BACKGROUND STUDY

Smart power grids and integration of renewables in Japan

Status and activities concerning smart grids implementation and integration of renewable energy sources in Japan

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Executive Summary

Like many other countries depending heavily on energy imports, Japan is trying to reduce its vulnerability to price shocks and geopolitical risks. It also set itself the goal of substantially reducing its greenhouse gas emissions by mid-century, and needs to keep the energy prices at affordable levels. This classic energy trilemma is flanked in Japan by the pressing need for improving the safety issues relating to energy supply, exposed by the environmental catastrophe and massive blackouts brought about by the Fukushima Daiichi disaster in 2011. The first revision after Fukushima of Japan’s central energy strategy document, the Strategic Energy Plan, introduced the 3E+S policy, which is still valid today: energy security, economic efficiency, protection of environment plus safety. The following, 5th Strategic Energy Plan from 2018 goes even further and for the first time designates renewable energy as a *"central cornerstone"* of the energy system.

The context in which these developments are taking place is in many ways unique. Not just urbanisation but also the aging of society have been so pronounced in Japan that they have had an effect on the national energy strategy. Further, Japan’s power sector, dominated for the entire second half of the 20th century by the 10 electric power companies (EPCOs), has been undergoing liberalisation since 1995. Renewables, playing a marginal role before 2012, are being deployed at a much higher rate since then, making their integration one of the central challenges of Japan’s energy transition.

Resilience to disruptions is envisioned to become a key feature of the energy system. The Japanese approach is that of smart communities. These are based on consumer participation enabled by smart technologies, enabling environmentally sound energy production and efficient consumption. They are, however, envisioned to go beyond energy issues and aim at establishing a *“new social system”* which will provide crucial *“life support services”,* including for example care for the elderly. A sort of paradigm shift is envisioned where energy supply is organised bottom-up instead of bottom-down. Indeed, citizen and communal energy services have already appeared in Japan, modelled on the German *Stadtwerke*.

This study focuses on smart grids and integration of renewable energy sources in Japan. It first elaborates on the current status of the Japanese power market, its electricity grid, and the trends taking place which result in the need for smart grids (chapter 1). It proceeds with strategic and legislative framework setting relevant for smart grids and renewables, and with current status of smart grids and renewables (chapter 2). Further, it focuses on relevant stakeholders, new business models, and public acceptance relevant for smart grids and renewables (chapter 3). It then puts the Japanese developments in international context and, where possible, compares it to Germany (chapter 4). Lastly, it derives recommendations and identifies where Japanese and German policymakers, regulators and private sector stakeholders might profit from closer collaboration (chapter 5).

Chapter 2 finds that while smart grids are an important element of the Japanese energy strategy, no single legislative act is primarily dedicated to promoting smart grids as such. Instead, different strategic documents and legislative acts address different aspects. For example, completion of smart meter rollout by early 2020s is foreseen in the Strategic Energy Plan. The electric power companies such as TEPCO have been very successful at deploying smart meters, driven by desire to cut operating costs and expand their service portfolios. Technical standards and data security regulations for smart meters are covered by the Electricity Business Act. The Electricity Business Act also handles the grid connection for the renewable energy plants. However, the current method for allocation of grid connection capacity known as “connectable amount” only exacerbates the problem of insufficient connection capacity in the power grid and is to be replaced by the Japanese version of Connect & Manage.

Pilot and demonstration projects and initiatives have been started to promote smart communities in Japan. Four pilot smart communities were started in 2010 under the Government’s Next Generation Energy and Social System. Since 2012, under the Project for Promoting Introduction of Smart Communities, different elements of smart grids have been implemented in 13 communities across the Tohoku region, hit the year before by the earthquake.

In addition, individual technologies crucial for smart grids such as energy management systems for homes, buildings and communities, as well as demand response (DR), virtual power plants (VPP), grid-connected battery energy storage systems (ESS) and electric vehicle (EV) charging networks have been promoted through numerous pilot projects, partnerships and initiatives, usually with participation of private companies and funding from the Government. Energy policy and industrial policy have traditionally gone hand in hand in Japan and this can also be observed with some of the technologies relevant to smart grids, e.g. battery ESS.

