficiency through a distributed model where the energy is generated, stored, consumed and sold locally.

Through the vehicle to grid (V2G) technology, electric vehicles' batteries, larger than the residential ones, will increase their importance as new smart management tools to operate the energy system, reinforcing the grid of that area when the demand is higher or during an unexpected natural disaster. Their charging could also be shifted to the middle of the day, to absorb high levels of solar generation, or at night, when the demand is the lowest, helping to integrate higher shares of variable renewable energy without interfering with the stability of the grid, increasing the flexibility of the electricity system, and enabling higher decarbonization ratio of both transport and power sectors. Therefore, the V2G technology will make electric vehicles part of the energy solution, reducing the cost of their ownership, and helping to increase their sales.

The power generation system is shifting to a more efficient and cheaper distributed model, closer to demand centers, promoting the self-consumption and a local trade between neighbours, without almost losses during the energy transportation and distribution from large facilities, and without affecting the stability of the main grid. A virtual power plant (VPP) digitally integrates/aggregates the energy and power capabilities of large numbers of connected distributed energy resources, mainly solar plus storage systems at households and commercial businesses, but also highly efficient energy equipment (air conditioners, heat sources, generators, thermal storage tanks, etc), and electric vehicles' batteries through the V2G technology.

All these aspects will be seen in the following chapters.

Costs

In Japan, and according to IRENA [10], the solar PV cost was reduced by 73% for the utility-scale from 2010 to 2017. The average total installed cost for residential PV systems fell 62% in 2017 compared to 2007. LCOE was also 73% lower for utility-scale from 2010 to 2017, and 58% lower for residential systems from 2007 to 2017. As the LCOE of solar PV is getting closer to retail electricity prices for commercial and industrial users, self-consumption will become an attractive option for companies to reduce CO_2 emissions [12].

Table 3 shows the prices of the PV system's components depending on the size of the installation. The total average cost is about JPY 270,000 per kW for a residential PV system and JPY 170,000 per kW for a utility-scale PV power plant.

Table 3: Prices of PV Systems (JPY/W)

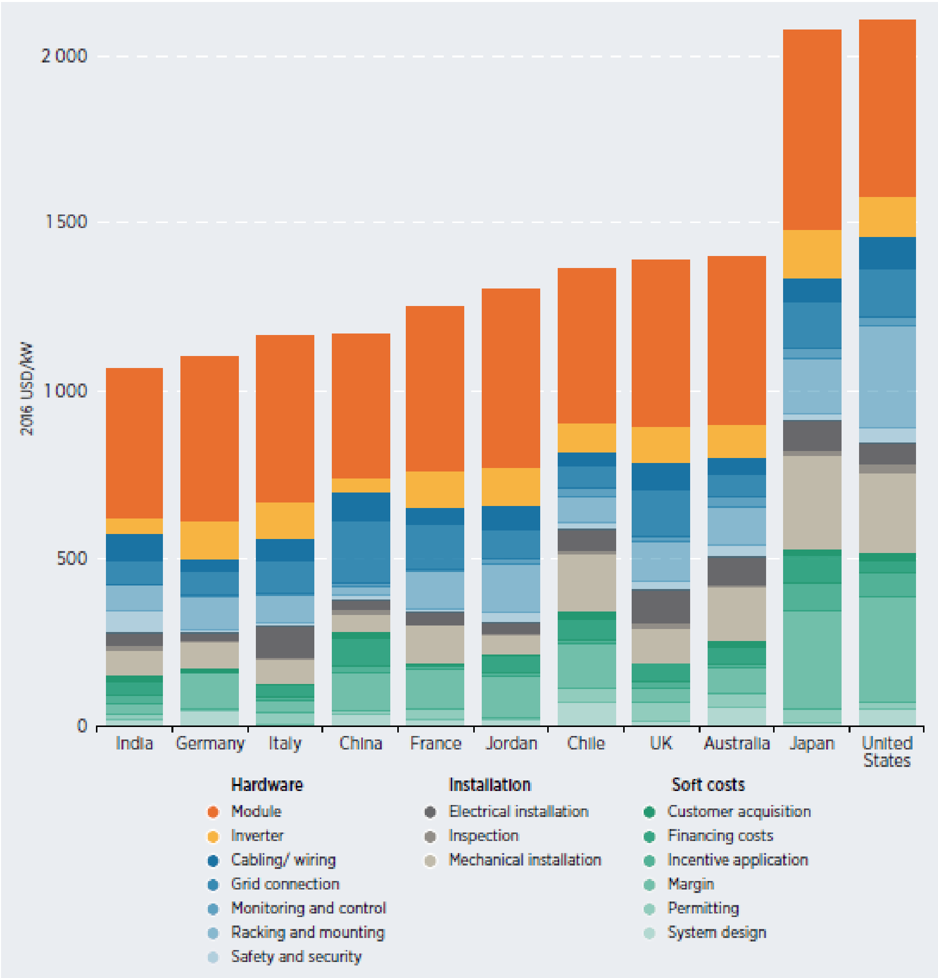
PV system type	Component	End of FY			
		2014	2015	2016	2017
Less than 10 kW (residential)	PV module	227	196	169	150
	Inverter	44	44	37	37
	Construction	66	64	60	59
	Other	29	28	27	26
	Total	366	332	293	272
Between 10 and 50 kW	PV module	172	152	127	110
	Inverter	41	38	35	31
	Construction	96	91	72	68
	Other	34	32	31	27
	Total	343	313	265	236
Between 50 kW and 1 MW	PV module	128	101	96	79
	Inverter	45	43	37	36
	Construction	83	79	67	63
	Other	35	32	27	25
	Total	291	255	227	203
Over 1 MW	PV module	101	89	78	69
	Inverter	38	35	32	29
	Construction	68	66	58	52
	Other	28	26	24	20
	Total	235	216	192	170

Source: Author, with data from RTS Corporation [14].

The utility-scale solar PV costs in Japan are almost double than in Germany, Italy or China. Figure 16 shows that, although the price of solar panel and power conditioner is not much different compared with other countries, soft costs, such as the licensing approval procedure and margin, and mechanical and electrical costs, differ greatly. In comparison with Germany, in 2016, the soft costs in Japan were around three times higher, and construction costs were about four times higher. This trend was common across systems of different scales, from small to large.

The REI's report about the comparison of the costs between Japan and Germany in 2016 [18], concluded that the main reason for larger construction costs were not labor costs per hour but average construction periods, much larger in Japan because of the use of manual machines instead of automatic ones (Table 4). In Germany, mounting system designs, as well as the hardware used for installation, are optimized to keep the installation time shorter. Besides, in Japan, more prone to natural disasters such as typhoons and earthquakes, the standards for wind load are higher, and mounting system designs with higher strength are required. Therefore, Japan needs to improve cost competitiveness and simplified procedures.

Figure 16: Detailed breakdown of utility-scale solar PV costs by country



Source: IRENA Renewable Cost Database [10].

Table 4: Comparison of the Average Construction Periods between Japan and Germany

Capacity	Japan	Germany	Difference
10 kW	2-5 days	1 day	2-5 times
50 kW	6-10 days	2-3 days	2-3 times
500 kW	2-3 months	1-2 weeks	4-6 times
1,000 kW	4-5 months	2-3 weeks	5-7 times

Source: Author, with data from REI.

Regarding the investment in renewable energy, it also falls 28% in 2017, up to USD 13.4 billion, because of uncertainties related to grid connection and to the shift in FIT policy [8].

3.1.1. Main Manufacturers

The main players in the Japanese solar PV market include domestic companies such as Kyocera, Solar Frontier, Panasonic, Toshiba, Mitsubishi Electric, Sharp, Kaneka, XSOL, Japan Solar, Energy Gap, SB Energy, Showa Shell Sekiyu K.K., F-WAVE or Choshu Industry, among others. But also foreign companies such as Hanwha Q-CELLS Japan, Jinko Solar, Canadian Solar Japan, JA Solar Japan, Yingli Green Energy Japan, Trina Solar Japan and Risen Energy.

In FY 2017, about 60% of the PV modules were produced by Japanese companies, both in Japan, 55%, and overseas, 45%. This is because Japanese companies with factories overseas such as Kyocera, Panasonic, Sharp and Kaneka produce modules overseas and export them to Japan. Foreign companies produce almost all their 40% share overseas. Totally, 67% of PV modules installed in Japan in FY 2017 were produced overseas.

Table 5: Japan's Total Shipments of PV Modules by Company and Location

Company	Domestic production	Overseas production	Total	Ratio (%)
Japanese	1,874	1,519	3,393	59.8%
Foreign	1	2,277	2,278	40.2%
Total	1,875	3,796	5,671	
Ratio (%)	33.1%	66.9%		

Source: Author, with data from JPEA.

Residential market supposed 21% of the total capacity installed in Japan in FY 2017, and it was still dominated by domestic manufacturers, mainly Sharp, Kyocera and Solar Frontier, with 74% of the share. In spite of their higher prices, most retail customers are still attracted to established local brands. On the other hand, the non-residential sector presents a more balance trend, with 52% of the modules produced by Japanese companies and 48% by foreign companies (Table 6).

According to Fuji Keizai research firm, the South Korean Hanwha Q CELLS led the market share in 2017 with 770 MW, becoming the first overseas producer to top Japan's solar panel market. About 70% of that capacity was installed in non-residential projects. That data represents about 14.5% of the total share, and about 34% among the foreign companies[48]. The quantity is a little different according to a survey conducted by Nikkei, until 12.9%[49]. The

[48] PVTech, July 25, 2018: https://www.pv-tech.org/news/hanwha-q-cells-touts-solar-module-supplier-leadership-in-japan-for-2017.
[49] Asia Nikkei, July 10, 2018: https://asia.nikkei.com/Business/Business-Trends/Foreign-solar-panel-makers-take-command-of-Japanese-market.

Korean company is also offering the Q.HOME+ all-in-one storage solution in Japan, including a battery, inverter and energy management system.

Table 6: Japan's Domestic Shipments of PV Modules by Application and Company (MW)

Use	Japanese company	Ratio (%)	Foreign company	Ratio (%)	Total	Ratio (%)
Residential	795	73.7%	284	26.3%	1,079	20.6%
Commercial	963	66.9%	476	33.1%	1,439	27.5%
Utility-scale	1,211	44.5%	1,508	55.5%	2,719	51.9%
Total	2,969	56.7%	2,268	43.3%	5,237	

Source: Author, with data from JPEA.

Canadian Solar Japan and Jinko Solar also managed to increase their share, and JA Solar's shipments in Japan reached 3.3 GW, with over 200 partners in Japan, and local customers including Marubeni Corporation, Hitachi, Mitsui & Co. or JGC Corporation among others[50]. Canadian Solar Japan also started to offer a solar package from August 2018, including the PV module, storage battery, HEMS and EV charger with V2G technology[51].

Kyocera, which had the first place in 2016, retreated to second with a 12.2% share, and Sharp, Panasonic and other domestic manufacturers also lost share.

Technological advancements have slowed, leaving companies increasingly differentiating themselves based on price instead of new features. This market environment, with increasing competition from Chinese and South Korean solar module manufactures, which have much larger production scale and cheaper prices, forced some domestic manufacturers out of production. For example, Mitsubishi Electric stopped producing solar cells at its factory in Nagano Prefecture in March 2018, though it keeps assembling panels at its factory in Kyoto Prefecture with cells from overseas.

The largest Japanese companies, such as Kyocera, Panasonic, Solar Frontier, Sharp or Kaneka are developing new highly efficient solar modules, with higher outputs at higher temperatures (lower temperature coefficient), better tolerance for shadows, and higher guaranteed performance during longer periods. Some examples are the Panasonic's HIT technology (heterojunction solar cell with a bifacial structure), the Solar Frontier's Copper Indium Selenium (CIS) technology or the Sharp's black solar modules. In March 2018, Sharp announced the achievement of 25.09% conversion efficiency from a cell utilizing both

50 Greentech Lead, August 14, 2018: https://www.greentechlead.com/solar/ja-solar-shipments-to-japan-reached-3-3gw-34540.

51 ITmedia, August 2, 2018: http://www.itmedia.co.jp/smartjapan/articles/1808/02/news024.html.

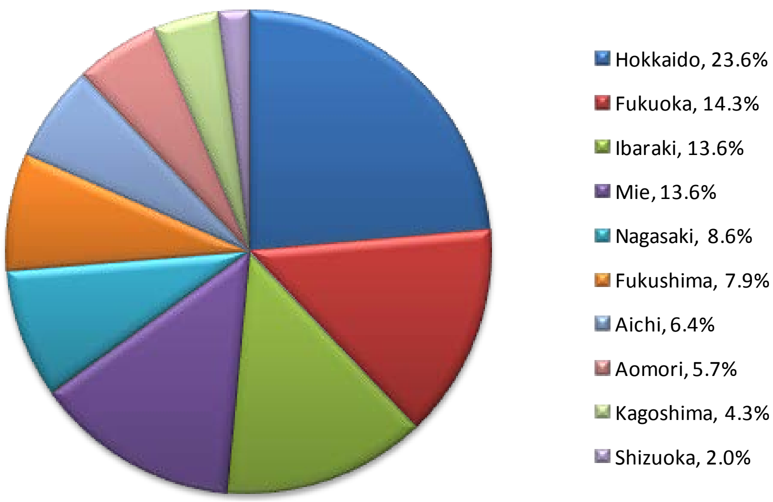
heterojunction (HJT) and black contact technologies, validated by Japan Electrical Safety & Environment Technology Laboratories (JET)[52].

But most important, they are shifting their solar business, offering high-value-added systems in the self-consumption model, including storage batteries and HEMS in the package, but also VPP solutions in which their customers will get revenues, and opening to more areas such as operation and maintenance (O&M), and seeking business expansion to overseas markets. They started to cover all the spectrum of the solar residential market and offering new products and services, a trend that foreign companies such as Hanwha Q CELLS and Canadian Solar Japan are also following, as it was said before.

Panasonic has been selling solar PV systems plus storage batteries and inverters since 2012. Kyocera and Sharp are also offering storage batteries. Solar Frontier and TEPCO Homepec started to sell a free installation model for residential sector combining solar power generation and energy saving equipment[53]. Consumers are also increasingly interested in energy storage in order to increase their self-consumption and, above all, to be prepared in case of natural disaster, in a country usually hit by typhoons and earthquakes.

Solarplaza presented an overview of the 30 largest solar portfolios in Japan as per end of 2017, with a total capacity installed of 4.7 GW[54] shown in Figure 17 and Table 7.

Figure 17: Largest 30 Solar Portfolios in Japan by Region



Source: Author, with data from Solarplaza.

[52] PV Magazine, March 27, 2018: https://www.pv-magazine.com/2018/03/27/sharp-hits-25-09-efficiency-on-full-size-hjt-cell/.
[53] Kankyo Business, July 10, 2018: https://www.kankyo-business.jp/news/020756.php?utm_source=mail&utm_medium=mail180711_d&utm_campaign=mail (only in Japanese).
[54] Solarplaza: https://solarassetmanagement.asia/top-30-portfolios-2018/.

Table 7: Largest 30 Solar Portfolios in Japan

Operational porfolio owner	Total projects	Total (MWp)	Fully owned (MWp)	Co-owned (MWp)	Largest plant (MWp)	Smallest plant (MWp)	Location
ORIX Corporation		520.0	520.0	0.0	-	-	
SB Energy	30	390.0	174.5	215.5	111.0	1.2	Hokkaido, Tochigi (3)
Mitsui & Co.	8	336.6	105.0	231.6	111.0	2.0	Tokyo, Tottori, Aichi, Hokkaido, Fukuoka
NTT Facilities Inc.	77	265.3	265.3	0.0	32.7	0.9	Ibaraki
Equis Energy	16	249.9			36.0	2.4	Aomori (8)
Eurus Energy Holding Corporation	9	247.5	247.5	0.0	115.0	4.0	Hokkaido, Fukushima (2)
Japan Renewable Energy	33	196.3	196.3	0.0	16.8	1.0	Ibaraki, Fukuoka (6)
Kyocera TCL Solar	58	166.9	69.2	97.7	-	-	-
Canadian Solar	25	163.0			49.7	0.6	
Sparx	17	157.1			22.0	0.4	Hokkaido, Chiba, Ibaraki, Kumamoto (2)
Renova, Inc.	7	140.1	19.0	121.1	40.0	7.5	Shizuoka (2)
Daiwa House Industry	68	136.6	136.6	0.0	22.6	0.1	Fukuoka, Chiba, Shizuoka
Mitsubishi Corporation	5	136.3	0.0	136.3	80.9	0.8	Fukushima (2)
Sojitz Corporation	5	135.9	119.3	16.6	71.0	9.1	Aichi (2)
Smart Solar	-	135.0			-	-	-
Obayashi Clean Energy	40	129.0			24.5	0.5	Kagoshima (6)
Vaitec Solar Energy	45	124.0			-	-	-
Japan Asia Group Limited	58	120.2	120.2	0.0	26.3	0.2	Hokkaido (11)
Itochu	3	115.6			44.8	33.8	Okayama, Ehime, Oita
Tokio Marine Asset Management	20	111.0	0.0	111.0	19.5	1.1	Yamaguchi (3), Hokkaido (3)
C-tech Corporation	13	110.3	26.5	83.8	80.9	1.0	Aichi (6)
Ichigo ECO Energy	34	100.4	74.6	25.8	43.3	0.5	Hokkaido (11)
Pacifico Energy	3	97.0	97.0	0.0	40.3	26.5	Okayama (2)
Marubeni Corporation	9	90.4	90.4	0.0	48.7	0.6	Nigata (3)
Shibaura Group Holdings	35	77.4	77.4	0.0	23.0	0.5	Fukuoka (12)
Crystal Clear Solar	22	63.0			13.9	1.0	Fukushima (5)
Saferay K.K.	6	55.8	55.8	0.0	19.8	0.7	Fukushima (2)
Sonnedix Japan KK	3	51.3			46.8	2.2	Yamanashi (2)
Chopro	14	45.2	45.2	0.0	30.0	0.9	Nagasaki (12)
Sanko Real Estate CO,LTD	20	44.8	44.8	0.0	15.4	0.3	Mie (19)

Source: Author, with data from Solarplaza.

Regarding the PCS market, IHS Markit forecasts that the Japanese market will be 1.8 GW in 2018[55]. There is a growing trend to use three-phase string inverters, such as 25 kW, to address the commercial market. Foreign suppliers are entering the Japanese market with that kind of products, as the Israeli SolarEdge, which launched a new three-phase inverter in Japan in 2018

[55] PV Magazine, January 31, 2018: https://www.pv-magazine.com/2018/01/31/solaredge-taps-omron-for-roll-out-of-three-phase-hv-inverter-solution-in-japan/.

via a partnership with the domestic company Omron. Huawei also doubled its presence in Japan in 2017[56]. Other foreign suppliers such as ABB, Schneider Electric, SMA and Delta are growing their share. GE has partnered with the Japanese solar projects developer Pacifico Energy KK for supplying inverters on two solar projects of 40.32 MW[57] and 96.2 MW[58] in Kyushu Island in 2018. Jinko Solar has secured a JPY 5.3 billion syndicated loan agreement for up to two years with a bank consortium led by Sumitomo Mitsui Banking Corporation (SMBC) to expand its business in Japan[59]. Table 8 provides a list of the main inverters' suppliers that are operating in Japan.

Table 8: Main Inverters' Suppliers in Japan

Domestic comapnies	**Foreign companies**
TMEIC	Huawei Technologies Japan Ltd. (China)
Omron	Sungrow Japan K.K. (China)
Tabuchi Electric Co., Ltd.	SMA Japan K.K. (Germany)
Nichicon Corporation	ABB Co., Ltd. (Switzerland)
DAIHEN Corporation	Power Electronics Japan (Spain)
Nisshin Denki Co. Ltd.	Schneider Electric (France)
Fuji Denki	SolarEdge Technologies Co., Ltd. (Israel)
Hitachi Ltd.	Delta Electronic Co., Ltd. (Taiwan)
Panasonic	General Electric (United States)
GS Yuasa Corporation	IDEC Corporation (United States)
Yaskawa Electric Corporation	
Meidensha Corporation	
Sanyo Denki Co., Ltd.	
Fujisaki Electric Co., Ltd.	
Shindengen Electric Industry Co., Ltd.	
Murata Manufacturing	
Mitsubishi Electric	
Sharp	
Kyocera	

Source: Author, with data from several sources.

56 PVTech, March 3, 2017: https://www.pv-tech.org/news/huawei-targeting-2gw-of-inverter-shipments-into-japan-this-year.
57 GE, April 11, 2018: https://www.genewsroom.com/press-releases/ge-delivered-40-megawatts-solar-inverters-pacifico-energy-furukawa-mega-solar-plant.
58 GE, June 13, 2018: https://www.genewsroom.com/press-releases/ge-commissioned-brilliance-inverters-one-largest-solar-farms-japan-284391.
59 PVTech, March 3, 2017: https://www.pv-tech.org/news/jinkosolar-in-us47.8-million-loan-agreement-to-expand-business-in-japan.

However, and although foreign companies are continuing to expand in Japan, the market is still dominated by domestic manufacturers, being Omron and TMEIC (Toshiba Mitsubishi-Electric Industrial Systems Corporation) the largest suppliers. This trend has not changed from the past, since according to IHS Markit, in the first three quarters of 2014, the three largest Japanese manufactures, Omron, TMEIC and Tabuchi, took 60% share[60]. Domestic suppliers that provide residential inverters with storage function (hybrid inverters) are Panasonic, Sharp, GS Yuasa, Eliiy Power, Omron, Tabuchi Electric, Kyocera, NEC and Nichicon.

A certification scheme by JET is required for inverters smaller than 20 kW, and it is categorized into three types of inverters: conventional, multiple-unit grid-connection and FRT-support (Fault Ride Though) [19]. It does not exit any certification scheme for bigger inverters.

3.1.2. Floating Solar PV Systems

More countries with limited ground space to install large-scale ground PV solar systems are placing those on stable bodies of water, a business that notably grew in 2017. Installation of solar panels on water is also relatively quick and inexpensive compared with ground-mounted systems. It can mitigate land cost, excavation is not required and, in the case of Japan, there is no need for the costly earthquake-proofing foundation work mandated for all ground installations. They are close to a grid connection point most of the times, reducing also development costs. They are less prone to shading, and there is no maintenance associated with clearing ways ground vegetation. In addition, floating solar plants can reduce evaporation and slow algae growth in freshwater[61].

According to GTM, a total of 100 MW of floating PV was installed in 2017, and based on the projects in the pipeline, it expects to reach 1.5 GW in 2019 (Figure 18). Grand View Research, Inc. expects the global floating solar panels market to reach USD 2.70 billion by 2025[62].

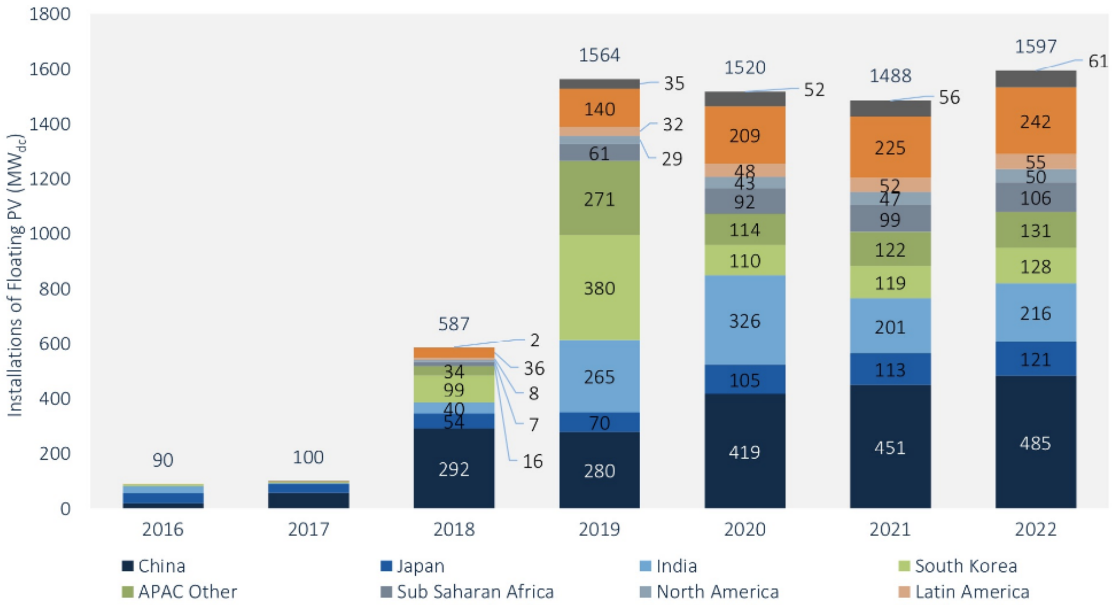
Since most areas in Japan that are suitable for large-scale solar power plants are already utilized or being planned for use, installers are starting to look for other places to set these systems, and those are stable water bodies and over agricultural lands among the most extended ones.

In a study completed in March 2015 in Hyogo Prefecture, local authorities concluded that solar panels on water generated 14% more power than those placed on the rooftop of an office

[60] PVTech, February 16, 2015: https://www.pv-tech.org/news/japan_and_us_to_lead_inverter_sales_in_2015_and_2016_predicts_ihs.
[61] Japan Today, April 18, 2017: https://Japan Today.com/category/features/lifestyle/Japan-sees-potential-in-solar-power.
[62] Gran View Research, January 2017: https://www.grandviewresearch.com/press-release/global-floating-solar-panels-market.

building due to the cooling effect that the water has on the panels, and that makes them work closer to their ideal temperature.

Figure 18: Installation of Floating PV by Country and Region from 2016 to 2022



Source: GTM Research.

Japan is the world's leader by capacity installed and the number of floating solar PV systems, due to the high FIT and the lack of suitable land, followed by China, South Korea and UK. However, China counts with the two biggest plants, with 40 and 20 MW, both on the old coal mining subsidence area of Huainan city. In June 2017, the French company Ciel & Terre started the construction of the world's largest plant, in the Chinese Anhui province, with a capacity of 70 MW, which is expected to be operational in 2018.

According to the list published by Solarplaza[63] in May 2018, 54 of the top 70 floating solar PV plants were located in Japan, with a total capacity of about 104 MW, 49% (Table 9). China, only with 5 plants, accounts for 37% of the total capacity of that top 70, about 78 MW, and it will lead the market when the mentioned plant become operational.

Ciel & Terre is the biggest installer in the market, with more than 50% of the total number of plants globally, and 38 of the largest 54 plants in Japan. Its projects are mainly located in the western part of Japan because it can use many reservoirs in that area and take advantage of good grid connections, compared with the north of the country, with heavy snow in winter[64]. Mitsui

[63] Solarplaza: https://solarassetmanagement.asia/top-70-floating-solar-plants-2018.
[64] Japan Today, April 18, 2017: https://Japan Today.com/category/features/lifestyle/Japan-sees-potential-in-solar-power.

Sumitomo Corporation also provides floating structures for 60 and 72 solar cells panels for the domestic market, and it is working on the overseas expansion, above all to Asian countries.

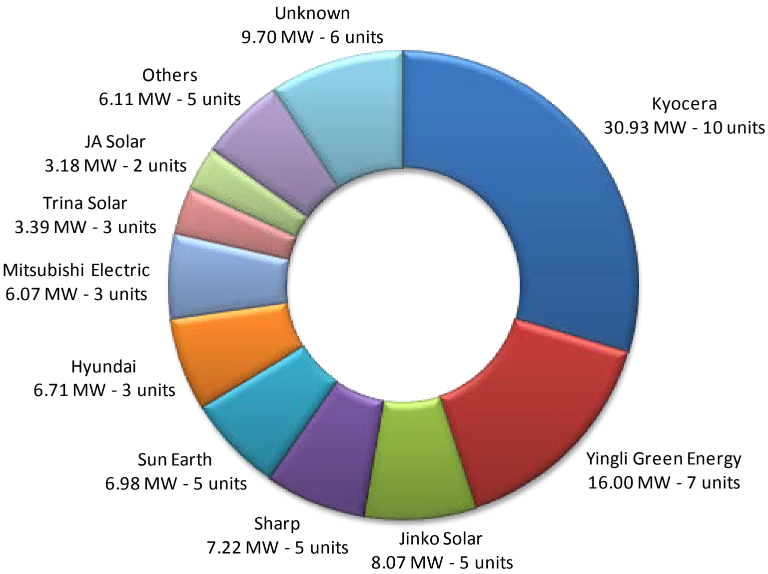
Table 9: Largest Floating Solar PV Power Plants in Japan (over 2.00 MW)

Size (MW)	Location	Developer	EPC	Solar Panels Supplier	System Provider
13.70	Chiba	Kyocera	Kyocera Communication System	Kyocera	Ciel & Terre
7.55	Saitama	Kawashima Taiyou to shizen no megumi Solarpark LLC	Kawashima Taiyou to Shizen no megumi Solarpark LLC	Yingli Green Energy	Ciel & Terre
2.87	Hyogo	Kyocera	-	Kyocera	Ciel & Terre
2.60	Kagawa	Sumitomo Mitsui Construction	SMC Tech	Mitsubishi Electric	Sumitomo Mitsui Construction
2.55	Mie	Ciel & Terre	Super Tool ECO, TOKS	Jinko Solar	Ciel & Terre
2.50	Osaka	-	Kaisei / Mera	-	Ciel & Terre
2.44	Kagawa	Joint Business of Japan Asia Investment & Local Partners	Kyocera Corporation	Kyocera	Ciel & Terre
2.40	Hyogo	-	Astec	Hyundai	Ciel & Terre
2.40	Mie	-	Kyocera Communication System	Kyocera	Ciel & Terre
2.40	Mie	Asahi Techno	-	Mitsubishi Electric	Ciel & Terre
2.31	Hyogo	Kyocera	Kyocera Communication System	Kyocera	Ciel & Terre
2.30	Saga	West Energy Solution	-	Sun Earth (West Energy Solution)	West Energy Solutions & Kyoraku
2.30	Hyogo	Ciel & Terre	-	Hyundai	Ciel & Terre
2.17	Kagawa	Ciel & Terre	-	Jinko Solar	Ciel & Terre
2.16	Hyogo	-	Miki Kygo	Sharp	Ciel & Terre
2.01	Hyogo	Comsys Create	Japan Comsys	Hyundai Heavy Industries	Takiron Engineering
2.00	Aichi	Ibiden Engineering	Ibiden Engineering	JA Solar	Ibiden Engineering

Source: Author, with data from Solarplaza.

Regarding the PV modules suppliers in Japan, Kyocera leads the market with about 30.9 MW installed, 29.6%, in 10 floating solar PV power plants, 18.5% (Figure 19). That is almost double than the second manufacturer, the Chinese Yingli Green Energy, with 16.0 MW installed. Without taking account the plants where the PV modules supplier is unknown, domestic and foreign companies installed a similar capacity, though the foreign companies supplied PV modules to 29 units while domestic companies supplied PV modules to 19 units. Globally, Kyocera also leads the market, accounting for over 50% of the floating panels installations.

Figure 19: PV Modules Suppliers for the 54 Largest Floating Solar PV Power Plants in Japan



Source: Author, with data from Solarplaza.

3.1.3. Solar sharing

Solar sharing is the concept used to define the agricultural solar power plants. This is the installation of PV solar modules at regular intervals on a frame that stands upright on agricultural land to generate energy while continuing farming. The height, with a minimum of two meters, and intervals of the structure with narrow lighter solar panels are set in order to allow the use of large agricultural machines such as tractors and to secure the necessary sunlight for cultivation. Some structures also allow a manual change of the solar panels' angles, optimizing the amount of solar radiation according to agricultural crops. It is said that solar sharing was invented in Japan in 2003 by Akira Nagashima, who patented his invention and made it free for public use.

Most plants do not need all the sunshine they receive in an open field. Everything beyond the plant's light saturation point does not increase the photosynthesis rate and can even be harmful, causing more evaporation and lack of moisture. Solar sharing takes advantage of this fact, and panels use the excessive sunlight for power generation while crops are cultivated below them. Therefore, it is appropriate for crops that do not need so much sunlight, and it has been already introduced in rice, tea, sweet potato, Japanese ginger, lettuce and soybeans lands, for example. Solar generation part can solve agricultural management problems by securing stable income other than agriculture. Solar sharing also promotes local production of renewable electricity and primary products, helping to reduce the GHG emissions.

A big percentage of Japanese land is forest and mountains. According to the Solar Sharing Network, there were about 4.44 million hectares (ha) of agricultural land in Japan in 2017, with a big potential of becoming solar sharing and produce a large share of the domestic electricity generation. About 1.2 million ha of agricultural land is currently abandoned from cultivation. The Japanese government published that the number of solar sharing plants was 1,182 by the end of March 2017, deployed in 330.9 ha. Assuming a standard size of 700 kW per hectare, they are producing about 230 MW.

In 2014, Slavka Batorova, with a Sustainability Science Master and building its own solar sharing plant, made a study concluding that if solar sharing was installed on 20% of Japan's farmland, and considering a shading rate of 25%, it could produce as much as 474.9 million MWh of electricity annually, representing about 57% of Japan's total electricity demand in 2014[65].

The legal regulation of agricultural land use, which required procedures for temporary conversion of farmland for non-agricultural purposes, blocked the deployment of solar sharing. Considering this barrier, MAFF announced a guideline about the handling of PV solar power generation facilities than continue farming in March 2013. The guideline described that a certain type of agricultural land can be temporarily converted as long as the farmer continues farming and its yield should not be lower than 80% of the annual average. Currently, farmland conversions are approved by the agricultural committee in each region. For the five years after that clear administrative definition, the solar sharing spread over 1,000 plants nationwide[66]. In addition, and because of the solar power generation, solar sharing applies to "industrial use", so it is possible to sell power at the price indicated by the FIT scheme for 20 years.

In May 2018, MAFF changed the period of the allowing temporary change of land category from up to three years with no exception to up to ten years. This measure reduces the workload for the renewal and the business risk, making easier the fundraising. The new rule applies to the following three cases: (1) when farmland is owned by a farmer or when the right to use farmland is established and the farmer does agriculture under solar panels, (2) when devastated farmland is used, including lands in agricultural areas, and (3) when class II or III farmland that is not located in an agricultural area is used[67]. The Basic Plan for Food, Agriculture and Rural Areas defines the farmers who are eligible for the ten years terms.

It is expected that this revision will help to promote solar sharing as a way to achieve sustainable development of local agriculture, and further expansion of scale in agricultural management due to the higher income that farmers will receive. The Solar Sharing Network estimates a growth of new 500 solar sharing plants per year, with an average size of 700 kW and an average initial cost of 250,000 JPY per kW (they are more expensive than standard solar plants). That would mean a business of about JPY 87 billion per year.

[65] GPSS-GLI, July 30, 2015: http://st.sustainability.k.u-tokyo.ac.jp/2015/07/30/solar-sharing/.
[66] Solar Sharing: http://solar-sharing.jp/.
[67] MAFF, May 15, 2018: http://www.maff.go.jp/j/press/shokusan/r_energy/180515.html.

In April 2018, the Solar Sharing Promotion Federation was established by stakeholders involved in this business with the aim of further promoting the spread of solar sharing in Japan, carrying out training and technical guidance.

According to data from the Solar Sharing Network, the main players in this market are the following:

- Loop Inc. (Japan): solar system developer, power producer and supplier.
- Luxor Solar Japan (Germany): solar panel and metal structure supplier.
- YINGLI Solar Japan (China): solar panel supplier.
- AISES Co., Ltd (Japan): solar system developer, installation.
- Building Giken Co., Ltd (Japan): solar system developer, installation.

Smart Blue Co., Ltd. has also more than 25 installations in Shizuoka Prefecture.

Some recent examples of solar sharing plants in Japan are the following:

- SJ Solar Tsukuba Power Plant, of 35 MW and on Korean ginseng, ashitaba, coriander and other crops, in Tsukuba City, Ibaraki Prefecture, started operation in April 2017. The power operator is Shanghai Electric Power Japan Co., Ltd[68].

- In September 2017, Sustainergy, a renewable energy firm, established a partnership with Hitachi Capital and manufacturer Daiwa House Industry to deploy solar sharing business model. It launched two pilot projects in Miyagi Prefecture of 2 MW each to produce mushrooms and sell the solar energy generated. Hitachi Capital provided the project financing, Daiwa House Industry performed the EPC and O&M, and the Power Purchase Agreements (PPAs) were signed with Tohoku Electric Power[69].

- Toyo Energy Farm Co., Ltd started a solar sharing business in several sites of Fukushima Prefecture in December 2017 with a total capacity of 11.3 MW over inactive lands that are producing Japanese ginger with this project. Solar panels were provided by AU Optronics Corp., inverter by ABB (Switzerland), and the power generation facilities were leased from Sumitomo Mitsui Finance and Leasing Co., Ltd.[70].

- In March 2018, Chiba Eco-Energy started the operation of a solar sharing power plant of 625 kW in Chiba city and cultivating garlic[71].

[68] Solar Power Plant Business, March 7, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/030701957/?ST=msbe.
[69] Climate Action, September 7, 2017: http://www.climateactionprogramme.org/news/japan-combines-agriculture-with-solar-power-generation-to-revive-unexploite.
[70] Solar Power Plan Business, March 22, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/032201989/?ST=msbe.
[71] Kankyo Business, April 11, 2018: https://www.kankyo-business.jp/news/020177.php?cat=solar.

- In 2018, three companies including Renewable Japan are developing two mega solar sharing power plants of 5.3 MW totally in Iwate Prefecture, with one of 2.6 MW already completed[72]. Barley will be grown. Renewable Japan received a loan from Tohoku Bank, Tohoku Real Estate and Japan Asia Investment.

- Sosa Mega Solar Sharing Daiichi Power Plant, of 1.2 MW and on abandoned fields, in Sosa City, Chiba Prefecture, was completed in April 2018.

3.1.4. Net-zero Energy House (ZEH)

From the oil crisis in 1973, the final energy consumption in the residential and commercial sectors grew 2.0 and 2.9 times respectively in 2013, while the energy consumption in the industrial sector dropped by 20%. They accounted for about 14% and 20.6% respectively of the total final energy consumption [20]. Because of this reason, and in response to a tightening of the electricity supply-demand balance after the Great East Japan Earthquake and an increase of energy prices, the importance of energy conservation in the residential and commercial (offices, schools, hospitals, hotels, etc.) sectors has grown. In order the country can achieve its GHG emissions target by 2030, it is essential to reduce the emissions from these sectors. Compared to the emissions in 2013, the targets for 2030 were established in 39% fewer emissions for the residential sector and 40% for the commercial sector [21].

Thus, ZEHs and ZEBs are receiving a lot of attention since they can minimize energy consumption, improving the energy supply-demand balance in the residential sector, and operate independently in terms of energy even during a disaster. But also they can increase the self-sufficiency rate of Japan, reduce the imports of fossil fuels and reduce GHG emissions.

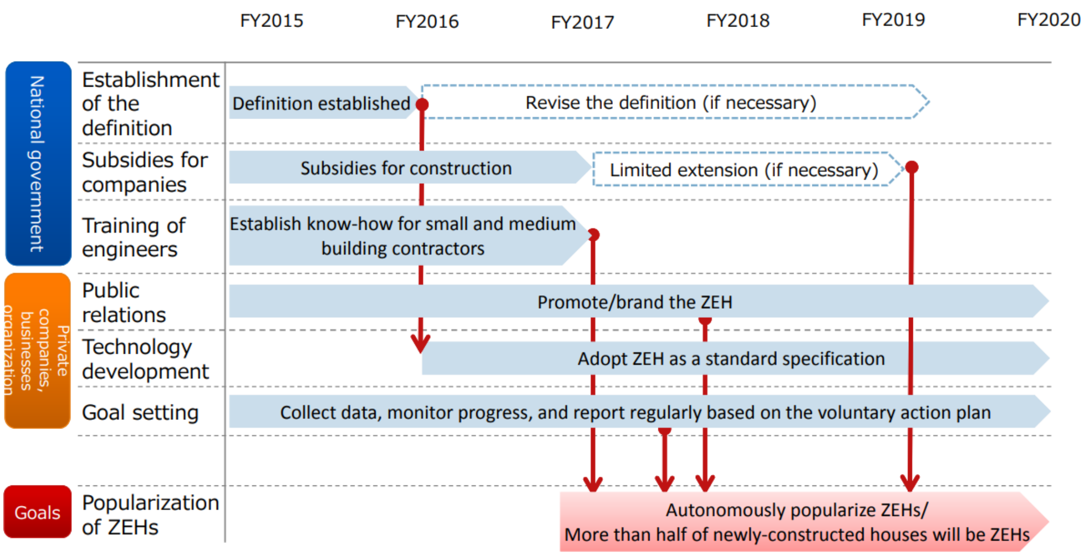
A ZEH is a house that achieves an annual net energy consumption of around zero, or less, by consuming roughly as much energy as it generates through solar panels or other renewable energy sources, after saving as much energy as possible through high heat insulation performance (walls and windows), high-efficiency equipment and high energy efficiency improvements in the house, while maintaining comfortable living environment[73]. Therefore, the cost is higher compared to regular homes, but it will greatly reduce annual utility expenses, and the added value will also increase the resale value of the house.

The Fourth Energy Basic Plan adopted in April 2014 set the targets to achieve zero emission in standard newly constructed houses and public buildings by 2020, and average zero emission in

[72] Kankyo Business, July 19, 2018: https://www.kankyo-business.jp/news/020818.php?utm_source=mail&utm_medium=mail180728_st&utm_campaign=mail.
[73] METI, February 12, 2016: http://www.meti.go.jp/english/policy/energy_environment/energy_efficiency/zeh.html.

newly constructed houses and public and private buildings by 2030[74]. To achieve those goals, the ZEH/ZEB Roadmap Examination Committees were established under the Agency for Natural Resources and Energy, and published the ZEH/ZEB Roadmaps in December 2015 (Figure 20 and Figure 21), which summarized the challenges and measures to achieve these goals, designed guidelines through demonstration projects and established incentives from FY 2016 to FY 2018.

Figure 20: Strategic Road Map for Promoting ZEH



Source: METI [20].

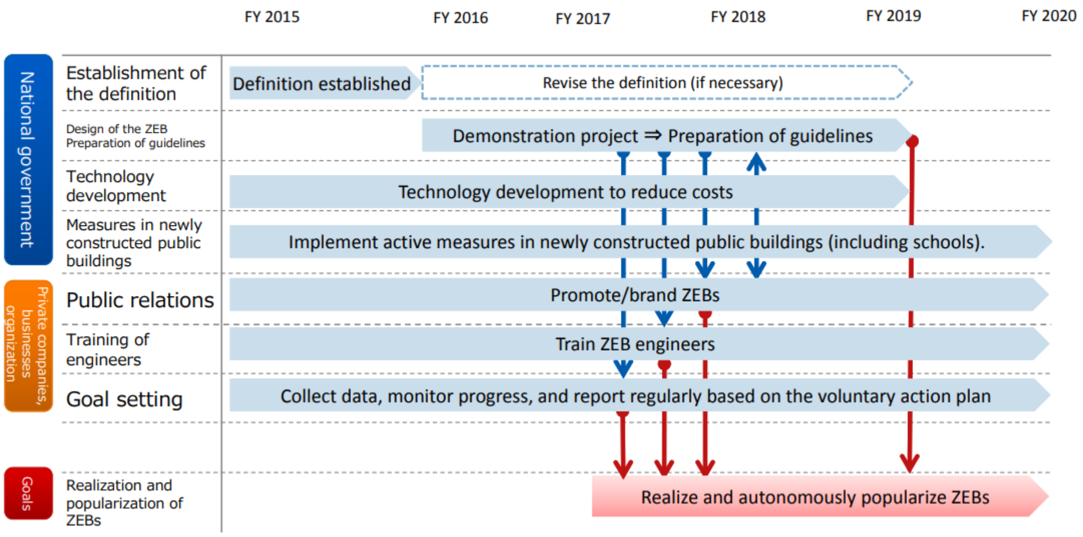
The ZEH directive is promoting a new growth of the PV Japanese residential sector, including not only the solar modules but also storage energy batteries and smart energy management systems, and new products such as solar glass. According to RTS Corporation, residential installations rather than commercial and utility-scale markets are expected to push 2018 PV installations in Japan to as high as 7.5 GW[75].