Chapter 3 finds that while the EPCOs are faced with considerable challenges due to the changing landscape they are operating in, at least some (e.g. TEPCO) have been proactive to adapt to the new environment, exploring new opportunities and seeking partnerships to deploy novel technologies and services. While the Japanese public is generally supportive of renewables, opposition from citizens directly affected by individual projects has been present, and increasing power prices due to high FIT tariffs have been seen as an issue. With regard to smart communities, a detailed investigation of one such community has come to conclusion that while the acceptance is generally given, participation levels have remained modest. Participants agreed relatively often to their data being collected and analysed, hinting at high levels of trust towards project owners.

In some cases, technologies associated with smart grids have established themselves well in the Japanese market, such as in the case of smart meters and grid-connected ESS. In other cases, deployment have so far been modest, for example in the case of DR, VPP and blockchain. Here, it was usually a combination of legislation and market design which precluded compelling business cases. Somewhere in between fall the business models based on vehicle-to-home (V2H) and vehicle-to-grid (V2G) technologies – the former has already been commercialised, the latter tested in pilot projects. Japan is also expanding its transmission network by high voltage direct current (HDVC) lines and upgrading the traditionally weak interconnections between the 10 EPCO service zones.

Chapter 4 finds that Japan is one of the global leaders in terms of smart meter and battery ESS deployment, while DR and VPP markets, as well as blockchain applications, have yet to establish themselves. It is also comparably well covered with publicly available EV chargers, with plans to improve the coverage further. Japan has also gathered more experience with smart communities than most countries.

Chapter 5 finds that while Germany and Japan find themselves at different stages in terms of renewable energies deployment and integration, as well as in different energy-political contexts, there are many opportunities where they can profit from closer cooperation with one another. Both are experiencing considerable challenges with grid expansion necessary for integration of renewables, at least partly due to lacking acceptance; both have battery ESS high on their industrial policy agenda; both have large untapped DR capacity; and both will have to answer the question if, and what exactly, the role of blockchain and especially peer to peer (P2P) power trading should be in their respective energy markets. Germany has integrated far more renewable energy capacity and has a more differentiated VPP market, while Japan has deployed more battery-based ESS, and is far ahead in terms of smart meter deployment. Japan’s experience with smart meter data collection, sharing and use, as well as with data security, might be especially interesting for Germany. Germany can also learn from Japan’s experience with microgrids, which would likely become more relevant if local energy consumption and resilience become higher priorities in the future.

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List of Abbreviations

BEMS	Building Energy Management Systems
BEV	Battery Electric Vehicle
CEMS	Community Energy Management System
EEG	Erneuerbaren-Energie-Gesetz
EGC	Electricity and Gas Market Surveillance Commission
EMS	Energy Management System
EPCO	Electric Power Company
ESS	Energy Storage System
ETPSG	European Technology Platform Smart Grid
GW	Gigawatt
GWh	Gigawatt hour
HEMS	Home Energy Management System
HVDC	High Voltage Direct Current (Transmission)
ICT	Information and Communications Technology
IoT	Internet of Things
ITRI	Industrial Technology Research Institute
ISGAN	International Smart Grid Action Network
JESC	Japan Electrotechnical Standards and Codes Committee
JPEX	Japanese Electric Power Exchange
JSCA	Japan Smart Community Alliance
JSWNW	Japan Stadtwerke Network
kW	Kilowatt
kWh	Kilowatt hour
METI	Ministry of Economy, Trade and Industry
MW	Megawatt
MWh	Megawatt hour
NSS	National Spatial Strategy
OCCTO	Cross-regional Coordination of Transmission Operators
PHEV	Plug-In Hybrid Electric Vehicle
PPA	Power Purchasing Agreement
P2P	Peer-to-Peer
P2X	Power-to-X

REI	Renewable Energy Institute (Japan)
TEPCO	Tokyo Electric Power Company
TDSO	Transmission and Distribution System Operator
VRES	Variable Renewable Energy Sources
V2G	Vehicle-to-Grid
V2H	Vehicle-to-House
VPP	Virtual Power Plant

Introduction

Japan and Germany declared in June 2019 the establishing of an energy partnership, intended to represent a framework for closer cooperation. Although the two countries find themselves in somewhat different energy-political contexts, their energy policies share some important priorities: ensuring supply security, lowering greenhouse gas emissions, and keeping energy prices at acceptable levels.

In addition, Japan's energy policy sees safety as one of the primary objectives since the Fukushima disaster of 2011. One approach is to improve resilience against disruptions. Here, microgrids as the technological foundation for smart communities play an important role. By relying on information and communications technology (ICT), smart communities profit from improved integration of distributed renewable energy sources, smart management of energy storage and consumption, and more opportunities for citizen participation. Japan has had much success with implementation of some of the core technologies necessary for microgrids, e.g. smart meters.

This study investigates the interplay of smart grids and integration of renewable energy in Japan on the intersection between policy, legislation, technology and market. It then derives conclusions and identifies areas where closer cooperation with Germany could be beneficial for both countries.

1 Japan's power market, electricity grid and the need for smart grids

1.1 Clarification of the term smart grids

The Federal Ministry for Economic Affairs and Energy (BMWi) defines a smart grid as following:

"*The concept of the "smart grid" describes the communicative connection of the actors in the energy supply system to the power supply grid, from power generation, transmission, storage and distribution through to the consumption of the electricity. /…/ This creates an integrated data and energy grid with completely new structures and functions,*" (BMWi without date).

Other sources might use other, slightly diverging definitions. However, central to virtually all of them is the nexus between the electric grid and ICT. Beyond that, smart grids are often considered the answer to the energy trilemma of environmental sustainability, economic viability and energy security, as evident from the definition by the International Smart Grid Action Network (ISGAN), adopted its definition from the European Technology Platform Smart Grid (ETPSG):

"Smart Grid is a concept and vision that captures a range of advanced information, sensing, communications, control, and energy technologies. Taken together, these result in an electric power system that can intelligently integrate the actions of all connected users—from power generators to electricity consumers to those that both produce and consume electricity ("prosumers")—to efficiently deliver sustainable, economic, and secure electricity supplies," (ISGAN 2015).

Smart grids encompass a wide range of technologies and overarching technology areas, spanning the entire power system from generation to transmission, distribution and storage to consumption (adapted from IEA 2011):

- Advanced metering infrastructure;
- Wide-area monitoring, sensing and automation;
- Integrated communication applications across different technologies, systems and platforms;
- Integrated variable and/or distributed renewable energy power sources;
- Enhanced transmission;
- Energy distribution and management systems;
- Electric vehicle charging infrastructure;
- Costumer-side systems such as smart appliances, smart home automation, systems.

A smart grid, together with further components and systems, unlocks a plethora of functions and benefits (adapted from IEA 2011):

- Enabling informed market participation by the consumers;
- Accommodating all generation and storage options;
- Enabling of new products, services and markets;
- Providing the power quality – and the corresponding price – for the entire range of needs;
- Optimising asset utilisation and operating efficiency; and

- Providing resiliency to disturbances, attacks and natural disasters.

Particular to Japan is a close association of smart grids with smart communities, a concept which goes beyond technical and market-based measures and emphasises sociological elements of transformation, creating a new and inclusive social system of self-sufficient and empowered prosumers (see section 2.1 for more information).

1.2 Structure, roles, regulatory framework and status of liberalization

Since the end of World War 2, the ten Electric Power Companies (EPCOs) have controlled the vertically integrated power market. They provided power generation, transmission and distribution in their service zones, enjoying a monopoly position. Until the 1970s, they nevertheless provided power at acceptable price levels. When this started to change, demands for government action became stronger, leading to the start of market liberalisation in 1995 (Kikkawa 2002).

Liberalisation took place in consecutive stages. In 1995, changes were introduced in the generation segment. An easier market entry was provided for new markets entrants, a power retail business framework was created, power rates regulation was relaxed, and safety regulation was streamlined. Next, in 2000, market liberalisation focused on retail, and the retail of power to high-voltage consumers (over 2,000 kW) was liberalised, enabling them to freely choose their power provider. The liberalisation also enabled third-party access to the transmission lines of the still vertically integrated EPCOs. Subsequent gradual lowering of the power threshold in 2004 and 2005 followed, until finally, in 2016, all power consumers, including small businesses and households, were able to choose their power provider. With this step, power retail was completely liberalised (IEA 2016, JETRO 2016).

The final step of market liberalisation is envisioned for 2020 with the unbundling of EPCOs. Their transmission and distribution segments are to be separated from generation. While the newly created transmission and distribution companies will retain the natural monopoly over the power grid, they will have to continue to enable third-party access via fair tariffs.