Installation of HEMS or BEMS is mandatory to automatically control, optimize and save energy. Connecting the electric equipment (PV solar system, storage battery, lighting, air conditioning, water heating, electric vehicle and smart meter), it is possible to know where, how and when the energy is consumed, and thus know how to save it. METI has also launched several incentives to promote the deployment of the Smart House concept in Japan, including subsidies to introduce HEMSs. Therefore, HEMS/BEMS market is expected to grow significantly under the

[74] Agency for Natural Resources and Energy: http://www.enecho.meti.go.jp/category/saving_and_new/saving/zeh/.
[75] PV-Tech, July 25, 2018: https://www.pv-tech.org/news/hanwha-q-cells-touts-solar-module-supplier-leadership-in-japan-for-2017.

ZEH/ZEB, Smart House and VPP projects, from JPY 11.3 billion in 2013 to JPY 30.3 billion in 2020[76].

Figure 21: Strategic Road Map for Promoting ZEB



Source: METI [22].

The design or construction has to be carried out by a registered ZEH Builder, which is a house maker with 50% or more of its business focus on ZEH by 2020 and has to publish that target on its website and try to make it real. As of January 2018, 6,303 companies, mainly house makers and construction shops nationwide, are registering as ZEH Builders.

The high insulation standard, which is the reinforced version of the Energy Saving Standard, was adopted as the ZEH standard and requires energy savings of more than 20% higher than the Energy Saving Standard via better insulation of the building envelope and higher equipment performance. Recently, the government released the ZEH+ (plus) concept, in which the required energy saving is more than 25%. The ZEB standard (ZEB Ready) should be set so that it is at least 50% higher than the Energy Saving Standard, evaluated at the design phase.

In the design phase, it is important to achieve energy savings by upgrading the envelope of the house and especially the building, since it has a long life and is difficult to improve or renovate after completion.

[76] Japan Industry News, May 24, 2016: https://www.japanindustrynews.com/2016/05/smart-house-japanese-technology-standards/.

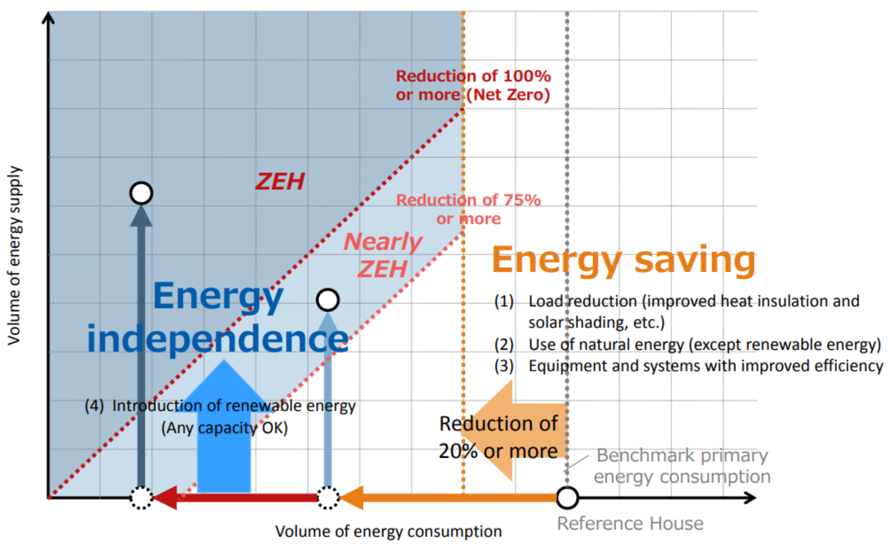
Table 10: Standards for the Average Heat Transmission Coefficient of the Envelope (UA Value – W/m²K)

Region category	Region 1 (Asahikawa, etc.)	Region 2 (Sapporo, etc.)	Region 3 (Morioka, etc.)	Region 4 (Sendai, etc.)	Region 5 (Tsukuba, etc.)	Region 6 (Tokyo, etc.)	Region 7 (Kagoshima, etc.)	Region 8 (Naha, etc.)
ZEH +	0.30	0.30	0.40	0.40	0.40	0.50	0.50	-
ZEH Standard	0.40	0.40	0.50	0.60	0.60	0.60	0.60	-
Energy Saving Standard	0.46	0.46	0.56	0.75	0.87	0.87	0.87	-

Source: Author, with data from METI.

If energy savings of 75% of the net value is achieved, the Nearly ZEH/ZEB status is granted, while if energy savings of 100% or more is achieved, the ZEH/ZEB status is granted. The method to determine 75% or 100% energy savings should follow the Energy Saving Standard and should be applied only to air-conditioning, hot water supply, ventilation, lighting and elevators. Reduction due to renewable energy should not be taken into consideration (Figure 22 and Figure 23).

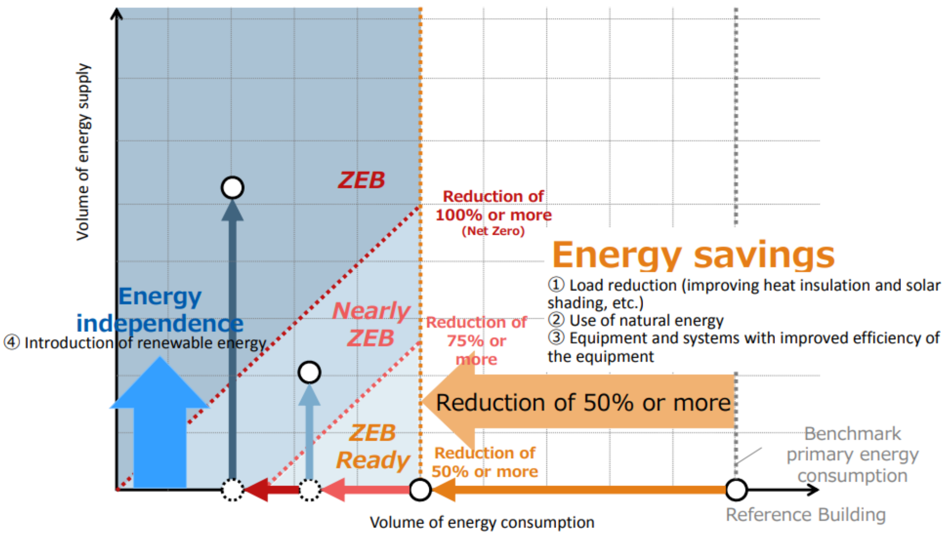
Figure 22: Definition of ZEH



Source: METI [20].

In 2016, and with a total budget of JPY 11 billion, the incentive established was JPY 1,25 million per house (JPY 1,5 million for houses with an average UA value of 0.25 or less in cold regions 1 and 2), without mattering the building size. If an energy storage system was installed, 50,000 yen per kWh were added, with a limit of one-third of the cost or 500,000 yen, whichever was lower.

Figure 23: Definition of ZEB



Source: METI [22].

In the “Global Warming Countermeasure Plan” released by the Cabinet in May 2016, it was established the goal of making more than half of newly constructed detached houses ZEH by 2020. To follow the status of efforts toward the 2020 target, and consider additional measures to realize the 2030 target, the ZEH Road Map Follow-up Committee was established in January 2017. In the “Future Investment Strategy 2017” decided by the Cabinet in June 2017, they aim to have ZEH/ZEB for newly built houses and buildings by 2030. They also set the energy conservation standard conformance rate of newly built houses in 2020 to 100%, and convert the majority of newly-ordered detached houses to ZEH[77].

The standards were extended to multi-family dwelling like condominiums in May 2018, with 1,500 zero-energy apartments scheduled for construction by 2021. Examples of Japanese companies building zero-energy apartments are Nomura Real Estate Development, which plans two or three condos in greater Tokyo, Mitsubishi Estate, which will build a large development outside the capital, and Daikyo, which is building a condo near Osaka[78]. Sekisui House also started the sales of a condominium where all the dwelling units will be ZEH.

The “FY 2017 Zero Energy House (ZEH) Support Project” had a budget of JPY 3 billion. As part of the 2018 ZEH support project, for individuals who build and purchase newly built detached houses or repair existing ones, the Sustainable open Innovation Initiative (SII) issued a new subsidy from August 2018 of 700,000 yen per house, without matter the region

[77] Agency for Natural Resources and Energy: http://www.enecho.meti.go.jp/category/saving_and_new/saving/zeh/.
[78] Asia Nikkei, August 29, 2018: https://asia.nikkei.com/Spotlight/Environment/Zero-energy-condos-spring-up-across-Japan2.

classification or building size. If an energy storage system is installed, 30,000 yen per kWh will be added, with a limit of one-third of the cost or 300,000 yen, whichever is lower[79].

As part of the FY 2018, SII also started a secondary public offering also in August 2018 of projects to support the renovation of existing houses with high energy saving performance (glass, windows, insulation etc.). The "Project cost for carbon dioxide emission control measures etc. (Insulation remodeling support project for houses with high-performance building materials / Insulation Renew)" was granted with a budget of about JPY 80 million for detached houses and around JPY 40 million for apartment housing (individual)[80].

In August 2018, the Ministry of Land, Infrastructure and Transport (MILT) started a second public offering to support housing and building projects that introduce leading technologies related to energy conservation and reduction of CO_2 emissions. The budget of this subsidy is JPY 500 million, covering one half of the cost[81].

MOE is focusing on measures to address climate change and the reduction of CO_2 emissions. In FY 2018, it has a budget of JPY 8.4 billion for supporting the installation of storage batteries in newly built and existing houses where PV systems are installed, encouraging the self-consumption of that solar power generation due to the end of the purchase period of FIT that will emerge from 2019. In June 2018, it also announced ZEH subsidies of 700,000 yen through the Association for Promoting the Creation of Low-carbon Society to promote low-carbonization projects in apartment houses of low (3 floors) and middle classes (4 and 5 floors) and converting them into ZEH. It will supplement a part of additional expenses when a new housing complex is built[82]. In September 2018, MOE announced a demonstration project in which solar shading film and double glazing will be installed on the windows of offices, shops, houses, etc.

This is, there are several subsidies regarding with ZEH/ZEB from three different ministries, showing that there is not a unique coordinated policy in the Japanese government.

In summary, this is a huge market with potential opportunities for European companies, not only for constructors with more experience in stricter building and house requirements regarding insulation, but also for suppliers of materials such as double glazed windows, insulation materials for walls or LED lights, among others. It will also increase the market for residential and commercial PV solar panels, storage batteries and HEMSs/BEMSs. The next

[79] Kankyo Business, August 17, 2018: https://www.kankyo-business.jp/news/020977.php?utm_source=mail&utm_medium=mail180820_d&utm_campaign=mail (only in Japanese).
[80] Kankyo Business, July 17, 2018: https://www.kankyo-business.jp/news/010062.php?utm_source=mail&utm_medium=mail180718_d&utm_campaign=mail (only in Japanese).
[81] Kankyo Business, August 20, 2018: https://www.kankyo-business.jp/news/011341.php?utm_source=mail&utm_medium=mail180821_d&utm_campaign=mail (only in Japanese).
[82] MOE, June 4, 2018: https://www.env.go.jp/press/105558.html (only in Japanese).

two points cover two growing products in Europe more related to the solar market in this house/building sector: hybrid solar panels and building-integrated PV.

Hybrid Solar Panels

A hybrid solar panel or PV-Thermal (PVT) system includes the photovoltaic and solar thermal technologies into a single unit, producing electricity and hot water (or hot air) simultaneously. Conventional PV panel converts to power approximately between 15% to 20% of the solar radiation received, depending on the technology used, losing the remaining energy, mostly in the form of heat. A hybrid panel takes advantage of it, heating water on the back of the panel. This combination provides upwards of 15% more produced power. The thermal part is responsible for keeping the solar panel cooler, closer to its ideal working temperature, improving the efficiency of the PV panel by at least 15%. It also helps to reduce space by 40% and cost compare to both systems separately.

Though this technology is still in an early stage, around 620 and 300 PVT systems were installed in France and Switzerland respectively in 2016, for example, and according to the Dutch Solar Energy Application Centre, about 60 products are available in Europe. Some European companies that already produce and install hybrid panels are the French DualSun[83] and the Spanish ECOMESH[84] and Abora[85]. To support a growing demand of this market in the last few years, mainly linked to the higher demand for net-zero buildings, the Solar Heating and Cooling Programme of the IEA (IEA SHC) launched a global research and communication project called “Task 60: Application of PVT Collectors and New Solutions in HVAC Systems”, that includes 200 experts from 21 countries and five organizations[86].

This hybrid technology has applications in hotels, onsen facilities, nursing homes, residential buildings, sports centers, hospitals and industries, but also in the residential sector. Since it increases the efficiency of the solar and heat installation, it will be covered by the ZEH/ZEB subsidies, becoming a potential market in Japan for the European companies that already have this product.

In Japan, there are no many commercial applications of this technology. NEDO and Nisshinbo Mechatronics Inc. developed a hybrid solar panel model[87] successfully testing during 2017. And Hara Trading Co., Ltd. installed its HTC Hybrid Solar Panel on the roof of several houses,

[83] DualSun: https://dualsun.fr/en/.
[84] ECOMESH: http://ecomesh.es/.
[85] Abora: https://abora-solar.com/productos/panel-solar-hibrido-ah60/.
[86] Solar Heat Europe, April 30, 2018: http://solarheateurope.eu/2018/04/30/increasingly-popular-heat-and-power-from-the-same-roof/.
[87] Solar Power Plant Business, November 28, 2016: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/112800984/?ST=msbe.

storing the hot water in a tank if its temperature reaches 45ºC, and the waste heat through water circulation pipes under the ground[88].

Therefore, European companies, because of their higher experience and number of PVT products already available, have an advantage compare to Japanese firms in this market, which is expected to grow following the ZEH/ZEB boost.

Building-Integrated PV (BIPV)

Building-integrated solar panels cover materials such as windows, cladding systems or roofs. One famous example is the solar roof of Tesla. Due to the increase in new and renovated ZEB, global green building materials market size is expected to reach USD 377 million by 2022 from USD 171 million in 2015, according to Allied Market Research, and solar building materials represent the highest market growth potential among all green building materials [89]. Solar PV glass as cladding material not only allows buildings to generate electricity but also get thermal and sound insulation. Besides, PV glass unlocks the access to clean energy incentives and tax credits that other standard cladding materials cannot get, improving their energy efficiency and reducing their carbon footprint. The Spanish company ONIX Solar is one of the world's leading manufacturers of transparent PV glass for buildings, and it claims that the price, from EUR 100 per sqm, is not more expensive than other conventional alternatives unable to generate electricity[90].

This is an almost new market in Japan, with potential opportunities for foreign companies, especially European and North American, which have already a long way working with these materials. However, there are few examples among big Japanese players:

- In 2011, Mitsubishi Chemical Corp. and Mitsubishi Plastics Inc. launched ALPOLIC ® / Gioa ® combining thin-film solar cells and aluminum resin composite that allows effective photovoltaic generation on vertical walls[91].

- Kaneka provides transparent PV glass, Taiyo See-through solar, produced by Taiyo Kogyo Corporation[92] from several years ago, which can generate clean electric power at the same time that functions as a heat shield. They installed this solar glass in the new Kanazawa bus terminal.

[88] Hara Trading: http://www.harabo.co.jp/solar/construct_eng.pdf.
[89] Allied Market Research, December 2016: https://www.alliedmarketresearch.com/green-buildings-materials-market.
[90] ONIX Solar: https://www.onyxsolar.com/.
[91] Mitsubishi Chemical: https://www.m-chemical.co.jp/news/mpi/201102280240.html.
[92] Taiyo Kogyo Corporation: http://www.taiyokogyo.com/tss/.

- Kyocera provides an integrated solar module with roof material, HEYBAN, reducing the weight compared to tile roof[93].

- Asahi Glass Co., Ltd (AGC) Solar provides Sunjoule, a laminated safety glass building material with embedded solar cells that can be integrated into facades, canopies or sunshades[94].

3.1.5. Solar Roads

The idea of solar roads is not new, it was already introduced on a cycling road in the Netherlands in 2014, on a motorway in France in 2016 and on a highway in China in 2017, though the concept is still on a testing phase. As the technology is not widely used, the components are not mass-produced, so the prices are still very high. Other disadvantages are that they store less energy than those installed at an angle, such as on rooftops, and they get shadows created by cars, nearby trees or buildings and the dirt that covers the pavement. On the other hand, they contain heating elements to prevent snow and ice accumulation, increase the renewable energy generation and reduce environmental impact.

The 1-kilometer-long French road built by Colas SA in Normandy was projected to produce 280 MWh annually, but its cost of EUR 5 million (between 2,000 and 2,500 euros per square meter including monitoring, installation and data collection) was too high, that the energy produced costs 13 times as much as installing rooftop solar panels. Solar panels were covered with a resin containing sheets of silicon to enhance its durability. France's goal is to install 1,000 kilometers of solar roads until 2020, which would provide electricity to around 5 million people[95]. Colas SA has other experimental solar roads and parking lots, mostly in France but also in Canada, the US and Japan.

The kilometer-long Chinese solar road built by Pavenergy teamed up with Qilu Transportation in Jinan, the capital of the northeastern Shandong province, had an installation cost around USD 458 per square meter versus the USD 5 per square meter of an asphalt road. It has three layers: a protective surface made of transparent concrete, PV panels in the middle and an insulation layer below to prevent dampness. It could handle 10 times more pressure than the normal asphalt variety and it will generate 1 GWh annually, used to power street lights and a snow-melting system on the road, and to charging stations for EVs, which will be added in the future.

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[93] Kyocera : https://www.kyocera.co.jp/solar/pvh/prdct/heyban/index.html.
[94] AGC Solar: http://www.agc-solar.com/agc-solar-products.html.
[95] Science Alert, December 23, 2016: https://www.sciencealert.com/the-world-s-first-solar-road-has-opened-in-france.

In Japan, a solar road was installed in a car park of a 7-Eleven store in Sagamihara, Kanagawa Prefecture in May 2018, on a trial basis, generating about 9% of the annual shop's electricity consumption.

The Tokyo metropolitan government plans to introduce solar roads ahead of the 2020 Olympics and Paralympics as part of its efforts to promote Tokyo as an eco-friendly city. The solar road will be made of solar panels with the surface covered with a special resin that makes them durable under the weight of traffic. As part of preparations for the trial introduction of the technology from FY 2019 or later, the Tokyo government also plans to install them on its owned facilities, such as parking lots, where the amount of electricity generated would justify the high cost. It said that there are no restrictions in terms of locations for installing solar roads since they would expand renewable energies in the city, with a target of 30% of power consumption generated by these sources by 2030, compared to around 12% in FY 2016. Tokyo government hopes that this movement will help to spread solar roads across the rest of the country[96].

The other new technology it wants to introduce is the power-generating floor, which uses special ceramics that produce a voltage when pressure is applied, converting the vibration of footsteps into electricity. The company who developed it, Soundpower Corp., claims that the energy of each step can momentarily light up 300 to 400 LEDs, and a 60 kilograms person could generate a current of 2 mW. Although the electricity generated is small, its energy-saving effect would be huge. The Tokyo government is studying the introduction of power-generating floors in hospitals and exhibition facilities.

3.2. THE FIFTH ENERGY BASIC PLAN

The Japanese government updates the energy plan every three years, and it approved the Fifth Basic Energy Plan on July 3, 2018[97]. The Government will keep the same targets for FY 2030 than in the past, describing the nuclear and coal-based thermal power stations as "important baseload power sources" that contributes, in the case of the nuclear generation, to the stability of the long-term energy supply and demand structure. No specific numbers were given for 2050, when it has a very ambitious goal in the fight against global warming.

Thought the energy plan says that the dependence on nuclear power generation will be cut "as much as possible", experts say that accomplishing the nuclear power target will require extending the life of many old reactors and building some new ones[98].

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[96] NDTV, June 10, 2018: https://www.ndtv.com/world-news/japan-solar-road-project-sunrays-hitting-the-road-can-generate-power-tokyo-shows-how-1865129.
[97] METI, July 3, 2018: http://www.meti.go.jp/english/press/2018/0703_002.html.
[98] The Asahi Shimbun, May 18, 2018: http://www.asahi.com/ajw/articles/AJ201805180028.html.

On the other hand, it seems contradictory to argue the use of nuclear energy to help create a decarbonized energy market and continue to promote the use of coal. There were proposals for 50 units and 23.32 GW in Japan since 2012, though 7 units (3.62 GW) were canceled. Therefore, Japan has 43 coal power plants planned all over the country, 8 units (9.9 GW) in trial-operation and 35 units (18.8 GW) under assessment, totaling 19.7 GW (Figure 24). Those 35 new plants would emit 107.920 million tons of CO_2 annually[99]. The main reason is that coal-fired power plants are still a "low-cost" option at present in Japan.

Figure 24: Coal Power Plants Planned in Japan

Source: Japan Coal Plant Tracker.
On operation in red, under construction in orange, in the process of getting the EIA in yellow, planning in black, and stopped operation in green.

However, this trend might reverse since five projects with 7 units (3.62 GW) have been canceled or switched to biomass by June 2018[100]. There are several reasons behind those cancelations. The ratio of renewables continued to increase while energy demand declined due to continuing energy conservation efforts, contributing to reduce the operation hours of fossil fuel power plants. A large part of the nuclear power generated before the Fukushima accident was substituted by energy conservation measures, and society is more aware of the importance of it since then. OCCTO does not expect an increase in the energy demand over the next ten

[99] Japan Coal Plant Tracker: http://sekitan.jp/plant-map/en/v2.
[100] REI, July 23, 2018: https://www.renewable-ei.org/en/activities/column/20180723.html.

years, and the target of the Japanese government is to reduce the electric power demand by 17% and the peak demand by 6% by 2030. Additionally, the government is working on controlling the peak demand through demonstration projects in DR and VPPs, a clean solution much cheaper than coal power plants (Chapter 5).

Coal-fired power plants are likely to face higher costs in order to take environmental countermeasures in the future, while the cost of renewables continues to decrease all over the world, also in Japan. The adoption of the Paris Agreement clearly showed the direction for decarbonization, and coal-fired power generation is the energy source that produces the largest amount of CO_2 emissions. Most of the countries in the world are phasing out the use of coal in power generation as an important step to fight against global warming. More than 20 countries launched the Powering Past Coal Alliance in 2017, that is committed to phasing out coal power by 2030, and utilities in 26 out of 28 EU member states signed an agreement to not build any more coal-fired power plants from 2020 onwards [8].

Many financial and other institutions in the US and Europe ended their investments and loans to coal-fired power projects. Nippon Life Insurance Co., the largest insurer in Japan, will no longer extend loans for or invest in coal power plants at home and overseas due to environmental concerns, except if they include CO_2 capture and storage technology, an expensive option used only in a few locations worldwide. This is the first such move by a major Japanese institutional investor that may influence other ones. Dai-ichi Life Insurance Co. also announced that it will end new coal projects financing overseas.

Japanese banks are among the largest financiers of coal-related projects globally, but that seems to be changing, in addition to tightening lending criteria for coal power in the last months. Sumitomo Mitsui Trust Bank Ltd. would stop providing financing for new coal power plants "as a basic rule", and Mitsubishi UFJ Financial Group Inc. and Mizuho Financial Group would also revise lending to coal-power plants, leaving an open possibility for highly efficient projects[101].

Critical opinions have arrived from both MOE and MOFA against the METI's proposal of making expansive use of coal, keeping an unrealistic target for nuclear power and give insufficient consideration to renewable power. There is a debate about the nation's energy future inside the own government. According to [23], MOE and METI have studied independently future paths towards 2050, with discrepancies in the uncertainties, risks and costs, and with the conclusion that there seem to be not integrated policies.

RTS research firm argues that METI needs to start aligning its aims more effectively with those of other industries that have a say in PV development, including MOE, MAFF and MLIT. It says that the four ministries now need to work together more effectively in pursuit of a common vision, as all of them are now promoting policies that will shape the deployment of solar in the

[101] The Business Times, July 23, 2018: https://www-businesstimes-com-sg.cdn.ampproject.org/c/s/www.businesstimes.com.sg/energy-commodities/japans-nippon-life-to-stop-financing-coal-fired-power?amp.

decades to come[102]. By now, each ministry is working on the utilization of renewable energy in its jurisdiction: the Fifth Strategic Energy Plan by METI, the Fifth Basic Environment Plan by MOE, the Act on Renewable Energy in Agriculture, Forestry and Fishery Villages and the solar sharing (PV systems on farmlands) by MAFF, promotion of ZEB by MLIT and recommendation by MOFA. Mika Ohbayashi, Director of the REI, during her lecture "Renewable Energy in Japan" of June 2018, pointed that a unique coordinated policy is needed for the growing of the renewables in Japan.

Local or regional governments have also their own projects. In addition to the national support measures, some local governments and municipalities are proactively supporting the introduction of PV systems and other renewable energy sources. Some programs require also the installation of storage batteries and HEMSs at the same time than the PV systems. Municipal leaders in Japan released the Nagano Declaration in September 2017, committing to work towards 100% renewable energy for cities and regions across the country[103]. As examples, the Tokyo Metropolitan Government is expanding the local production and consumption of renewable energy, and Yokohama City, in Kanagawa Prefecture, is establishing VPPs.

The current ratio of renewable energy generation was about 15% in 2017 (Figure 13). A 22% target for 12 years from now seems too low. Based on a report by IEA, Japan could easily achieve a 24% renewable energy share in 2022, and raise that ratio to more than 40% by 2030. And JPEA expects a PV solar installed capacity of 100 GW by 2030 and 200 GW by 2050, according to its "JPEA Outlook 2050" report. Besides, JPEA thinks that the national solar PV target of 64 GW by 2030 will be reached around 2020.

In February 2018, the Renewable Energy Institute (REI) issued a recommendation titled "Transitioning Energy Policies for a Decarbonized Society: Redirecting Discussions on the Basic Energy Plan and Long-term Low Emission Development Strategies" [104]. This recommendation shows that policies focused on energy efficiency and renewable energy expansion can have a positive effect not only on decarbonization but also on the Japanese economy and society. Three are the basic policies:

- Achieving 100% renewable electricity by 2050: renewable energy has become the cheapest power source in many countries and areas, and the deployment targets of other countries are set to around 40% by 2030. Therefore, Japan should raise the 22-24% target to attract private local and foreign investments.

- Immediate phase-out of coal-fired power plants: projects to construct 43 new coal-fired power plants have been in progress in Japan after 2011, which make difficult to meet the national target of GHG emissions reduction.

[102] PV Magazine, June 18, 2018: https://www.pv-magazine.com/2018/06/18/japanese-government-must-be-more-unified-in-pursuit-of-pv-goals-report/.
[103] Local Renewables, September 8, 2017: http://local-renewables-conference.org/fileadmin/repository/LR_Nagano/LR2017-Nagano-Declaration-JP-EN.pdf.
[104] REI, February 15, 2018: https://www.renewable-ei.org/en/activities/reports/20180215.html.

- Energy efficiency as the first fuel: energy efficiency and conservation efforts helped Japan with the energy emergency resulted from the Great East Earthquake. But there is a lot of work to do in the transport, industry and building sectors. In the latter, mandatory compliance with energy performance standards has just been started.

On the other hand, the Agency of Natural Resources and Energy, which is part of METI, noted that roughly JPY 2 trillion (around USD 18 billion) a year is already added to household and company electricity bills because of the FIT[105]. That burden, that should not continue to be increased, is one of the main concerns of METI.

3.3. THE FEED-IN TARIFF SCHEME

The events following the Great East Japan Earthquake and nuclear disaster accelerated the promotion of renewable energy sources with the ratification of the Act on Special Measures Concerning the Procurement of Renewable Energy on August 26, 2011, and the released of a new Feed-in Tariff (FIT) scheme in July 2012.

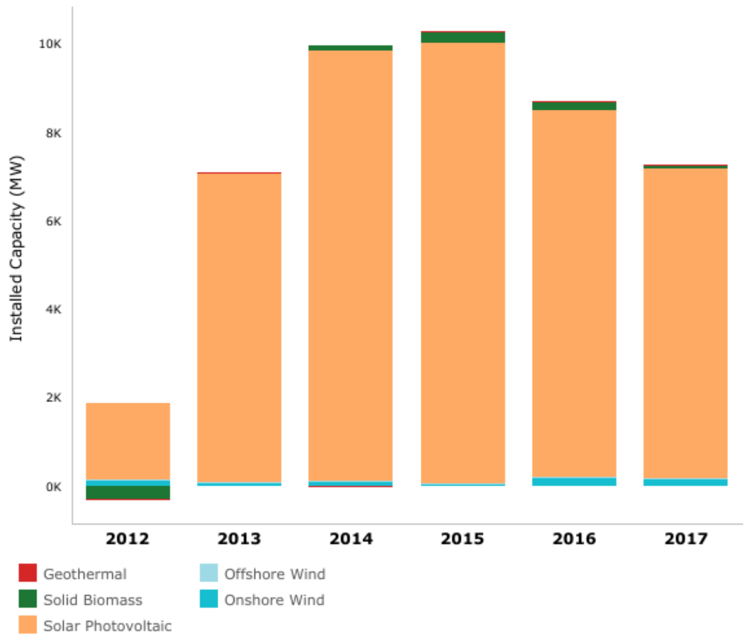
Prior to 2012, the accumulated Japanese PV capacity amounted to 5.6 GW, of which 84% were for residential purposes [15]. This development was largely due to early demand-side policy efforts, such as the Residential PV System Dissemination Program from 1994 to 2005. The market decreased during the following years because of the end of national support. Subsequently, the government launched a new subsidy program in November 2009 for ten years, the New Purchase System for Photovoltaic. Under that FIT scheme, both residential PV systems and non-residential systems up to 500 kW were eligible for purchasing tariffs.

The new FIT scheme introduced in July 2012 changed this dynamic and boosted the non-residential market, accounted for about 75% of the total shipments PV modules until the end of the FY 2017, and about 79% of the total capacity installed in FY 2017 (Figure 25).

Through this scheme, electric power companies are obliged to purchase electricity generated from renewable energy sources at a fixed price on a fixed-period contract, that in the solar PV case, is 10 years for projects under 10 kW, residential systems, and 20 years for projects over 10 kW. Cost for purchasing is paid by electricity users in the form of a nationwide equal surcharge. Electric power companies also pay a part of the cost, equal to their avoided generation costs (Figure 26).

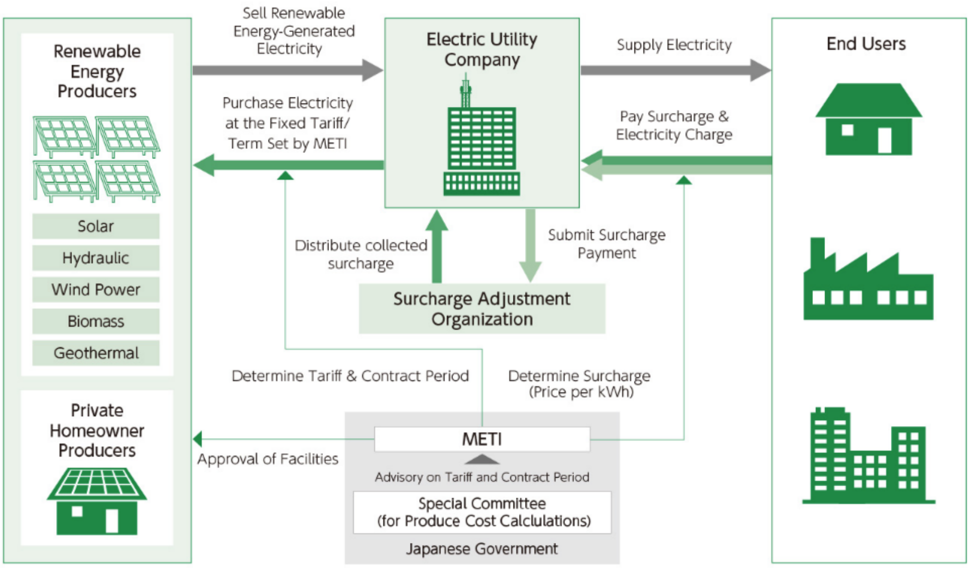
[105] The Asahi Shimbun, May 17, 2018: http://www.asahi.com/ajw/articles/AJ201805170049.html.

Figure 25: Installed Capacity of Renewable Energy in Japan after the New FIT Scheme



Source: IRENA[106].

Figure 26: Basic Mechanism of the FIT System

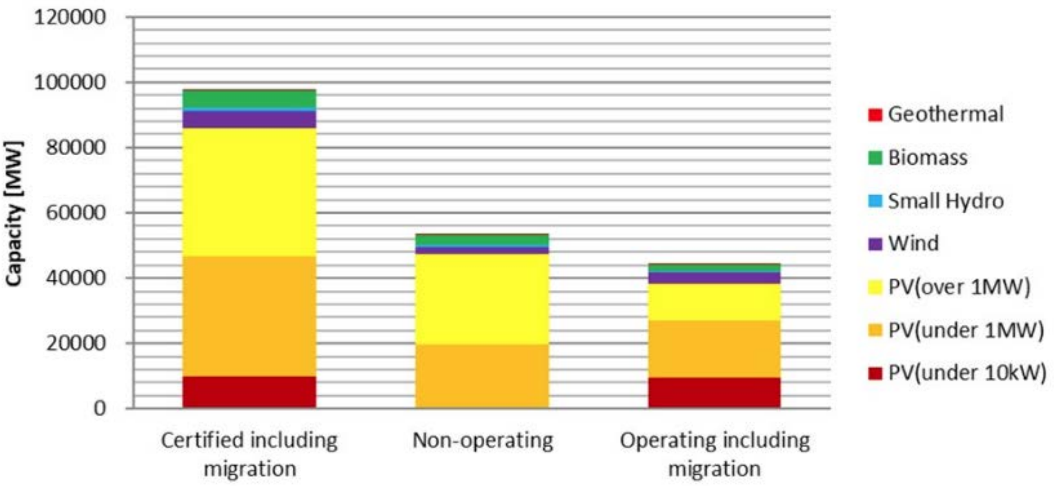


Source: Ichigo Green[107].

[106] IRENA, Solar Energy Data: http://www.irena.org/solar.
[107] Ichigo Green Infrastructure Investment Corporation: https://www.ichigo-green.co.jp/en/operation/purchase.php.

Because a large number of approved projects never moved forward to the operational stage, the FIT scheme was partially amended in April 2017 (enacted in May 2016 and put into force in April 2017). Initially, there were no fixed deadlines for plant operation, so operators could wait indefinitely after obtaining approval, and thereby secure the highest rates of the first years, to take advantage of a cheaper and more efficient technology of the future. Due to this lack of regulation, only about 38 GW of more than 86 GW solar projects approved until March 2017 had started their operation[108] (Figure 27).

Figure 27: Status of FIT in Japan (as of March 2017)



Source: METI, prepared by ISEP.

On the other hand, approved capacity under FIT is greater than off-peak demand in Kyushu, Hokkaido and Tohoku regions (Figure 28).

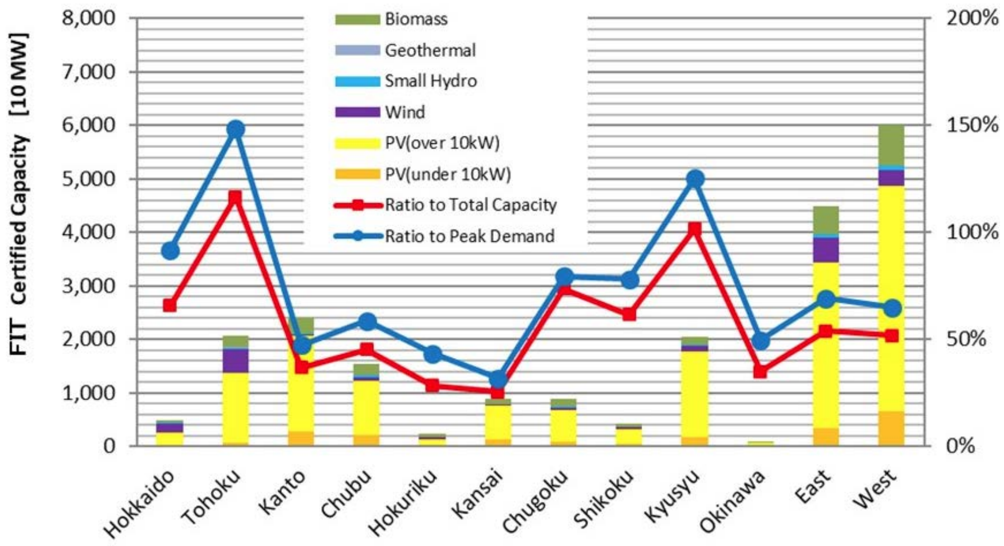
The revised system addresses this issue by only approving business plans that have concluded a grid connection agreement with an electrical utility. Besides, a big number of already approved but non-operating (without a grid connection contracts) solar PV plants, 27.7 GW, were all canceled at once. And according to an estimation of the RTS consulting firm, there is about 30 GW of solar PV capacity approved for development under the old program still waiting to be commissioned[109].

The amendment ensures appropriate project implementation by requiring maintenance and inspection during the project construction and operation, and assures appropriate project decommission and panel disposal at the end of the project lifetime. Solar power projects must also be operational within prescribed time frames once certification has been obtained, three

[108] ISEP: https://www.isep.or.jp/en/statistics.
[109] PV Magazine, February 15, 2018: https://www.pv-magazine.com/2018/02/15/japan-to-install-up-to-7-gw-in-2018-despite-cancellation-of-14-6-gw-of-approved-capacity-report/.

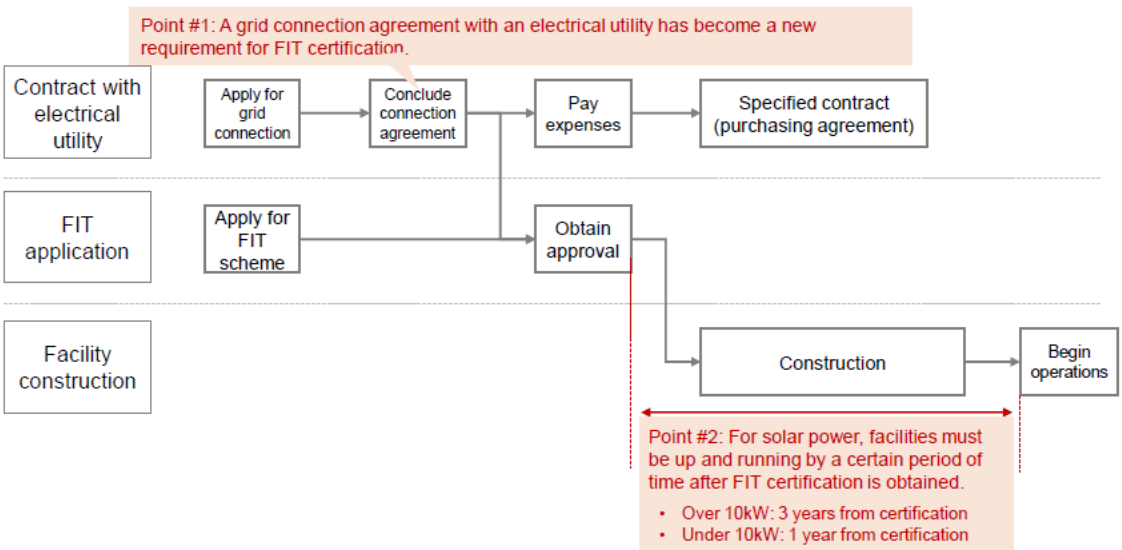
years for facilities over 10 kW and one year for facilities under 10 kW. The amendment enables METI to order improvements to the project or to rescind authorization of offenders (Figure 29).

Figure 28: Status of FIT Certified Capacity in each Utility (as of March 2017)



Source: METI, prepared by ISEP [24].

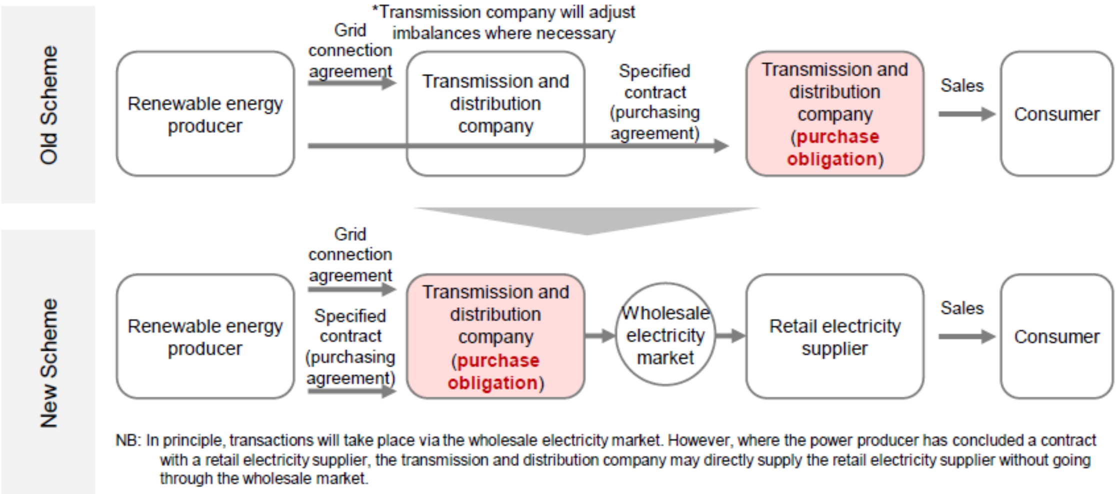
Figure 29: Business Plan Utilizing FIT



Source: Agency for Natural Resources and Energy's report "Preliminary Briefing on the Amended FIT Act (March 2017)", prepared by the Japan External Trade Organization (JETRO) [25].

Besides, retail electricity providers had the obligation to purchase electricity from FIT certified facilities in the old scheme. The revision transferred the obligation to transmission and distribution companies, which are responsible for power system operations and adjusting supply and demand. After purchase, transactions are usually taking place in the wholesale electricity market. However, for contracts established before March 31, 2016, the retail electric utility companies can continue to purchase them (Figure 30).

Figure 30: Contractual Supply of Electricity



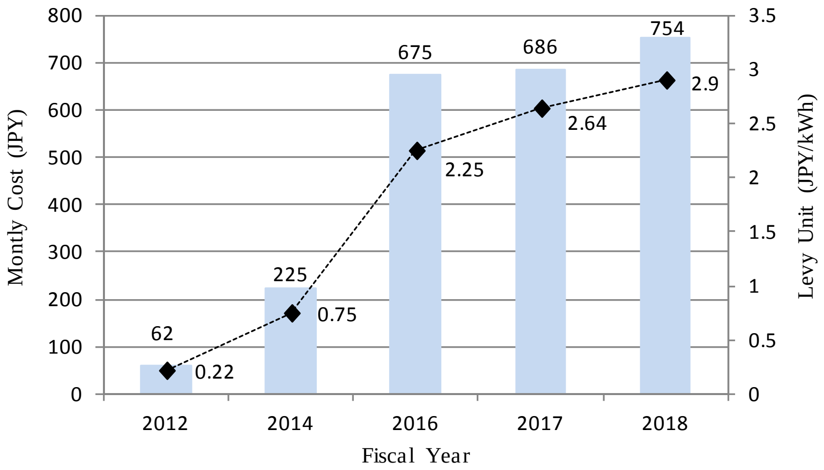
Source: Agency for Natural Resources and Energy's report "Preliminary Briefing on the Amended FIT Act (March 2017)", prepared by JETRO [25].