Parallel to market liberalisation, the power grid is being rapidly equipped with smart meters. The rollout started in 2016 with the largest industrial consumers and should conclude between 2020 and 2025 with households, deploying about 80 million units (section 2.5) (ITA 2016).

In 2015, the Japanese Electric Power Exchange (JPEX), a private forward and spot power exchange, and the Organization of Cross-regional Coordination of Transmission Operators (OCCTO) were created. The OCCTO is tasked with balancing demand and supply over the entire territory of Japan and coordinating the transmission and distribution system operators (TDSOs) to ensure adequate transmission in both normal and emergency situations (IEA 2016). It has the authority to order the utilities to increase power generation when necessary, and to order the construction of new transmission lines. Membership in OCCTO is obligatory for all power producers. The Electricity and Gas Market Surveillance Commission (EGC) was also established in 2015, in order to supervise and monitor the power trading market, including making recommendations regarding transmission tariffs to METI.

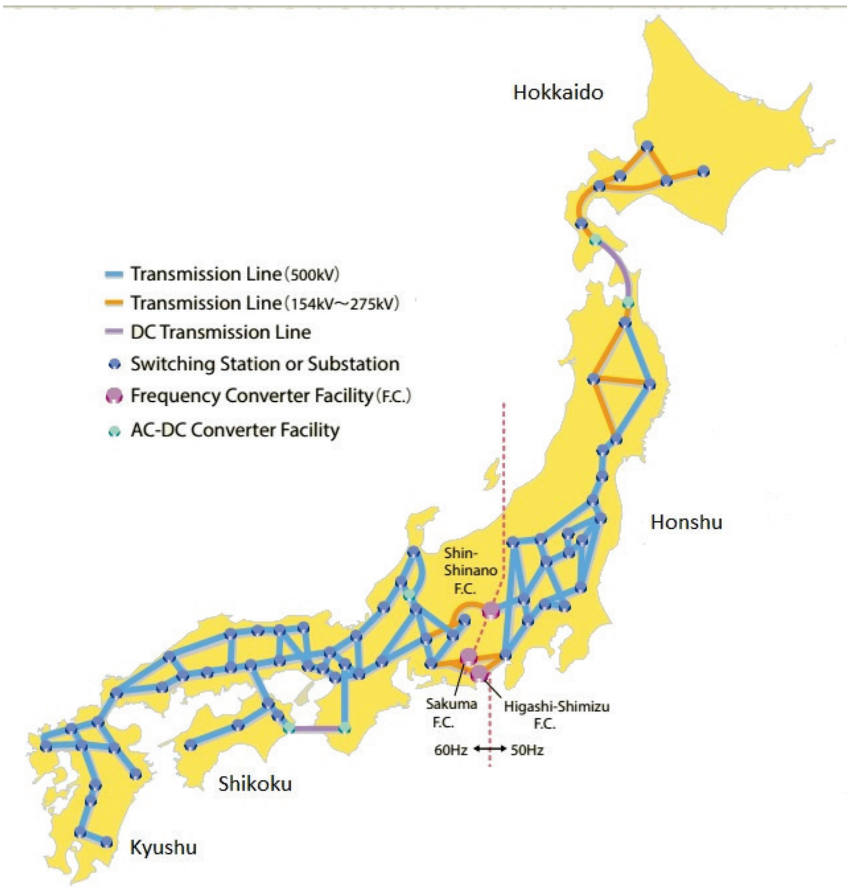
In 2017, four of the 10 ESCOs announced their intention to create a nationwide backup power market with the aim of lowering the costs, and to accommodate the rising share of renewables in the power system (Nikkei Asia Review 2018).

Despite the presence of the JEPX, the ten EPCOs maintain their own retail companies that can sell power directly to end-consumers, and only sell excess power on JEPX. Contracts for direct sales of electricity are not subject to any regulation. Effectively, only a small share of power is traded at JEPX (6.8% in September 2017) (EMSC 2018), but measures are being introduced to activate to increase this share and activate the wholesale market (IZES, JEPIC 2017). The spot market is also split due to the low interconnection between EPCO's service zones (section 1.3) (IEEJ 2016).

1.3 The power grid

Japan's electricity grid is not connected to any neighbouring countries. In addition, the country has two frequencies areas: 50 Hz is used in the north-eastern part of Honshu, including Tokyo and Yokohama, and on the island of Hokkaido. A 60 Hz network covers south-eastern Honshu, including Osaka, Kyoto and Nagoya, as well as on Shikoku and Kyushu islands. The interconnections between both frequency areas are currently standing at only 1.2 GW with plans to increase them to 3.0 GW by 2027 (section 2.5). This weakness was exposed in 2011 after the power plants along the eastern coast of Honshu had to be shut down.

Figure 1: Japan's national transmission grid

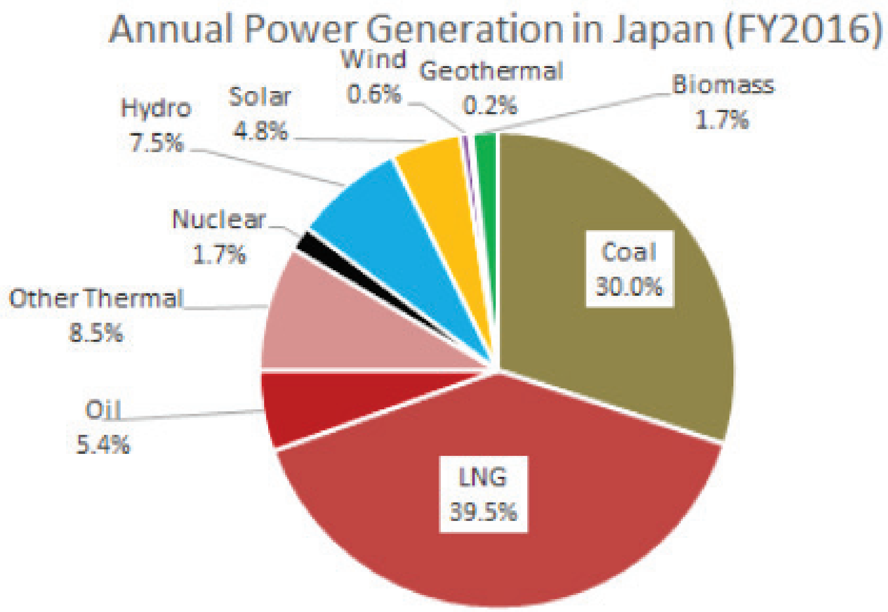


Source: FEPC (2018) (image manipulated and supplemented with additional information)

1.4 Current power mix

Despite this rapid increase of renewables capacity, especially of solar photovoltaic (PV) (section 2.3), the total share of renewables in electricity production only reached 14.8% in FY2016. Large hydro remains the biggest contributor with 7.5% of the total electricity produced. Solar PV had a share of 4.8% in FY2016, biomass of 1.7%, wind of 0.6% and geothermal of 0.2%. The share of variable renewable energy sources (VRES) stood at under 6%. Nuclear power generation accounted for only 2% in FY2016. The rest of power – over 80% – was generated from fossil-based sources (FES 2018).

Figure 2: Power generation by sources in Japan in FY2016



Source: FES (2018)

1.5 The need for smart grids

In Japan, most of the trends driving the needs for smart grids in other countries are present, as well as some specific to Japan (roughly in descending order of significance):[1]

- Ageing infrastructure and relatively high frequency of typhoons and earthquakes[2];

[1] The information was partly obtained in direct correspondence with IEEJ

[2] For example, one week after Hurricane Faxai in September 2019, almost 56,000 households in Chiba Prefecture just east of Tokyo, were still without electricity.

- Falling prices and increasing shares of VRES in the power systems, together with decentralisation of energy generation (section 2.1**Fehler! Verweisquelle konnte nicht gefunden werden.**);
- Power market liberalisation, together with new market mechanisms, and entrance of new players in generation and retail segments (section 2.1), as well as the need to keep electricity prices at acceptable levels;
- Electrification of transport (both as vehicle-to-grid (V2G) and vehicle-to-home (V2G)) and to a lesser extent, of heating sector;
- Market readiness and deployment of battery storage systems and to a lesser extent, of P2X technologies;
- In the mid- to longer term, hydrogen and fuel cell technologies;
- Increased commitment to decarbonisation of the energy system, as well as diminished role of nuclear power.

Specific to Japan in comparison to many other developed countries is stagnant power consumption (or even falling in small municipalities outside of urban centres) since the turn of the century, whereas most developed countries have seen an increase (REI 2017). Apart from that, grid stability has traditionally been one of the top priorities in Japan, and smart grids are considered a measure that can contribute to grid resiliency in Japan. Another upside associated with smart grids is strengthening of local economies (see section 2.11.1).