As in several European countries at a beginning stage, the initial Japanese subsidies for solar PV were too high, even considering the high cost for acquiring land and without considering the underlying costs' increase. The overall cost for renewable grew from about JPY 900 billion in FY 2014 to about JPY 2.7 trillion in FY 2017 [3]. METI expects this to rise to between JPY 3.7 and 4.0 trillion by 2030 with the current ratio for renewable power generation of 22-24%, becoming in its main reason for not increasing that ratio in the next revision of the Energy Plan.

Based on the purchase prices, Figure 31 shows the levy burden to average households (260 kWh of electricity use per month).

Therefore, FIT has been reexamined every year by METI, and because of the growing costs shouldered by consumers, prices were lowered for solar power in the revised law, which had experienced the biggest growth. For offshore wind power, geothermal, hydropower and biomass, prices remained the same to promote their further growth, while they were slightly lowered also for the onshore wind power. Additionally, the government introduced an auction system for solar power plants over 2MW, with the winning bid receiving FIT certification, and the bid's pricing becoming the official purchasing price. Table 11 shows the last revision published in April 2018 for the solar power generation. FIT phase-out will start in 2019.

Figure 31: Levy Burden to Average Households



Source: Author, with data from METI [3].

Table 11: Purchase Price for New Entrants by Fiscal Year (Solar power)

Solar Power supply	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**	**Purchase period**
	Purchase Price (JPY/kWh)				
Residential (less than 10 kW)					
Output control equipment not required	28	26	24	-	10 years
Output control equipment required	30	28	26	-	
Output control equipment not required (doble power generation)	25		24	-	
Output control equipment required (doble power generation)	27		26	-	
Non-Residential (10 kW or more, but less than 2,000 kW)	21 yen + tax	**18 yen + tax**	-	-	20 years
Non-Residential (over 2,000 kW)	Transition to an auction system from FY 2017				

Source: Author, with data from METI[110].
(NOTE: The purchase prices for the rest of the renewable energies are also available in this source).

However, from 2015, the Electricity Power Companies (EPCOs) are allowed to curtail power generation from renewable power plants without compensation, for up to 360 hours a year for

[110] METI, March 23, 2018: http://www.meti.go.jp/press/2017/03/20180323006/20180323006.html (only in Japanese).

PV plants and 720 hours a year for wind plants (under the prior rule, utilities were allowed to curtail on a daily basis and for up to 30 days per year) [26]. This potential risk of losing revenues for investors will be translated to the total cost of the projects, increasing the bid prices instead of reducing them, what is the original intention of the auction system.

The first tender was conducted in October 2017 by METI for a capacity of 500 MW and a ceiling price of 21 JPY/kWh. According to Solarplaza[111], 29 projects with a total capacity of 490 MW were submitted for the examination of tender qualification, of which 23 projects totaling 388 MW were qualified to participate. Only 9 projects totaling 141 MW were selected. The lowest bidding price was 17.2 JPY/kWh, and the highest one was 21 JPY/kWh, which corresponded to the ceiling price. Of all the winning tenders, 5 projects totaling 100 MW were withdrawn, as they did not pay the required deposit after winning the tender. The remaining 4 projects totaling 41 MW were required to obtain approval of their project business plan by the deadline for approval (Table 12).

Table 12: Winning Projects in the First Auction

Company	Installed Capacity (MW)	Bid Price (JPY/kWh)
HINA	7.26	17.20
Canadian Solar Project	15.4	17.97
Royal Lease	5.6	21.00
Shinnippou	12.6	21.00

Source: Author, with data from Solarplaza.

The average volume-weighted price around 20 JPY/kWh is still much higher than in most of the other countries. According to SolarPower Europe [12], in 2016, power supply contracts were awarded for 0.0291 USD/kWh in Chile (about 3.2 JPY/kWh) and 0.0242 USD/kWh in the United Arab Emirates (about 2.7 JPY/kWh). In February 2018, a 300 MW tender in Saudi Arabia was won by the local company ACWA Power at a new world record low price of 0.0234 USD/kWh (about 2.6 JPY/kWh).

Independent Power Producers (IPPs) pointed out the difficulty of finding proper sites and concluding a grid connection contract with utilities before participation, and, with the auction rules, this meant a high risk of losing the secondary deposit (5,000 JPY/kW) in case the connection contract is delayed.

The auction system will slow down the solar market for projects over 2 MW, increasing the interest in projects under 2MW, including the industrial and residential rooftop sector, with

[111] Solarplaza, February 9, 2018: https://www.solarplaza.com/channels/markets/11769/tender-results-and-new-directions-fy-2018/.

higher tariffs. Some developers prefer to concentrate on all the formerly projects in the pipeline, already approved and with FIT over 30 JPY/kWh. Therefore, it seems that, in the short term, the auction's effect on prices will be limited.

METI reviewed the details of the bidding system for the second (500 MW) and third (250 MW) tenders, taking place during 2018. The FIT certification acquisition deadline will be the end of the fiscal year, this is, end of March 2019. If the winning bidder fails to acquire the certification within the deadline, the successful bidder certification will be canceled as before. However, the secondary deposit will not be confiscated immediately and could be used as the deposit of the first bid to be implemented after the certification acquisition deadline expires.

However, in September 2018, the second auction finally opened with only 250 MW, and no bids were submitted below the tariff ceiling of 15.50 JPY/kWh set by the Green Investment Promotion Organization, the government-owned procurement agency, declaring that there were no winners. Only nine companies submitted bids with prices between 16.47 and 20.99 JPY/kWh and for a total capacity of 196.96 MW. METI said that they "cannot ensure competitiveness and there is a risk that (the tender process) will not contribute to cost reductions". For the third solar auction in December 2018, METI will limit the amount of capacity to just 196.96 MW[112].

3.3.1. Secondary Market

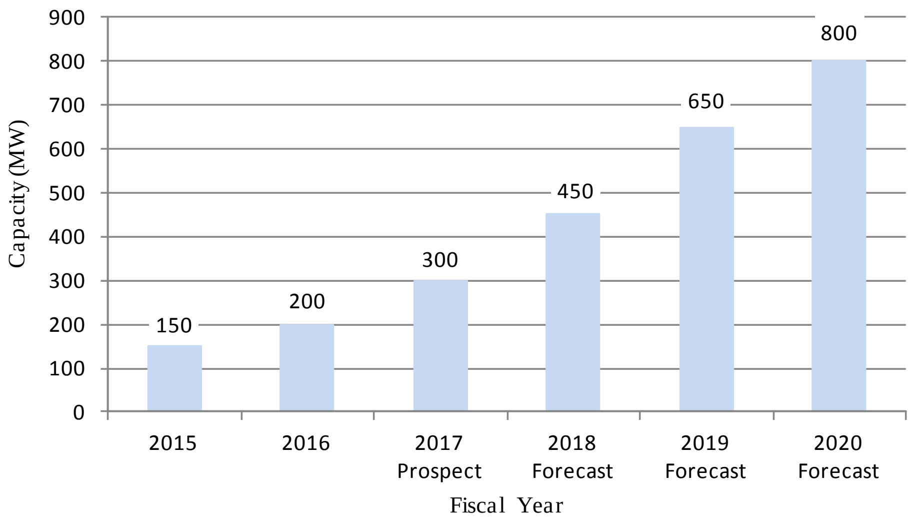
With the increase in the number of stocks of PV power plants, a secondary market of transactions of PV assets and land rights has appeared as a new market. Especially after the revision of the FIT scheme in 2017, when projects that had not concluded a connection agreement with a power company were canceled, many facilities and rights were sold, which led an expansion of the secondary market. Figure 32 shows the size of this market according to Yano Research Institute and based on the power generation output of the operated solar power plant which was traded or planned to be traded[113]. Taking into account the total size of the Japanese solar market, some experts claim that the current size of this secondary market is likely greater since there is a lack of reliable and accurate information.

One of the problems in this market is the lack of a standardized method for asset valuation. JPEA published the "Evaluation Guide for Solar Power Generation Projects" in June 2018 (revised in July 2018) for evaluating the risk related to the continuity of power generation business[114]. Since the new FIT scheme started, it pointed that there have been some solar power businesses running without enough expertise, with inappropriate design, construction, etc.,

[112] PV Magazine, September 14, 2018: https://www.pv-magazine.com/2018/09/14/japan-auctions-197-mw-in-second-pv-tender/.
[113] Kankyo Business: https://www.kankyo-business.jp/event/detail.php?id=332&utm_source=mail&utm_medium=mail180712_d&utm_campaign=mail) (only in Japanese).
[114] JPEA, July 2018: http://www.jpea.gr.jp/topics/hyouka_guide.html (only in Japanese).

putting at risk not only the appropriate operation during the FIT purchasing period but also after it, and the needed reinvestment for the continuous operation. JPEA expects this guideline will be used as a standard manual for future evaluations, spreading the use of solar power as a long-term stable power source, ensuring proper operation and maintenance, and activating the secondary trade (sale and purchase) of solar power plants in stable operation. Japan Association of Independent Appraiser (JAREA) is also developing a valuation methodology of solar facilities, following the professional plant, machinery and equipment valuation methodology and format[115].

Figure 32: Trend and Forecast for the Solar Power Plant Secondary Market



Source: Author, with data from Yano Research Institute.

In addition to those who trade solar power plants, such as power generation companies or IPPs, financial institutions, domestic and overseas institutional investors, intermediation services companies, and legal advisors, for example, are also involved in this market. But also engineering, procurement and construction (EPC) and O&M companies that perform technical evaluations of the solar assets.

Some active companies in this market include Pattern Energy, Pacifico Energy, Canadian Solar, GSSG Solar, Sparx, Renewable Japan Energy Infrastructure Fund, SB Energy, Mitsubishi, Ichigo, Daiwa, Japan Asia Investment and Sonnedix, amongst many others. For small and medium-sized projects, specialized project brokers are more active, according to Solarplaza. Some examples are SOLxSELL, MEGAHATSU, Taiyokokaitori.com (solar purchase) / ComPower Inc., Kurabe-ru (Vital Force Co. Ltd.) and Tainabi Hatsudensho (Tanabi Power

[115] Solarplaza, September 3, 2018: https://solarassetmanagement.asia/news/2018/9/3/current-status-of-japans-secondary-solar-market.

Station), operated by Goodfellows. The latter launched a web service to evaluate the risk of the photovoltaic power plant in four stages.

The following are some examples of transactions in this secondary market during 2018:

- The Japanese solar projects developer Pacifico Energy KK successfully completed its first solar investment fund in January 2018, raising JPY 15.5 billion from local institutional investors[116]. It purchased three solar power plants in Chiba and Miyagi Prefectures, including Pacifico Energy Furukawa solar plant (Osaki City, Miyagi Prefecture, 56.87 MW, in operation from December 2016). Mitsubishi UFJ Morgan Stanley Securities Co. Ltd. served as financial advisor, and Baker McKenzie acted as legal advisor. In July 2018, it completed the acquisitions of two more facilities, Yuza solar plant (Yamagata Prefecture, 23.9 MW, in operation from January 2017) and Yanai solar plant (Yamaguchi Prefecture, 12.3 MW, in operation from July 2017). It announced that its first solar investment fund was completed after that purchase with a totaling about 100 MW, and they are planning a second fund in 2018.

- The US-based Pattern Energy acquired 39 MW of solar assets (Futtsu power plant, with 29 MW, and Kanagi power plants, with 10 MW) from Green Power Investments in February 2018.

- X-Elio sold solar assets in Japan with a total capacity of 187 MW for USD 700 million in 2018, the largest transaction of its kind in the country and one of the largest in the world in 2018. The portfolio, consisting of four operating plants (106 MW) and three under construction expected to start operations at the end of 2018 (81 MW), has been acquired by a consortium of Japanese institutional investors whose name is unknown. Nomura International acted as exclusive financial advisor, while Morrison & Foerster was the legal advisor[117]. X-Elio is a Spanish company of Gestamp and KKR Global Infrastructure Investors II dedicated to the development, construction, operation and maintenance of photovoltaic solar plants and with an international presence.

- Solar Create, a developer of renewable energy, launched a trading intermediary business of PV power plants in April 2018. It sold 35 projects in two months, mediating 53 MW of land and rights transactions for certified projects[118].

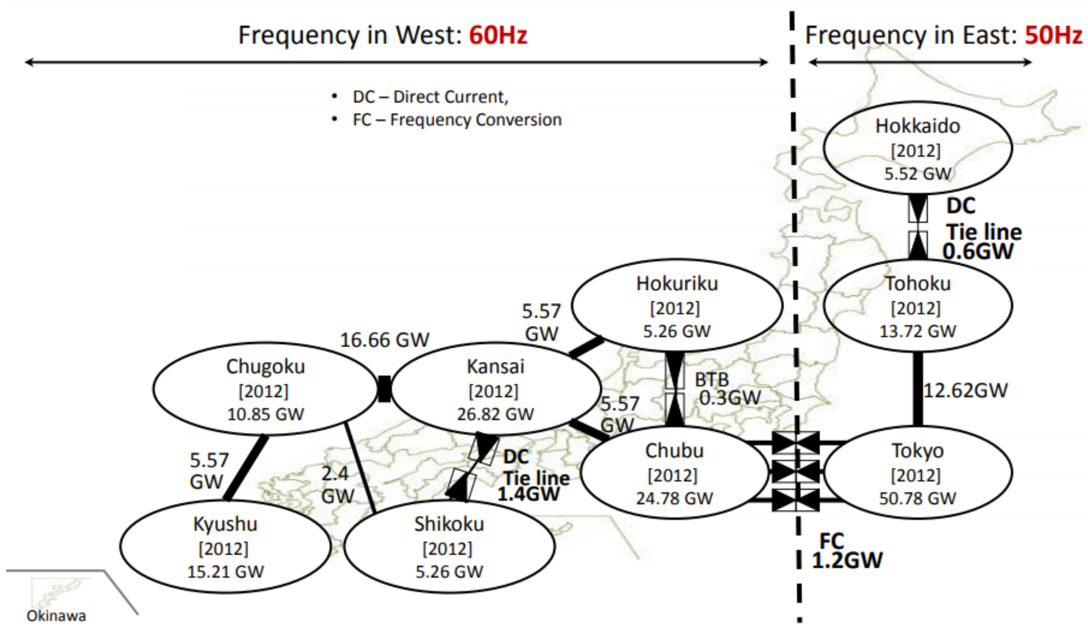
- Fuji Kosan Co., Ltd. purchased the solar sharing plant completed in Zao-machi, Miyagi Prefecture, in June 2018, when it started the power generation[119].

[116] Renewables Now, February 1, 2018: https://renewablesnow.com/news/japans-pacifico-energy-launches-usd-141m-solar-investment-fund-600238/.
[117] X-ELIO: https://x-elio.com/x-elio-sells-seven-of-its-pv-energy-plants-in-japan-for-an-aggregate-enterprise-value-of-c-700mn/.
[118] Kankyo Business, July 17, 2018: https://www.kankyo-business.jp/column/020680.php?utm_source=mail&utm_medium=mail180807_s&utm_campaign=mail (only in Japanese).

3.4. ELECTRICITY MARKET DEREGULATION

The Great Earthquake revealed a big problem in the Japanese electricity market: the impossibility of transmitting electricity beyond regions. It also showed an absence of competition with a strong price control, keeping electricity prices too high, and a limit in handling the change in energy mix including the increase in renewables. Those were the negative aspects of a regional monopoly system, with 10 big and vertically integrated EPCOs, relatively isolated from each other, and two frequencies systems, 50 Hz in the East and 60 Hz in the West, only connected by three converter stations with a total capacity of 1.2 GW (Figure 33).

Figure 33: Electricity Connection Network in Japan



Source: METI [27].

Table 13 shows the name and website of the 10 EPCOs, which established The Federation of Electric Power Companies of Japan (FEPC) in 1952[120].

In contrast, European and North America grids have extensive plans for the use of the High Voltage Direct Current, which offers more flexibility in energy flows from one region to another and easier integration. The development of global energy interconnections has become an important issue since the Paris Agreement in order to promote an efficient and economic use of renewable energy resources and reduce CO_2 emissions.

[119] Solar Power Plant Business, March 7, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/030701957/?ST=msbe.
[120] FEPC: http://www.fepc.or.jp/english/index.html.

Table 13: Electricity Power Companies

Electric Company	**Website**
Hokkaido Electric Power Co., Inc. (HEPCO)	http://www.hepco.co.jp/english/
Tohoku Electric Power Co., Inc.	http://www.tohoku-epco.co.jp/english/index.html
Tokyo Electric Power Company (TEPCO)	http://www.tepco.co.jp/en/index-e.html
CHUBU Electric Power	http://www.chuden.co.jp/english/
Hokuriku Electric Power Company	http://www.rikuden.co.jp/english/
Kansai Electric Power (KEPCO)	http://www.kepco.co.jp/english/
The Chugoku Electric Power Co., Inc.	http://www.energia.co.jp/e/
Shikoku Electric Power Co., Inc.	http://www.yonden.co.jp/english/
Kyushu Electric Power Co., Inc.	http://www.kyuden.co.jp/en_index.html
The Okinawa Electric Power Co., Inc. (OEPC)	https://www.okiden.co.jp/en/

Source: FEPC.

Japan has no interconnection lines to any other closer countries, such as China or South Korea. It is an isolated nation from the electricity point of view, with poor prospects for importing it from neighboring countries. The objective of the Asia Super Grid (ASG) project is to create an interconnecting electric power system for the Asian countries which allows the exchanging of renewable energy resources. REI has worked since 2011 to establish the ASG, conducting research in cooperation with international partners. There is more information in its website[121]. The future construction of this huge transmission lines could be a potential market for foreign companies.

However, this project is still far from becoming a reality. Therefore, Japan needs to ensure a stable electricity supply, establishing an optimal combination of power sources and reinforcing the existing transmission and distribution lines. The capacity of east-west grid connection is planned to be increased to 2.1 GW by FY 2020 [28]. One example is the project to increase interconnection capacity between Hokkaido and Honshu from 600 MW to 900 MW by 2019. The line will help to promote the wind power generation from Hokkaido and ensure a stable supply in that region. Kyushu Electric Power Co., Ltd. is expanding the transmission capacity of renewable energy of the line that connects Kyushu and Chugoku from March 2018, with a budget of JPY 4.25 billion[122].

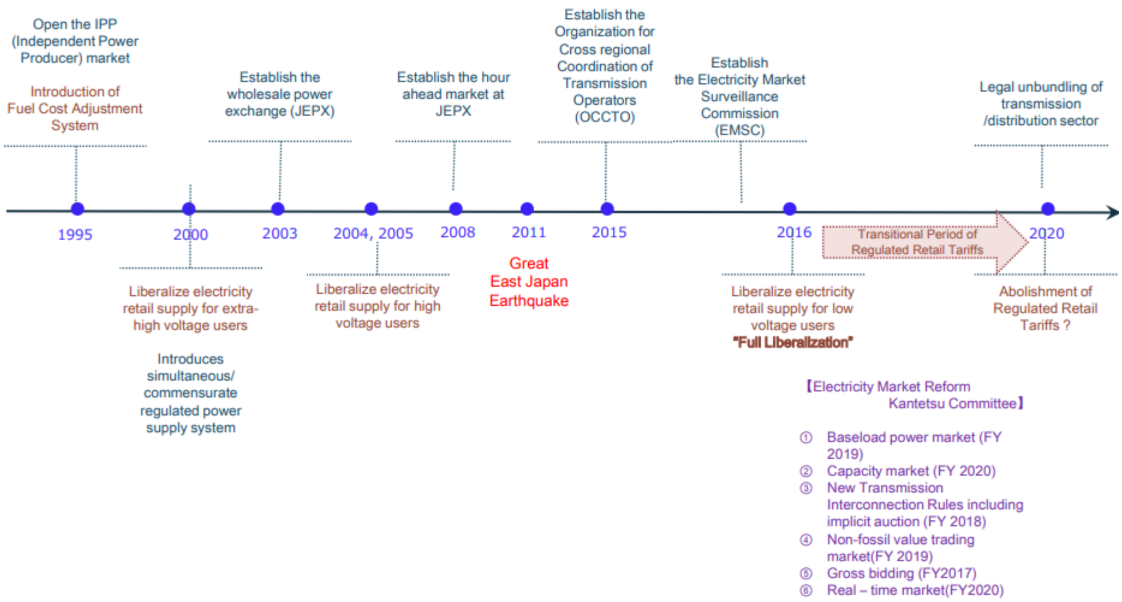
Because of the lack of competition, METI started a series of gradual reforms in the electricity market in 1995, allowing IPPs to participate in the power generation market. In 2000, the retail market was partially liberalized for extra-high voltage customers, over 2,000 kW (large-scale

[121] REI: https://www.renewable-ei.org/en/asg/.
[122] Kankyo Business, March 6, 2018: https://www.kankyo-business.jp/news/016869.php (only in Japanese).

factories, department stores and office buildings), allowing power producers and suppliers (PPSs) to sell them electricity using the transmission and distribution networks of EPCOs (from March 2012, METI change the name PPS to “new power”). After that, the range or retail liberalization was gradually expanded to high voltage users (small and medium-sized buildings and factories) of more than 500 kW in 2004 and of more than 50 kW in 2005[123]. In November 2003, The Japan Electric Power Exchange (JEPX) was established as a market for electric power trading.

However, there was almost no competition across regional boundaries, and the generation and delivery of electricity were generally bundled together by the same EPCO. To deal with this issue and the weaknesses of the Japanese electricity market revealed after the Great Earthquake and already described, the Cabinet approved the Policy on Electricity System Reform in April 2013. It included three objectives: securing a stable supply of electricity by facilitating power interchange between regions, suppressing electricity rates to the maximum extent possible, and expanding choices for consumers and business opportunities[124]. Market liberalization was also emphasized in the Fourth Strategic Energy Plan released in April 2014, promoting open competition in the energy supply industry, and providing consumers with a wider range of choices.

Figure 34: Electricity Market Reform



Source: Tokyo Commodity Exchange (TOCOM) [29].

[123] Agency for Natural Resources and Energy: http://www.enecho.meti.go.jp/en/category/electricity_and_gas/electric/electricity_liberalization/what/.
[124] OCCTO: https://www.occto.or.jp/en/about_occto/about_occto.html.

To achieve these three goals, the electricity system is being reformed in the following 3 steps:

- In April 2015, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) was established. Its main functions are assessing generation adequacy and ensuring that adequate transmission capacity is available, reviewing utility power supply and demand plans, and prescribe the utilities the construction of new transmission lines otherwise. All electricity companies including EPCOs and new retailers are obliged to become a member of OCCTO.

  In September 2015, the Electricity Market Surveillance Commission, as the regulatory authority for electricity under METI, was established to monitor the electricity trading market, ensure the neutrality of the networks and make policy recommendations to the Minister. In 2016, its name was changed to the Electricity and Gas Market Surveillance Commission (EGC) since its authority was expanded to cover also the gas and heat power markets to prepare for the liberalization of these markets.

- In April 2016, the full liberalization of the retail market was completed by expanding it to low voltage users, including households and shops. From that time, everyone was free to choose an electric power supplier and price menu, which also meant the elimination of the geographic boundaries among operators.

  For the 10 EPCOs, regulated tariffs will be maintained until at least the unbundling. Business categories under the Electricity Business Act were also revised into "electricity generation", "electric power transmission and distribution" and "electricity retailers".

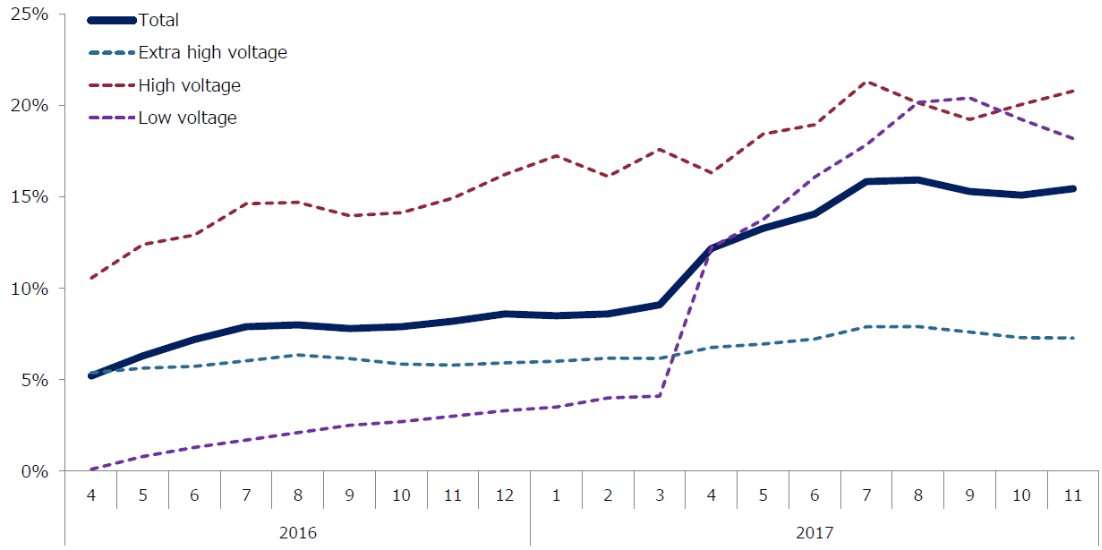
- In April 2020, the legal unbundling of the electricity transmission and distribution operations from the generation and retail segments will be implemented, ensuring the further neutrality of the sector, enabling the fairer use of these networks by new players, and lowering the transmission prices. The retail price regulations will be abolished.

The Japanese government has also started the reform for the gas market, dominated by a few vertically integrated companies, with the same three objectives than the electricity market reform. A full retail market competition was already introduced in 2017, and the separation of the commercial pipeline sector will be legally implemented also in 2020. As a result of the full liberalization of retail sales, a gas market worth about JPY 2.4 trillion, including households, shops, offices, etc., was opened with about 26 million users. Consequently, the worth of the total gas market is about JPY 5 trillion, including the large-lot trade sector, which had already been liberalized, and it is expected a decline in costs due to competition [30].

The real-time market, capacity market and supply and demand adjustment market are also expected to be opened in 2020. Capacity market refers to the market that trades future supply capacity (kW) instead of supply quantity (kWh), to ensure adequate supply capacity throughout Japan over the medium to long-term. Thus the value of the capacity of the power source is recognized, and a fee to business operators who provide it and make it available to various businesses on the market will be paid. The aim is to promote investment and secure economic supply capability, stimulating the wholesale electricity trade and expanding the introduction of naturally fluctuating renewable sources[125].

The positive signs of more competition have been that over 400 companies entered in the retail market after 2016, including foreign companies, stimulating competition with a wide range of price menus and services, and making also new investments in power generation network (Figure 35). Registered retail electricity suppliers comprise a wide variety of business categories, including electric and gas companies, oil companies, trading firms, finance/real estate/developers, telecommunications companies, manufacturers, engineering companies, and energy management companies.

Figure 35: Market share of new entrants



Source: TOCOM [29].

Examples of foreign companies that entered in the electricity generation market were Spark Energy (US), ABB (Switzerland), First Solar (US), Canadian Solar (Canada-China), Gestamp Solar, now X-ELIO (Spain), Solar Power Network (Canada) and GE (US).

Traditional EPCOs are offering power retail business in other EPCO's regions, and they are promoting partnerships between them, between electric and gas utilities, and between energy and non-energy companies. For example, TEPCO and Chubu Electric Power established JERA

[125] Kankyo Business: https://www.kankyo-business.jp/event/detail.php?id=331&utm_source=mail&utm_medium=mail180820_d&utm_campaign=mail (only in Japanese).

Co., Inc., the world's largest energy company for both LNG procurement and thermal power generation.

The number of contracts that changed the supplier of power to new power was 6,433,500 since the full liberalization in April 2016, and until January 31, 2018[126]. METI announced that the number of households (low-pressure) who switched power contracts to new electric power reached about 6.22 million as of the end of March 2018, for the first time exceeding 10% on a case-by-case basis[127].

The almost JPY 8 trillion electricity retail market formerly monopolized by EPCOs has grown to JPY 20 trillion in size after liberalization. In FY 2016, traditional power utilities still had over 90% of the market share, and among the new electricity businesses, Japanese companies dominate sales. It's expected that a higher number of international companies enters into this market.

According to JETRO, the deregulation of the electricity market also brought the growth of the smart meters and smart grids market, since all meter reads for customers utilizing an alternative retailer to be pushed to a common portal every 30 minutes, allowing an almost real-time access to the customer data. Both in front of and behind the meter sectors, including the energy storage, are growing as market forces encourage energy efficiency and demand low prices and reliable electricity.

3.4.1. Non-Fossil Value Trading Market

METI opened a new market in FY 2018 to trade the value of electricity produced from non-fossil energy sources (renewable and nuclear) at JEPX, where the certificates that represent the value of that electricity will be traded. For the electricity traded on the wholesale electric power exchange, it is not distinguished between fossil and non-fossil power source, but this new market will use that certificates to increase the non-fossil power supply ratio.

In order Japan can reduce its GHG emissions by 26% by 2030 compared to its level in 2013, Japanese electricity retailers are required to increase their ratio on non-fossil electricity sources to 44% or more by 2030, as it is said in the Act on the Promotion of Use of Non-Fossil Energy Sources and Effective Utilization of Fossil Energy Materials by Energy Suppliers and in the Act on Promotion of Global Warming Countermeasures. They can purchase certificates on the

[126] Kankyo Business, July 10, 2018: https://www.kankyo-business.jp/news/014338.php?utm_source=mail&utm_medium=mail180711_d&utm_campaign=mail (only in Japanese).
[127] Kankyo Business, June 19, 2018: https://www.kankyo-business.jp/news/013815.php?utm_source=mail&utm_medium=mail180630_st&utm_campaign=mail (only in Japanese).

market to raise their ratio, and the proceeds from the sale of certificates will be used to reduce the burden of consumers levied to the electricity tariff. It is expected to expand the choices of consumers since new retailers can purchase certificates to make renewable electricity products and sell them to consumers. However, consumers cannot choose the types of renewable or the location and other information about the facility.

The first auction held in May 2018 brought to the market a total 53 billion kWh of non-fossil certificates from the power generated under the FIT program from April to December 2017. However, only 0.01% was contracted, this is, 5,155,738 kWh, leaving the most unsold. Most of the traded certificated were contracted at the lowest bid price, 1.30 yen/kWh, being the highest price 4.00 yen/kWh. Therefore, the sales of the auction did not reach JPY 10 million, and the value of the unsold certificates will be distributed to all the consumers [14].

Other four auctions will be implemented between August 2018 and May 2019 for the electricity generated between January and December 2018.

Other environmental attributes from renewable energy projects that can be purchased in the Japanese market are the Green Power Certificates and the renewable J-Credits, which are unbundled from the electricity itself and overseen by the government[128]:

- Green Power Certificate: if an entity introduces a renewable energy power project, along with fulfilling certain criteria, the increase in environmental value can be certificated into a green power certificate. The initial holder can sell it to a third party, but the purchaser cannot resell it. This certificate has encouraged European and American companies to use renewable power but has not been fully utilized in Japan, where it is more expensive and only a voluntary and legally non-binding scheme, and not applicable to renewable sources under the FIT system. Therefore, it is not expected a widespread application of it.

- J-Credit: if an entity reduces its GHG emissions or increases its absorption by introducing energy-saving equipment and forest management, along with fulfilling certain criteria, that can be certified as J-Credit, which can be sold to a third party.

- A local cap and trade program was established in Tokyo metropolitan and Saitama Prefectures, in which entities that reduce GHG emissions can sell that reduced volume in accordance with the system. There is not a nationwide cap and trade program.

[128] Getting The Deal Through, September 18: https://gettingthedealthrough.com/area/99/jurisdiction/36/renewable-energy-japan/.

3.5. OPERATION AND MAINTENANCE (O&M) BUSINESS

O&M are recognized for their important role in ensuring long-term operation and revenues. Once an add-on to EPC contracts, O&M has become an independent business and a critical component of the solar energy value chain. Even more important is in utility-scale plants that are moving from favorable FIT schemes to projects that require long-term maximum outputs by their self. One of the main challenges in O&M is to accurately detect defective panels at an early stage, and take appropriate action for stable operation and maintain feasibility.

O&M load is reduced by remote monitoring systems that can detect anomalies or failures quickly and minimize the power generation loss. Drones with cameras and cleaning machines (robots) are also being incorporated. O&M companies are starting to cover also residential PV systems, with services combining diagnosis, maintenance and damage insurances.

In Japan, with the amended of the FIT Act in April 2017, the operation management and maintenance of each power generation plant was mandated, including those already in operation, increasing inspections and implementing more robust security measures. Projects certified by FIT are obliged to submit periodic reports, including the power generation data, to prove that their plants are operating properly, with the possibility of revocation of certification if they are not, or they do not send the report. And for solar power generation facilities over 50 kW, legal annual inspection by electrical chief engineers are required by that law. This will bring an increased in the O&M business in Japan, and it is expected to advance even further, bringing new investments in the solar market, as it was said in the secondary market chapter (Chapter 3.3.1).

METI said that the FIT is not only an investment opportunity. IPPs are responsible to keep plants stable over the long term, assuring their contribution to increasing the solar generation in the country. Before this amended, developers got a tax break in the first year, and they did not have to worry about the performance of the plant after that.

Maintenance has to meet the technical standards specified by the Electricity Utilities Industry Law. In addition, METI recommends referring to the guidelines prepared by private organizations, such as the “Photovoltaic Power Generation System Maintenance and Inspection Guidelines” published by JPEA in December 2016[129]. Although remote monitoring it is not required to be installed on the basis of the certification criteria, it is considered effective and therefore desirable to install.

In May 2017, Kyushu Electric Power Co. announced a guide for solar power operators to switch to a power console with an output control function. About 20,000 output control systems will be needed only inside the area of Kyushu Electric Power Co., and it is expected a similar trend from other electric companies, even more with an increase in the solar power generation in the

[129] JPEA, December 28, 2016: http://www.jpea.gr.jp/pdf/161228_pv_maintenance.pdf (only in Japanese).

future. From the beginning of 2018, this electric company will cancel the connection of any PV power plant not equipped with PCS with output control function to secure a stable power supply.

In June 2018, JPEA published the “Evaluation Guide for Solar Power Generation Projects" for evaluating the risk related to the continuity of power generation business[130]. Since the new FIT scheme started, it pointed that there have been some solar power businesses running without enough expertise, with inappropriate design, construction, etc., putting at risk not only the appropriate operation during the FIT purchasing period but also after it, and the needed reinvestment for the continuous operation. JPEA expects this guideline will be used as a standard manual for future evaluations, spreading the use of solar power as a long-term stable power source, ensuring proper operation and maintenance, and activating the secondary trade (sale and purchase) of solar power plants in stable operation.

EPC and solar modules manufacturer companies are offering O&M services, such as Suntech Power Japan Corporation, XSOL Co., Ltd., Solar Frontier, Solarig Japan, Juwi Shizen Energy Operation and NEC Networks & System Integration Corp, among others, showing that this is an open market also for foreign companies, with more experience than Japanese ones in this market.

Several tools are available for remote monitoring, such as the one from Meteor Control, NTT Smile Energy, Omron, Panasonic, Kyocera, Delta Electronics, OSTEC, Huawei or TAOKE, among others. The Chinese company TAOKE has been providing its solar power cloud-type remote monitoring system SmartPV in Japan since 2014, reaching the top market with more than 3,000 units sold. The system monitories directly each PCS, making possible to detect any anomaly in real time, respond quickly and minimize the problem and the power generation loss[131].

Two of the largest IPP developers in the power sector, the Japanese Marubeni Corporation and the French ENGIE S.A., signed a Memorandum of Understanding (MoU) in June 2018 for collaboration in the introduction and further development of the digital management platform DARWIN in order to improve the performance of its power generating facilities and develop predictive maintenance[132].

An inspection system that accurately and quickly detects defective panels at an early stage using pulse signals was developed by System JD Co., Ltd. (Fukuoka city), and has been widely introduced to many mega solar power plants in Japan[133].

The use of drones is also becoming a trend among companies involved in the business, since they can reduce the labor costs, especially in mountainous terrains, and in areas where up to two

[130] JPEA, June 29, 2018: http://www.jpea.gr.jp/topics/hyouka_guide.html (only in Japanese).
[131] TAOKE: https://www.smartpv.net/en/index.html.
[132] Marubeni, June 26, 2018: https://www.marubeni.com/en/news/2018/release/00016.html.
[133] Solar Power Plant Business, July 12, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/071202222/?ST=msbe.

meters of snow can accumulate, such as in Hokkaido island. They contribute to the design and development phase, getting important terrain data difficult to obtain otherwise, and they also reduce the cost during the O&M because of their combination of aerial mobility and automatic monitoring. Some recent examples in the world are the following:

- Iberdrola SA, Spain's biggest utility, is using drones with cameras and sensors to reduce costs of green electricity, spotting faulty solar panels and wind-turbine blades way ahead of engineers on the ground. They gather infrared images, detecting power-sapping hot-spots on solar panels and weak areas on turbine blades in need of maintenance. It has invested 500,000 euros in startup drone maker Arborea Intellbird SL, which also started serving other manufacturers like Siemens Gamesa Renewable Energy SA[134].

- The US subsidiary of Enel Green Power partnered with startup Raptor Maps, Inc. to integrate the use of drones, providing immediate data through an artificial intelligence (AI) machine, and reducing fault detection from days to just hours. Currently, drone captured data has to be downloaded and analyzed after flights, which causes a data post-processing bottleneck. This will increase the efficiency and automation of their inspections, yield more accurate results in real-time, and improve O&M across their solar facilities[135].

In Japan, drones are included in the Aviation Law and are defined, alongside unmanned aircrafts, as "an airplane, rotorcraft, glider or airship that cannot accommodate any person on board and can be remotely or automatically piloted", excluding the ones lighter than 200 grams, and are classified in three categories[136].

Sohgo Security Services Co., Ltd. (ALSOK) provides services using drones for solar power plants in Japan since April 2015, prior to other companies. Images are shot by a normal digital camera and an infrared camera, detecting defective areas or panels that are hotter than others. Cost is around 155,000 yen for 2 MW solar plants, about 315,000 yen for a 10 MW plant and around 515,000 yen for a 20 MW plant[137]. FLIR, with drones with infrared thermal cameras[138], and DJI[139] companies are also operating in Japan.

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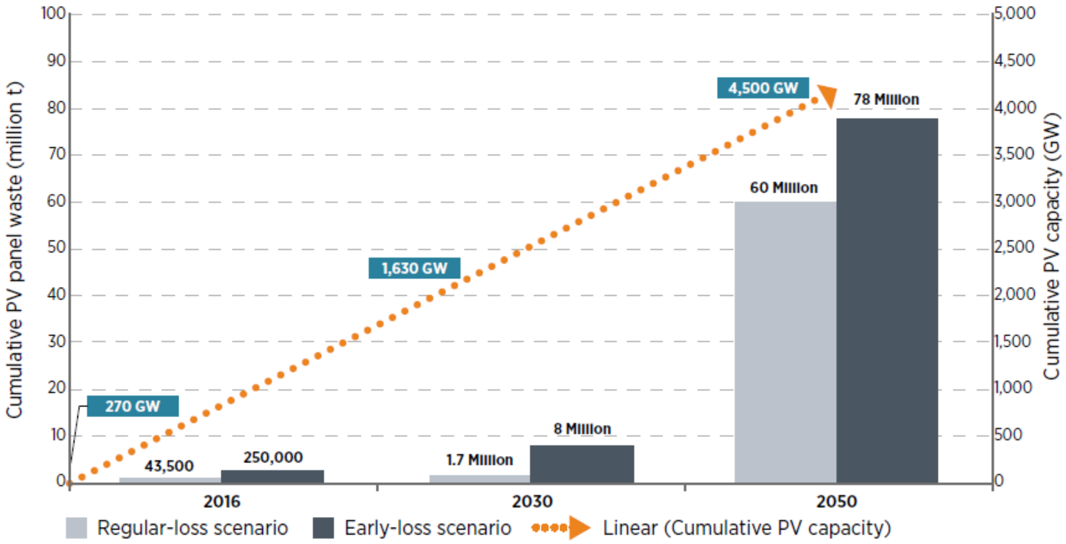
[134] Bloomberg, July 13, 2018: https://www.bloomberg.com/news/articles/2018-07-13/drones-backed-by-iberdrola-helping-slash-the-cost-of-green-power.
[135] PVTech, August 3, 2018: https://www.pv-tech.org/news/enel-green-power-collaborating-with-raptor-maps-to-integrate-drones-and-ai.
[136] Japantimes, January 20, 2018: https://www.japantimes.co.jp/life/2018/01/20/digital/entering-drone-age-japan-seeks-tap-potential-unmanned-flying-vehicles/#.W6C24tIzbIX.
[137] Solar Power Plant Business, July 24, 2017: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/072401473/?ST=msbe?ST=msbe&P=1.
[138] FLIR: http://www.flir.jp/home/
[139] DJI: https://www.dji.com/jp.

3.6. RECYCLING AND REUSE BUSINESS

A report published by IEA Photovoltaic Power Systems (IEA-PVPS) and IRENA in 2016 [32] projected that the waste of PV modules globally will be between 1.7 and 8.0 million tons cumulatively by 2030, and between 60 and 80 million tons cumulatively by 2050 (Figure 36).

Figure 36: Global PV Solar Panel Waste Projections, 2016-2050

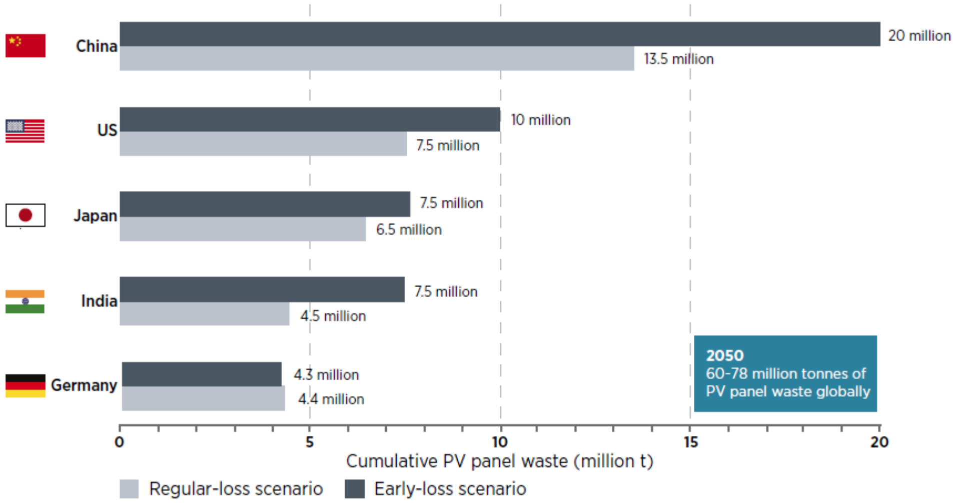


Source: IEA-PVPS-IRENA.

In anticipation of the large volume of PV modules waste, and to retain PV's position as a clean energy technology, PV module recycling has become an important emerging market with great economic and business opportunities. China, Germany and Japan are expected to be the top three countries for solar PV panel waste by 2030, while China, US, Japan, India and Germany will have the highest amount of waste by 2050 (Figure 37).

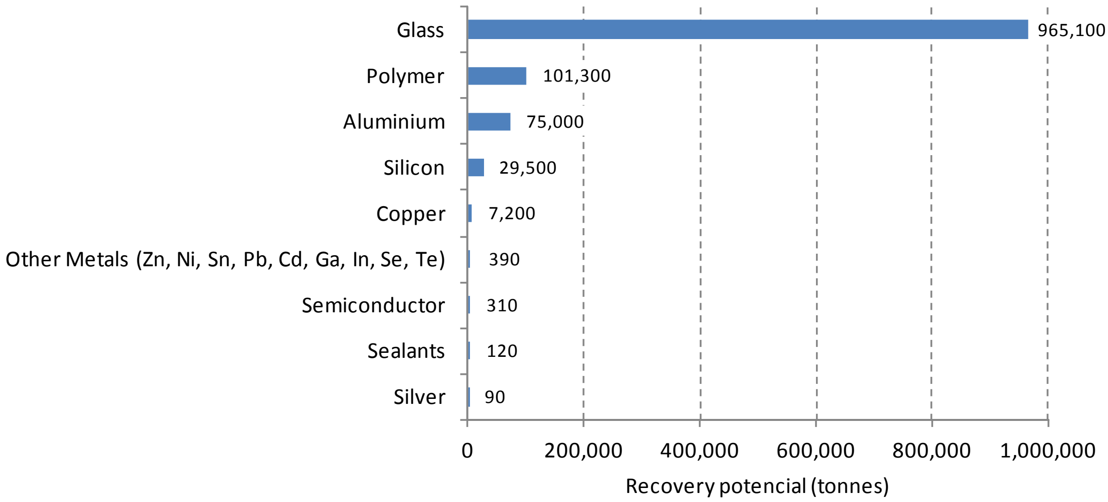
Recycling and recovery raw material are preferable to disposal since it will allow collecting useful resources (aluminum, silver, flat glass, copper, plastics from the cables and junction box and certain semiconductors), which will be purchased by specialists and reused as resources. Since over 80% of the weight of a solar PV panel is glass, the largest mass of recycling material will be glass, about 960,000 tonnes by 2030 (Figure 38). IEA-PVPS and IRENA estimated a total potential value of USD 450 million by 2030 for this market, with enough recovered raw material for producing 60 million of new panels. Those numbers are, respectively, USD 15 billion of value and 2 billion of new panels by 2050.

Figure 37: Cumulative Waste of the Top Five Countries for End-of-life PV Solar Panels in 2050



Source: IEA-PVPS-IRENA.

Figure 38: End-of-life Recovery Potential under IEA-PVPS-IRENA's Regular-loss Scenario to 2030



Source: Author, with data from IEA-PVPS-IRENA.

Only EU has specific regulations for PV modules waste, while most countries around the world classify them as general or industrial waste. In EU, PV module recycling became mandated from 2012 through the Waste Electrical and Electronic Equipment Directive, which also included PV panels waste. It requires 80%/75% (recovery/recycling rate) of waste PV modules by mass to be recycled through 2018, and to 85%/80% thereafter. All producers are required to manage their own take-back and recycling systems or join what is known as producer compliance schemes. In addition, several research and development (R&D) initiatives are being carried out to improve the recycling technologies, reducing costs and increasing the potential revenue streams from the recovered raw materials. This experience could lead European companies to other potential markets such as Japan.

In June 2018, Veolia, a French water and waste group, opened what it is said Europe's first recycling plant for solar panels in southern France, and aims to build more in the future as thousands of tonnes of aging solar panels are set to reach the end of their life in coming years. The plant has a contract with PV CYCLE France to recycle 1,300 tonnes of solar panels in 2018, in theory, all solar panels that will reach their end of life in France in 2018, and is scheduled to increase up to 4,000 tonnes by 2022[140]. PV CYCLE, the non-profit solar industry recycling organization, has a strong partner network, especially in Europe, and has already processed 19,195 tons of PV panels waste since it started its operation in 2010, and 4,153 tons in 2017 alone.

As the installation of PV solar systems has increased throughout Japan, especially after the new FIT scheme, annual disposal amount of solar panels that will reach their end of life after 20-30 years is also increasing annually. MOE forecasts that the country's solar panel waste will exceed 10,000 tons by 2020, reaching 300,000 tons in 2033, when will be the 20th anniversary of the beginning of the new FIT scheme. There will be about 800,000 tons of waste per year between 2034 and 2040. Its projected peak of 810,000 tons is equivalent to 40.5 million of solar panels, meaning that Japan will have to deal with 110,000 solar panels waste as a daily average[141]. According to the two scenarios studied by IEA-PVPS-IRENA, the cumulative amount could reach between 200,000 and one million tons by 2030, and between 6.5 and 7.6 million tons by 2050.

Japan has no specific regulations for the disposal of PV solar waste, which therefore must be treated under the general regulatory framework for industrial waste management: the Waste Management and Public Cleansing Act. Nevertheless, since 2013, MOE and METI have been working on how to handle end-of-life renewable energy equipment, including PV solar panels. They released a report in June 2015 that covered the collection, transportation and recycling. On the basis of that roadmap, a guideline for promoting proper waste's treatment including recycling was published in April 2016, which covered also relevant laws and regulations on decommissioning, transportation, reuse, recycling, and industrial waste disposal. It is expected that those reports will lead soon to specific, mandatory policies for the disposal of wastes related solar products [33].

In December 2017, JPEA published voluntary but recommended guidelines on how to properly dispose of end-of-life solar PV modules[142]. Before that, manufacturers, importers and distributors were called to provide information about the chemical substances of PV modules,

[140] Business Insider, June 25, 2018: https://www.businessinsider.com/r-europes-first-solar-panel-recycling-plant-opens-in-france-2018-6.
[141] Recycling International, December 15, 2016: https://recyclinginternational.com/e-scrap/solar-panel-recycling-push-in-japan/.
[142] JPEA, December 2017: http://www.jpea.gr.jp/topics/171211.html (only in Japanese).

and local governments, waste disposers and industrial waste disposal companies were requested to provide information on how to properly dispose of them.

In May 2018, MOE established the "Working Group Concerning Recycling, Appropriate Disposal, etc of PV Systems". It has been discussing measures for the disposal of PV solar modules and environmental consideration. As results, MOE will introduce a system to promote the reuse, recycle and appropriate disposal of solar panels, and it will consider adding large-scale solar power plants to the objects of environmental impact assessment[143]. It said that it will be done in conjunction with METI to secure a disposal fee collected from power producers in advance, in order a third party can manage the waste.

A criterion that renewable power plants have to meet for receiving the FIT certification includes an installation cost report and an annual operation cost report. In July 2018, METI mandated to add items related to disposal costs inside the last one[144].

The government, NEDO and private companies have been working on the development of low-cost PV recycling technology through several projects such as the following:

- Development of high-level recycling technology of crystalline Si solar cell module by the wet processing (FY 2015-2016) through Toho Kasei Co., Ltd.

- Research and development of PV system low-cost general-purpose recycling processing method (FY 2015-2017) through Shinryo Corporation.

- Development of recycling technology for crystalline Si PV modules - FY 2015-2018 - through Mitsubishi Materials Corporation.

- Development of complete recycling technology of glass and metals by separating with heated cutter (FY 2015-2018) through Hamada Corporation, NPC Incorporated.

- Low cost disassembling technology demonstration of laminated glass PV Modules (FY 2015-2018) through Solar Frontier K.K.

Because of one of those projects, in 2016, NPC Group, a Japanese company specialized in solar panels, developed the hot knife separation technology to efficiently separate the cells of a panel from the glass in around 40 seconds. It acquired three patents related to this recycling process. Together with Hamada Co., an industrial waste disposal company, it established PV Techno Cycle Co., Ltd., a joint venture specialized for reuse and recycling solar panels. It already sells several models of reused solar panels[145]. It set a target of processing between 50,000 and

[143] Solar Power Plant Business, July 6, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/070602216/?ST=msbe.
[144] Kankyo Business, August 1, 2018: https://www.kankyo-business.jp/news/020894.php (only in Japanese).
[145] PVTechnoCycle: https://pvtechno.info/reuse-panel-sales.

100,000 solar panels within three years (80% for recycling and the rest for reusing) and generating JPY 500 million per year.

In June 2018, the Japanese AC Corp. developed a machine for automatically separating glass covers from solar panels during the recycling process, eliminating the need for manual work and reducing the time it takes[146].

PV CYCLE and its partner in Japan, Japan PV Recycling Model Executive Committee (JPV), operates a collective service for small quantities of discarded PV modules, as well as its tailor-made waste management service for larger productions.

The recycling of solar panels is, therefore, a relatively new area in Japan with great growth projections where European companies with experience in this business could find great opportunities. There are also potential opportunities of collaborations in R&D of new technologies, transfer technology and patents.

Due to the heavy rain disaster in the western of Japan in July 2018, JPEA prepared a list of five waste disposal companies capable of proper recycling PV solar modules damaged mainly in Chugoku area[147]. Trina Solar Japan also offered to collect and arrange recycling solar panels manufactured by the company through the Glass Recycling Committee of Japan (GRCJ)[148]. Because of this, and responding to the need of more information about industrial waste intermediate processors across Japan, JPEA created a list of suppliers in August 2018, shown in Table 14, which can be handled by business operators as reference information[149].

Reuse of solar panels

On the other hand, and due to the rapid global PV growth, which is expected to generate a secondary market for repaired PV panels and other components that can be sold as used panels at a reduced price, it is also important to highlight and promote this reuse business because of the economic and environmental benefit. There are internet platforms that support this used solar products market, such as pvXchange[150] and SECONDSOL[151]. After 20 years, a solar panel operates about 80% efficiency, still high enough for less demanding purposes, or even poor countries that want to increase its solar energy generation. For example, Eiki Shoji Co. Ltd., a Japanese PV power producer which has a reuse/repair/recycling business, is installing its reuse solar panel in Myanmar, Indonesia, Nepal, Uganda and Congo.

[146] Solar Power Plant Business, June 12, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/061202159/?ST=msbe.
[147] JPEA, July 18, 2018: http://www.jpea.gr.jp/topics/180717.html (only in Japanese).
[148] Solar Power Plant Business, July 20, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/072002242/?ST=msbe.
[149] JPEA, August 27, 2018: http://www.jpea.gr.jp/pdf/t180827.pdf (only in Japanese).
[150] pvXchange: www.pvXchange.com.
[151] SECONDSOL: https://www.secondsol.com/en/index.htm.

Table 14: Waste PV Solar Modules Processing Companies in Japan

Company	Location	Website
MATEK Corporation (Ishikari branch)	Hokkaido	http://www.matec-inc.co.jp/
Konan Shoji Co., Ltd. (SEINAN)	Aomori prefecture	http://www.seinan-group.co.jp
Kankyo Hozen Service Co., Ltd.	Iwate prefecture	http://www.khs.ne.jp/
Kankyoukaihatsukousya MCM	Miyagi prefecture	http://www.kk-mcm.co.jp
Nippon Keikin Kagaku Co., Ltd.	Fukushima prefecture	http://www.nmcc.co.jp
Mizukaido Industry Co., Ltd.	Ibaraki prefecture	http://www.mitsukaido.net/
Hamada Co., Ltd.	Tokyo city	https://www.kkhamada.com/
Toshiba Environmental Solutions Co., Ltd.	Kanagawa prefecture	http://www.toshiba-tesc.co.jp/index_j.htm
eCONeCOL Inc.	Shizuoka prefecture	http://www.econecol.co.jp/
HARITA METAL Co., Ltd.	Toyama prefecture	http://www.harita.co.jp/
Recycle Tech Japan Co., Ltd.	Nagoya city	http://www.r-t-j.co.jp
Hamada Co., Ltd.	Osaka prefecture	https://www.kkhamada.com/
HIRAKIN Co., Ltd.	Okayama prefecture	http://www.hirakin.co.jp/
SNADA Co., Ltd.	Hiroshima city	http://www.e-sunada.com
Eco Tec Kaneshiro Sangyou Co., Ltd.	Ehime prefecture	http://www.eco-kaneshiro.com
Recicle Tec Co., Ltd. (Shinryo Corporation)	Fukuoka prefecture	https://www.shinryo-gr.com/recycle-tech.html
Kyushu Northern Co., Ltd.	Miyazaki prefecture	http://www.k-hokusei.co.jp
Waste Glass Recycling Business Cooperative Association	Iwate prefecture	http://www.glassrecycle.ne.jp
The Glass Recycling Comittee of Japan	Tokyo city	http://www.grcj.jp
Keiaisha Co., Ltd.	Tokyo city	http://www.keiaisha.co.jp/index.html
PV Techno Cycle Co., Ltd.	Tokyo city	http://www.pvtechno.info

Source: Author, with data from JPEA.

In 2016, Next Energy & Resources Co. Ltd., which works on renewable energy projects and started a reused solar panel business in 2005, announced a limited liability company called R2 Solution with other three companies to reuse and recycle solar panels. They were Ichikawa Kankyo Engineering Co. Ltd., Recycle Tech Japan and Kinki Industrial Co. Ltd, which provide waste treatment/recycling services[152]. It purchases used solar panels and separates then into reusable panels or waste to be recycled.

Next Energy & Resources Co. Ltd. built a PV solar power plant in Komagane city, Nagano Prefecture, in June 2018 using only reuse solar modules of five different types, for a total of 1,202 panels and a capacity of 281 kW[153]. The names of the manufacturers of the used solar panels were not disclosed.

[152] Solar Power Plant Business, March 11, 2016: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/031100437/?ST=msbe.
[153] Solar Power Plant Business, June 8, 2018: https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/060802150/?ST=msbe)

4. ENERGY STORAGE BATTERIES IN JAPAN

The global threat of climate change is currently driving a higher penetration of variable renewable energy, and also the energy transition from a centralized model to a distributed model. With electricity grids dealing with this higher VRE penetration, there is an increased needed for flexibility, and as a consequence, development of renewable projects that include battery storage system is becoming standard. Energy storage increases the overall reliability of the electricity grid and avoids high investments in other infrastructures. It implies a reduction of the total fuel imported for the same thermal power generation and its associated GHG emissions. Electricity storage also supports 100% renewable mini-grids, a transport sector dominated by electric vehicles and 24-hour off-grid solar home systems.

Solar PV plants are dealing with some interconnection issues, such as conditions for the maximum allowed power ramp rates and frequency control, encouraging the integration of storage into the plant. Among the benefits of this combination are the resulting ability to time-shift solar supply into more valuable peak demand periods, help the solar plant to ramp up to meet grid demand, regulate voltage and frequency, increase self-supply consumption, helping in power outages moments, enhance grid stability and increase the economic viability of the overall project. Storage not only becomes a tool to meet system needs but also to reduce system costs.

According to IAE [34], the main use for storage batteries to 2030 will be likely to increase self-consumption (behind-the-meter storage) or avoid peak demand charges in the residential and commercial sectors. Its combined use with renewable generation at the utility scale, and its use for frequency regulation given its rapid response characteristic will be also important.

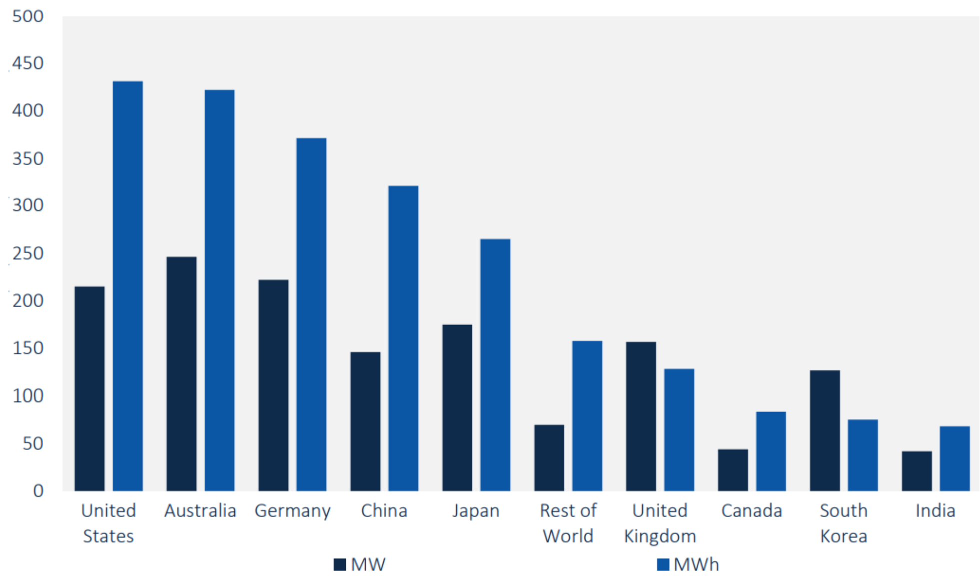
Therefore, policies need to advance in the development and deployment of energy storage technologies as an integral part of the electrical supply, transmission and distribution systems. Because energy storage is at the heart of the acceleration in the renewable energy deployment and the energy transition to a distributed generation and self-consume model, it is seeing a boost compared to what solar PV had several years ago. The technology is mature and with clear and well-mitigated risks. According to BNEF, the arrival of cheap batteries will increase the boom in energy storage projects, which will help wind and solar power produce about 50% of global electricity generation by 2050[154].

GTM Research, in its "Global Energy Storage: 2017 year in review and 2018-222 outlook" report, estimated a globally storage deployment of 1.4 GW and 2.3 GWh in 2017[155], being Australia the leader of the market in terms of power capacity with 246 MW, while the US led

[154] renews, June 19, 2018: http://renews.biz/111521/battery-boom-fuels-re-charge/.
[155] GTM, April 2018: https://www.greentechmedia.com/research/report/global-energy-storage-2017-year-in-review-and-2018-2022-outlook#gs.j3FMMFM.

the world in terms of energy capacity with 431 MWh. It expects that the global Lithium (Li)-ion battery installations over the next five years will grow by 55% annually until reaching 18 GWh in 2022[156].

Figure 39: Energy Storage Deployment in 2017



Source: GTM Research.

Those numbers are slightly different in the 2018 report of the research firm HIS Markit, in which the total utility-side-of-the-meter pipeline of announced battery storage projects globally reached 10.4 GW at the end of the first quarter of 2018, from 7.5 GW at the end of 2017. From this total grid-connected capacity, 40% are solar-plus-storage projects, mostly driven by some very large projects in Australia and the US[157].

However, and unlike GTM Research's 2017 report, IHS identified South Korea, not the US, as the largest national market for energy storage deployments in 2017 (Figure 40), due to new policies for C&I spaces, which established as mandatory the inclusion of energy storage to manage peak grid demand. KEPCO, the main utility and grid operator of South Korea, deployed four projects with 112 MW of energy storage in 2017.

The stationary storage capacity is also emerging in European markets, particularly in Italy and UK, as a way to improve grid stability because of an increase of VRE penetration. Halfway

[156] GTM, August 22, 2018: https://www.greentechmedia.com/articles/read/lithium-ion-storage-installations-could-grow-by-55-percent-annually#gs.6L25jzU.
[157] Energy Storage, April 18, 2018: https://www.energy-storage.news/news/ihs-markit-40-of-energy-storage-pipeline-is-co-located-with-solar-pv#.WtltLU0v78E.twitter.

through 2018, the large-scale battery storage in the UK has reached over 450MW installed capacity, with around 250MW being completed in 2018 alone[158].

Distributed residential (behind-the-meter) battery storage in combination with rooftop solar PV is a major growth market, with installations doubling each year in the last three years. The largest residential storage market in the world in 2017 was Australia with 1.1 GW installed. Because of the high retail electricity rates and the reduction or expiration of FIT, customers are choosing storage solutions to increase the self-consumption benefits. The Australian installed costs decline 80% from 6.40 USD/W in 2010 to 1.40 USD/W in 2017 [13].

Figure 40: Global Energy Storage Installations in 2017 by Country

Source: HIS Markit.

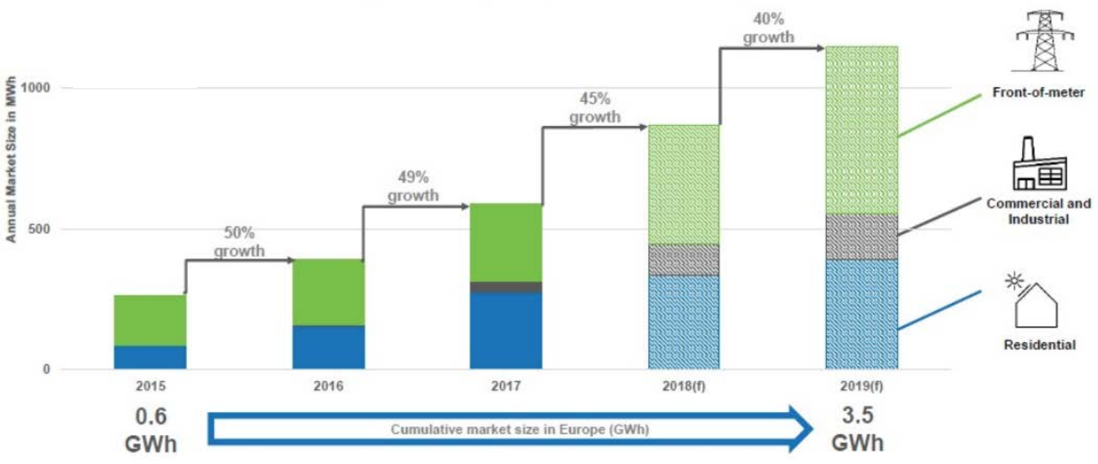
According to the "European Market Monitor on Energy Storage" [159], a six monthly report produced by Delta-EE research firm and the European Association for Storage of Energy (EASE), the overall European market, including behind-the-meter residential and C&I, as well as front-of-meter grid-scale installations, grew by 49% to close to 600 MWh, compared with around 400 MWh in 2016[160] (Figure 41).

The German behind-the-meter storage market is the most developed globally. Germany installed around 280 MW of residential storage capacity in 2017, spread across roughly 85,000 installations, 51% higher than in 2016. During 2018, Germany already reached 100,000 home battery storage installations, with prices fallen by over 50% since 2013[161]. GTM estimates

[158] Energy Storage, July 11, 2018: https://www.energy-storage.news/blogs/the-uks-year-of-large-scale-storage-new-capacity-to-top-500mw-in-2018)
[159] Energy Storage, July 5, 2018: https://www.energy-storage.news/news/behind-the-meter-energy-storage-behind-europes-49-yearly-increase-in-instal.
[160] PVTech, July 10, 2018: https://www.pv-tech.org/news/behind-the-meter-energy-storage-powered-europes-49-yearly-increase-in-insta.
[161] Energy Storage, August 28, 2018: https://www.energy-storage.news/news/germany-reaches-100k-home-battery-storage-installations.

German residential battery market will grow 38% in 2018 reaching 385 MW[162], and it is expected that the country will install about 50,000 PV plus storage systems annually by 2020. The growth during the last few years is due to policy support for distributed battery storage, expiring solar FIT and high electricity prices. C&I and utility-scale battery storage segment will also grow about 81% until a capacity of about 323 MW.

Figure 41: Electrical Energy Storage Capacity Annually Installed in Europe (MWh)



Source: Delta-EE/EASE.

According to a study presented at the German Renewable Energy Federation (BEE) in 2016, the LCOE for PV plus Li-ion battery storage system will be 23% cheaper than electricity grid rates in Germany by 2021. Usage of a cheaper second-life EV battery could cause LCOE level to drop by further 10%, down to 33% under grid rates[163].

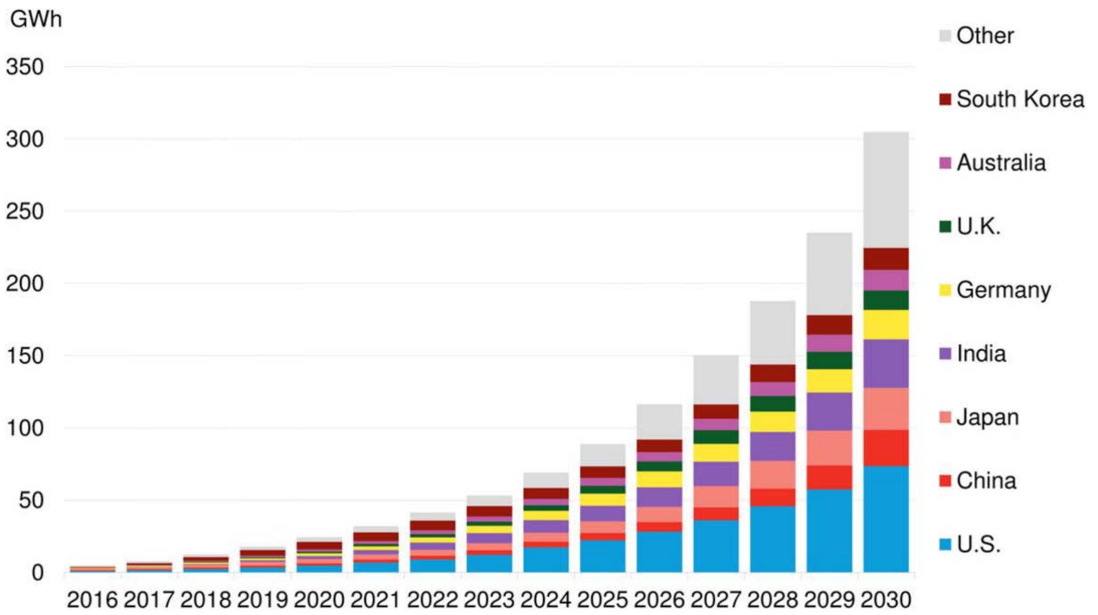
For Navigant Research firm, out of Australia and Germany, the other countries that leaded the behind-the-meter energy storage market in 2017 were the US, Japan and South Korea, with a fast growing also in the UK due to lower FIT rates and the emerging opportunities for distributed systems to be aggregated into VPPs[164]. The UK government closed the FIT scheme to new applicants from April 2018, which led more than 800,000 households to install PV system since it was launched in 2010[165]. Lower FIT rates together with strong solar resources are also increasing the Italian residential storage market.

[162] GTM, April 6, 2018: https://www.greentechmedia.com/articles/read/german-energy-storage-sector-employs-half-number-people-as-lignite#gs.dVPLEfM.
[163] PV Magazine, April 7, 2016: https://www.pv-magazine.com/2016/04/07/study-second-life-ev-batteries-to-offer-1-twh-capacity-by-2030_100024056/.
[164] Energy Storage, July 10, 2017: https://www.energy-storage.news/blogs/understanding-the-energy-storage-world-leaders-anticipating-the-next-big-ma.
[165] The Guardian, July 19, 2018: https://www.theguardian.com/environment/2018/jul/19/subsidies-for-new-household-solar-panels-to-end-next-year.

Major players in Europe are including storage in their offerings, and large energy European companies, such as the Italian Enel, the French Total and ENGIE, and the German Siemens, have taken clear positions for going into the energy storage business. In the US, the top utility-scale solar installers such as First Solar or Florida Power & Light have also become storage developers or are actively pursuing it.

According to GTM forecast, the annual energy storage deployment will reach 8.6 GW and 21.6 GWh by 2022 globally. The US will still lead the market from 2018 to 2022, with a goal of 35 GW deployed by 2025, while China will reach the second position. The market is forecast to exceed the previous four years in 2018 alone because of falling prices and favorable policies[166].

Figure 42: Global Cumulative Storage Deployments



Source: BNEF (New Energy Outlook 2018).

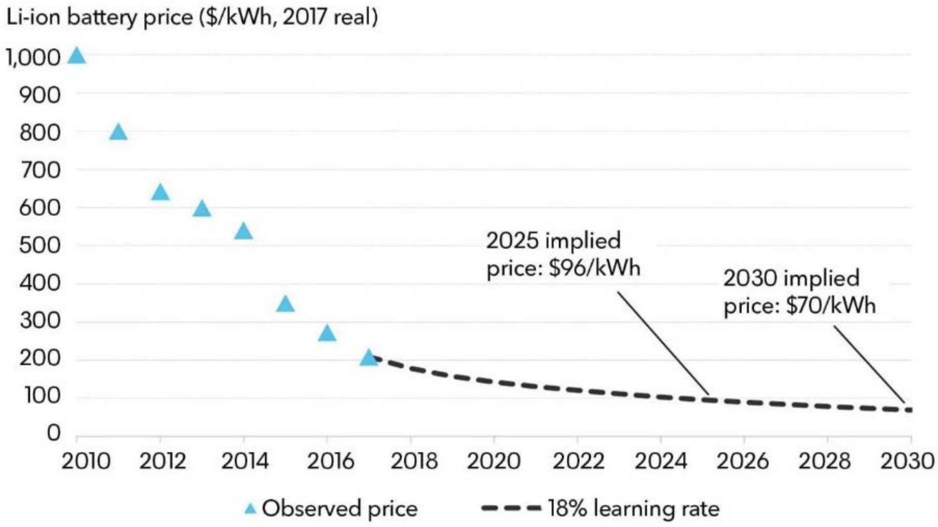
Navigant Research firm's forecast expects that the stationary energy storage market (utility-scale) grows from USD 2.9 billion in 2017 to over USD 23.1 billion by 2026, reaching 29 GW by that year[167]. By 2030, BNEF predicts that the global energy storage market will double six times between 2016 and 2030 to a total of 125 GW/305 GWh. Only eight countries will lead the market (US, China, Japan, India, Germany, UK, Australia and South Korea), with 70% of the total capacity installed[168]. Besides, USD 103 billion will be invested in the battery energy

[166] Forbes, March 15, 2018: https://www.forbes.com/sites/kensilverstein/2018/03/15/energy-storage-markets-forecast-to-double-with-falling-prices-and-favorable-policies/#1c77cc5872eb.
[167] Navigant, Research: https://www.navigantresearch.com/research/navigant-research-leaderboard-lithium-ion-batteries-for-grid-storage.
[168] BNEF, November 20, 2017: https://about.bnef.com/blog/global-storage-market-double-six-times-2030/.

storage market to 2030, and USD 548 billion by 2050, with two-thirds at the grid level and the remainder behind-the-meter[169]. BNEF expects 1,291 GW of new battery capacity added globally to 2050, some 40% of which will be placed behind-the-meter.

Prices are decreasing fast, especially for Li-ion batteries, driven by the massive deployment of EVs, being close to the inflection point where energy prices, generally rising, and battery costs, decreasing, will combine to make the behind-the-meter operation profitable in its own right. According to BNEF, Li-ion battery price fell by 79% between 2010 and 2017, to an average price of 209 USD/kWh. A similar trend is expected for 2018, and it predicts a price under 70 USD/kWh by 2030, though Tesla's target is to produce batteries with a cost under 100 USD/kWh by 2020. Reach this goal would be a great step forward for the expansion of EVs worldwide since it would allow them to have acquisition prices equal to or even lower than their counterparts with combustion engines.

Figure 43: Lithium-ion Battery Price, Historical and Forecast



Source: BNEF (New Energy Outlook 2018).

In 2017, the average cost for wind-plus-storage was 0.021 USD/kWh, and 0.036 USD/kWh for solar-plus-storage[170]. In February 2018, it was announced that Hawaii's utility KIUC will pay 0.1085 USD/kWh during 25 years for a new PPA in which the solar power plant will have 19.3

[169] BNEF, June 19, 2018: https://about.bnef.com/blog/batteries-boom-enables-world-get-half-electricity-wind-solar-2050/.

[170] Forbes, March 15, 2018: https://www.forbes.com/sites/kensilverstein/2018/03/15/energy-storage-markets-forecast-to-double-with-falling-prices-and-favorable-policies/#1c77cc5872eb.

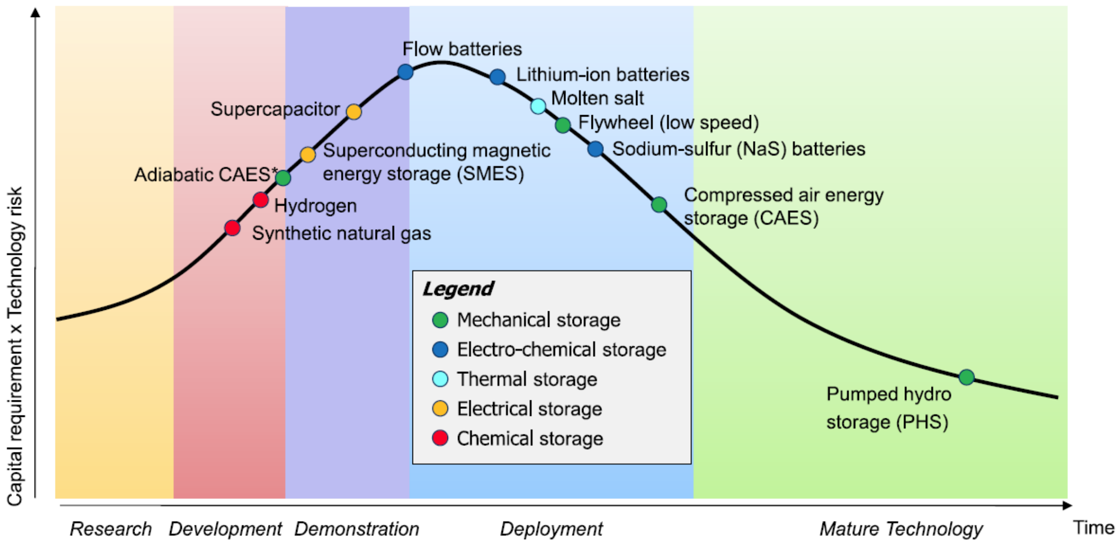
MW with 70 MWh of battery energy storage capacity[171]. This shows that the technology cost keeps its downward trend and is becoming competitive with conventional generation.

Storage Technologies

Regarding with the different storage energy technologies available, it is not the intention of this report include an exhaustive description of each one, but just a brief review through a couple of figures (Figure 44 and Figure 45), focusing on the Li-ion batteries because of the purpose of this document.

Pumped hydro storage is the most widely deployed, mature and large-scale energy storage technology by far, with 96% of the total globally installed storage power capacity. Over three-quarters of global energy storage capacity was installed in only ten countries, with China, Japan and the US accounting for almost half (48%). The other electricity storage technologies already in significant use around the world include thermal storage, with 1.9%, batteries, with 1.1%, and other mechanical storage with 0.9% [34]. Its main disadvantages are the limited number of suitable sites, high initial investment costs, long construction periods and major environmental effects.

Figure 44: Maturity of Energy Storage Technologies



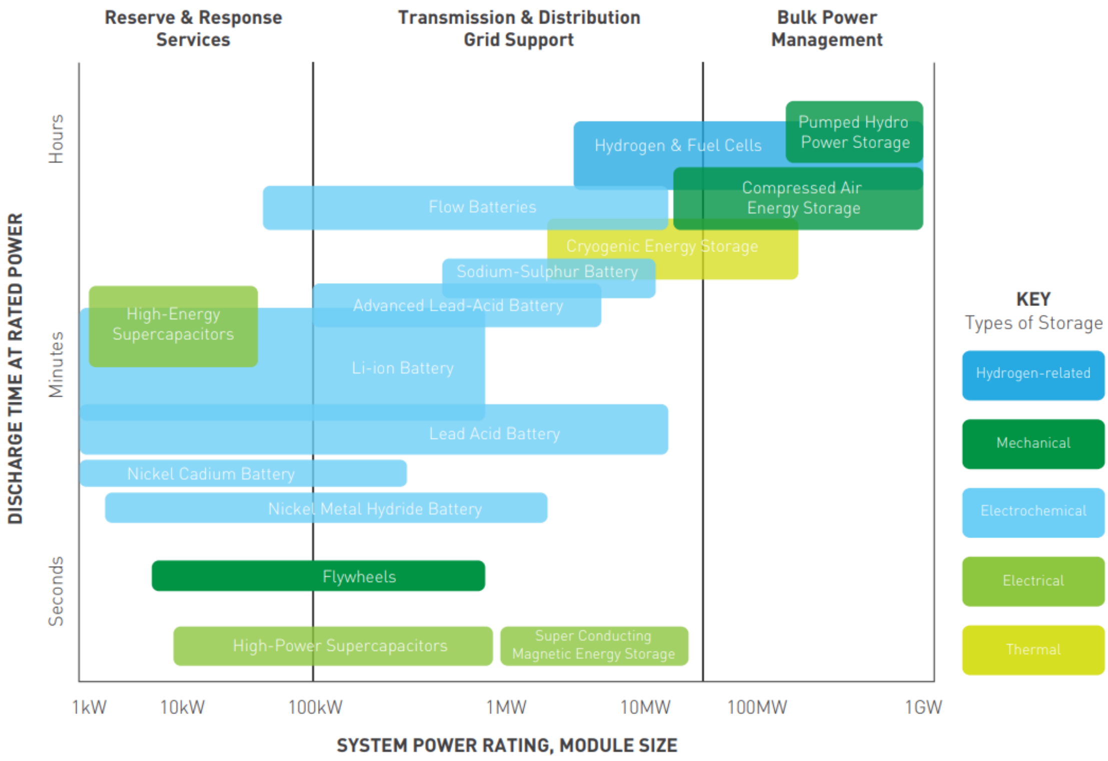
Source: SBC Energy Institute [35].

[171] PVTech, June 27, 2018: https://www.pv-tech.org/news/big-solar-plus-storage-project-will-be-one-of-hawaii-utilitys-lowest-c.

Flywheels energy store is most suitable for short-term applications due to its high self-discharge ratio and high installation cost. It has fast charge capabilities and long cycle life, but low energy density compared with battery systems. Its installation cost could drop by 35% by 2030. The last mechanical storage technology used compressed air (CAES). It is a mature technology, but its main disadvantages are low rate of discharge, low efficiency and a limited growth due to requiring specific geological formations for the reservoir such as caverns and disused mines. Its cost could also decrease by 17% by 2030.

Thermal energy storage application is dominated by concentrated solar plants, being the molten salt technology the standard commercial solution.

Figure 45: Energy Storage System (EES) Technologies by Power Rating and Discharge Times



Source: Centre for Low Carbon Futures [36].

Flow batteries, with vanadium redox and zinc bromine as the main two technologies, have lower energy density than Li-ion batteries, but they work at ambient temperatures, their power and energy storage characteristics are independently scalable and they can rapidly release large amounts of energy. They compensate the high initial cost with a very high lifetime energy throughputs. Their cost could decrease two-thirds by 2030. According to Navigant Research firm, it will be one of the fastest growing electrochemical storage technologies in the next decade since they can be used in a variety of energy storage applications. It is being deployed in recent projects in 2018 by the Canadian Cellcube Energy Storage Systems (vanadium flow battery) and the Australian Redflow (zinc-bromine flow batteries) companies[172]. A 200 MW system with a vanadium-flow battery is being built on the Dalian peninsula in China, which will serve 7 million residents[173].

The lead acid battery is a mature, reliable and tested technology that has been used in off-grid energy systems for decades. Its initial cost is the less compared to other rechargeable battery technologies, though it has a relatively short life, low energy density and high mass, and need more maintenance.

In recent years, deployment of the sodium-sulfur (NaS) storage has increased globally. Its advantages include its relatively high energy density, which is at the low end of Li-ion batteries, but significantly higher than the redox-flow and lead-acid technologies. It also offers the potential for high cycle lifetimes at comparably low costs, and the benefits from using non-toxic materials. The main disadvantage is the relatively high annual operating cost and some safety issues because of high working temperatures that lead to corrosion issues. It is expected an installation cost's reduction up to 75% by 2030.

The vast majority of utility-scale stationary energy storage capacity in 2016 was Li-ion batteries. Other types of batteries, such as redox flow or lead-acid, accounted for an estimated 5% of capacity installed, with all other storage technologies combined accounting for the remaining 5% [34].

Due to a combination of low cost, energy density, high life-cycle, efficiency and discharge speed, Li-ion battery has been the technology leader in stationary storage projects, electric cars' batteries and even consumer electronics, making possible an economy of scale that brought a very competitive market which drove down the prices. And future years will bring lower prices while maximizing longevity and safety.

Li-ion technologies have benefitted from significant investment in recent years due to their versatility that enables them to be deployed in a wide range of energy storage applications, from small-scale batteries for residential use with rooftop PV systems (1-10 kW), to utility-scale batteries for grid ancillary services, ideal for example for frequency regulation and other applications requiring relatively short discharge and high power performance.

However, because of its high cost and some safety issues related to its sensitivity to temperature, several technologies are being explored as alternatives, with Li-air (and other metal-air chemistries) at the head. One of the active electrode materials in this technology is oxygen, which could be drawn from the air, with the advantage in cost, and it would reduce by half the weight of the battery to store the same amount of energy, especially interesting for EVs. Li-air battery shows the highest potential energy and power density, five times higher than the current Li-ion battery used, but its commercialization is not expected in the next years. Softbank and

[172] Energy Storage, Jul 16, 2018: https://www.energy-storage.news/news/redox-flow-energy-storage-deployed-on-both-trial-and-proven-technology-basi.

[173] Metals, April 29, 2018: http://metals.visualcapitalist.com/vanadium-the-energy-storage-metal/.

National Institute for Materials Science (NIMS) started a collaboration research in this technology in April 2018, with the aim of its commercialization around 2025[174].

English company Oxis Energy Ltd received USD 5.2 million to develop a Li-sulfur battery, with a technology and chemistry safe and environmentally friendly, and could pack five times the energy of conventional Li-ion, which means is also lighter. The cells are already being deployed for testing in vehicles[175].

However, it looks that the closer future of the next-generation batteries is on the development of solid-state battery, in which the solid electrolyte is not flammable, unlike the liquid electrolyte used in the conventional Li-ion battery. Therefore, it is safer and easier to manufacture, but it also has fewer components, cost less, fast charging, lighter and provides higher energy than the Li-ion battery. Toyota is working on a fast charging solid-state battery what will commercialize during 2020[176]. BMW partnered with American startup Solid Power to also develop this technology[177]. Solid Power claims that its technology provides from 2 to 3 times higher energy than the current Li-ion battery, and it got USD 20 million in investment from several firms including Hyundai and Samsung in September 2018[178]. Other startups working on the solid-state battery technology are QuantumScape, Ionic Materials and Sakti3.

Main Players

Navigant Research firm established the ten globally leading Li-ion batteries vendors in the stationary storage market in February 2018. The top leader vendors were LG Chem and Samsung SDI (South Korea), and the "contenders" companies were BYD (China), Panasonic (Japan), Kokam (South Korea), Toshiba (Japan), Saft (France) and Leclanché (Switzerland). Finally, in the "challengers" category were Electrovaya (Canada) and the Chinese Contemporary Amperex Technology Limited (CATL).

In 2018, only the Li-ion battery manufacturing capacity is around 131 GWh per year, and it will increase to over 400 GWh per year by 2021 based on plants announced and under construction, with 73% concentrated in China[179]. In 2018, China has 59% global share of batteries production capacity, compared to the 70% share of Japanese companies in the global automotive battery

[174] ITmedia, April 13, 2018: http://www.itmedia.co.jp/smartjapan/articles/1804/13/news041.html (only in Japanese).
[175] OXIS Energy, October 14, 2016: https://oxisenergy.com/oxis-energy-advances-lithium-sulfur-li-s-cell-technology-400whkg/.
[176] Asia Nikkei, October 25, 2017: https://asia.nikkei.com/Business/Toyota-promises-auto-battery-game-changer.
[177] The Drive, December 18, 2017: http://www.thedrive.com/sheetmetal/17050/bmw-partners-with-us-based-company-to-develop-solid-state-batteries-for-evs.
[178] GTM, September 11, 2018: https://www.greentechmedia.com/articles/read/industry-giants-samsung-and-hyundai-invest-in-solid-state-batteries?utm_medium=email&utm_source=Storage&utm_campaign=GTMStorage#gs.HgYB7=A.
[179] BNEF: https://about.bnef.com/electric-vehicle-outlook/.

market in 2013, dominating both manufacturing and technology. During the last months, at least 10 new plants have been announced. Largest Chinese and South Korean suppliers are expanding their production capacity in Europe trying to gain a foothold in the fast-growing European market.

Both Chinese battery makers CATL and BYD have announced plans for increasing their production capacity. They have grown on the back of the country's massive development and deployment of electric vehicles. The Government recently announced higher subsidies for EVs that can travel longer distances on a single charge, especially for those with a range of 400 km and beyond. Both competitors are preparing to present battle to Tesla (and Panasonic) and its 35 GWh Gigafactory 1, which plans to build other macro factories in China, to produce 500,000 vehicles per year[180], and in Europe, where it was in conversation with authorities in the Netherlands and two German states.

CATL, the Chinese largest automotive battery maker, has the target to become a global player during the next years. It already has a production capacity of 17.5 GWh, and its new factory would add another 24 GWh more by 2020, enough to equip 1.2 million zero-emissions cars. CATL already counts automakers Volkswagen, BMW, Renault, Nissan and Hyundai as customers. Besides, it will invest 240 million of euros by 2022 in its first facility in Europe, in Germany, with an annual capacity of 14 GWh, and has signed a long-term partnership with BMW[181].

BYD, the largest manufacturer of electric cars in China, announced in June 2018 the construction of what will presumably become the world's largest battery factory for vehicles next year. The new plant, in the western province of Qinghai, rich in lithium, will have a production capacity of 24 GWh per year in 2019, with plans to close the year with a capacity of 48 GWh per year and reach 60 GWh by 2020[182].

Regarding with the largest South Korean manufacturers, SK Innovation, that supplies batteries to Mercedes-Benz, Kia Motors and Chinese BAIC Motor Corp., will boost its battery production to 10 GWh by 2020[183]. LG Chem will increase its production of lithium-nickel-manganese-cobalt oxide and lithium-manganese oxide batteries in Poland. And Samsung SDI will increase its manufacturing in Hungary[184].

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[180] Asia Nikkei, July 12, 2018: https://asia.nikkei.com/Spotlight/Electric-cars-in-China/Tesla-Shanghai-factory-to-drive-China-s-electric-car-dominance.
[181] PV Magazine, July 12, 2018: https://www.pv-magazine.com/2018/07/10/chinas-catl-to-invest-e240-million-in-europes-first-battery-cell-fab/.
[182] Bloomberg, June 27, 2018: https://www.bloomberg.com/news/articles/2018-06-27/byd-builds-massive-car-battery-plant-to-boost-capacity-fourfold.
[183] Reuters, August 31, 2017: https://www.reuters.com/article/southkorea-skinnovation-battery/s-koreas-sk-innovation-starts-production-of-batteries-with-more-nickel-idUSL4N1LH25Y.
[184] GTM, August 6, 2018: https://www.greentechmedia.com/articles/read/battery-manufacturers-fight-for-a-foothold-in-europe?utm_source=Storage&utm_medium=email&utm_campaign=GTMStorage#gs.Eun3eeg.

The Germany Accumotive, the Daimler subsidiary, will increase its annual Li-ion battery production from 80,000 to around 320,000 units through an investment of USD 550 million. The Swedish Northvolt will install a facility in Sweden with an initial production capacity of 8 GWh per year. The Thai company And Energy Absolute will increase its capacity from 1 GWh to 50 GWh per year by 2020 through an investment of USD 2.9 billion. A consortium including Boston Energy and Innovation (BEI), Charge CCCV, C&D Assembly, Primet Precision Materials and Magnis Resources will build a 15 GWh per year facility in New York, and probably another similar one in Australia[185].

PEVE, a joint venture between Toyota and Panasonic, it is scaling up Li-ion battery pack manufacturing in Japan with four new facilities in Miyagi Prefecture and a total capacity of about 800,000 batteries per year. While the first plant is currently under construction, the construction of the other three is expected to start in 2020 and 2021. PEVE also manufactures nickel-metal hybrid (NiMH) battery packs in Miyagi, with three facilities opened between 2010 and 2015 and a total annual capacity of 500,000 batteries[186]. Panasonic already supplies battery cells for Toyota hybrids vehicles, but the automaker will need a larger supply because of its intention to produce also EVs in a near future. Toyota will also build a new plant for electric vehicles in Guangzhou, China, to produce about 200,000 vehicles per year in the country because of the stricter environmental regulations in that country[187].

In the stationary storage market there are also non-lithium-ion batteries providers including sodium sulfur (NaS) batteries, widely deployed around the world, flow batteries, advanced lead-acid batteries, and zinc-based batteries. The top leader vendors for Navigant Research in this category in its report of September 2017 were ViZn Energy (US – flow battery) and Sumitomo Electric (Japan - redox flow battery). The "contenders" companies were Gildemeister Energy Storage* (Germany – redox flow battery), UniEnergy (US – vanadium flow battery), Eos Energy Storage (US - zinc-based battery), Fluidic Energy (US – zinc-air battery), Vionx Energy Inc. (US – vanadium redox flow battery), Primus Power (US – zinc-bromide battery), NGK Insulators (Japan - NaS battery) and FIAMM (Italy – lead-acid battery). Finally, in the "challengers" category were redT (UK – vanadium redox flow battery), Ecoult (Australia – lead-acid battery) and Redflow (Australia - zinc-bromine flow battery)[188].

** The German company's vanadium flow battery assets were acquired by Canada's Stina Resources Group. After that, the company changed its name to Cellcube Energy Storage System[189].*

[185] GTM, June 29, 2017: https://www.greentechmedia.com/articles/read/10-battery-gigafactories-are-now-in-progress-and-musk-may-add-4-more#gs.vA8YAGk.
[186] PV Magazine, July 25, 2018: https://www.pv-magazine.com/2018/07/25/japan-large-scale-battery-project-plans-auction-update/.
[187] Asia Nikkei, August 26, 2018: https://asia.nikkei.com/Business/Companies/Toyota-to-build-China-plant-for-electrics.
[188] Navigant Research, 2017: https://www.navigantresearch.com/research/navigant-research-leaderboard-non-lithium-ion-batteries-for-grid-storage.
[189] Energy Storage, July 16, 2018: https://www.energy-storage.news/news/redox-flow-energy-storage-deployed-on-both-trial-and-proven-technology-basi.

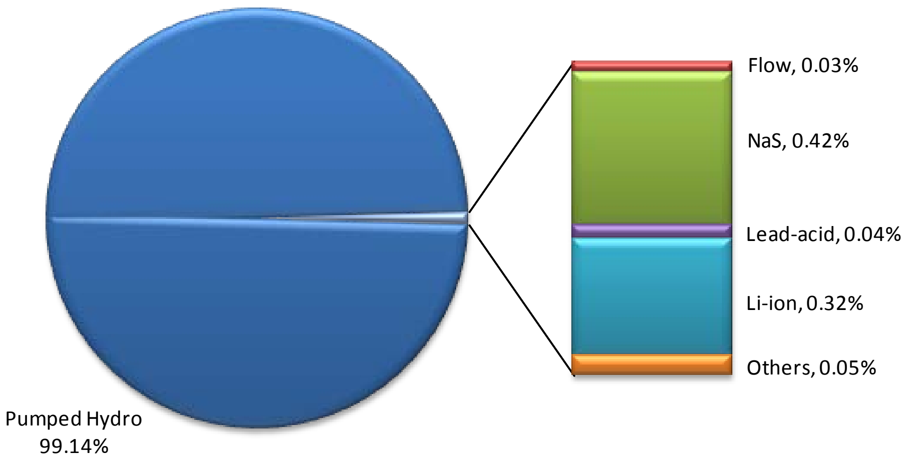
The American Johnson Controls will also add 13.5 units to its current production capacity of 16 million of lead-acid batteries through new plants in China and an investment of USD 250 million[190].

Finally, in the residential sector, the most popular residential energy storage batteries are provided by Tesla (US), Sonnen (Germany) and LG Chem (South Korea). Other main suppliers are the Japanese Panasonic and Sharp, the Chinese BYD, the English Powervault and Moixa or the US Sunverge, among others. Automakers such as Nissan, Mercedes-Benz and BMW also started to offer solutions in this market.

4.1. CURRENT STATUS IN JAPAN

As it was said before, only China, Japan and the US have almost half of the global pumped hydro storage capacity. According to DOE Global Energy Storage Database, more of 99% of the total storage capacity in Japan is pumped hydro, though the batteries deployment is growing rapidly. There are 42 pumped hydro storage operational projects in Japan, and another 43 electro-chemical storage projects. Of the last category, 17 projects are based on Li-ion batteries, 12 in NaS batteries, 7 in lead-acid batteries and 5 in vanadium-redox flow batteries[191] (Figure 46). Since the market is growing fast, probably this database is not updated. Table 15 shows the largest hydroelectric power plants in Japan.

Figure 46: Japanese Energy Storage Capacity by Technology



Source: DOE Global Energy Storage Database.

[190] GTM, June 29, 2017: https://www.greentechmedia.com/articles/read/10-battery-gigafactories-are-now-in-progress-and-musk-may-add-4-more#gs.vA8YAGk.
[191] DOE Global Energy Storage Database: http://www.energystorageexchange.org/.

Table 15: Largest Hydroelectric Power Plants in Japan (400 MW or larger)

Name of Plant	Company	Installed Capacity (MW)
Okutataragi	Kansai Electric Power	1,932
Okumino	Chubu Electric Power	1,500
Shin Takasegawa	TEPCO	1,280
Okawachi	Kansai Electric Power	1,280
Okuyoshino	Kansai Electric Power	1,206
Tamahara	TEPCO	1,200
Kazunogawa	TEPCO	1,200
Matanogawa	Chugoku Electric Power	1,200
Omarugawa	Kyusyu Electric Power	1,200
Shin Toyone	J-Power	1,125
Imaichi	TEPCO	1,050
Shimogo	J-Power	1,000
Okukiyotsu	J-Power	1,000
Kannagawa	TEPCO	940
Shiobara	TEPCO	900
Okuyahagi Daini	Chubu Electric Power	780
Numappara	J-Power	675
Azumi	TEPCO	623
Nabara	Chugoku Electric Power	620
Hongawa	Shikoku Electric Power	615
Tenzan	Kyusyu Electric Power	600
Okukiyotsu Daini	J-Power	600
Okutadami	J-Power	560
Ohira	Kyusyu Electric Power	500
Kisenyama	Kansai Electric Power	466
Daini Numazawa	Tohoku Electric Power	460
Tagokura	J-Power	400

Source: FEPC[192].

Japan was an early leader in the deployment of both solar power generation and storage energy batteries due to the government policies and programs. In the 1970s, it launched some projects such as the "New Sunshine Project" to promote new energy technologies and to research in energy saving and energy efficiency. Storage became a crucial technology to ensure

[192] FEPC, as of March 1, 2015: http://www.fepc.or.jp/english/energy_electricity/location/hydroelectric/.

uninterrupted power supply, and government funds were towards research into lead acid, NaS and flow batteries. The government kept releasing new projects in the 2000s.

Therefore, Japan became the world leader in the deployment of NaS batteries, dominating the market through the company NGK Insulators Ltd. NaS technology has been providing grid services in Japan since the 1990s, and the country has more than 300 MW of NaS storage power installed in more than 170 projects [37]. NGK Insulators, Ltd. and TEPCO jointly developed NaS battery technology over the past 25 years. TEPCO has been operating a 6 MW/48 MWh system for load leveling in Tokyo since the 1990s. “NAS” is the registered trademark for the NGK’s sodium-sulfur battery system.

Since the Great East Japan Earthquake, storage batteries became a core technology because of their application as an emergency power supply, more important in Japan that is an isolated island from the energy point of view, and because of the two frequency system. Besides, storage energy allows Japan to increase its share of renewable energy power generation and its energy self-sufficiency ratio, and reduce its CO_2 emissions.

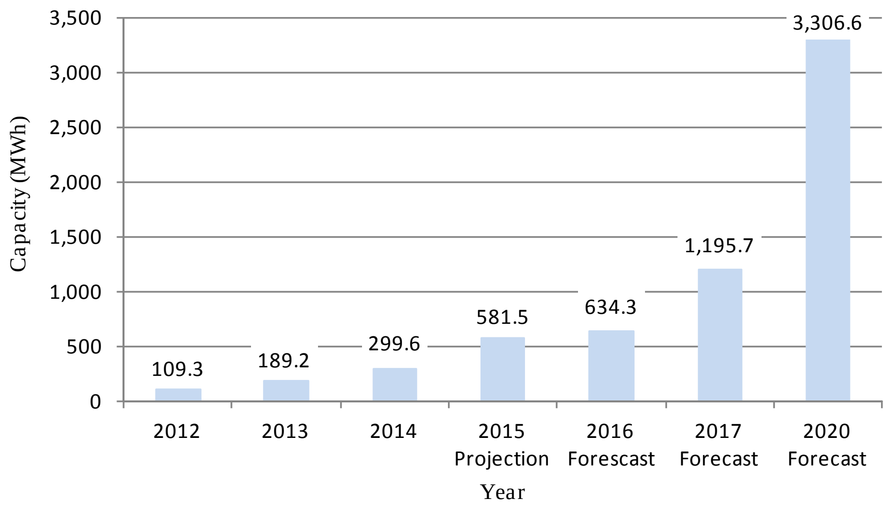
In 2015, both research firms Fuji Keizai and Yano Research Institute already predicted a fast expansion of the Japanese stationary storage battery market, including an important growth in the residential sector. Power system stability and automotive were the other two purposes with higher expected growth. In the future, and due to the residential and automotive sectors, Li-ion battery technology will dominate the Japanese energy storage market.

Yano Research Institute expected a growth from 581 MWh in 2015 (projection based on manufacturers shipping capacity), already a 194.1% higher than the previous year, to 3,366 MWh in 2020, with residential use accounted for a ratio of at least 50%[193] (Figure 47). Fuji Keizai research firm predicted an important growth in this market from JPY 72.64 billion in 2015 to JPY 116.31 billion in 2020 (Figure 48).

The energy storage in residential and C&I sectors was expected to increase more than three times from 2015 to 2025. Several factors will drive this growth in the residential sector. In November 2019, thousands of houses will start to see their FIT agreement established in 2009 expire (Figure 15), and storage battery will be a way to maximize the value of their PV solar system increasing their self-consumption. The shift to a distributed generation system is a fact, not only in Japan, and main Japanese players are already offering solutions that include a package with PV system plus storage and HEMS. The government’s target about ZEH/ZEB for new houses and buildings will also increase the installation of both solar PV systems and storage batteries. In Chapter 3.1.4, several subsidies for ZEH/ZEB covering also the installation of storage batteries were described. Storage batteries will become an important VPP resource, selling the surplus power to an aggregator (Chapter 5). Finally, storage batteries can supply energy during natural disasters such as typhoons and earthquakes, so frequent in Japan.

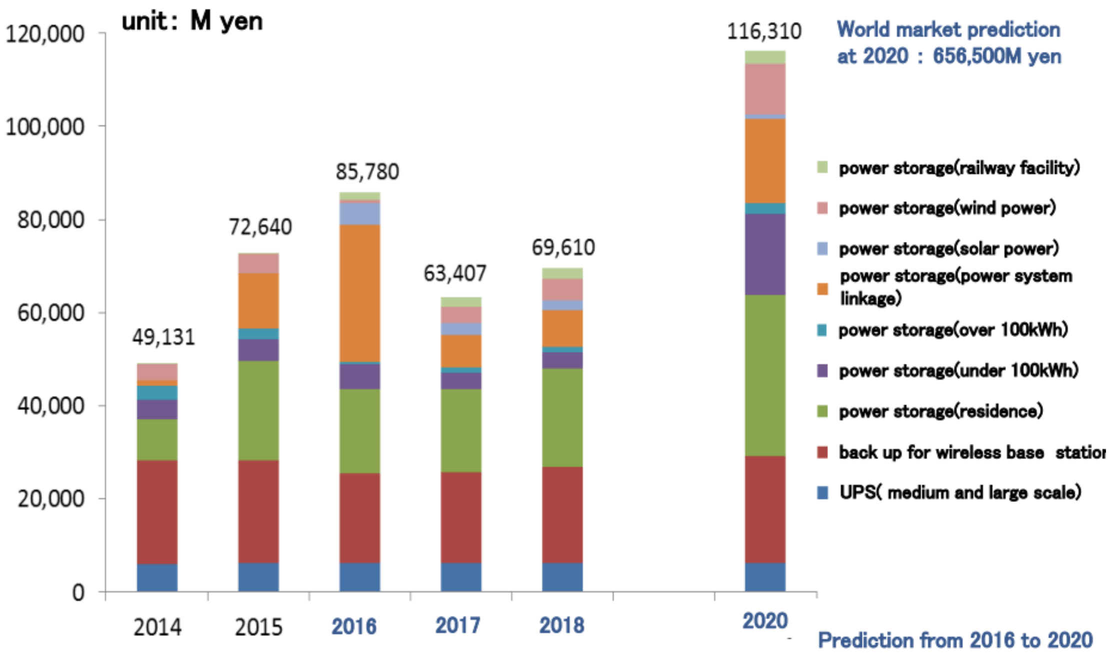
[193] Nikkei xTEH, October 14, 2015:
https://tech.nikkeibp.co.jp/dm/atcl/news/15/101400729/?bpnet&rt=nocnt.

Figure 47: Stationary Storage Battery Market in Japan



Source: Author, with data from Yano Research Institute

Figure 48: Demand Forecast for ESS in Japan



Source: Battery Association of Japan (BAJ), with data from Fuji Keizai [5].

Therefore, the Japanese government has been promoting the deployment of the national storage capacity through several and continuous subsidies programs, and the development of demonstration projects, funding also research projects on new or/and more efficient technologies.

In 2012, METI established a Storage Battery Strategy Project Team, integrating the Agency for Natural Resources and Energy, the Commerce and Information Policy Bureau and the Manufacturing Industries Bureau. Its mission was to formulate and implement integrated strategic policies for storage batteries, including the creation of future storage battery markets, industrial competitiveness enhancement, and international standardization of relevant technologies. Its strategy is that Japanese companies related to the storage battery business will capture a share of 50% in the global storage battery market, around JPY 20 trillion, by 2020. Within this share, a little more than one third was foreseen for large-scale storage batteries.

The Battery Research Platform is a collaborative programme established in FY 2012 to accelerate R&D of next-generation batteries, including metal-air and all-solid-state batteries. NIMS is the main institution in this platform, and it is working with the National Institute of Advanced Industrial Science and Technology (AIST) and Waseda University on ALCA-SPRING (Advanced Low Carbon Technology Research and Development Program, Specially Promoted Research for Innovative Next Generation Batteries). It also supports initiatives in other next-generation battery R&D areas carried out by universities, institutions and private companies across Japan, including battery, automotive and materials manufacturers, which are also affiliated to this project[194].

Between 2012 and 2013, METI launched several major energy storage technology subsidies. The stationary Li-ion battery program, with a budget of JPY 21 billion, covered one-third of the cost. Though the PV system was not required, most of the suppliers (Kyocera, Sharp, Panasonic, NEC, Toshiba or Sekisui House, for example) offered the package solar plus storage. The stand-alone renewable energy generation program (with batteries) covered one-half of energy storage costs and had a smaller budget of JPY 30 million. Other three related subsidy programs were focused on the area affected by the earthquake in 2011. About 130 MWh of residential battery storage was installed as a consequence of these subsidies. MOE also launched the storage battery for renewable energy generation program in that time for systems higher than 1 MW and covering one-half of the cost, and the renewable energy in local areas program, with a budget of JPY 1 billion and covering also one-half of the cost.

In July 2013, NEDO revised the Technology Roadmap for Stationary Battery in Japan, as it is shown in Figure 49 [39]. It identified the challenges for each technology in the R&D programs, with some targets as cost reduction, energy density, discharge/charge efficiency and enhance the safety.

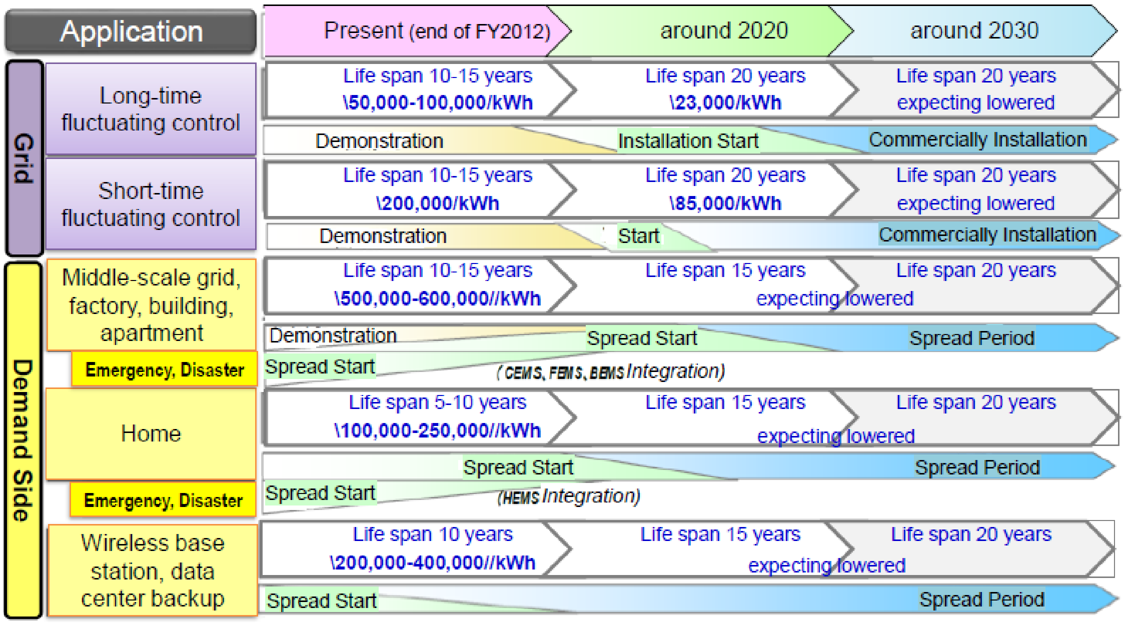
In August 2013, METI selected Hokkaido Electric Power Co. Inc. and Sumitomo Electric Industries, Ltd. (60 MWh of redox flow battery) and Tohoku Electric Power Co., Inc. (20 MWh of Li-ion batteries) to undertake projects to develop large-scale storage batteries into electricity grids, and examine their function integrating more VRE generation, as well as developing technology to optimally control and manage the battery system[195]. It also announced a program

[194] ALCA-SPRING: http://www.jst.go.jp/alca/alca-spring/en/index.html.
[195] PV Magazine, August 14, 2013: https://www.pv-magazine.com/2013/08/14/japan-selects-projects-to-develop-large-scale-storage-batteries_100012383/.

of JPY 10 billion for installing Li-ion batteries in individual households and entities, in order to reduce battery prices by mass production effect, and facilitating the further expansion of renewable energies[196].

The Fourth Strategic Energy Plant also promoted the introduction of storage batteries in 2014 "by lowering their cost and improving their performance through technological development and international standardization, so that Japanese companies related to the storage battery business will capture a share of 50% in the global storage battery market (20 trillion yen) by 2020" [40].

Figure 49: Technology Roadmap for Stationary Battery in Japan



Source: NEDO ("Technology Roadmap for Stationary Battery", Revised 2013), modified by The Institute of Energy Economics, Japan (IEEJ).

To develop this potential growth sector into a strategic industry, the government accelerated sophistication, cost reduction and widespread use of storage batteries through grants for R&D, and subsidies for installations. Regulations were also relaxed for expanding the market, simplifying or even removing some procedures. Energy storage became a necessary requirement for the construction of new renewable energy facilities.

METI introduced then a subsidy program of USD 100 million that provided up to two-thirds of the cost of a Li-ion battery system, with a maximum of USD 10,000 for household's users and

[196] PV Magazine, March 19, 2014: https://www.pv-magazine.com/2014/03/19/japan-proposes-new-fits-unveils-lithium-ion-battery-subsidies_100014545/.

USD 1 million for commercial users. The applications for energy storage systems exceeded the budget well before the year finished.

In 2015, METI set a new incentive scheme of JPY 93 billion for increasing the deployment of distributed energy storage and other energy efficient technologies at the commercial sector, targeting factories and small-sized businesses. In addition, METI also set a JPY 81 billion in response to grid issues because of the penetration of more VRE[197]. This support to the deployment of storage batteries also helped utilities to deal with the VRE generation, since at the end of the previous year, five power companies refused to sign more renewable energy purchase agreements because they were not allowed to curtail production from installations smaller than 500 kW[198].

In that year, Kyushu Electric Power received government subsidies to install a large storage battery system with an output of 50MW and a capacity of 300 MWh to test the battery system for controlling the voltage of the grid[199].

In May 2016, a new certification facility for large Li-ion batteries started its operation in Osaka. It is managed by the National Institute of Technology and Evaluation (NITE), and it represented an important step for Japan to establish a world-class certification institution for batteries.

The government has launched several subsidies programs for ZEH/ZEB that also cover the installation of storage batteries (see Chapter 3.1.4.). Local governments also have their own battery related subsidies[200].

Considering the current EVs travel range and energy density of around 400 km and 200 Wh/kg, the target of the government is to achieve a range of around 800 km by 2025 (400 Wh/kg) with the solid-state battery technology, and about 1,000 km (500 Wh/kg) after 2030 through other innovative battery technologies [41], recovering the lost leadership of Japanese companies in the global automotive battery market. With that goal in mind, the main two current METI's battery R&D projects are the following:

- RISING2, from 2016 to 2020, with a budget of JPY 2.88 billion in FY 2016 and JPY 3.1 billion in FY 2018. The organizations involved in this project are the AIST, automotive and battery companies, the Kyoto University and other universities.

- All Solid State LIB: leading Japanese manufacturers have teamed up with METI in a program from 2018 to 2022 to develop solid-state batteries. The responsible organization is the Lithium Ion Battery Technology and Evaluation Center (LIBTEC), a

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[197] BNEF, January 9, 2015: https://about.bnef.com/blog/japan-to-support-energy-saving-storage-battery-installations/.

[198] GTM, January 20, 2015: https://www.greentechmedia.com/articles/read/japan-pumps-cash-into-energy-storage#gs.V0CDqzk.

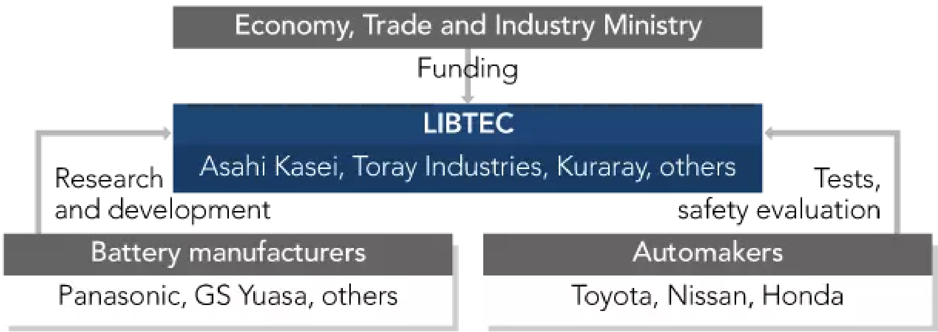
[199] GTM, May 19, 2015: https://www.greentechmedia.com/articles/read/japanese-utilities-invest-in-big-batteries#gs.B6ruHHo.

[200] Kankyo Business: https://www.kankyo-business.jp/subsidy/accumulator/ (only in Japanese).

research body whose members include, among others, the automotive component manufacturers Asahi Kasei and Toray Industries. It will work with automakers Toyota, Nissan and Honda, and battery manufactures Panasonic, GS Yuasa and others (Figure 50), and has received a budget of JPY 1.6 billion in FY 2018. It is believed that Toyota's solid-state battery is the world's most advanced one, and this program will make possible its commercialization[201].

In April 2018, NEDO created a new department for Advanced Battery and Hydrogen Technology since these technologies are regarded as "core technology to promote low carbonization of Japanese energy supply and demand structure". Storage batteries, hydrogen and fuel cell technologies have energy-saving properties as well as affinity with renewable energies, so NEDO promotes R&D on these technologies[202], especially for reducing their costs and increasing their efficiency. It has been launching demonstration tests in different locations and regarding different storage technologies.

Figure 50: Public-private Project to Develop Solid-state Battery in Japan



Source: METI and Nikkei media.

There are also several storage battery industrial clusters across Japan, such as in Osaka (Battery Strategy Research Center), Yokohama (Storage Battery SCADA – Supervisory Control And Data Acquisition – under the Yokohama Smart City Project), Saitama Prefecture (Leading-Edge Industry Design Project, under the Saitama Eco-Town Project) or Fukushima Prefecture (Research Institute for Energy Conservation, under AIST), involving private companies and also universities such as Waseda University and Shinjuku University.

Some of the main domestic manufactures per technology are the following:

- Li-ion: GS Yuasa International, Hitachi Maxell, Hitachi Chemical, Mitsubishi Heavy Industry, NEC Energy Solutions, FDK Corporation, Panasonic Corporation (SANYO),

[201] Asia Nikkei, May 6, 2018: https://asia.nikkei.com/Business/Business-Trends/Japan-juices-efforts-for-new-electric-vehicle-battery.
[202] NEDO, April 2, 2018: http://www.nedo.go.jp/news/press/AA5_100941.html (only in Japanese).

Toshiba Corporation, Kyocera Corporation, Sharp, Marubeni Corporation, ELIIY Power, Shecom K.K., SEIKI, Asahi Kasei Corporation, Edison Power Corporation and 4R Energy.

- Sodium-Sulfur (NaS): NGK Insulators.

- Redox flow: Sumitomo Electric Industries.

- Lead acid: GS Yuasa International, Shin-Kobe Electric Machinery, B&B Battery, and Furukawa Battery.

- Nickel-Metal Hydride (NiMH): Kawasaki Heavy Industry, FDK Corporation, Panasonic Corporation (SANYO), Hitachi Maxell.

It was said before that also Softbank and NIMS started a collaborative research in the Li-air battery technology in April 2018, with the aim of its commercialization around 2025.

Since cobalt's prices have multiplied over the last years and it is expected that the increase of the EVs deployment results in eventual shortages of this mineral, there are several companies developing batteries that do not need cobalt. GTM provided a list of some of those manufacturers in July 2018, including the following Japanese ones[203]:

- AESC: a joint venture between Nissan Motor Co., Ltd. and the batteries electrodes supplier NEC Group, that produces Li-ion batteries for the Nissan Leaf model, makes combined Lithium Manganese Oxide (LMO)-Lithium Nickel oxide cells. However, they transferred the battery business of both companies to the Envision Group, a Chinese operator of renewable energy projects[204].

- Ionic Materials: an American startup that develops solid-state cobalt-free battery materials, and in which the Renault-Nissan-Mitsubishi alliance has invested, as well the French oil and gas company Total.

- Murata Manufacturing: it bought Sony's Li-ion battery business in the past, and now it builds its energy storage modules from olivine-type Lithium Metal Polymer (LMP) batteries.

- Toshiba: it makes Lithium Titanium Oxide (LTO) batteries for vehicle, industrial and infrastructure applications. It announced a collaboration with Japan's Sojitz Corporation

[203] GTM, July 9, 2018: https://www.greentechmedia.com/articles/read/11-lithium-ion-battery-makers-that-dont-need-cobalt?utm_source=GridEdge&utm_medium=email&utm_campaign=GTMGridEdge#gs.nCco3Qs.

[204] Kankyo Business, August 6, 2018: https://www.kankyo-business.jp/news/020914.php?utm_source=mail&utm_medium=mail180807_d&utm_campaign=mail.

and Companhia Brasileira de Metalurgia e Mineração of Brazil in June 2018 to develop a next-generation Li-ion battery.

- Panasonic is currently the exclusive battery cell supplier for Tesla's Model 3 sedan, producing them at their gigafactory plant in Nevada (US). It has already cut down cobalt usage substantially and plans to develop automotive batteries without using that mineral in the near future due to the higher prices[205].

- As it was said before, Toyota, Panasonic, GS Yuasa, Nissan, Honda and others have teamed up with METI to develop solid-state batteries.

Some foreign companies already in the Japanese's storage batteries market are the South Korean LG Chem and Samsung SDI, the Chinese BYD, the American General Electric, the Italian FIAMM and the German Bosch Power Tech GmbH (100% subsidiary of Robert Bosch GmbH). Moixa, a UK-based leading smart home battery company, signed a partnership with Japanese ITOCHU Corporation for expanding its battery management platform in Japan, already installed in 1,000 homes in the UK. Its platform uses AI to optimize battery performance based on patterns of behavior, weather conditions and market prices, and can also manage large numbers of PV solar systems, control the charging of EVs and provides services to the electricity grid. They expect that the number of energy storage systems in Japan will increase from 125,000 in 2016 to more than 500,000 in 2020[206].

LG Chem and Samsung SDI are dominating the Japanese utility-scale storage market according to Solarplaza[207]. Table 16 shows the largest 15 centralized PV plus storage projects in Japan, both in operation and under construction state at the beginning of 2018. The current cumulative storage capacity of the top 7 operational plants is 46.5 MW, while the estimated cumulative capacity of the pipeline is 117.8 MW, 2.5 times more.

87% of the largest solar plus storage projects in Japan are located in Hokkaido. As in other islands, storage is required in the PPA, which helps to increase the market in this region. According to HEPCO, the storage is a technical necessity against the fluctuation of the energy generated by solar plants.

The market of battery components, such as cathodes and anodes materials, electrolytes and separators, will also grow in Japan following the expansion of the storage batteries. Some foreign manufacturers such as the South Korean SK Innovation and UNID (UNID Japan Branch), the Belgian Umicore (Yumi Core Japan) and the American Oxidantal Chemical Corporation (OxyChem) already entered. There are many domestic companies working in this area, where European suppliers could find a partner as the first step to enter into the Japanese

[205] Reuter, May 30, 2018: https://www.reuters.com/article/us-panasonic-battery/panasonic-plans-to-develop-cobalt-free-car-batteries-idUSKCN1IV14Y.
[206] GOV.UK, February 6, 2018: https://www.gov.uk/government/news/smart-battery-business-signs-deal-to-supply-in-japan.
[207] Solarplaza, April 11, 2018: https://www.solarplaza.com/channels/top-10s/11817/15-largest-japanese-solar-pv-storage-projects/.

market. Some of the main ones are Toray Industries, Sumitomo Metal Mining, Mitsubishi Chemical Corporation, Mitsui Mining & Smelting, Asahi Kasei Corporation or Nippon Chemical Industrial, among many others.

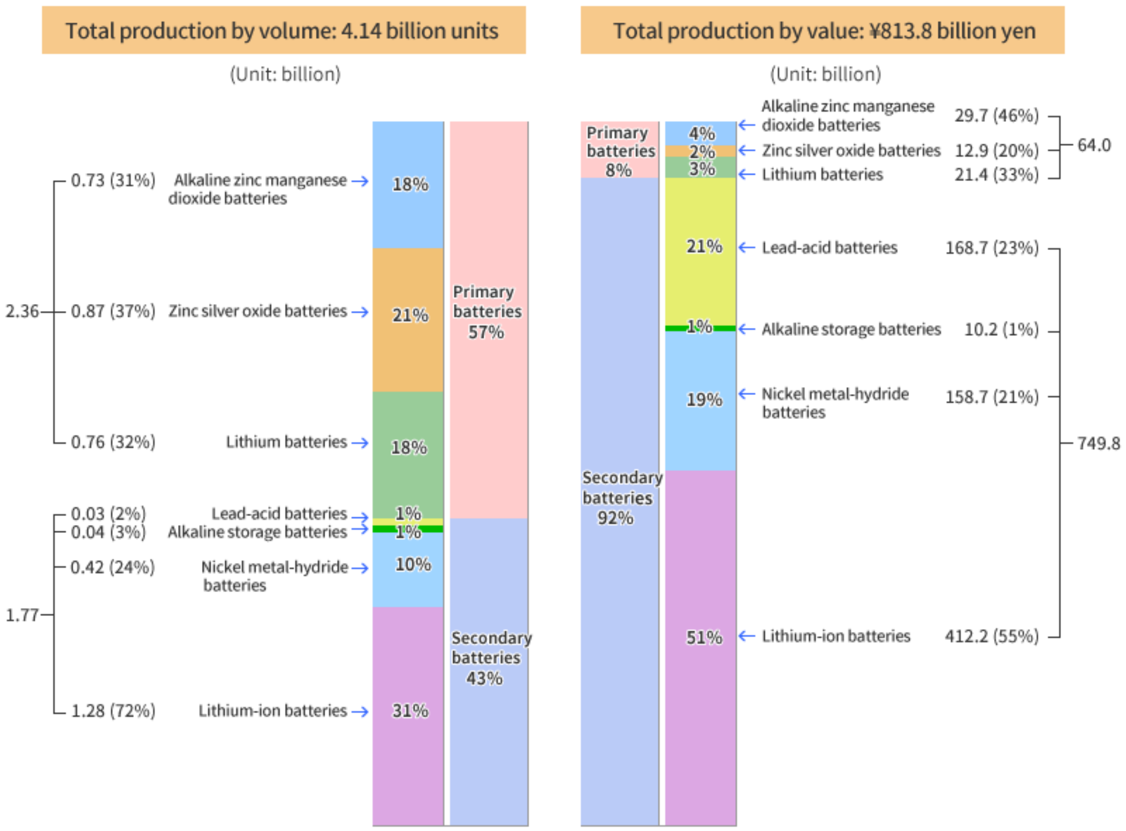
Table 16: 15 Largest Centralized PV + Storage Projects in Japan

Status	Plant (MW)	Investor	Prefecture	Storage (MWh)	Storage	Modules	PCS	EPC
OP	28	KEPCO & Energy Products	Hokkaido	14	ABB	-	ABB	LSIS
OP	24	Orix & Solar Frontier	Hokkaido	12.5	-	Solar Frontier	TMEIC	Toshiba Plant Systems
OP	14.5	Obayashi Clean Energy	Hokkaido	6.75	Obayashi Corporation, Mitsubishi Electric & GS Yuasa	-	-	Obayashi Corporation
OP	10.2	Hoosiers Holdings	Hokkaido	3.6	LG Chem Ltd.	Yingli Solar	Fuji Electric	Kita Koudensya
OP	2.6	(unknown)	Kagoshima	1	TMEIC	Jinko Solar	TMEIC	Universal Ecology
OP	1.2	Hayashi Contruction	Kagoshima	6.5	LG Chem Ltd.	-	YAMABISHI	Chuo Bussan
OP	4.4	Japan Asia Investment	Hokkaido	2.2	Samsung SDI	Canadian Solar	Fuji Electric	-
UC	102	SB Energy & Mitsubishi UFJ Lease & Finance Company	Hokkaido	27	LG Chem Ltd.	Toshiba	TMEIC	Toshiba & TMEIC
UC	92	Tokyu Land Corporation, Mitsubishi UFJ Lease & Finance Company & Green Power Development Corporation	Hokkaido	25	-	-	-	Fuji Electric
UC	64.6	SB Energy & Mitsubishi UFJ Lease & Finance Company	Hokkaido	17.5	LG Chem Ltd.	Toshiba	TMEIC	Toshiba & TMEIC
UC	38.4	Green Power Development Corporation, Aquila Capital & other local institutional investors	Hokkaido	10	LG Chem Ltd.	Jinko Solar	-	Fuji Electric
UC	34	Smart Solar, RISA PARTNERS Inc.	Hokkaido	14.4	LG Chem Ltd.	Trina Solar	Fuji Electric	Kandenko
UC	31.6	Looop & Green Power Development Corporation	Hokkaido	6.6	LG Chem Ltd.	JA Solar	Fuji Electric	Nippon COMSYS
UC	21	Smart Solar	Hokkaido	9	Samsung SDI	Trina Solar	ABB	Kandenko
UC	15.7	Smart Solar & Japan Asia Investment	Hokkaido	8.3	Samsung SDI	Hanwa Q Cells	ABB	-

Source: Author, with data from Solarplaza.

Finally, total production, sales, exports and imports statistics of batteries in Japan according to BAJ are shown in Figure 51, Table 17 and Table 18. Secondary Li-ion batteries represented 31% on the total production in Japan in 2017, but more than half of the total value, and increasing each year, as well as the exports of this technology.

Figure 51: Total Battery Production in Japan in 2017



Source: BAJ, from machinery statistics released by METI[208].

Table 17: Secondary Battery Sales in Japan by Volume and Value

Type of secondary battery	Units (1,000 pcs)					Value (million JPY)				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
For vehicles	24,107	24,053	23,633	23,855	24,814	99,621	106,490	108,425	109,938	120,121
Other lead-acid	8,065	8,142	7,684	7,637	7,721	62,127	62,027	63,286	65,251	66,314
Nicket metal-hydride	455,132	432,936	434,397	478,210	471,105	178,748	168,157	160,294	167,785	166,583
Lithium-ion	844,622	955,644	1,031,850	1,277,108	1,320,502	279,364	349,761	360,705	385,368	422,366
Other alkaline	147,445	99,651	94,005	65,745	50,015	20,237	16,942	16,467	12,466	11,412
Total	**1,479,371**	**1,520,426**	**1,591,569**	**1,852,555**	**1,874,157**	**640,097**	**703,377**	**709,177**	**740,808**	**786,796**

Source: BAJ, from machinery statistics released by METI[209/210]
(Motorcycle batteries and small valve regulated lead-acid batteries are included in "other lead-acid" category. Other alkaline batteries include industrial alkaline and small sealed nickel-cadmium batteries).

[208] BAJ: http://www.baj.or.jp/e/statistics/01.html.
[209] BAJ: http://www.baj.or.jp/e/statistics/06.html.
[210] BAJ: http://www.baj.or.jp/e/statistics/07.html.

Table 18: Secondary Battery Export and Import Statistics in Japan by Volume and Value

Type of secondary battery	Units (100 million pcs)					Value (100 million JPY)				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Total batteries exported	**10.8**	**11.2**	**12.0**	**15.1**	**14.6**	**3,775**	**4,000**	**4,247**	**4,434**	**5,011**
Lead-acid	0.0	0.0	0.0	0.0	0.0	106	107	135	136	158
Nickel cadminum	1.1	0.6	0.6	0.4	0.2	96	56	59	30	23
Nickel iron	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Nicket metal-hydride	1.5	1.3	1.5	1.8	1.6	667	610	655	733	832
Lithium-ion	7.7	8.8	9.6	12.0	11.8	2,004	2,152	2,460	2,840	2,884
Others	0.5	0.5	0.3	0.9	1.0	902	1,075	938	695	1,114
Total batteries imported	**1.0**	**0.9**	**0.9**	**0.9**	**0.9**	**1,126**	**1,074**	**1,335**	**1,342**	**1,471**
Lead-acid	0.1	0.1	0.1	0.1	0.1	294	316	332	327	362
Nickel cadminum	0.0	0.0	0.0	0.0	0.0	23	21	21	17	20
Nickel iron	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Nicket metal-hydride	0.2	0.2	0.2	0.2	0.2	55	61	61	51	50
Lithium-ion	0.5	0.4	0.5	0.6	0.6	639	568	768	815	906
Others	0.2	0.2	0.1	0.0	0.0	115	108	153	132	133

Source: BAJ, from trade statistics released by Ministry of Finance[211].

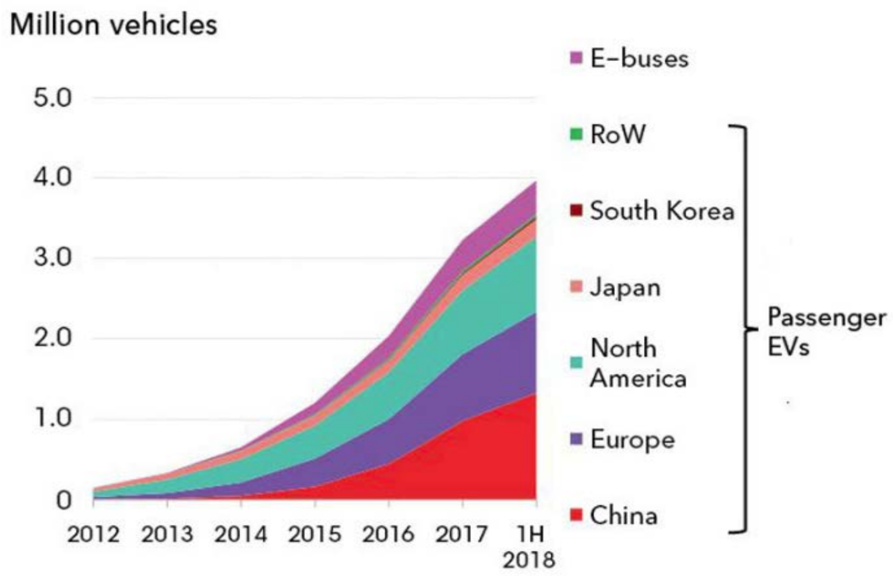
4.2. ELECTRIC VEHICLES AND V2G CONNECTION

According to a study published by Macquarie Bank in January 2018, electric vehicles accounted for 1.7% share of new global car sales in 2017, about 1.1 million units, increasing from 1.1% in 2016. BNEF announced that cumulative passenger EV sales hit 4 million at the end of August 2018, or at the beginning of July 2018 if the e-buses are included, being China responsible for around 37% of the passenger EVs sold[212] (Figure 52). The stock of electric buses and two-wheelers also grew to 370,000 and 250 million respectively, accounting China for 99% of both sectors[213]. Finally, almost 250,000 electric light commercial vehicles were on the road in 2017, often part of a company or government fleet [42]. BNEF forecasts it will take only another six months to sell the next million, with 42% of upcoming EVs sold in China, 26% in Europe and 25% in North America.

According to IEA, the eight countries with the largest EV fleet in the world are China (1,227,770 units), the United States (762,060 units), Japan (205,350 units), Norway (176,310 units), UK (133,670 units), the Netherland (119,330 units), France (118,770 units) and Germany (109,560 units). However, Norway was still the world’s largest market of EVs in terms of new car sales share in 2017 with 39%, following by Iceland with 11.7% and Sweden with 6.3%. Norwegian EV stock share was also the largest in the world with 6.4% [42].

[211] BAJ: http://www.baj.or.jp/e/statistics/09.html.
[212] BloombergNEF, August 30, 2018: https://about.bnef.com/blog/cumulative-global-ev-sales-hit-4-million/.
[213] IEA, July 6, 2018: http://www.iea.org/tcep/transport/evs/.

Figure 52: Cumulative Global Electric Vehicles Sold



Source: BNEF.

Plug-in Electric Vehicles (PEV) or just electric vehicles (EV) include both Plug-in Hybrid Electric Vehicles (PHEV, or PHV) and Battery Electric Vehicles (BEV) or pure electric[214]. The share of BEVs was 62% in 2017. The Chinese BAIC, Tesla and Nissan reached the top 3 of sales in BEV models, following by the Chinese BYD and BMW Group. BAIC sold 98% of its electric vehicles in China. However, considering also PHEV models, BYD reached the first place[215].

Bloomberg estimates a worldwide increase to 11 million EVs by 2025 and to 30 million by 2030, becoming competitive on an unsubsidized basis starting in 2024. Almost half of the municipal buses on the road worldwide will be electric within seven years, with about 1.2 million e-buses in 2025. China will keep leading the market with almost half of the global EVs sales in 2025 and 39% in 2030. EVs will make up 44% of all new vehicle sales in Europe by 2030, 41% in China, 34% in the US and 17% in Japan. EVs will dominate the global vehicle market with a share of 55% and about 60 million of EVs sold by 2040[216].

This implies big opportunities for Li-ion battery manufacturers. China is leading this market with 59% global share of batteries production capacity in 2018, compare to the 70% share of

[214] It is common to find EV for representing either PEV or BEV, which it is confusing. In this report, EV represents only PEV, this is, PHEV plus BEV. However, there are document's titles from official sources such as METI that uses EV instead of BEV, though there are easy to be identified since they are always together with PHV abbreviation.
[215] EV-Volumes, Global Plug-in Sales for Q1-2018: http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/.
[216] BloombergNEF: https://about.bnef.com/electric-vehicle-outlook/.

Japanese companies in the global automotive battery market in 2013, dominating both manufacturing and technology. This figure is forecast to increase to 73% by 2021[217].

In Europe, 195,000 EVs (51% BEV and 49% PHEV) were sold in the first half of 2018, 42% higher than for the same period of 2017, and a 2.2% share of the European light vehicle market. The German market is the strongest contributor in terms of volume, with 88,500 registrations expected in 2018, following by Norway with 84,000 units[218].

In 2017, the global stock of fuel-cell electric vehicles (FCEV, or FCV) surpassed 7,200 units, with more than 3,500 in the US, in particular in California, about 2,300 units in Japan and almost 1,200 in Europe, especially in Germany and France [42].

On the other hand, Norway committed to selling only electric cars by 2025, the Netherlands, Slovenia and India from 2030, France and UK from 2040, and China and California are studying about it. Carmaker Volvo announced that it will only launch new electric or hybrid models from 2019.

In 2017, EVI, a multi-governmental policy forum dedicated to accelerating the deployment of EVs worldwide, launched the EV 30@30 campaign, setting a collective goal of an average 30% market share for EVs by 2030 (passenger cars, light commercial vehicles, buses and trucks), including several implementing actions. Ten countries accounting over 60% of the global EV stock support this campaign: Canada, China, Finland, France, India, Japan, Mexico, the Netherlands, Norway and Sweden[219]. As part of this initiative, EVI also launched the Global EV PCP with the aim to build a network of 100 EV-friendly cities. According to IEA, a total of 30 cities currently committed to participate in the PCP, including the Japanese Aichi Prefecture, Kanagawa Prefecture, Kyoto Prefecture and Tokyo Metropolitan Government[220].

The impact of charging depends on when it occurs. Without smart energy management, a large number of EVs charging at the same time could cause peaks in electricity demand, affecting grid stability, efficiency and operating costs. To address these concerns, several countries, manufacturers and electric utilities continue to experiment with smart charging in order EVs power demand can follow wind and solar power output, and V2G technology that allows using EVs' batteries as VPP sources.

[217] PV Magazine, May 22, 2018: https://www.pv-magazine.com/2018/05/22/affordability-and-lack-of-charging-points-stalls-electric-vehicle-take-up-in-india-bloomberg/.
[218] EV-Volumes, Europe Plug-in Sales Results for 2018 H1: http://www.ev-volumes.com/country/total-euefta-plug-in-vehicle-volumes-2/.
[219] IEA, June 8, 2017: https://www.iea.org/newsroom/news/2017/june/new-cem-campaign-aims-for-goal-of-30-new-electric-vehicle-sales-by-2030.html.
[220] IEA, May 24, 2018: https://www.iea.org/newsroom/news/2018/may/global-ev-pilot-city-programme-launched-at-clean-energy-ministerial.html.

4.2.1. Current Status in Japan

The transportation sector contributed with 19% to entire CO_2 emissions in Japan in 2015, and the government target is to reduce it 25% by 2030 increasing the popularization of the next-generation vehicles, and reaching an electric vehicles' share in the new car sales of 20%-30% by 2030 [41]. Expecting to effectively reduce CO_2 emissions and bringing new value, including contributions to disaster response, METI published the Road Map for EVs and PHVs toward the Dissemination of Electric Vehicles and Plug-in Hybrid Vehicles in March 2016[221].

The Road Map established the goal of achieving a ratio of next-generation vehicles (hybrid, plug-in hybrid, electric, fuel cell, clean diesel, and other new-energy vehicles) among new vehicle sales of 50-70% by 2030 (Table 19). In 2017, that share was more than 36% of new passenger car registrations. It also set the target to increase the number of BEVs and PHVs to up to one million by 2020, though, according to the Japan Automobile Manufacturers Association (JAMA), there were only 205,185 units at the end of 2017. While the target for hybrid electric vehicles (HEV) has already been achieved successfully, it looks difficult that Japan meets the BEV/PHV targets of 2020 (1 million units) and 2030. Bloomberg's estimation is that EVs will make up 17% of all new vehicle sales in Japan by 2030.

Table 19: Next-generation Target in 2030

Year		2017	2030
Conventional cars		63.97%	30 - 50%
Next generation cars		36.02%	50 - 70%
	HEV	31.2%	30 - 40%
	BEV PHV	0.41% 0.82%	20 - 30%
	Fuel Cell Vehicle (FCV)	0.02%	3%
	Clean Diesel Vehicle (CDV)	3.52%	5 - 10%

Source: Author, with data from METI [41].

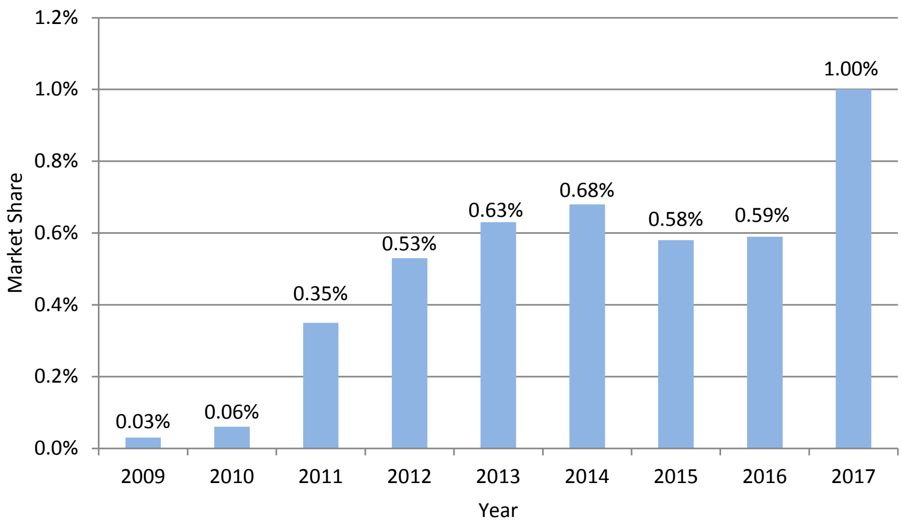
Though it is not within the purpose of this report to cover this topic, the Strategic Road Map for Hydrogen and Fuel Cells, including the deployment of FCV, was compiled separately also in March 2016. It established a target of about 40,000 FCVs by 2020, about 200,000 by 2025 and about 800,000 by 2030. Regarding the infrastructure, it included the installation of about 160 stations by 2020 and 320 by 2025.

[221] METI, March 23, 2016: http://www.meti.go.jp/english/press/2016/0323_01.html.

As an active member of EVI, and because of the Government Fleet Declaration announced at the Marrakech Climate Change Conference in November 2016 [1], the Japanese government is making efforts to ensure that all government vehicles will be next-generation vehicles by 2030. As an intermediate goal, approximately 40% of the government vehicle fleet, around 9.000 units, will be next-generation vehicles by 2020, which will contribute to the one million target by 2020.

In 2017, the Japanese electric car fleet was the third largest in the world, after China and the US, but it only represented a market share of 1.0%. Therefore, at this stage of EVs deployment in Japan, policy support from the government is still indispensable.

Figure 53: Market Share of Electric Vehicles in Japan



Source: Author, with data from IEA.

In April 2018, a Strategic Commission for the New Era of Automobiles was launched by METI, and has been studying the strategies that the Japanese automobile industry should take to lead global innovations and proactively contribute to solutions to global issues including climate change. In August 2018, METI released a report with the conclusions, setting long-term goals such as having all new passenger cars be electric by 2050 and reducing GHG emissions of a single passenger vehicle by 90% by 2050. Realize a “Well-to-Wheel Zero Emission” policy to reduce vehicles’ total emissions footprint to zero, from fuel and power production to automobile operation, is also a target. It established policies and key actions to achieve these goals[222].

In order to increase the acceptance and market entry of EVs, METI encouraged the research, development and demonstration (RD&D) programs with the aim to reduce the cost of the

[222] METI, August 31, 2018: http://www.meti.go.jp/english/press/2018/0831_003.html.

batteries and increase their durability, such as the RISING2 and All Solid State LIB programs already described. The promotion of next-generation low-emission vehicles, traffic flow improvements, eco-driving, and the use of public transports were also included in the Plan for Global Warming Countermeasures in 2016.

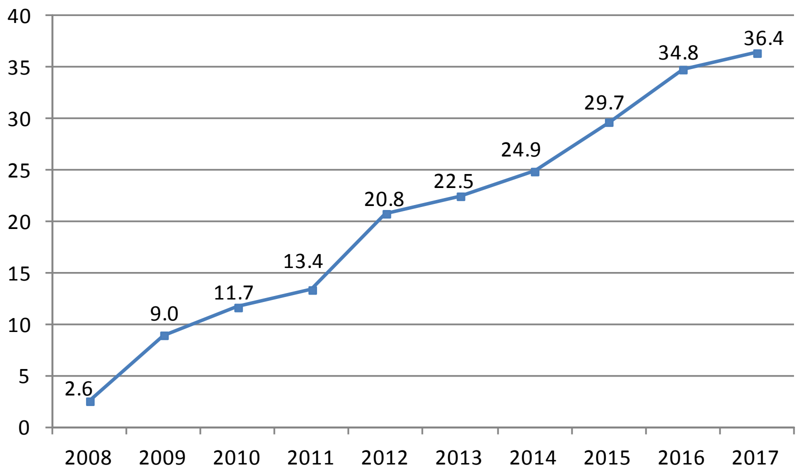
Table 20 and Figure 54 show the number of next-generation vehicles sales and their shares in Japan from 2008 to 2017.

Table 20: Next-generation Passenger Car New Registrations

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
HEV	108,518	347,999	481,221	451,308	887,863	921,045	1,058,402	1,074,926	1,275,560	1,385,343	7,992,185
PHV	0	0	0	15	10,968	14,122	16,178	14,188	9,390	36,004	**100,865**
BEV	0	1,078	2,442	12,607	13,469	14,756	16,110	10,467	15,299	18,092	**104,320**
FCV	0	0	0	0	0	0	7	411	1,054	849	2,321
CDV	0	4,364	8,927	8,797	40,201	75,430	78,822	153,768	143,468	154,803	668,580
Total	108,518	353,441	492,590	472,727	952,501	1,025,353	1,169,519	1,253,760	1,444,771	1,595,091	8,868,271

Source: Author, with data from JAMA [43].

Figure 54: Next-generation Vehicle Share in New Passenger Car Registration



Source: Author, with data from JAMA [43].

The Japanese electric vehicle market is comprised almost entirely of Japanese auto manufacturers, with the Nissan Leaf leading it with more than three-quarters of the share. In April 2018, Nissan Leaf (first and second generation) sales surpassed 100,000 units in Japan since its introduction in December 2010, and sales worldwide exceeded a cumulative total of

320,000 units in March 2018[223]. Nissan plans to increase EVs' sales by 50% by 2025. Mitsubishi is the only other Japanese automaker that produces EVs, but it is part of the Nissan-Renault alliance since 2016, when Nissan purchased a 34% stake in Mitsubishi Motors[224]. It started the sales of its "iMiEV" EV model also in 2010. Out of the domestic manufacturers, BMW and Tesla get a small share with different models.

On the other hand, Toyota sold 658,000 electrified vehicles in Japan and 1,520,000 worldwide in 2017, with cumulative sales of these vehicles close to 5.5 million in Japan and nearly 11.5 worldwide. It dominates the global hybrid and plug-in hybrid sectors, following by Honda, Kia, Ford and Hyundai. Mitsubishi also produces hybrid models, though Toyota and Honda reached more than 95% share of the hybrid market in Japan in 2017. More than 50% of Japanese hybrid sales in 2017 were overseas. Toyota will start the production of BEV in China and India from 2020, and later in Japan, the US and Europe. Toyota's target is to sell 5.5 million electrified vehicles per year by 2030[225].

Purchases of next-generation cars are encouraged through taxation. In Japan, three kinds of taxes are imposed on vehicles: the automobile tax, imposed on the owner every year, the automobile weight tax, imposed according to the weight of the vehicle at new registration and at every vehicle inspection, and the automobile acquisition tax.

New next-generation vehicles are exempt of the acquisition tax, or with a reduction of 450,000 yen for the used ones, and of the tonnage tax on initial mandated inspection. These two taxes are also reduced when purchasing a vehicle with high fuel efficiency and emission levels, such as HEV.

The government also encourages carmakers to extend the range of their models with a subsidy scheme that progressively increases with the range of the battery, 1,000 yen/km. For PHEV, there is a fix subsidy of 200,000 yen.

4.2.2. Quick Chargers

As of mid-2017, an estimated 400,000 public charge points were in operation worldwide, double than in late 2015 [8]. As the EV market grows, the infrastructure to support it has to grow as well. According to GTM Research, growth in EVs sales worldwide will boost demand for charging points up to 40 million installed by 2030, with North America, Europe and Asia

[223] Nissan, April 20, 2018: https://newsroom.nissan-global.com/releases/release-36a71146ed04eaba0f0dff94b50c8dfe-180420-03-e?query=100%2C000.
[224] Nissan, October 20, 2016: http://nissannews.com/en-US/nissan/usa/releases/nissan-strengthens-alliance-with-acquisition-of-34-stake-in-mitsubishi-motors.
[225] Toyota, February 2, 2018: https://newsroom.toyota.co.jp/en/corporate/20966057.html.

(China and Japan) dominating infrastructure deployments[226]. Swiss bank UBS estimates that USD 360 billion will be needed over the next eight years from 2018 to build global charging infrastructure, though the issue of different types of connectivity and communication will need to be resolved[227].

Today, electric companies, car manufacturers, and national and local governments are collaborating to conduct demonstration experiments on quick charging stations. As infrastructure development progresses, it is reduced one of the biggest customers' concerns about EVs, the battery range. It would be even possible to reduce the amount of expensive Li-ion batteries installed in EVs, reducing the price of the cars. Therefore, an important element of the continued EV market growth is the deployment of the charging infrastructure.

In Japan, commitments by the government to reduce its carbon footprint through the use of EVs have resulted in large investments towards the development of EVs infrastructure. The government is also supporting the use of EVs for long distances and the research of more advanced EV charging solutions to shorten the duration for fully charging.

In 2010, METI and MLIT released the "guidelines for installing charging equipment at residential housing and parking lots for EVs and PHVs" for normal-charging. In 2013, METI published the "model planning to install charging infrastructure on roads and in cities" for quick-charging stations. And in March 2016, METI published the "EV & PHV roadmap" with the aim to increase the spread of EVs and PHVs and charging infrastructure across the country.

Regarding the subsidy scheme for supporting the charger installation, the government has spent more than JPY 55 billion for supporting the installation of public chargers: JPY 24 billion in FY 2012, JPY 30 billion in FY 2014, JPY 2.5 billion in FY 2016 and JPY 1.8 billion in FY 2017 [41]. It classifies charging stations into four categories shown in Table 21. The subsidy for each charger is JPY 5 million (around USD 47,000) and up to JPY 45 million (about USD 420,000) for construction costs, compared to an industry average of USD 40,000-100,000, according to a 2017 report published by the International Council on Clean Transportation.

In July 2013, METI announced a supplementary budget of JPY 100.5 billion in FY 2012 for the "project to promote the development of next-generation car charging infrastructure", in order to promote the further popularization of next-generation cars. Under this subsidy, four automaker leaders, Toyota, Nissan, Honda and Mitsubishi, two power companies and the Development Bank of Japan established a company, Nippon Charge Service, to deploy the installation of chargers for EVs across the country and maintain their network service[228]. This accelerated the charging infrastructure in Japan.

[226]GTM, August 9, 2018: https://www.greentechmedia.com/articles/read/electric-vehicle-charging-points-40-million-gtm?utm_source=GridEdge&utm_medium=email&utm_campaign=GTMGridEdge#gs.2QHmzWQ.
[227]Japantimes, January 25, 2018: https://www.japantimes.co.jp/news/2018/01/25/business/tech/plug-wars-leading-charge-battle-electric-car-supremacy/#.W48-CiQzbIV.
[228]Auto Prove, July 30, 2017: https://autoprove.net/toyota/138211/ (only in Japanese).

In September 2013, METI requested all of 47 prefectural governments established their plans to install charging infrastructure. Some of them launched their own subsidy schemes for installers.

Table 21: Subsidies for Charger Installation

Installation Site	Type	Elegibility	Subsidy Rate
En route charging (service areas on highways, stations on the way, convenience stores, car dealerships, etc)	Public	Apparatus	Fixed amount
		Construction	Fixed amount
Destination charging (hotels, shopping centers, etc)	Public	Apparatus	1/2
		Construction	Fixed amount
Basic charging (detached houses, apartments, workplaces, factories, etc)	Private	Apparatus	2/3 or 1/2
		Construction	Fixed amount
Billing devices	-	Apparatus	1/2
		Construction	Fixed amount

Source: Author, with data from METI [41].

Nissan reported that there were more EV charging points in Japan than petrol stations in 2016, with 40,000 charging points against 35,000 stations. However, many of those are in private homes[229]. According to IEA, there were 7,327 fast chargers in Japan at the end of 2017, and a total of 28,834 charging points nationwide [42]. METI think that they "have almost enough for the time being", with nearly 400 quick chargers installed along highways, but it could be insufficient if the number of EVs rapidly increase in the next years.

According to the Japanese map provider Zenrin, the largest numbers are located at car dealerships (2,300), convenience stores (1,000) and shopping malls (400). METI's goal is to have a fast charger every 15 km or within every 30 km radius. By region, 1,766 quick-charging stations, one-fourth of the nationwide total, are in Greater Tokyo, including Yokohama to the south, Saitama to the north and Chiba to the east. Elsewhere, there are 1,012 in Kyushu, 874 in the Kyoto-Osaka-Nara area, 834 in Aichi and surrounding prefectures and 716 in Tohoku[230].

METI will relax restrictions of the Fire Safety Law, which regulates where fueling stations can install plug-in points in their facilities, which makes difficult for many gas stations to add EV charging points, with the aim of revitalizing the distribution network and promote the

[229] World Economic Forum, May 9, 2016: https://www.weforum.org/agenda/2016/05/japan-now-has-more-electric-charging-points-than-petrol-stations?utm_content=bufferd2475&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer.
[230] WardsAuto, May 9, 2018: https://www.wardsauto.com/engines/hybrids-dominate-japan-makes-room-evs-0.

deployment of new generation cars. Currently, charging and refueling stations for electric and hydrogen fuel cell vehicles must be around 10 meters away from a gas pump. For small stations, that rule severely limits how many of these vehicles they can accommodate. METI is reviewing the standards to allow gas stations to install charging points alongside pumps regardless of space from FY 2019. The code would be relaxed on a trial basis while monitoring safety[231].

The Tokyo Metropolitan Government, through The Tokyo Metropolitan Area Global Warming Prevention Promotion Center (CoolNet Tokyo), started a new subsidy project called “project to promote the introduction of charging facilities etc. in apartment houses” from June 2018. It provides subsidies to the charging facilities of BEV and PHV installed in houses or apartment houses, but also to the PV power generation systems and storage batteries use as the power source of the charging facility. This subsidy will be conducted for three years, from FY 2018 to FY 2020, and it will cover 100% of the installation cost if it is combined with the national subsidy[232].

The price of charging differs depending on whether the user belongs to a payment plan. For example, Nissan offers Leaf owners a plan that provides unlimited charging at its high-speed charging stations (more than 5,500) for 2,000 yen/month, and a cheaper plan that costs 1,000 yen/month and then 15 yen/minute for high-speed charging and 1.5 yen/minute for regular charging. Nippon Charging Service, which operates about 20,000 charging stations on behalf of four car makers, also offers several plans that combine monthly fees of 3,800 yen for high-speed and 1,400 yen for regular, with fees of 15 yen/minute for high-speed and 2.5 yen/minute for regular-speed per use. Some EV owners charge their cars at home with a 200 volt outlet, taking about 8 hours to fully recharge a battery from zero using regular speed[233]. In July 2018, Volkswagen Group Japan began offering the "Volkswagen charging card" service for BEV and PHEV in the Nippon Charging Service network[234].

Most of the plugs used to charge EVs at home use alternating current (AC), and are slow, while fast chargers on the roads use more powerful direct current (DC), able to charge EVs up to seven times faster, within 10 minutes. There are several fast charging standards, in contrast to the universal nozzle that can refill all gas-powered cars. The four most spread fast charging standards are the following:

- Combined Charging System (CCS): it has about 7,000 charging points worldwide, with more than half in Europe, and has a double-plug than can charge DC and AC, which increases the number of points where drivers could recharge.

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[231] Asia Nikkei, February 21, 2018: https://asia.nikkei.com/Politics/Japan-paves-way-for-gas-stations-to-charge-up-electric-cars.

[232] Kankyo Business, June 12, 2018: https://www.kankyo-business.jp/news/020560.php (only in Japanese).

[233] Japantimes, January 12, 2018: https://www.japantimes.co.jp/news/2018/01/12/national/electric-vehicles-practical-economical/#.W480qyQzbIU.

[234] Kankyo Business, July 5, 2018: https://www.kankyo-business.jp/news/020723.php?utm_source=mail&utm_medium=mail180706_d&utm_campaign=mail (only in Japanese).

- Tesla's Supercharger system: it is exclusive to its customers and has about 10,900 charging points, mostly in the US[235].

- Charge de Move (CHAdeMO): it was developed by Japanese firms including carmakers Nissan and Mitsubishi, includes the V2G technology, and has more than 18,690 charging points, most in Japan and Europe, according to the CHAdeMO Association[236].

- GB/T: it has more than 127,400 charging points only in China, the world's biggest EV market, according to the China Electric Vehicle Charging Infrastructure Promotion Alliance. Considering the size of this market, no carmakers want to lose it. Tesla, for example, modifies its vehicles for China to add a second charge port compatible with this standard, same than other competitors.

Trying to increase the importance of the CCS standard, the IONITY project is a joint venture between car manufacturers Ford, BMW Group, Mercedes-Benz maker Daimler AG and the Volkswagen group, including Audi and Porsche, which are developing 400 high-power charging stations on main roads in 18 European countries by 2020, teaming up with companies that have service station networks in Europe, such as Shell, OMV, Germany's Tank & Rast and retailer Circle K[237]. On the other hand, the Swiss company ABB launched Terra High Power DC, a 350 kW high power car charger that will allow getting a range up to 200 km with just 8 minutes of charge[238].

However, in August 2018, CHAdeMO Association and China Electricity Council signed a MoU for co-development a next generation ultra-fast EV charging standard with more than 500 kW, which is expected to lead the way towards a single harmonized future standard, all the while ensuring backward compatibility with both current CHAdeMO and GB/T standards. The venture is not only focusing on the shape of the charging plug but also in the protocols, and it has been supported for both governments[239].
Nevertheless, a new technology that would solve this "war" would be the development of the wireless EV charging technology, which is the target of several research projects in this area, and would increase the interoperability of EV charging, which means ensuring car owners can charge their vehicles at any station regardless of vehicle size and type:

- Qualcomm Technologies, which has been developing the inductive technology for charging electric vehicles without cables with various car manufacturers for 7 years, ensures that wireless charging will be available in most cars that go into production after 2020. And the static wireless charging is just the first step in developing a dynamic wireless charge, where vehicles will be constantly charged while they are in circulation.

[235]Tesla: https://www.tesla.com/jp/supercharger.
[236]ChadeMo: https://www.chademo.com/.
[237] Japantimes, January 25, 2018: https://www.japantimes.co.jp/news/2018/01/25/business/tech/plug-wars-leading-charge-battle-electric-car-supremacy/#.W48-CiQzbIV.
[238] ABB, April 24, 2018: https://new.abb.com/news/detail/4439/abb-powers-e-mobility-with-launch-of-first-350-kw-high-power-car-charger.
[239] INSIDEEVs, August 24, 2018: https://insideevs.com/china-chademo-fast-charging/.

In May 2018, Qualcomm announced that, together with Renault and Vedecom and under the FABRIC project, mostly funded by the EU, it achieved to charge an EV traveling at highway speeds with 20 kW through the surface of a 100-meter-long test road[240]. Both Mercedes-Benz and BMW have already announced their intention of installing the wireless charging systems in their plug-in electric and hybrid models.

- WiTricity, the industry pioneer in wireless power transfer over distance, and Nissan announced in February 2017 a collaboration project to drive adoption of wireless EV charging systems. The WiTricity DRIVE™ wireless charging system allows for a charging pad on or under the ground that uses WiTricity's patented magnetic resonance technology to send energy to the vehicle parked above it, requiring no cables or moving parts[241].

- Toshiba has developed a safe, easy-to-use contactless battery charger using wireless power transmission for electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The test has verified that the charger has a capacity of 7 kW, which halves the charging time compared with the 3 kW-class wired onboard chargers that are most widely used in Japan. The charger controls both the power transmitter and receiver via wireless LAN and dynamically selects the optimal charging voltage[242].

- Nissan, Kansai utility KEPCO and electronics company Sumitomo are testing charging BEV and PHEV via remote control. The cars will be equipped with the hardware needed to enable remote charging and linked to a server for data collection. The initiative is part of the Kansai VPP Project[243].

- The Japanese Hi-Corp is developing, testing and will launch a wireless EV charging technology by 2019, that uses magnetic resonance coupling, which effectively supplies electricity even when the power source and the recipient are apart from one another. This technology would allow wireless EV charging on highways even when an EV is in motion.

In March 2017, the German and Japanese governments also signed a MoU to joint in research, develop and pilot of ultra-fast charging stations, focusing on the development of international standards for the interoperability of EV charging stations with grid networks.

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[240] Qualcomm, May 18, 2017: https://www.qualcomm.com/news/releases/2017/05/18/qualcomm-demonstrates-dynamic-electric-vehicle-charging.

[241] WiTricity, February 9, 2017: http://witricity.com/witricity-collaborating-nissan-wireless-charging-electric-vehicles/.

[242] Toyota: https://www.toshiba.co.jp/rdc/rd/fields/14_e01_e.htm.

[243] The Drive, January 12, 2018: http://www.thedrive.com/tech/17620/nissan-will-test-remote-electric-car-charging?iid=sr-link1.

4.2.3. V2G Connection

The Vehicle to Grid (V2G) technology allows bi-directional charging between electric vehicles and the energy grid system, providing energy when the demand is higher, or during an unexpected natural disaster, reinforcing the grid of that area and its stability. It also allows the owner to get revenues selling the energy of the EV's batteries to the system in those countries where this use is already regulated, reducing the cost of an EV's ownership.

In September 2018, Mitsui Sumitomo Corporation and Tokyo University of Marine Science announced the result of a demonstration test in the event of a blackout due to a disaster, and in which a residential elevator made 100 round trips to the top 43 floor with fully charged EV power supply, confirming the potential of the V2G technology[244].

EVs' battery has between 20 and 100 kWh storage capacity, larger than conventional house storage batteries available in the market, between 2 and 12 kWh most of them, and spend more than 90% of their lives parked. Therefore, V2G technology converts EVs into portable batteries and, as a consequence, into important grid assets and VPPs' sources, which can help with the load balancing and frequency regulation and being part of the energy solution.

Their charging could be shifted to the middle of the day, to absorb high levels of solar generation, and at night, when the demand for electricity is the lowest, and therefore cheaper, helping to integrate higher shares of variable renewable energy without interfering the stability of the grid, increasing the flexibility of the electricity system, and enabling higher decarbonization ratio of both transport and power sectors. Because of these advantages, V2G technology will support the increase of EVs' sales and manage the anticipated increase in electricity demand. Regulation is needed to facilitate and enable energy storage in the EVs' batteries to be used and sold in the grid.

Technical and economic viability has already been demonstrated in a variety of markets and pilot projects. Europe has taken the lead in this development, as it is currently conducting approximately 55% of all global V2G projects, according to IHS Markit. The Japanese automaker Nissan is at the forefront of V2G technology.

For example, a Japan (NEDO) and US collaborative smart grid demonstration project (JUMPSmart Maui) successfully implemented a V2G program on the island of Maui, Hawaii, between October 2011 and February 2017. EVs' batteries were used for providing ancillary service to the grid. The system shifted EVs charging peak to the time when more renewable were expected to be available. The Japanese HITACHI and Nissan participated in this project, which had a budget of JPY 6.4 billion [41].

A collaborative project between Spain and Japan in Malaga demonstrated load management by EVs and demand response during the period between 2012 and 2015 [44]. BMW and

[244] Kankyo Business, September 4, 2018: https://www.kankyo-business.jp/news/021082.php?utm_source=mail&utm_medium=mail180905_d&utm_campaign=mail (only in Japanese).

Californian utility PG&E successfully tested managed EV charging as a grid resource in the San Francisco Bay in a project ending in December 2016.

The American company Nuvve Corporation is already operating V2G projects that utilize PHEVs/BEVs in Europe and the US, providing frequency regulation service to each electrical grid. It partnered with automotive manufacturer Nissan and energy company Enel to commercially integrate and host V2G units at its headquarters in Copenhagen, Denmark [43].

In March 2015, Endesa (Enel) and Nissan signed an agreement to study the commercial development of V2G technology in Spain, and the second use of exhausted electric vehicle batteries, which can continue to be used with less intensive uses before being recycled[245]. In May 2016, both companies, Nissan and Enel, launched the first-ever V2G trial in the UK comprising of 100 V2G units at locations agreed by private owners of Nissan Leaf and eNV200 vehicles. They had the flexibility to sell stored energy from their vehicle battery back to the grid[246].

In January 2018, Nissan announced a V2G demonstration project in 1,000 installations across the UK with £9.8 million funding from the government to understand the technical characteristics of V2G charging for both the vehicles and electricity networks involved. Nissan will lead a consortium with V2G infrastructure/aggregator provider Nuvve, two distribution network operators, UK Power Network and Northern Powergrid, and Newcastle University and Imperial College London, which will support the research and analysis[247]. This is part of 21 projects (8 feasibility studies, 5 collaborative research and development projects, and 8 real-world V2G trial projects) funded in the UK by Office for Low Emission Vehicles and the department for Business Energy and Industrial Strategy, and delivered by Innovate UK, in January 2018, with a total budget of £30 million, to develop the business proposition and core technology around V2G, and demonstrate those with large-scale trials. The projects involve more than 50 industrial partners and research organizations from both the energy and automotive sector, marking the largest and most diverse activities on V2G in the world.

Because of that development, Nissan launched a combined solar panel and energy storage system for UK households, to reduce their carbon footprint and energy bills by as much as 66%. The new product also includes a HEMS to allow users to control how and when they want to use their energy, and a charger for the Nissan vehicle[248]. It is the same that Tesla did in the US, but with the difference that Nissan is using old EVs' batteries in its storage units, making them as environmentally friendly as possible.

[245] Endesa, March 12, 2015: https://www.endesa.com/es/prensa/news/d201503-endesa-y-nissan-se-alan-para-dar-un-nuevo-impulso-a-la-movilidad-elctrica-en-europa.html (only in Spanish).

[246] Nissan, May 10, 2016: https://newsroom.nissan-europe.com/uk/en-gb/media/pressreleases/145248/nissan-and-enel-launch-groundbreaking-vehicle-to-grid-project-in-the-uk.

[247] Nissan, January 30, 2018: https://newsroom.nissan-europe.com/uk/en-gb/media/pressreleases/426218103/media-advisory-governments-announcement-on-nissan-led-vehicle-to-grid-iuk-winning-project1.

[248] Engadget, May 17, 2018: https://www.engadget.com/2018/05/17/nissan-energy-solar/.

Next Kraftwerke, a VPP operator, and Jedlix, an EV aggregator and smart charging platform provider, will work on a two-year project from 2019 to test if EVs' batteries can deliver automatic frequency reserve through the transmission system operator TenneT grid in the Netherlands and large part of Germany[249].

In the "EV & PHV roadmap" published by METI in March 2016, it was defined the importance of BEVs & PHVs as a backup power supply in the event of a power outage through the V2G technology. But also their use as energy storage systems to stabilize the power grid and to smooth power demand, using them as VPPs sources and encourage a more active cooperation of the local governments to incorporate them into plans to reduce global warming.

Since the demonstration projects of the V2G technology conducted in Japan are part of the VPPs projects, they will be described in the corresponding Chapter 5.2.

4.2.4. Solar Panels in Electric Vehicles

As logic next step for both solar panels and electric vehicles, there is a new market integrating solar panels on the roof of electric vehicles, buses and trucks to feed the electric auxiliary systems, such as lights or air conditioning, charge the battery and increase therefore its range. Though it is a technology in an early-stage yet, there are already examples from large manufacturers and small startups that show its potential as a future business. R&D projects will become also a good opportunity in this market for domestic and foreign stakeholders in order to get more power from the solar panel roofs.

In September 2016, a2-solar launched the solar roof of the new KARMA Revero plug-in-hybrid car, originally Fisker KARMA, with a solar roof module of 200 W. Its overall range is 500 km without recharging and refueling, and on pure electric mode, it is even up to 80 km[250]. The a2-solar's solar roof system was also integrated into the Audi e-tron in 2015, with 400 W, and the Volvo Super Truck in 2016, with 270 W.

In February 2017, Panasonic announced that its 180 W HIT technology solar roof panel would optionally energize Toyota Prius Prime in the Japanese market, for powering electric accessories and charge the battery. Tesla also announced that their Model 3 will probably have a solar roof option, and Nissan offers an optional small solar panel for is Leaf model to provide power to the electronic accessories like the air conditioning[251]. According to Toyota, the solar roof in the Prius model only provides about 6 extra kilometers.

[249] Energy Storage, September 13, 2018: https://www.energy-storage.news/news/virtual-power-plant-to-test-if-electric-vehicle-batteries-can-deliver-frequ.
[250] a2 solar: https://a2-solar.com/en/new-solar-car-roof-module-karma-revero/.
[251] Hybrid Cars, March 1, 2017: https://www.hybridcars.com/panasonic-solar-roof-will-energize-toyota-prius-prime-in-japan/.

Furthermore, and under a 2018 NEDO project, Panasonic and Sekisui Chemical are developing a new technology of flexible very thin solar panels with perovskite instead of silicon, which could be used on the bodywork of electric cars, even on the curved surfaces. Besides, perovskite is a lighter material and its production costs are lower than current silicon panels, but less durable[252].

In July 2017, the German company Sono Motors presented Sion, an electric car capable of recharging its batteries from 330 solar cells integrated on the body of the vehicle, enough to cover 30 km per day under proper conditions. Its battery, manufactured by the also German ElringKlinger, provides autonomy of 250 km, and can also be charged at a recharging point. The cost will be 16,000 € excluding the battery and 20,000 including it, and the distribution will begin in 2019. They have had over 5,000 reservations from more than 30 countries in two years[253].

In 2017, the Dutch manufacturer Lightyear launched the Lightyear One electric car, powered by solar energy, which can drive for months without charging and has autonomy of between 400 and 800 km depending on the battery configuration[254].

In August 2017, Audi announced cooperation with Alta Devices, a subsidiary of the Chinese solar energy company Hanergy, to incorporate thin-film solar photovoltaic roofs in all its electric cars in order to increase the autonomy of those vehicles. The electricity generated will flow into the car's electrical system to supply power to the air conditioning system or the heated seats[255]. Hanergy already applied that concept in four vehicles in 2016, though without a commercial production. It also signed a collaboration agreement with the French industrial holding company Bolloré in 2018 to develop and manufacture electric cars powered by thin-film solar panels and solid electrolyte batteries through their respective subsidiary companies, Donghan New Energy Automotive Technology and Bluecar[256].

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252 Híbridos y Eléctricos, March 26, 2017: https://www.hibridosyelectricos.com/articulo/tecnologia/coche-electrico-podria-usar-paneles-solares-valen-premio-nobel/20180326090617018416.html (only in Spanish).
253 Sono Motors: https://sonomotors.com/.
254 Lightyear: https://lightyear.one/.
255 Híbridos y Eléctricos, August 24, 2017: https://www.hibridosyelectricos.com/articulo/tecnologia/audi-incorporara-techos-solares-fotovoltaicos-todos-coches-electrificados/20170824122302014876.html (only in Spanish).
256 Híbridos y Eléctricos, August 4, 2018: https://www.hibridosyelectricos.com/articulo/actualidad/hanergy-bollore-cooperaran-desarrollar-coche-electrico-movido-energia-solar/20180803210301020841.amp.html (only in Spanish).

4.3. REUSE AND RECYCLING BUSINESSES

About 50% of batteries installed in electric cars are recycled after 5 to 7 years, when they still have between 60% and 80% of their original capacity, being sufficient to run a profitable second business, in which both material and financial costs can be distributed across a longer life-cycle. New storage systems cost can be as much as USD 1,000/kWh. The cost of a reuse EV's battery converted to stationary could be less than the half[257]. Since their use will be less stressful, that second-life batteries could be used for another 10-15 years before being recycled, according to a study presented at BEE in 2016. After that, batteries can be recycled to harvest raw material, so automakers and battery producers can profit from the same pack several times.

The study says that Germany's plan includes 1 million of EVs on the road by 2020. Considering an average size of 40 kWh per battery, a secondary life rate of 80%, and a battery upgrade after 7 years, it means 25 GWh of second-life storage capacity for the country. According to BNEF, global pool of EVs' used batteries is ready to grow rapidly, reaching 200 GWh by 2025[258]. In 2030, when the number of EVs sold worldwide is expected to reach 88 million, the cumulative installed capacity of secondary batteries will increase up to 1,000 GWh[259].

The EU signed a voluntary agreement in March 2018 to identify barriers to the reuse of batteries from EVs and explore ways to ensure that EU rules promote their recycling and reuse[260]. China, where about half the world's EVs are sold, has established a system to make carmakers responsible for used and retired batteries, and transport them to companies contracted to process and recycle. Those guidelines will take effect from August 2018, in an effort to boost the development of the fast-growing market. To facilitate recycling, car battery producers should adopt standardized and easy-to-dismantle designs[261].

There are already a lot of projects worldwide with a secondary use of the EVs' batteries, also in Japan:

- In November 2015, automaker Daimler and Getec Energie started a "second use" project of EVs' batteries of 13 MWh system installed at a recycling facility in Lünen, Germany.

- Wärtsilä, a Finnish-based energy-solution provider, signed an agreement with automobile producer Hyundai Motor Group in June 2018 to establish a commercial

[257] PV Magazine, August 25, 2016: https://www.pv-magazine.com/2016/08/25/second-life-ev-batteries-could-drive-low-cost-storage-sector-says-bnef-report_100025911/.
[258] Bloomberg, June 27, 2018: https://www.bloomberg.com/news/features/2018-06-27/where-3-million-electric-vehicle-batteries-will-go-when-they-retire.
[259] PV Magazine, April 7, 2016: https://www.pv-magazine.com/2016/04/07/study-second-life-ev-batteries-to-offer-1-twh-capacity-by-2030_100024056/.
[260] European Commission, March 12, 2018: https://ec.europa.eu/info/news/european-commission-tackles-barriers-innovation-second-innovation-deal-focuses-batteries-electric-vehicles-2018-mar-12_en).
[261] ECNS, March 5, 2018: http://www.ecns.cn/business/2018/03-05/294592.shtml.

partnership for the use of second-life EVs' batteries for utility-scale and C&I storage solutions[262].

- From beginning 2018, batteries from Nissan's Leaf will help illuminate streets in Namie, a Japanese coastal town, as part of an effort to rebuild the town's infrastructure after the earthquake and tsunami of 2011. The system is completely independent of the grid, and batteries could be used as an emergency power source in case of power outages[263]. Also a mix of new and used batteries from 148 Nissan Leaf batteries, a total storage capacity of 2.8 MWh, power Amsterdam Stadium from June 2018[264].

- Toyota will install retired batteries outside 7-Eleven stores in Japan in 2019. The hybrid batteries will store power from solar panels, and then use it when needed to help run the drink coolers, fried chicken warmers and sausage grills inside the stores[265].

- Nissan partner Renault is using second-life batteries as part of its "smart island" project on an island off the coast of Portugal[266].

- CONNEXX SYSTEMS, a Japanese manufacturer of storage systems based on Kyoto Prefecture, will take used EVs' batteries for using as stationary energy storage systems in India, in a feasibility study project for solving the problems of the grid with a larger penetration of renewable generation[267].

- Chubu Electric Power and Toyota Motor Corporation started a verification project that implies the construction of a large-capacity storage battery system that reuses batteries from EVs manufactured by Toyota, which will be used for energy supply-demand adjustments, frequency fluctuation management and voltage fluctuation management in distribution systems, all factors derived from the widespread introduction of renewable energy. They will also establish a mechanism to recycle reused batteries by collecting materials such as rare-earth metals and re-utilizing them[268].

[262] PV Magazine, June 28, 2018: https://www.pv-magazine.com/2018/06/28/wartsila-hyundai-ink-agreement-on-second-life-ev-batteries-for-grid-storage-comment/.
[263] Nissan, March 22, 2018: https://newsroom.nissan-global.com/releases/release-487297034c80023008bd9722aa000f93-180322-01-j.
[264] The Drive, July 4, 2018: http://www.thedrive.com/tech/21946/nissan-uses-148-leaf-batteries-to-power-amsterdam-stadium.
[265] Bloomberg, June 27, 2018: https://www.bloomberg.com/news/features/2018-06-27/where-3-million-electric-vehicle-batteries-will-go-when-they-retire.
[266] The Drive, February 21, 2018: http://www.thedrive.com/tech/18666/renaults-smart-island-is-powered-by-renewable-energy-and-used-electric-car-batteries?iid=sr-link8.
[267] Kankyo Business, June 1, 2018: https://www.kankyo-business.jp/news/020494.php?cat=recycle (only in Japanese).
[268] Chubu Electric Power, January 21, 2018: http://www.chuden.co.jp/english/corporate/ecor_releases/erel_pressreleases/3266976_18939.html.

Recycle

The global battery recycling market was valued at about USD 10 billion in 2017 by Transparency Market Research, which predicts an annual growth rate of 11% until 2026, when the market worth will be over USD 25 billion[269]. In terms of battery chemistry, lead-acid was the dominant segment with more than 45% share, and it is expected to keep leading the market during the forecast period. However, Li-ion batteries will expand quickly in the next years due to fast deployment of EVs. The extraction of materials made up more than a 45% share of global battery recycling practices in 2017. Battery recycling is also important for efficient waste management in order to eliminate hazardous environmental impacts.

With their increased use in the automotive industry, as well as in a wide variety of devices, the need to recycle Li-ion batteries is becoming critical. According to a new report by Circular Energy Storage, an estimated 58% or 97,000 tonnes of Li-ion batteries will be recycled once they reach end-of-life stage in 2018. This figure is up from 55% in 2017. Therefore, over 14,000 tonnes of cobalt and upwards of 5,000 tonnes of lithium will enter the Li-ion battery supply chain in 2018 from recycled batteries and production scrap[270]. Creation Inn estimates that the total amount of recycled lithium (lithium carbonate) and cobalt could reach 5,800 to 30,000 tonnes and 22,500 tonnes, respectively, by 2025[271]. Raw materials account for 50% to 70% of the cost of lithium battery cells, according to Avicenne Energy firm. Copper, cobalt, manganese and nickel also have high recycling value, and they are already important components in today's batteries, and some manufacturers, especially in China, rely on them.

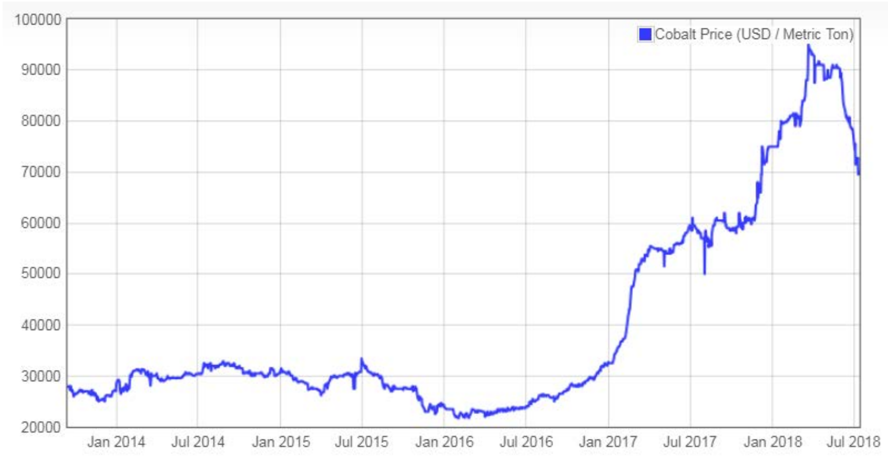
According to the China Association of Automobile Manufacturers, a total of 777,000 electric cars and plug-in hybrids were sold in the Chinese market in 2017, and 5 million are expected on its roads by 2020. The Ministry of Industry and Information Technology expects retired batteries will weigh around 200,000 tons by 2020, and The China Automotive Technology and Research Center estimated that figure would reach 350,000 tons by 2025. Therefore, China Securities Journal says that the battery recycling segment is a new gold mine thanks to its market size, which stands at 5 billion yuan (around USD 788 million) in 2018, and is expected to double by 2020. The vast potential is attracting companies to this sector. For example, in January 2018, China Tower signed agreements with 16 Chinese car and battery-maker companies in battery recycling, with BYD and Chongqing Changan Automobile among the partners[272].

At the beginning of 2016, the price of one tonne of cobalt was around USD 23,000, and it grew up until around USD 95,000 in March of 2018 (Figure 55). Battery makers and energy storage researchers are working to find a substitute for cobalt, or at least reduce its required quantity.

[269] Recycling International, July 27, 2018: https://recyclinginternational.com/batteries/battery-recycling-market-worth-over-25-billion-dollars-by-2026/.
[270] Recycling International, June 21, 2018: https://recyclinginternational.com/batteries/second-life-how-recyclers-can-capitalise-on-the-true-value-of-batteries/.
[271] Waste Management World, April 27, 2018: https://waste-management-world.com/a/in-depth-lithium-battery-recycling-the-clean-energy-clean-up.
[272] ECNS, March 5, 2018: http://www.ecns.cn/business/2018/03-05/294592.shtml.

UK consultant Creation Inn estimates that around 20% of cobalt will be recycled by 2025, while new chemistries aim to reduce its use. However, that will not have a big impact on the supply chain or pricing because of the expected growth in demand.

Figure 55: Cobalt's Price



Source: Daily Metal Prices[273].

Some of the raw materials needed for batteries are extracted with a high human and environmental cost. The Democratic Republic of Congo has 60% of the cobalt mined resources, with high levels of corruption, child labor and unhealthy and unsafe working conditions. Most of the mining companies working in the Democratic Republic of the Congo are Chinese, which could allow China to develop a monopoly on cobalt's supply.

In 2017, the Global Battery Alliance was established to create a responsible value chain for the battery market, from the mining and chemical industries to manufacturers, electronics, automotive and energy businesses. They are joining forces with UNICEF, the African Development Bank and other international organizations to create a responsible global supply of batteries to safeguard workers, ban child labor, eradicate pollution and promote re-use and recycling[274].
Indeed, some blockchain firms are creating ethical sourcing platforms amid these concerns over mining conditions, such as the partnership between Cobalt Blockchain and DLT Labs to develop a mineral traceability, Mintrax, which complies with the Organisation for Economic Co-Operation and Development's framework for the provenance of ethically sourced minerals.

[273] Daily Metal Prices: https://www.dailymetalprice.com/metalpricecharts.php?c=co&u=lb&d=0.
[274] Waste Management World, April 27, 2018: https://waste-management-world.com/a/in-depth-lithium-battery-recycling-the-clean-energy-clean-up.

Circulor, another blockchain startup, is working on a pilot project for BMW to map cobalt[275]. The blockchain's potential in the Japanese's energy market can be checked in Chapter 5.3.

A research project named 'Automotive Battery Recycling 2020' launched by the German Fraunhofer Institute in June 2018 and funded by the EU is identifying efficient and environmentally recycling practices for EVs' batteries and getting "a truly smart and economically attractive value chain"[276].

The recycling market is currently dominated by Asian players. The largest volumes of Li-ion batteries are exported to China, where technology is. Some recycling companies pointed out that while lithium is a cheap raw material, recovery is an expensive process. Therefore, the problem in Europe has been mainly economic, while the question from Creation Inn firm is whether the Asian players are really having a profitable business or if they are being supported by the governments in order to create a powerful industry in a fast-growing market[277].

The South Korean company SungEel HiTech, a battery recycler leader, confirms that the country's recycling market is booming, and it has already increased its recycling capacity threefold this year[278]. Samsung SDI and LG Chem are some of its big customers. SungEel HiTech processes about 8,000 tonnes of discarded Li-ion batteries and metal scrap annually, which produces around 830 tonnes of lithium phosphate, 1,000 tonnes of cobalt metal equivalent and 600 tonnes of nickel. It will increase its capacity to 24,000 tonnes by 2019.

SungEel HiTech also cooperates with Posco, which produces steel and converts lithium phosphate into lithium carbonate, which is the commodity itself. The facility that Posco opened in South Korea in 2017 produces 2,500 tonnes of that commodity each year, enough to manufacture about 70 million of new batteries for laptops[279]. It sells part of the lithium carbonate to battery manufacturers LG Chem and Samsung SDI, closing the loop of the Korean market.

China has several companies working on the batteries recycling business. Ganfeng Lithium produces and recycles lithium, reaching 1,000 tonnes of lithium carbonate from used batteries in 2017. Guangdong Brunp Recycling Technology Co. Ltd., a subsidiary of the automotive battery maker CATL, produces few hundred tons of lithium carbonate but is about to scale it up. Brunp processes more than 6,000 tons of waste batteries and produces 4,500 tons of hydroxide of nickel, cobalt and manganese with a total yield of more than 98.58%. Its recycling capacity is

[275] GTM, August 21, 2018: https://www.greentechmedia.com/articles/read/blockchain-firms-see-rich-seam-in-ethical-materials#gs.QHjFoYE.
[276] Recycling International, June 13, 2018: https://recyclinginternational.com/e-scrap/how-to-bring-car-battery-recycling-to-a-higher-level/.
[277] NyTeknik, April 10, 2018: https://www.nyteknik.se/energi/experterna-har-ar-pionjarerna-som-redan-atervinner-litium-6908006 (only in Swedish).
[278] Recycling International, May 4, 2018: https://recyclinginternational.com/batteries/south-korean-battery-recycler-riding-the-e-cycling-wave/.
[279] NyTeknik, April 10, 2018: https://www.nyteknik.se/energi/experterna-har-ar-pionjarerna-som-redan-atervinner-litium-6908006 (only in Swedish).

the largest in Asia. BYD, the Chinese manufacturer of EVs, is also building a battery recycling plant in Shanghai in 2018.

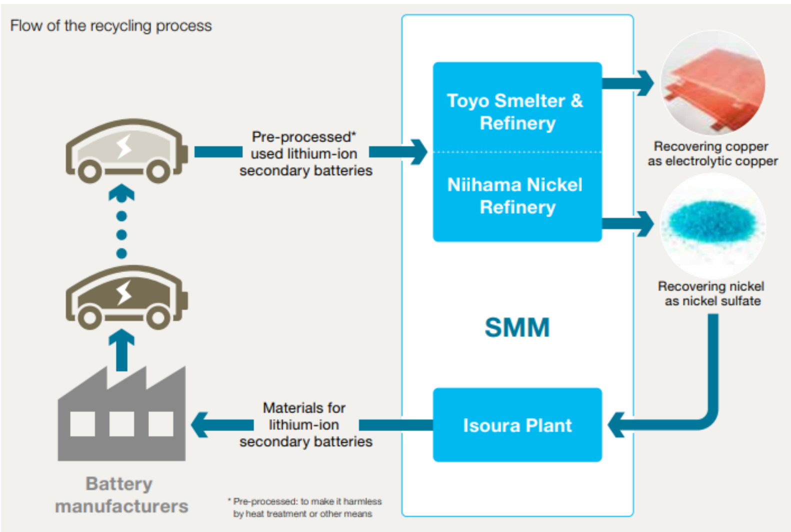
German ALBA Group subsidiary Interseroh and the Saubermacher recycling company established a joint venture in 2018 for the collection and recycling of Li-ion batteries. Its facility at Bremerhaven, in north Germany, has the capacity to process 10,000 tonnes of Li-ion batteries per year[280].

UK-based recycling major Axion, the remanufacturing and reuse company Aspire Engineering Ltd., and the Li-ion battery reuse specialist Aceleron will focus on the reusing and recycling of EV's used batteries market. They estimate that around 100,000 end-of-life batteries from EVs will be recycled or reused in UK over the next decade[281].

In Japan, consumers pay recycling fees in advance when they purchase new vehicles, and reusable parts and metals are collected when they are scrapped. Automobile companies formulated voluntary collecting system about NiMH and Li-ion batteries.

In July 2017, the manufacturer company Sumitomo Metal Mining Co., Ltd. achieved the first practical "battery to battery" recycling process in Japan for EVs' Li-ion batteries, recovering copper and nickel from used batteries and producing cathode material for Li-ion batteries[282] (Figure 56).

Figure 56: Flow of the SMM's "Battery to Battery" Recycling Process



Source: Sumitomo Metal Mining Co., Ltd.

280 Recycling International, June 15, 2018: https://recyclinginternational.com/business/first-global-recycling-service-for-lithium-ion-batteries/.
281 Recycling International, August 30, 2018: https://recyclinginternational.com/business/triple-a-partnership-tackles-end-of-life-batteries/.
282 Sumitomo Metal Mining Co., Ltd.: http://www.smm.co.jp/E/ir/library/annual/pdf/2017EN_22.pdf.

Toyota is also developing technologies to recycle rare metals and non-ferrous metals from Li-ion batteries. In partnership with Toyota Chemical Engineering Co., Ltd, Sumitomo Metal Mining Co., Ltd. and Primearth EV Energy Co., Ltd., it started a "battery to battery" recycling operation for NiMH batteries from hybrid vehicles in 2010, but in comparison, Li-ion batteries use fewer metal resources to produce the same capacity[283].

In March 2018, 4R Energy Corporation, a joint venture between Nissan and Sumitomo Corporation established in 2010 will operate the first plant specializing in the reuse and recycling of used Li-ion batteries from EVs in Japan[284]. This new factory, which is set up in Namie, in eastern Japan, can process 2,250 battery packs per year. The batteries recycled and refabricated will be used to offer the world's first exchangeable refabricated battery for EVs, sold for 300,000 yen in Japan, and will be also used in large-scale storage systems and electric forklifts. 4R may consider partnering with other company to retrieve reusable materials.

In August 2018, the Strategic Commission for the New Era of Automobiles released a report with the strategies that the Japanese automobile industry should take to lead global innovations and proactively contribute to solutions to global issues including climate change. It included the development of a battery system, establishing guidelines for evaluating the health of Li-ion batteries used in EVs, building up a scheme to collect used batteries and creating battery reuse/recycle markets in FY 2018[285].

[283] Toyota, October 27, 2010: http://www2.toyota.co.jp/en/news/10/10/1027.html.

[284] Nissan, March 26, 2018: https://newsroom.nissan-global.com/releases/release-487297034c80023008bd9722aa069598-180326-01-e.

[285] METI, August 21, 2018: http://www.meti.go.jp/english/press/2018/0831_003.html.

5. VIRTUAL POWER PLANTS AND DEMAND RESPONSE IN JAPAN

Since the Great East Japan Earthquake of March 2011, the necessity of suppressing power consumption on the demand side rose in Japan, and the government has been promoting a low-carbon society through energy efficiency and the development of a stable and reliable supply of renewable energy, reducing electricity cost and CO_2 emissions.

However, the rapid adoption of renewable energies in Japan, especially solar energy, has brought problems affecting the stability of the power grid, including output fluctuations and surplus power generation. A conventional solution for stabilizing the grid uses the thermal power, which means large costs for owning, operate and maintain that kind of power plants. Therefore, virtual power plants (VPPs) are being promoted as a cheap and clean solution.

Several market dynamics are driving forward the interest in behind-the-meter demand response (DR) and VPPs in Japan. As it has been said, the grid is constrained in some regions because of the large growth of the solar market after the introduction of the FIT scheme in 2012. In November 2019, thousands of houses will start to see their FIT agreement established in 2009 expire, and storage battery will be a way to maximize the value of their PV solar system (Figure 15). The liberalization of the electricity retail market, which will be completed by 2020, brought hundreds of new suppliers. By that time, capacity and real-time energy trading markets will be opened, and the law of the "zero-energy" for new residential buildings will be ready, which will also involve solar PV systems, storage batteries and HEMSs. Therefore, energy storage batteries will be on the heart of the Japanese energy transition, and their deployment will keep being promoted for using them as an aggregated and flexible resource[286]. Smart meter rollouts will be completed across the country by 2024. More than 200,000 EVs are in Japan, a number that will grow in the coming years, becoming EVs' batteries an important and large VPP and DR sources.

As the share of VRE grows, the need for players who can quickly and flexibly balance their fluctuation grows too, including the importance of automated demand response (ADR) solutions. A VPP digitally integrates/aggregates the energy and power capabilities of large numbers of connected distributed energy resources (DERs), mainly solar plus storage systems at households and commercial businesses, but also highly efficient energy equipment (air conditioners, heat sources, generators, thermal storage tanks, etc), and EVs' batteries through the V2G technology, which are growing rapidly. It remotely monitors and controls that energy generated and stored through accurate HEMSs, and adjusts the energy supply and demand.

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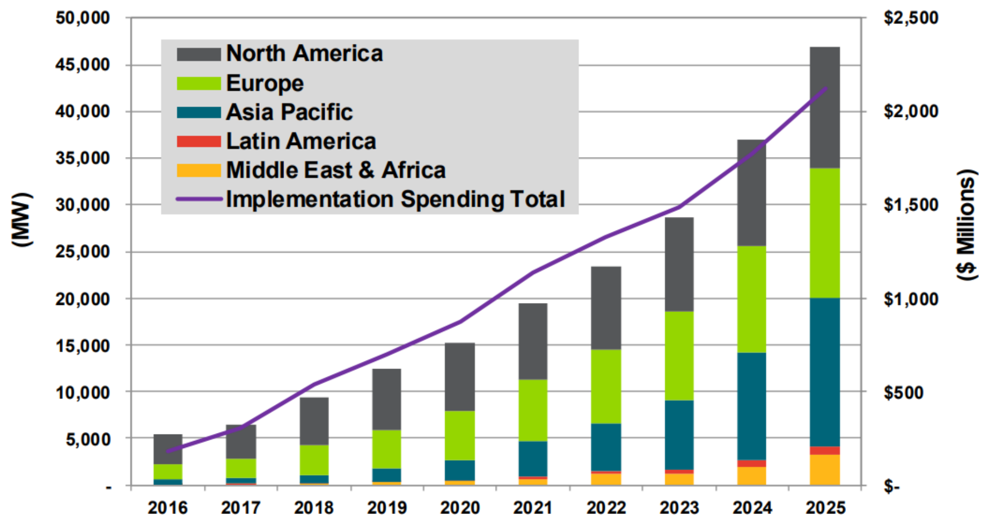
[286] Energy Storage, June 27, 2018: https://www.energy-storage.news/news/japanese-solar-pv-players-join-telecoms-and-utilities-in-creating-virtual-p.

A VPP replaces the 24/7 centralized thermal power plants as adjustment power, providing the same essential services. But it also promotes the expansion of more distributed renewable energy resources, reduces CO_2 emissions, improves the energy self-sufficient rate, reduces the energy cost and increases the stability of the electricity system. Therefore, the world's electricity system is shifting from centralized to distributed models, which additionally offer passive consumers the possibility of becoming to active prosumers who can produce, store, consume and sell their own energy through new technologies.

The U.S. Energy Information Administration notes that the cost of building a new coal-fired power plant ranges from USD 2,934 to USD 6,599 per kW, and from USD 676 to USD 2,095 per kW for a natural gas-fired plant, both options with environmental and investment risks. Often, utilities activate large and less efficient power plants to deal with small gaps in demand, deploying a 600 MW gas plant when only 5 MW is needed. On the other hand, VPP maintains a reliable supply and demand balance of the electric grid at a cost of about USD 80 per kW. In addition, when the operator asks for 5 MW, a VPP will look for places to reduce load, so the system may not need the 5 MW, or will look for places where electricity could be self-generated by discharging batteries or dispatching hydropower, wind or solar facilities.

In 2016, Navigant Research estimated the total VPP market in USD 731.4 million, including the investment in energy storage, growing until USD 68.6 billion by 2025, with North America capturing 38.1% share, Asia Pacific 34.6% and Europe 26.4%[287].

Figure 57: World's Annual VPP Capacity and Implementation Cost by Region, excluding Energy Storage



Source: Navigant Research ("Virtual Power Plant Enabling Technologies Report, 3Q 2016").

[287] Energy Storage, November 1, 2016: https://www.energy-storage.news/blogs/transforming-the-market-for-virtual-power-plants-with-advances-in-energy-st.

“Energy storage is not a prerequisite to the creation of a VPP. Instead, it enhances the flexibility and underlying value of other generation and load assets being assembled within the mixed asset VPP portfolio. Once storage is included in a VPP, it becomes dispatchable and schedulable, and other assets that are not schedulable become more attractive”. Despite the great value of energy storage assets being deployed within VPPs, the main driver for their implementation is still software. Its cost will represent nearly 90% of total VPP implementation cost by 2025, excluding energy storage. According to Navigant Research, global VPP implementation cost excluding energy storage will reach USD 2.1 billion per year by 2025, of which USD 1.8 million annually will be spent in software.

A more recent research report published at the beginning of 2018 by P&S Market Research projected the global VPP market to reach USD 5.5 billion by 2023, mainly driven by the growing penetration of renewable energy sources[288].

Some of the major players operating in the global VPP market are Enbala Power Networks Inc. (Canada), AutoGrid Systems Inc. (US), Sunverge Energy Inc. (US), Siemens AG (Germany), AGL Energy Limited (Australia), Limejump Ltd (UK), EnerNoc Inc. (US), ENGIE Storage Services NA LLC (US), ABB Ltd. (Switzerland), Schneider Electric SE (France), Sonnen (Germany), Itron Inc. (US) and GE Energy Company (US).

At the beginning of 2018, it was announced that Tesla, with support from the South Australian government, will develop the world’s largest virtual power plant, 250 MW, with at least 50,000 home solar PV and Tesla storage battery systems across South Australia over the following four years. The participants’ energy bill will be reduced by 30%, and all South Australians will benefit with lower energy prices and increased energy stability[289].

Also in Australia, the utility Origin Energy will launch a 5 MW VPP (650 home solar-plus-battery storage systems) in the state of Victoria, aggregating capacity to the grid particularly at times of peak demand. It will be supported financially by the Microgrid Demonstration Initiative of the Victorian government with AUD 10 million[290].

Elsewhere, Green Mountain Power offers discounts or no-money-down deals to its customers in the US state of Vermont on Tesla Powerwalls if the customers allow the utility to use the batteries as a grid resource. Moixa and Reposit Power in the UK offer their customers payments in return for their batteries being used for capacity, frequency regulation and other network services.

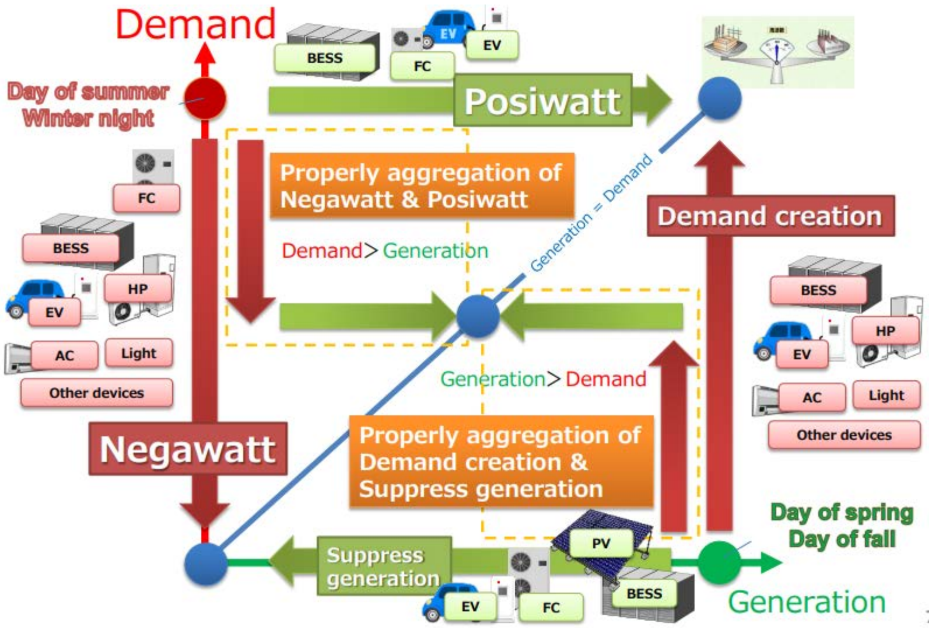
[288] POWER, February 4, 2018: https://www.powermag.com/press-releases/global-virtual-power-plant-market-will-hit-5-5-million-value-by-2023/.
[289] OILPRICE, February 8, 2018: https://oilprice.com/Alternative-Energy/Solar-Energy/The-Worlds-Largest-Virtual-Power-Plant.html.
[290] Energy Storage, September 5, 2018: https://www.energy-storage.news/news/first-5mw-virtual-power-plant-from-major-utility-origin-gets-funding-in-vic.

5.1. NEGAWATT TRADING MARKET

The negawatt or negative watt trading market is an incentive-style DR that conserves electricity at the timing of the electricity peak demand based on prior agreements with aggregators, which control the flow of transactions. Generally speaking, about 10% of the cost of the electric power system is spent on peak demand, less than 1% in the time proportion. Therefore, by suppressing peak demand, it is possible to reduce power generation costs.

A negawatt aggregator, or negawatt business operator, integrates and controls resources of various customers (DERs) using remote control technology (HEMS/BEMS), internet of things (IoT) and big data analysis, making it functions as if it was a single power station, providing services to power generation businesses, power distribution and transmission businesses, and electricity retailing businesses. Based on requests from electric power companies when the supply and demand of electricity is tight, they issue ADR orders depending on the situation of each customer (usage situation and equipment) to control their electric power demand (consumption) from the demand side for short periods of time, and thus securing electric power and stabilizing the electricity grid (Figure 58). In contrast, the conventional approach adjusts supply and demand in the electric power system by increasing or decreasing the amount of electricity generation on the supply side.

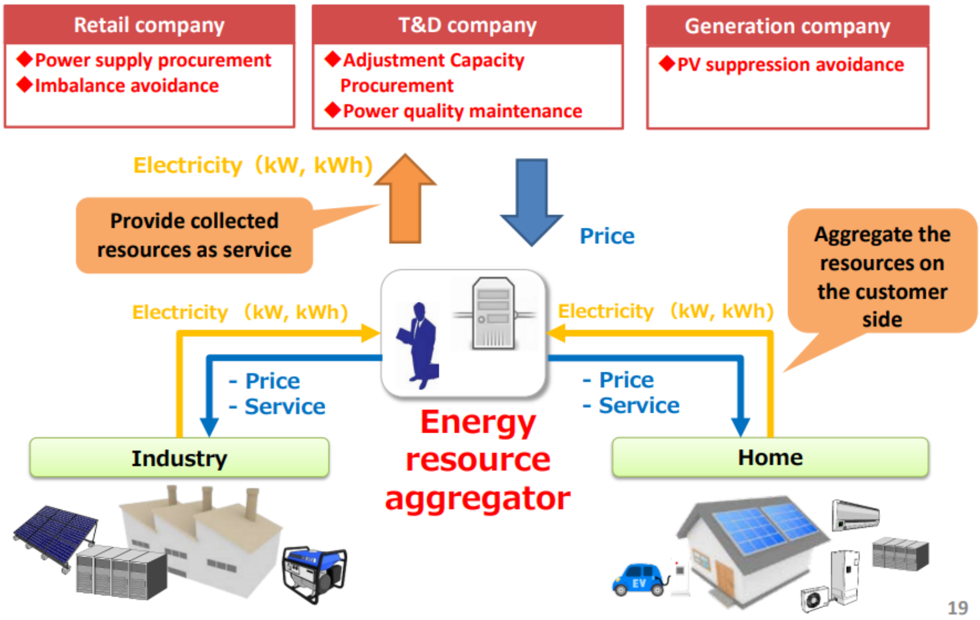
Figure 58: Energy Resources Aggregation



Source: Waseda University [45].

An aggregator is, therefore, a mediator between consumers and electric power companies. The electric power companies pay a reward to the aggregator against the amount of electricity saved generated by its service, and customers receive a reward from the aggregator for controlling their electricity demand. Even small customers can be treated as resources, participating in the electric trading market through aggregators, and getting rewards in addition to reducing electricity charges because of the energy saving (Figure 59).

Figure 59: Business of Energy Resource Aggregator



Source: Waseda University [45].

The types of rewards that consumers can receive are:

- kW regard: the demand response may be invoked at any time decided by the contract, meaning that the customer needs to have a system that can respond to any invocation. Regardless of actual activation or not, it is a remuneration paid according to capacity (kW) that the demand can suppress.

- kWh regard: it is paid according to the real amount of electricity reduced.

Demand response has the largest share in the VPP market and is already introduced on a commercial basis in Europe, the US, Canada, Australia, New Zealand and South Korea. The US is the world's first country to implement DR and thus North America is the largest market for this technology as well as for VPP solutions as a whole. It contributes to the reliability, efficiency and stability of the electric power system, and to reduce electricity costs and CO_2

emissions. But also to expand the penetration of more distribute renewable power generation since it is an effective method for using the excess output of renewable energies.

In Japan, initiatives to increase efficient energy use have generated business chances for negawatt aggregators, especially for reducing the electricity peak demand. METI has been conducted demonstration projects in DR since FY 2013, and it was already mentioned in the Fourth Energy Basic Plan [40]. Because of the introduction of smart meters, the full retail competition after the electricity system reform, and the capacity and real-time markets that will be open in 2020, electricity will be priced in a more effective, automate and real-time way.

In June 2015, the negawatt trading was clearly positioned in the Electricity Business Act. Concerning the Guidelines for Trading Negawatts formulated in March 2015[291], METI established a Negawatts Working Group of experts and business operators in April 2016, and the revised guidelines were published in September 2016[292]. In December 2016, METI published the "Handbook for Demand Response (Negawatt Trading)", mainly for consumers, which contains the summary of the program, procedures for participating and other information[293]. The negawatt trading started in April 2017. METI published a new revision of the guidelines in November 2017, changing also the name to "Guidelines on Energy, Resources, Aggregation and Business" as an anticipation of the future business model expansion. They cover matters related to VPP and DR, including negative watts transactions[294].

The Japanese government expects to reduce peak demand by 6% by FY 2030 through negawatt trading, which would save the need of about 10 GW in power generation capacity, similar to the energy produced by 10 nuclear power plants. That would also allow utilities to save about JPY 90 billion per year in facilities renovation, construction, operation and maintenance costs. Due to that saving, they will pay an annual 3,000 to 5,000 yen/kW of power saved to negawatt aggregators, which will use part of that to reward to customers[295]. Already in FY 2017, four utilities (TEPCO, KEPCO, Chubu Electric Power and Kyushu Electric Power) worked to reduce power demand by a combined 960 MW, comparable to the output of one typical nuclear power plant. Therefore, DR is attracting attention as a cheap, efficient and environmentally friendly energy resource.

In November 2013, several companies were awarded for working on a METI-sponsored pilot project with TEPCO, "The Incentive-based Demand-Response Program", which was organized by the New Energy Promotion Council at the third invitation of the Next-Generation Energy and Social Systems Demonstration Project under the FY 2013 budget[296].

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[291] METI, March 30, 2015: http://www.meti.go.jp/english/press/2015/0330_02.html.
[292] METI, September 1, 2016: http://www.meti.go.jp/english/press/2016/0901_01.html.
[293] METI, December 28, 2016: http://www.meti.go.jp/english/press/2016/1228_001.html.
[294] METI, November 29, 2017: http://www.meti.go.jp/press/2017/11/20171129001/20171129001.html (only in Japanese).
[295] Asia Nikkei, February 16, 2017: https://asia.nikkei.com/Business/NTT-Osaka-Gas-to-get-into-negawatt-brokering-in-Japan.
[296] NEPC: http://www.nepc.or.jp/topics/pdf/131122/131122.pdf (only in Japanese).

It was first deployment in Japan of aggregator-based quick-response DR for the C&I sector, as the first step to include DR in Japan's electric system. It was part of the national effort to achieve significant reductions in energy and power consumption while making more effective use of renewable energy. The Negawatt Transaction Working Group supported the creation and design of the negawatt market by the Japanese government.

As an example, in 2014, Kyocera, IBM Japan, and Tokyo Community participated in an earlier phase of this project, as part of an ADR collaborative demonstration by Waseda University at the EMS Shinjuku Demonstration Center, and supported also by METI and the Institute of Applied Energy (IAE), to establish an ADR system with aggregators in anticipation of the negawatt power exchange market[297]. Later, in 2016, Kyocera tested its ADR system as an aggregator for improving electricity management in Japan[298].

In March 2015, the Demand Response Council (DRC)[299] was established with the aggregators participating in the demonstration projects:

Figure 60: Members of the Demand Response Council

Source: Author, with data from DRC.

Only three of those are foreign companies:

- Energy Pool (France) is Europe's largest industrial DR operator, mainly for industrial facilities, and manages a 6 GW portfolio globally. On June 15, it established a subsidiary in Japan (Energy Pool Japan Co., Ltd) partnered with the also French Schneider Electric, a global specialist in energy management and automation, with who

[297] Kyocera, October 6, 2014: https://global.kyocera.com/news/2014/1002_qptn.html.
[298] Kyocera, September 13, 2016: https://global.kyocera.com/news/2016/0905_mvid.html.
[299] DRC: http://www.dr-council.jp/about.html.

it already had an alliance in Belgium and the UK. Schneider Electric had already partnered with the Japanese Sojitz before to enter in Japan[300].

- EnerNOC Inc. (US) is a provider of energy intelligence software with about 7 GW of negative watts in 11 countries worldwide. It established a joint venture with Marubeni Corporation, a Japanese global energy firm, in 2013 to develop DR business in Japan. The name is Enanok Japan Co., Ltd[301]. EnerNOC was acquired by Enel Group in June 2017, a global leader in renewable energy and smart grid technologies, though it continues to operate as a separate entity, also in Japan.

- Comverge Inc. (US) established a subsidiary in Japan in 2013 called Comverge Japan Co., Ltd. It was acquired by Itron in May 2017, an American world-leading technology and service company[302].

Nine of them are also members of the OpenADR Alliance[303], as well as other Japanese companies such as Sumitomo Electric, Panasonic, Omron, NEC or Fujitsu, for example. It was established in 2010 by industry stakeholders to promote the development, adoption and compliance of the Open Automated Demand Response (OpenADR). It is an open and standardized way for electricity providers and system operators to communicate DR signals with each other and with their customers using a common language over any existing IP-based communications network, such as the Internet. It helps system operators reduce the operating costs of DR programs while increasing DR resource reliability, but its successful implementation requires standardization. Without an ADR standard, automated DR would be difficult and costly to implement.

DR is already used in Japan when supply and demand of electricity are tight. The following are two examples in 2018:

- Due to heavy snow and frigid temperatures in Tokyo, power usage on TEPCO' grid hit 95% of capacity on January 22nd night. As a consequence, the utility sent out its first order for negawatts during four consecutive days through Energy Pool Japan, and big customers (industries) reduced their consumption at peak times and thus the overall load. It also had to use about 2,000 MW from other utilities[304].

- On July 13th, Energy Pool Japan successfully operated an implicit demand response activation, the first ever of its kind in Japan, curtailing 100 MW in order to optimize the supply-demand balance and reduce reliance on the most expensive and polluting peak thermal power capacities[305]. Explicit demand response activations are ordered by the

[300] Energy Pool: https://www.energy-pool.eu/en/.
[301] EnerNOC: https://www.enernoc.com/japan.
[302] Itron: https://www.itron.com/na/.
[303] OpenADR Alliance: https://www.openadr.org/.
[304] Asia Nikkei, January 26, 2018: https://asia.nikkei.com/Business/Companies/Snowy-cold-snap-strains-Tokyo-s-power-grid-and-highways.
[305] LinkedIn: https://www.linkedin.com/feed/update/urn:li:activity:6424909864669106176.

grid operator when capacity margins get too low (emergencies). Implicit demand response activations are ordered by the supplier to optimize demand-supply balance.

5.2. VIRTUAL POWER PLANTS IN JAPAN

Virtual Power Plant technology is still in the demonstration stage in Japan, though there is high demand for VPPs that can be used to remotely control and integrate DRE, and they have become a priority for the Japanese government during the last years. METI has been supporting several projects since 2014 to test VPPs utilizing consumer renewable energy resources, helping to establish technologies and businesses for that, and helping to construct a stable energy supply and demand structure. In January 2016, it established the Energy, Resource, Aggregation, Business Review Committee (ERAB), with experts, academia, business operators and affiliates, to consider the overall policy of the aggregation business. On the other hand, TEPCO and other utilities are also accelerating the implementation of VPPs and resource aggregation businesses through these demonstration projects.

The aim of the government's new program is to establish at least 50 MW of VPPs during five years from FY 2016 to FY 2020, with a subsidy amount of JPY 4 billion in FY 2017 and JPY 4.1 billion in FY 2018[306]. These projects are being executed jointly by the IAE and the SII (Table 22).

Under METI and supported by the "Subsidy for the Verification Project for Building Virtual Power Plant Using Energy Resources on the Side of Utility Customers" for FY 2017, SB Energy Corporation, an affiliated company of Softbank group, was selected to test a large-scale VPP in the service area of Kyushu Electric Power Co., Inc and Iki city, in Nagasaki Prefecture. It worked in cooperation with other Japanese aggregators such as Efficient Inc; Koyo Electric Co., Ltd; Sanix Inc; Smart Tech Co., Ltd; TMEIC; Mediotec Co., Ltd and Looop Inc. SB Energy established a remote-control system that uses consumers' storage batteries and EVs' batteries for the "VPP Construction Verification Project" and the "Resource Aggregator Project"[307].

As part of the METI's FY 2018 "Demonstration Project on Virtual Power Plant (VPP) utilizing Demand Side Energy Resources" and its goal to increase the renewable energy penetration, the initiative will focus on implementing control technologies in VPPs with over 50 MW by 2020. In June 2018, 20 companies started to build a VPP to aggregate DER at the megawatt level in order to introduce renewable energy while stabilizing the power system. The group will improve and demonstrate the systems used by aggregation coordinators to accommodate

[306] METI, : http://www.meti.go.jp/main/yosan/yosan_FY 2018/pr/en/shoshin_taka_07.pdf (only in Japanese).
[307] Solar Power Plant Business, July 21, 2017: http://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/072101471/?ST=msbe.

changes in energy supply and demand, and will examine different approaches to stabilize the distribution system[308]:

- 3 aggregation coordinators: TEPCO; Global Engineering Co., Ltd. and NEC Corporation.

- 5 verification and cooperation companies: Tokyo Electric Power Grid Co., Ltd.; Tokyo Electric Power Energy Partner Co., Ltd.; Toko Takayama Co., Ltd.; Sekisui Chemical Co., Ltd. and Hitachi Systems Power Service Co., Ltd.
- 12 resource aggregators: ONE Energy Co., Ltd.; NTT FACILITIES, INC.; Osaki Electric Industry Co., Ltd.; Family Net Japan Co., Ltd.; Next Energy & Resources Co., Ltd.; Kyocera Corporation; JGC Corporation; Efficient Co., Ltd.; Mitsubishi UFJ Leasing Co., Ltd.; Shizuoka Gas Corporation; Erie Power Co., Ltd. and Energy Optimizer Co., Ltd.

Table 22: Subsidies for VPP Projects

Classification	Business name	Executive body	Business contents	Main subsidized expenses	Subsidy rate
A	VPP construction demonstration project	IAE	Project to conduct VPP demonstration jointly with resource aggregator and VPP based operators adopted in B and D business, to demonstrate technology and establish institutional issues for VPP construction.	Personnel, system development, etc.	Within 1/2
B	Resource Aggregator Business	SII	A business that carries out contracts concerning control of VPP resources directly with customers, and the verification, in cooperation with parent aggregators adopted in business A by operators conducting remote control and integrated management of VPP resources.	Personnel, system development, etc.	Within 1/2
C	VPP resource introduction promotion business	SII	A project that supports the introduction of VPP resources, such as storage batteries and control devices controlled by a parent aggregator adopted in business A and resource aggregator businesses adopted in business B.	Storage battery, PCS, EMS, control equipment, installation cost, etc.	Within 1/2 fixed amount
D	VPP-based business	IAE	A project that supports VPP demonstration of parent aggregator adopted in business A, conducts research and analysis of project issues, etc. and develops necessary systems.	Personnel, system development, etc.	Fixed amount

Source: Agency for Natural Resources and Energy[309].

308 TEPCO, June 6, 2018: http://www.tepco.co.jp/press/release/2018/1495474_8707.html (only in Japanese).
309 Agency for Natural Resources and Energy: http://www.enecho.meti.go.jp/category/saving_and_new/advanced_systems/vpp_dr/measure.html#page2-1 (only in Japanese).

In June 2018, Kyocera and Softbank Energy were partnering with utilities TEPCO and KEPCO, energy management specialist ENERES and national telecoms provider KDDI Corp. to test and development projects for VPP in northern Japan until February 2019. Kyocera will install storage batteries and HEMSs in participating households. The latter ones will be used to remotely manage energy from the batteries. The other partners will serve as aggregation coordinators, integrating multiple resources to create a virtual power trading market. Kyocera designed the system to respond to demand signals within 5-15 minutes[310].

Since EVs' batteries will become an important VPP and DR resource, some EV-based VPP initiatives have also recently been conducted in Japan, all in a demonstration stage. The following are some examples:

- In December 2017, TEPCO and Nissan launched a demonstration project to determine how EVs can help stabilize power grid demand[311]. When power grid demand is low, TEPCO will notify it to participants, and those who charge their vehicles during those periods can qualify for incentives based on the amount of energy charged. They will use Nissan's telematics system, a service that lets them remotely monitor their car's condition and control charging via a smartphone application. This is Nissan's first project of its kind in Japan, and plans to partner with power companies globally to create VPPs using EVs.

- In January 2018, KEPCO, Nissan and Sumitomo Electric Industries, Ltd. started a VPP demonstration project to evaluate the use of EVs as a power source, testing control instruments to enable remote-control charging, collect vehicle information and identify available charging capacity[312].

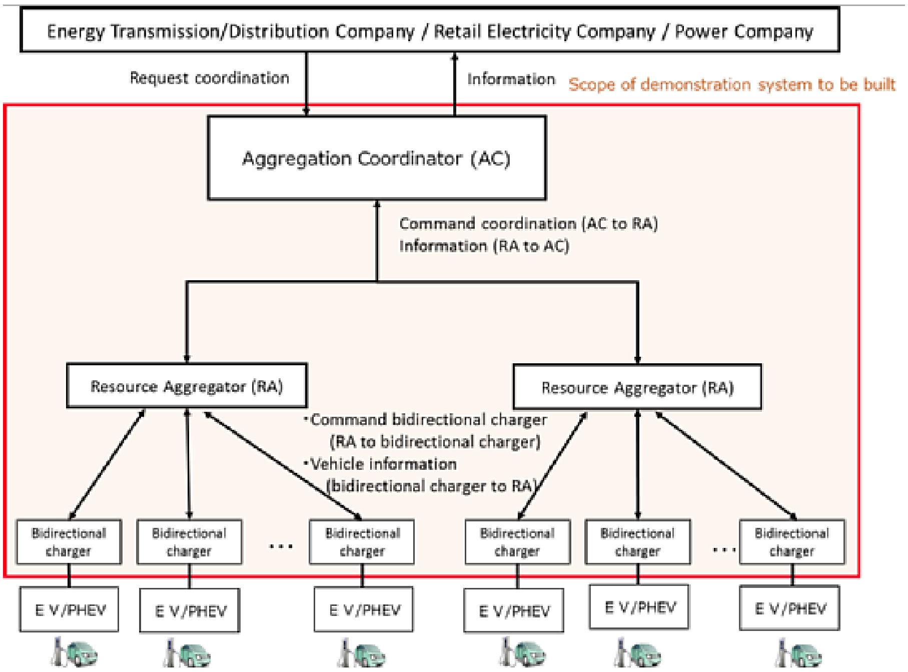
- In May 2018, five companies, including Kyushu Electric Power, are conducting a demonstration test in 2018 of V2G technology to supply electricity from EVs to the grid and use it for electricity supply and demand adjustment[313].

- In June 2018, METI selected seven companies to receive grants under its FY 2018 SII for a V2G demonstrator project using EVs as resources of VPP. The name of the project is "A demonstrator project for a virtual power plant utilizing consumer energy resources (V2G aggregator project)". They were TEPCO; TEPCO Energy Partner, Inc.; TEPCO Power Grid, Inc.; Hitachi Systems Power Service, Ltd.; Hitachi Solutions, Ltd;

[310] Energy Storage, June 27, 2018: https://www.energy-storage.news/news/japanese-solar-pv-players-join-telecoms-and-utilities-in-creating-virtual-p.
[311] Nissan, December 13, 2017: https://newsroom.nissan-global.com/releases/release-917079cb4af478a2d26bf8e5ac000f71.
[312] Nissan, January 11, 2018: http://nissannews.com/en-CA/nissan/canada/channels/ca-canada-nissan-technology/releases/nissan-kepco-and-sumitomo-electric-launch-vpp-pilot-program-2.
[313] Kankyo Business, June 1, 2018: https://www.kankyo-business.jp/news/020493.php?utm_source=mail&utm_medium=mail180609_st&utm_campaign=mail%20%E2%80%93%20only%20in%20Japanese (only in Japanese).

Mitsubishi Motors Corporation (MMC) and SHIZUOKA GAS Co., Ltd[314]. They will work to build a V2G system and establish a V2G aggregator business model that makes effective use of the EVs' batteries.

Figure 61: Scope of the Demonstrator Project



Source: METI.

- In July 2018, Japanese utility Chubu Electric Power and automaker Toyota partnered with the American company Nuvve Corporation to implement a V2G pilot project funded by METI under the "FY 2018 Subsidies for Virtual Power Plant Demonstration Project for Improvement of Energy Management in Demand Side initiative"[315]. The target is to verify the feasibility of the V2G technology to adjust power supply and demand and provide balancing control power in response to short-term fluctuations. They will install a bi-directional charger at parking facilities in Toyota City, Aichi Prefecture, using the V2G technology of the American company Nuvve Corporation. Toyota will establish the V2G control system as an aggregator, and Chubu Electric Power will evaluate the influence on electricity grid from the perspective of a transmission system operator[316].

[314] Green Car Congress, June 7, 2018: http://www.greencarcongress.com/2018/06/20180607-v2g.html.
[315] Smart Energy, July 27, 2018: https://www.smart-energy.com/industry-sectors/electric-vehicles/pilot-exports-v2g-knowledge-japan/.
[316] Toyota, May 31, 2018: https://www.toyota-tsusho.com/english/press/detail/180531_004196.html.

Therefore, electric vehicles are part of the energy solution, and connecting their batteries through the V2G technology will generate income for their owners.

More foreign companies continue to enter in this expanding market. Two California-based behind-the-meter battery startups, Stem Inc. and Survenge Energy Inc., partnered with Mitsui to build VPPs in TEPCO's service area[317]. The Swiss ABB launched a portfolio of VPP solutions in Japan at the end of February 2018[318]. The US startup Growing Energy Labs, Inc. will collaborate with Osaka Gas Co., Ltd using its VPP platform and energy storage control technology to demonstrate the optimum operation of storage batteries for adjusting the supply and demand balance[319].

5.3. BLOCKCHAIN TECHNOLOGY

The rapid penetration of distributed renewable energy resources and smart home industry are shifting the energy system from a central one to a distribution one with bi-directional flows of energy and thousands of active prosumers. This new era will need an increase of automation, but there are still concerns about data security and protection.

Blockchain technology could solve issues related to the energy transactions. It allows an energy trade between individual participants without a third central party to track, verify and approve the digital exchange in order for the system to function, reducing transaction costs and increasing efficiency. It leverages decentralized peer-to-peer (P2P) internet technology where people share a distributed ledger, providing a secure, decentralized, and highly efficient way to manage and keep track of transactions. It is designed to be reliable, neutral and secure. Transaction records are successively stored in blocks, and these are added to a chain of existing blocks. Therefore, it is extremely difficult to falsify, change or remove.

After the terms of an agreement between two or more parties are programmed and stored on a blockchain, transactions can be executed automatically if the specific conditions in the agreement are met. This is what it is called smart contract. Since the blockchain ledger is immutable, a radical interpretation of smart contracts would reduce the contract to the code, effectively declaring the code as the law itself: self-contained, self-performed and self-enforced [47]. Each transaction is verified and time-stamped in an encrypted but transparent process, which could be inspected by authorized auditors.

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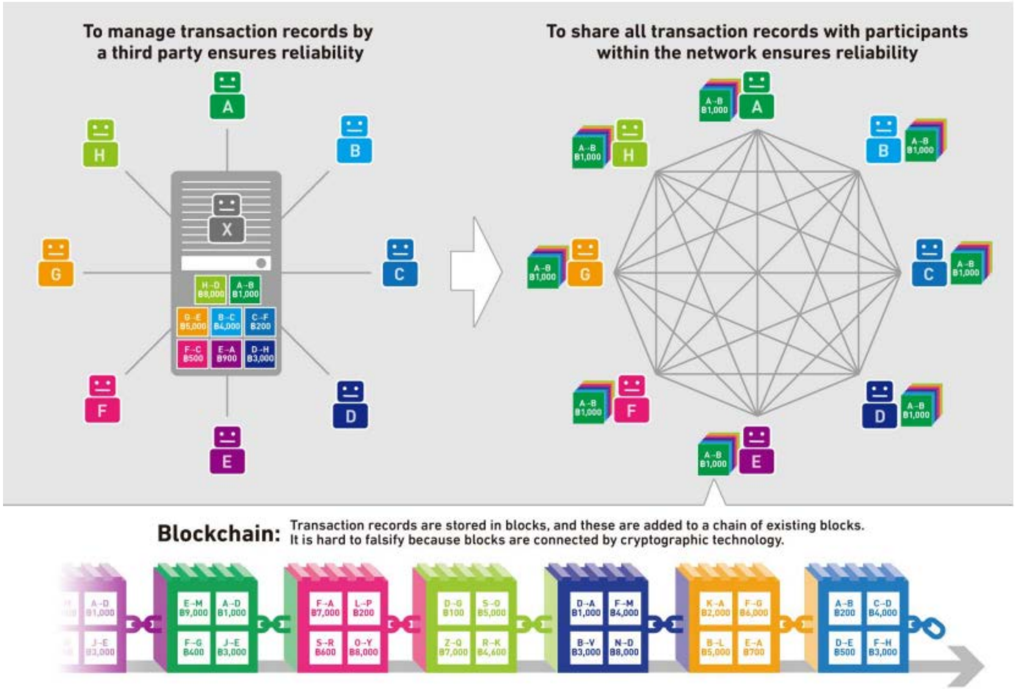
317 GTM, December 13, 2017: https://www.greentechmedia.com/articles/read/tokyo-tepco-test-stem-sunverge-behind-the-meter-batteries-as-virtual-power.

318 ABB, : http://www.abb.com/cawp/seitp202/fa6e2b8f1b5b0ccfc125824a003c2aa3.aspx.

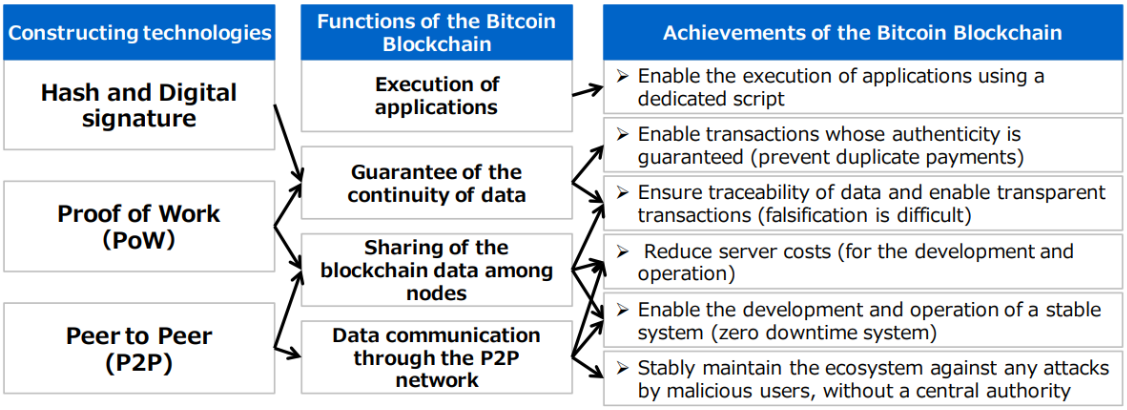
319 Osaka Gas, August 7, 2018: http://www.osakagas.co.jp/en/whatsnew/1272640_11885.html.

Figure 62: Blockchain Technology



Source: METI [46].

Figure 63: Functions and Challenges of Bitcoin Blockchain



Source: METI [46].

However, the technology is not mature yet and has some technical (scalability and security) and regulatory limitations to solve before moving from pilot projects to a full commercial deployment. Trust between participants depends on trust in blockchain technology, but this is not completely free from vulnerabilities, including both accidental errors and malicious attacks. Automation will not guarantee the elimination of bugs, conflicts of interest or corruption in complex global supply chains [47]. There is also an argument that blockchain may not still be applicable for real-time data processing because it takes from a few seconds to 10 minutes to create and add a new block of information to the chain. And there are a limited number of transactions per specific time. This is, the number of transactions per second is worse than present settlement systems like VISA because blockchain specification provides a limitation of block data volume and a delay to create new blocks [46][320].

Blockchain may accelerate the deployment of VPP and DR at smart connected homes because it would allow automatic execution, improving real-time event validation, while maintaining security through smart contracts. According to Frost & Sullivan, blockchain technology could transform current utilities and consumer business transaction models by enabling a decentralized energy production model, and it identifies five application opportunities for it in the digital grid sector[321]:

- Billing platform for retail sales and net metering.
- Platform for P2P trading and renewable energy certification.
- International energy trading: the volume of international electricity trade, both exports and imports, is forecast to grow to almost 83,000 TWh over the next 10 years.
- Electric vehicles and V2G technology.
- Customer management.

Initiatives in the world

According to GTM Research, more than 120 energy-related blockchain companies raised a total of more than USD 324 million in 2017. A significant amount of this total was invested by energy companies. Initial coin offerings (ICOs), the practice of getting investors to trade real money for shares of cryptocurrency in various forms, represent 75% of that funding. Most of the pilot projects are focused on P2P energy trading, though it is not the most commercially viable function. Wholesale trading is finding success, demonstrated by two European pilots led by BTL and Ponton, respectively, with dozens of industry partners, and with other startups breaking into this market. GTM expects EV charging and renewable energy credit (REC) trading will be some of the first uses to find revenues.

The blockchain technology is already being used worldwide, mainly in the US and Europe. The following are some examples:

- In Brooklyn, New York, LO3 Energy has teamed up with Siemens to create a sustainable micro-grid in which participants can choose their preferred energy sources.

[320] GTM, July 2, 2018: https://www.greentechmedia.com/articles/read/blockchain-might-not-be-best-for-energy-trading#gs.sFSAPNo.
[321] Frost&Sullivan, February 13, 2018: https://ww2.frost.com/news/press-releases/frost-sullivan-explores-five-different-applications-blockchain-us-digital-grid-sector/.

The system connects about 60 solar sites to about 500 consumers, who can buy and sell it via the EXERGY, a blockchain enabled platform[322].

- LO3 also has two new projects underway in Germany: The Landau Microgrid Project, a 20 households local energy market experiment with utility Energie Südwest AG and Karlsruhe Institute of Technology[323], and "virtual microgrid" with energy provider Allgauer Uberlandwerk.

- The US energy retailer Direct Energy is also using LO3's blockchain platform in Texas for offering its commercial and industrial customers the possibility of design and submit orders for energy hedges as short as an hour in Texas. Direct Energy is owned by British energy supplier Centrica, which is one of LO3's main investors[324].

- Centrica and LO3 are also together in a trial in south-west England to explore how blockchain technology could be used to transform the way consumers buy and sell energy and unlock savings for homes and business power users in south-west England[325].

- The Australian Power Ledger, one of the market's leaders globally, has implemented blockchain energy solutions in Australia, New Zealand, Japan, the US, India and Thailand, including P2P trading, microgrid trading or VPP solutions, among others. The system allows customers to choose their electricity sources, and trade their electricity generated with their neighbours through transparent and automated transactions[326].

- In March 2018, Chile's National Energy Commission started to use Ethereum-based smart contracts to verify data related to marginal costs, fuel prices, compliance with the renewable energy law and average market prices, becoming the first public entity worldwide to do so. The data will become available via the Energía Abierta (Open Energy) platform. Blockchain technology will allow it to improve the security of energy data published[327].

- In Germany, TenenT, a transmission system operator, and Sonnen, the world's largest residential energy storage company, are using decentralized networked home energy storage systems operated by Sonnen e-Services into TenenT's grid via blockchain technology developed by IBM to stabilize the power grid[328].

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[322] Brooklyn MICROGRID: https://www.brooklyn.energy/.
[323] Karlsruhe Institute of Technology: https://im.iism.kit.edu/english/1093_2058.php.
[324] GTM, April 12, 2018: https://www.greentechmedia.com/articles/read/direct-energy-uses-lo3s-blockchain-to-offer-micro-energy-hedging#gs.uge04Kc.
[325] Investing, May 11, 2018: https://www.investing.com/news/cryptocurrency-news/uks-centrica-brings-blockchain-to-power-generation-sector-1442850.
[326] Power Ledger: https://www.powerledger.io/#projects.
[327] PV Magazine, February 27, 2018: https://www.pv-magazine.com/2018/02/27/chiles-energy-regulator-to-use-blockchain/.
[328] TenenT, February 11, 2017: https://www.tennet.eu/news/detail/europes-first-blockchain-project-to-stabilize-the-power-grid-launches-tennet-and-sonnen-expect-res/.

- Also in Germany, Swytch, an American blockchain-based energy platform, will work with Energy2market GmbH, a leader in aggregated energy trading, on a pilot program to power 500,000 homes with renewable energy while rewarding users with tokens. The large-scale pilot program aims to distribute roughly 3.5 GW of solar, wind, hydro and biogas energy capacity[329].

- Utility PG&E is working with BMW in California to create carbon credits for EV's drivers based on the emissions profile obtained when they charge their cars, crossing users' charging behavior with real-time energy mix data. This promotes a charging out of peak hours when more energy produced by carbon-based resources has to be included in the balance. Customers would gain the chance to monetize their clean charging choices by trading their credits[330].

- BCPG, a subsidiary of state-owned oil refiner Bangchak, recently joined forces with real estate developer Sansiri to offer blockchain-linked solar power system in Bangkok, and they expect to expand the service to 20 projects over the next few years. Banpu Infinergy, a subsidiary of coal miner Banpu that installs rooftop solar panels, is also developing its own blockchain platform to take advance of the growing demand in the Thai residential solar energy market. Electrify, a Singapore startup, is also using the blockchain technology to develop a P2P energy trading market[331].

Initiatives in Japan

METI published the survey "Survey on Blockchain Technologies and Related Services" in April 2016[332], with market value expanded up to JPY 67 trillion in Japan, and the document "Evaluation Forms for Blockchain Based System" in March 2017[333]. METI already had the concern that overseas companies will take the initiative in this technology, with the potential to be the next-generation platform in all industries.

Energy trading using blockchain is mostly in the demonstration stage in Japan. However, the fact that the Japanese utilities, especially the two largest ones, TEPCO and KEPCO, are exploring the blockchain technology as a solution is a clear indication that the industry has accepted that this change is inevitable:

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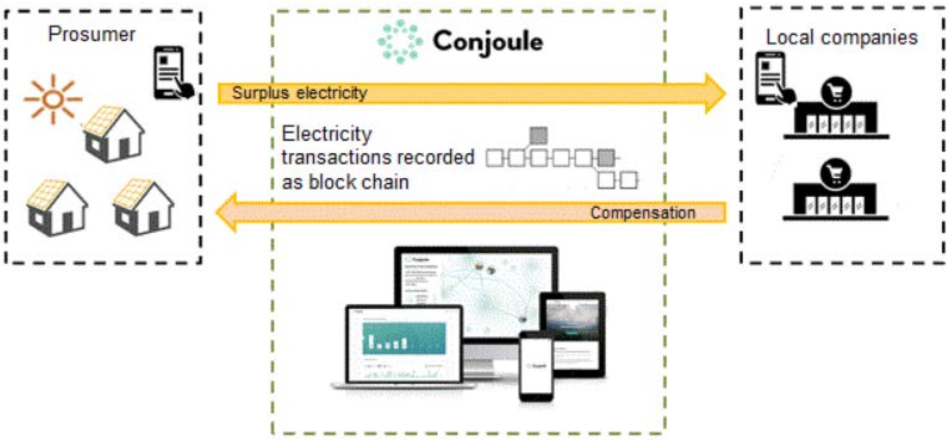
329 Bitcoin Magazine, June 13, 2018: https://bitcoinmagazine.com/articles/new-blockchain-based-renewable-energy-pilot-power-500000-homes/.
330 GTM, September 12, 2018: https://www.greentechmedia.com/articles/read/for-utilities-exploring-blockchain-theres-beauty-in-the-mundane#gs.RXm7dnw.
331 Asia Nikkei, September 6, 2018: https://asia.nikkei.com/Business/Business-Trends/Thailand-braces-for-surge-of-blockchain-enabled-solar-power?utm_campaign=RN%20Subscriber%20newsletter&utm_medium=daily%20newsletter&utm_source=NAR%20Newsletter&utm_content=article%20link.
332 METI, April 28, 2016: http://www.meti.go.jp/english/press/2016/0531_01.html.
333 METI, March 29, 2017: http://www.meti.go.jp/english/press/2017/0329_004.html.

TEPCO is getting know-how on the blockchain technology through several international investments and alliances. In May 2017, it joined forces with Centrica plc, Elia, Engie, Royal Dutch Shell plc, Sempra Energy, SP Group, Statoil ASA, Stedin and TWL (Technical Works Ludwigshafen AG) to support the Energy Web Foundation (EWF), a non-profit organization whose mission is to accelerate the commercial deployment of blockchain technology in the energy sector[334]. In July 2017, TEPCO closed a €3 million investment in Conjoule GmbH, a start-up developing P2P energy markets for producers and consumers of renewable energy, as well as owners of batteries and other sources of flexibility, to transact with each other without the need for traditional intermediaries (Figure 64). Its platform is being piloted in two German cities. Conjoule is another example of the Innogy Innovation Hub (Innogy SE, Germany's leading energy company) portfolio[335]. Besides, in January 2018, TEPCO invested in UK-based blockchain firm Electron in a project from centralized structures to decentralized systems for the energy sector. Using the Ethereum blockchain, Electron proved a platform simulating data from 53 million metering points at individual homes from 60 energy providers, showing that energy supplier switches could be executed up to 20 times faster than current switching rates336.

Figure 64: Diagram of Conjoule's P2P Electricity Purchasing Platform



Source: TEPCO.

[334] Rocky Mountain Institute: https://www.rmi.org/press-release/press-release-energy-web-foundation-launch/.
[335] TEPCO, July 10, 2017: https://www7.tepco.co.jp/newsroom/press/archives/2017/1443967_10469.html.
[336] CCN, January 22, 2018: https://www.ccn.com/decentralized-future-japans-biggest-energy-giant-invests-ethereum-blockchain-startup/.

- In March 2018, Chubu Electric Power together with Nayuta Inc. and Infoteria Corporation started demonstration tests on a technology that manages EVs' charging data using the blockchain technology[337].

- In April 2018, KEPCO announced a partnership with Australian P2P energy startup Power Ledger to test its blockchain enabled energy sharing platform in Osaka. KEPCO plans on implementing this platform in order to develop VPPs where local energy demands can be met by consumer-owned generating and storage facilities. The aim is to allow electricity generating consumers to monetize on their investment of renewable energy while providing their community with cheaper energy. Power Ledger's technology is already in use in a number of trial programs across Australia, New Zealand and South East Asia[338].

Other recent examples of demonstration projects in Japan using the blockchain technology are the following:

- In 2017, the Japanese company ENERES, with the support of the authorities of Fukushima Prefecture, tested the capabilities of the distributed registry technology for its application in renewable energy, and in particular, for building smart micro networks on the blockchain. The experiment involved 1,000 households[339].

- In February 2018, the Japanese company Minna Denryoku Co., Ltd. announced the collaboration with Aerial Lab Industries for developing a P2P power trading platform utilizing blockchain technology[340].

- In June 2018, a group of Japanese technology and energy companies launched a pilot project to allow consumers in rural areas to trade renewable energy through a blockchain-based platform. The project is supported by MOE, the energy trading startup Power Sharing, TEPCO and financial giant Softbank[341].

- In July 2018, MOE announced the success in a demonstration project of a real-time P2P trading system of CO_2 reduction value of re-energy consumed at homes and factories using blockchain technology. The name of the project is "Re-energine CO_2 reduction value creation model business utilizing 2018 blockchain technology"[342].

[337] Chubu Electric Power, March 1, 2018: http://www.chuden.co.jp/english/corporate/ecor_releases/erel_pressreleases/3267347_18939.html.
[338] Top Cryptocurrency News, April 25, 2018: https://topcryptocurrencynews.com/power-ledger-to-trial-blockchain-based-energy-trading-in-japan/.
[339] Hype.Codes, September 4, 2017: https://hype.codes/japan-will-use-blockchain-energy-management.
[340] Minden, February 28, 2018: http://minden.co.jp/archives/2435 (only in Japanese).
[341] Coindesk, April 23, 2018: https://www.coindesk.com/softbank-eyes-carbon-emissions-cuts-with-green-energy-blockchain-pilot/.
[342] Kankyo Business, July 12, 2018: https://www.kankyo-business.jp/news/020769.php?utm_source=mail&utm_medium=mail180721_st&utm_campaign=mail (only in Japanese).

- Through the TAKE Energy Pilot Project, Electrify, a Singapore-based energy retail marketplace, will soon make possible to trade excess solar power in Kyushu region using its P2P energy trading platform, Synergy. Homeowners will be able to take control of their electricity by selecting preferred sources, such as rooftop solar. The consequence of the disintermediation, this is, removal of third parties, will be a cost saving. Components critical to enable this ecosystem include an IoT device to accurately track and audit the production from small-scale producers, and eWallet, which will be used to facilitate payments via the smart contracts[343].

[343] Red Green and Blue, July 10, 2018: http://redgreenandblue.org/2018/07/10/solar-energy-trading-trial-japan-will-use-blockchain/.

6. CONCLUSIONS AND POTENTIAL OPPORTUNITIES

Since the Great East Japan Earthquake, the necessity of suppressing power consumption on the demand side rose in Japan, and the government has been promoting a low-carbon society through energy efficiency measures and the development of a stable and reliable supply of renewable energy, reducing electricity cost and CO_2 emissions.

Despite the progress made in recent years and becoming in the third largest market in the world with a total capacity installed of 49 GW, solar photovoltaic systems in Japan continues with a downward trend respect to the previous years. The main reasons are grid constraints and curtailment risks, difficulties to find suitable land for large projects, reduction in the FIT's purchase prices, and an unsuccessful auction system for projects over 2 MW.

In spite of this trend, it is expected that the government's solar target of 64 GW by 2030 will be achieved around 2020. Since the ratio of renewable generation was 15% in 2017, the goal of 22-24% by 2030 seems too low. Because of this insufficient consideration to renewable power, and the proposal of making expansive use of coal and maintaining an unrealistic target for nuclear generation, critical opinions to METI's strategy have arrived from MOE and MOFA. A unique coordinated policy is needed for the growing of the renewables in Japan.

Since most areas in Japan that are suitable for large-scale solar power plants are already utilized or being planned for use, there are two solutions growing in importance:

- Floating solar PV systems, where Japan is the world's leader by capacity installed and the number of plants. The installation is faster and cheaper, and they generate more power due to the cooling effect of the water.

- Solar sharing, or the agricultural solar power plants, which is expected to expand due to the last regulation from MAFF regarding the temporary change of land category. The Solar Sharing Network estimates a growth of new 500 solar sharing plants per year in the following years, with an average size of 700 kW and an average initial cost of around 250,000 JPY/kW, what would mean a business of about JPY 87 billion per year.

One concern is that the utility-scale costs in Japan are almost double than in Germany, Italy or China, due to the larger licensing approval procedure costs, mechanical and electrical costs, and constructions costs, with larger construction periods because of the use of manual machines instead of automatic ones.

With the increase in the number of stocks of PV power plants, a large secondary market of transactions of PV assets and land rights is rapidly growing, involving players such as power generation companies, IPPs, EPC and O&M companies, financial institutions, investors, intermediation services companies and legal advisors.

Another market that will grow in Japan is the O&M service, which is mandated since the amended of the FIT Act in April 2017, also for those power plants already in operation, increasing inspections and implementing more robust security measures for ensuring long-term operation and revenues. Remote monitoring systems and drones with cameras are being incorporated to accurately detect defective panels at an early stage, and take appropriate action for stable operation and maintain feasibility. From the beginning of 2018, Kyushu Electric Power Co. will cancel the connection of any PV power plant not equipped with PCS with output control function to secure a stable power supply, a trend that is expected in other regions.

Nevertheless, it will be the residential and C&I installations that will push the solar market in Japan in the next years, largely on the back of rising storage battery deployment and the growing importance of the net-zero energy houses/buildings, which are receiving lot of attention as a key for reducing energy consumption in these sectors. The Japanese government set the targets to achieve zero emission in standard newly constructed houses and public buildings by 2020, and average zero emission in newly constructed houses and public and private buildings by 2030.

This large market involves also PV systems, energy storage batteries and energy management systems, a package that is already being offered by the largest domestic and also foreign companies. It also includes insulation materials and double glazed windows, among others. Two related more efficient and relatively new products in expansion in Europe are the building-integrated solar panels, including solar windows, cladding systems and roofs, and hybrid solar panels or PV-Thermal systems. European companies that manufacture this kind of products and have more experience could find a potential market in Japan.

The rapid adoption of renewable energies, especially solar energy, has brought problems affecting the stability of the power grid, including output fluctuations and surplus power generation. Energy storage allows integrating higher levels of solar (and wind) power into the grid, removing the curtailment risk from PV power plants output, which has been seen as a barrier to investment in some of the more saturated grid areas in Japan. Additionally, storage batteries became a core technology after the Great East Japan Earthquake because of their application as an emergency power supply. Therefore, the Japanese government has been supporting their deployment through several subsidies and programs as the way to solve these problems and achieve more flexibility.

It was predicted a fast growing of the Japanese stationary storage battery market from about 581 MWh and JPY 72.64 billion in 2015 to around 3,366 MWh and JPY 116.31 billion in 2020, with residential use reaching a ratio of at least 50%. This is also due to the new regulation about the net-zero energy houses/buildings, and because the previous FIT agreement will expire for about 700,000 householders from November 2019, and increase their self-consumption ratio through storage batteries will be a way to maximize the value of their PV solar system. In some European countries such as Germany, UK and Italy the energy storage market is mature and has many companies with experience and good products that could find a potential market in Japan.

Through the vehicle to grid (V2G) technology, electric vehicles' batteries, larger than the residential ones, will increase their importance as new smart management tools to operate the energy system, reinforcing the grid of specific areas when the demand is higher or during an unexpected natural disaster. Their charging could also be shifted to the middle of the day, to absorb high levels of solar generation, or at night, when the demand is the lowest, helping to integrate higher shares of variable renewable energy without interfering with the stability of the grid, increasing the flexibility of the electricity system, and enabling higher decarbonization ratio of both transport and power sectors. Therefore, the V2G technology will make electric vehicles part of the energy solution, reducing the cost of their ownership, and helping to increase their sales. Technical and economic viability has already been demonstrated, with the automaker Nissan at the forefront of this technology. Some demonstration projects in Japan are being conducted as part of VPP projects.

In 2017, the Japanese electric car fleet was the third largest in the world with 205,350 units, but it only represented a market share of 1.0%. The target of the government is to have one million of electric vehicles (BEV and PHEV) by 2020 and reaching an electric vehicles' share in the new car sales of 20%-30% by 2030. However, with the current state of EV deployment, it looks difficult that Japan meets these targets, and more efforts and policy support are still indispensable. The charging points across the country, 7,327 fast chargers and 28,834 in total at the end of 2017, could be also insufficient if the number of EVs rapidly increase in the next years.

Considering the current EVs travel range and energy density of around 400 km and 200 Wh/kg, the target of the government is to achieve a range of around 800 km by 2025 (400 Wh/kg) with the solid-state battery technology, and about 1,000 km (500 Wh/kg) after 2030 through other innovative battery technologies, promoting R&D projects in this area in which European institution and companies could participate.

In August 2018, CHAdeMO Association and China Electricity Council signed a MoU for co-development a next generation ultra-fast EV charging standard with more than 500 kW, compatible with both current CHAdeMO and GB/T standards, and which is expected to lead the way towards a single harmonized future standard. Nevertheless, a new technology that would solve this issue will be the wireless EV charging technology, which is the target of several research and demonstration projects.

As another way to increase the energy efficient, reduce electricity costs and GHG emissions, the distributed power generation model is being promoted, closer to demand centers, where the energy is produced, stored, consumed and sold locally. As a consequence, the Japanese government is supporting the development of virtual power plants (VPPs), which digitally integrate/aggregate the energy and power capabilities of large numbers of connected distributed energy resources, mainly solar plus storage systems at households and commercial businesses, but also highly efficient energy equipment (air conditioners, heat sources, generators, thermal storage tanks, etc), and electric vehicles' batteries through the V2G technology. Besides, they offer passive consumers the possibility of becoming active prosumers who can participate in the electricity trading market and get revenues.

Demand response (DR) solution has the largest share in the VPP market, and it has already been used successfully in Japan when supply and demand of electricity were tight. The negawatt or negative watt trading was opened in Japan in April 2017 and is an incentive-style DR that conserves electricity at the timing of the peak demand.

The Japanese government expects to reduce peak demand by 6% by 2030 through negawatt trading, which would save the need of about 10 GW in power generation capacity, similar to the energy produced by 10 nuclear power plants. That would also allow utilities to save about JPY 90 billion per year in facilities renovation, construction, operation and maintenance costs. Due to that saving, they will pay an annual 3,000 to 5,000 yen/kW of power saved to negawatt aggregators, which will use part of that to reward to customers.

Several market dynamics in Japan are stimulating the growth of VPPs and DR, such as the rapid deployment of storage batteries and electric vehicles, and the liberalization of the electricity retail market, that brought hundreds of new suppliers which also are required to increase their ratio on non-fossil electricity sources to 44% or more by 2030. It also brought the growth of the smart meter market, whose rollout will be completed across the country by 2024, and the capacity and real-time energy trading markets that will be opened in 2020.

Blockchain technology may accelerate the deployment of VPPs and DR at smart connected homes because it would allow automatic execution, improving real-time event validation, while maintaining security through smart contracts. However, and even main Japanese utilities are investing and exploring this technology, it is in the demonstration stage in Japan, and European firms, with more experience, could find a big market in the near future.

Finally, there is a huge emerging market reusing and recycling both PV solar panels and energy storage batteries:

- Japan will have the third largest PV modules waste in the world by 2030. MOE forecasts that it will exceed 10,000 tons by 2020, 300,000 tons by 2033, and reaching about 800,000 tons of waste per year between 2034 and 2040. Its projected peak of 810,000 tons is equivalent to 40.5 million of solar panels. Japan has no specific regulations for the disposal of PV solar waste, which therefore must be treated under the general regulatory framework for industrial waste management, though it is expected that MOE and METI establish specific mandatory policies soon. The government has been also supporting the development of low-cost PV recycling technology through several projects. Some European companies already have more experience in this business and could find potential opportunities to enter in the Japanese market, also through collaborations in R&D of new technologies, transfer technology and patents.

On the other hand, it is expected a growing secondary market for repaired panels that can be sold as used panels at a reduced price since they can operate at about 80% efficiency after 20 years, still high enough for less demanding purposes.

- About 50% of the batteries installed in electric cars are recycled after 5 to 7 years, when they still have between 60% and 80% of their original capacity, being sufficient to run a profitable second business. Global stock of used EVs' batteries will rapidly grow up to around 200 GWh by 2025 and 1,000 GWh by 2030. There are already several projects in Japan with a secondary use of EVs' batteries.

  With the increased use of Li-ion batteries in the automotive industry, their recycling is becoming critical. Raw materials account for 50% to 70% of the cost of lithium battery cells, and it is estimated that the total amount of recycled lithium and cobalt could reach from 5,800 to 30,000 tonnes, and 22,500 tonnes, respectively, by 2025. The global battery recycling market will grow from about USD 10 billion in 2017 to around USD 25 billion in 2026.

Recommendations for the European Commission:

1. In August 2018, CHAdeMO Association and China Electricity Council signed a MoU for co-developing a next generation ultra-fast charging standard for electric vehicles compatible with both current CHAdeMO and GB/T standards, the two most extended ones, also in Europe in the case of CHAdeMO. Tesla also modifies its vehicles for the Chinese market to add a second charge port compatible with the GB/T standard.

   This new harmonized standard makes that the future of the CCS one is not clear, and the EU should then promote among European automakers and utilities to join this agreement searching, finally, a globally unique standard.

2. It was not possible to cover in this report such an important and related topic as the hydrogen and fuel cell vehicles. The Japanese government aims to build a hydrogen-based society as a key for energy security and the fight against global warming. Hydrogen and fuel cell technology will play an important role in applications such as stationary and portable power, energy storage and transportation.

   Specifically, the Strategic Road Map for Hydrogen and Fuel Cells released in March 2016 established a target for fuel cell vehicles of 40,000 units by 2020 and 800,000 units by 2030. The current fleet at the end of 2017 was only 2,321 units. This means that it will be difficult for the Japanese government to meet those targets, but also that there is huge opportunities in this market.

3. Other potential markets in Japan that EU should analyze are biomass and geothermal renewable sources, with a deployment level much lower than in Europe. The CO_2 capture technology also presents a big potential as a way to reduce the GHG emissions in a country that wants to reduce their emissions by 80% by 2050.

Recommendations for the Japanese government

1. METI has to increase the power generation ratio for renewable energies, reducing the use of the coal. The government's solar target of 64 GW by 2030 will be achieved around 2020. Since the ratio of renewable generation was 15% in 2017, a goal of 22-24% by 2030 seems too low. Municipal leaders in Japan released the Nagano Declaration in 2017, committing to work towards 100% renewable energy for cities and regions across the country, and several Japanese companies joined the RE100 initiative.

   On the other hand, it is contradictory to argue the use of nuclear energy to help create a decarbonized energy market and continue to promote the use of coal. Critical opinions arrived from MOE and MOFA, and the adoption of the Paris Agreement clearly showed the direction for decarbonization, being coal-fired power generation the energy source that produces the largest amount of CO_2 emissions. Most of the countries in the world are phasing out the use of coal in power generation as an important step to fight against global warming.

   METI cannot ignore these movements and leave Japan behind in the race towards renewable energies and against climate change. Besides, a unique coordinate energy policy is needed in Japan.

2. In order to reduce the utility-scale solar PV costs in Japan, the government should work on simplifying the licensing approval and grid connection procedures and reducing their cost.

3. Together with the EU, European automakers and utilities, and CHAdeMO Association, the Japanese government should promote an agreement that leads to a globally unique fast charging standard for electric vehicles.

4. The targets of electric and fuel cell vehicles deployment by 2020 will not be met, so it is needed more efforts and policy support from the Japanese government, from taxes exemptions to free access to highways, among others.

5. Future huge amounts of both PV modules and Li-ion batteries waste will require that the Japanese government clearly define and promote their treatment establishing mandatory regulations for their recycling and disposal.

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ANNEX

RELEVANT EXHIBITIONS IN JAPAN

The most relevant exhibitions related with the energy market in Japan in 2018 are list below. Most of them can be found in the JETRO website's database[344], but other sources were also used.

10th Automotive World 2018 – Tokyo Edition, consisting in the following 6 shows:

Car Electronics	**EV/HEV/FCV Technology**
Lightweight	**Processing**
Autonomous Driving Technology	**Connected Car Technology**

The world's largest exhibition for the advanced automotive technologies.
Tokyo Big Sight, Tokyo — January 17 - 19
http://www.automotiveworld.jp/en/

Kawasaki International Eco-Tech Fair 2018
Todoroki Arena, Kawasaki (Kanagawa) — February 1 - 2
http://www.kawasaki-eco-tech.jp/index.html

ENEX 2018 (Energy and Environment Exhibition), consisting in the following 2 shows:
Smart Energy Japan 2018
Energy Supply & Service Showcase 2018
Tokyo Big Sight, Tokyo — February 14 – 16
https://www.low-cf.jp/east/eng/index.html

World Smart Energy Week 2018 – Tokyo Edition, consisting in the following 8 shows:
14th FC EXPO – International Hydrogen & Fuel Cell Expo
11th PV EXPO – International Photovoltaic Power Generation Expo
9th PV SYSTEM EXPO – International Photovoltaic Power Generation System Expo
9th BATTERY JAPAN – International Rechargeable Battery Expo
8th INT'L SMART GRID EXPO
6th WIND EXPO – International Wind Energy Expo & Conference
3rd INT'L BIOMASS EXPO
2nd THERMAL POWER EXPO – Next-generation Thermal Power Generation Expo

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[344] JETRO: http://www.jetro.go.jp/j-messe/?action_enFairList=true&type=v2&v_2=009&v_3=002.

Tokyo Big Sight, Tokyo February 28 – March 2
http://www.wsew.jp/en/To-Visit-Tokyo/Venue-Info-Access/

N-EXPO 2018

N-EXPO (New Environmental Exposition) and GWPE (Global Warming Prevention Exhibition) in consideration of the 2020 Tokyo Olympic and Paralympic Games.

Tokyo Big Sight, Tokyo May 22 - 25
https://www.nippo.co.jp/eng/n-expo018/ne18_a.htm

Solar Asset Management - Asia

Tokyo Conference Center Ariake, Tokyo May 24 - 25
https://solarassetmanagement.asia/#solar-asset-management-asia

Grand Renewable Energy 2018 International Conference and Exhibition

Pacifico Yokohama, Yokohama June 17 – 22
http://www.grand-re2018.org/english/index.html

PVJapan 2018

Pacifico Yokohama, Yokohama June 20 – 22
http://www.jpea.gr.jp/pvj2018/en/

Smart Engineering Tokyo 2018

Tokyo Big Sight, Tokyo July 18 – 20
https://www.jma.or.jp/set/en/index.html

Energy Innovation Japan & Smart Energy Japan West 2018

Myodome Osaka, Osaka August 28 – 29
https://www.low-cf.jp/east/eng/index.html

1st Automotive World Nagoya 2018 – Nagoya Edition, consisting in the following 5 shows:

Car Electronics **EV/HEV/FCV Technology**
Lightweight **Processing**
Autonomous Driving Technology

Portmesse Nagoya, Nagoya September 5 - 7
http://www.automotiveworld-nagoya.jp/en/

World Smart Energy Week 2018 – Osaka Edition, consisting in the following 8 shows:

6th PV EXPO – International Photovoltaic Power Generation Expo Osaka
6th PV SYSTEM EXPO – International Photovoltaic Power Generation System Expo Osaka
5th BATTERY JAPAN – International Rechargeable Battery Expo Osaka
5th INT'L SMART GRID EXPO
3th FC EXPO – International Hydrogen & Fuel Cell Expo Osaka
3rd INT'L BIOMASS EXPO
2nd THERMAL POWER EXPO – Next-generation Thermal Power Generation Expo Osaka
2th WIND EXPO – International Wind Energy Expo Osaka
INTEX, Osaka September 26 – 28
http://www.wsew.jp/en/To-Visit-Osaka/Venue-Info-Access/

EVS31 & EVTeC 2018: The 31st International Electric Vehicles Symposium & Exhibition and International Electric Vehicle Technology Conference 2018.
Kobe Convention Center, Kobe September 30 – October 3
http://www.evs31.org/

Kyoto Smart City Expo 2018
Keihanna Open Innovation Center, Kyoto October 4-5
https://expo.smartcity.kyoto/en/

Energy Storage Summit Japan (ESSJ 2018)
Lino Hall & Conference Center, Tokyo October 16-18
https://essj.messe-dus.co.jp/en/home/

Japan Solar + Energy Storage Congress & Expo 2018
Osaka October 29-30
http://www.leader-associates.com/japan2018.html

REIF Fukushima (Renewable Energy Industry Fair)
Big Palette Fukushima, Fukushima November 7 - 8
https://www.big-palette.jp/

EcoPro 2018 – Environment and Society of the SDGs Era, and to the Future
Tokyo Big Sight, Tokyo December 6 - 8
http://eco-pro.com/2018/english.html

EU-Japan Centre for Industrial Cooperation