Further, Agora Energiewende and Renewable Energy Institute, in their 2019 Study Integrating renewables into the Japanese power grid by 2030, identify the measures necessary for grid integration of higher shares of variable renewables. Many of these rely on incorporating ICT into the power grid (REI, Agora Energiewende 2019):

- Fostering data transparency regarding grid data, including grid parameters, generation data, and real-time data;
- Improved monitoring of power system parameters (such as system inertia);
- Integrating renewable energy sources into ancillary services provision necessary to maintain grid stability (such as fast frequency response, synthetic inertia, reactive power and balancing).

2 Strategic and regulatory framework in Japan, status of implementation of smart grids and renewable energies

2.1 Strategic framework setting

Energy policy

The Strategic Energy Plan, revised every three years by the Japanese Government, defines the general direction of the country's energy policy. In its latest, 5th edition from 2018, it defines Japan's main structural issues as following: vulnerability due to high dependency on overseas energy resources; mid- to long-term changes in the energy demand structure (including population decline); instability of resource prices; and the increasing global greenhouse gas emissions (The Government of Japan 2018). The 4th Strategic Energy Plan, the first one released after the Fukushima Daiichi accident, introduced the so-called 3E+S policy (still valid in the 5th edition): energy security, economic efficiency, protection of environment, plus safety.

The 5th Strategic Energy Plan also defines the *"optimal"* 2030 power generation mix (which it adopts from the Long-term Energy Supply and Demand Outlook from 2015) (Government of Japan 2015):

- 22% to 24% renewable energy,
- 27% LNG
- 20% to 22% nuclear
- 26% coal
- 3% oil

The 5th Strategic Energy Plan for the first time designates renewable energy as a *"central cornerstone"* of the energy system; however, the absolute renewable energy targets it sets are considered low (see section 2.3). The 5th Strategic Energy Plan also admits that the existing power grid faces challenges with integrating increasing capacity of variable renewable sources. The short-term strategy answer is the Japanese version of Connect & Manage (see section 2.2 for more details), as well as improving load-following by flexible use of thermal generators, adjusting the feed-in from the renewables themselves, and increasing the interconnection capacities between the 10 EPCO service zones. Gradually, measures and technologies such as cogeneration, virtual power plants (VPPs), V2H/V2G and stationary energy storage systems (ESS) are to be introduced. In the long term, power-to-gas applications for hydrogen production as *"the next-generation load following capacity"* is envisioned.

Smart Grid and Smart Communities

In Japan, smart grid is closely related to the concept of smart community. Smart communities are typically implemented in a geographically restricted area at local level with large companies playing a major role in its realization. As Mah (2015) puts it, Japan follows a „*government-lead, community-oriented and business-driven approach*". A smart community can be a cluster of residences, public facilities, factories, commercial buildings, or mix of these.

Its technological basis is the smart grid, coupled with energy efficiency measures, disaster resilience measures etc. (DeWit 2018). A smart community in the 4th Strategic Energy Plan is defined as follows (Government of Japan 2014):

„A smart community is a community of a certain scale in which various consumers participate and which has created a new social system. The new social system, while utilizing a distributed energy system, including renewable energy and cogeneration, comprehensively manages energy supply and demand of the distributed energy system through an energy management system using IT, storage battery and other technologies so as to optimize use of energy and incorporates life support services, including the provision of care for elderly people."

The concept of smart communities came into the focus of Japan's policymaking especially after the Fukushima Daiichi disaster as resilience became a higher priority. Plans for establishing smart communities usually receive fiscal, administrational and regulatory support by government agencies.

Apart from the 4th and 5th Strategic Energy Plan, smart communities with smart grids as their technological foundation play a key role in national strategy documents going beyond energy policy. One such overarching document is the National Spatial Strategy (NSS), adopted in 2015 after extensive inter-ministerial coordination, stakeholder involvement and public consultation. Compared to its predecessor, it gives a much higher priority to smart communities, as well as to renewable energies, distributed energy, and energy issues in general sense (DeWit 2016).

2.2 Legislative framework setting

The Basic Energy Act

The Basic Energy Act was passed in June 2002. Its intention is to translate Japan's energy policy into a legislative framework. The act defines the role of relevant stakeholders such as central government, local governments, businesses etc. The Basic Energy Act instructs the government to develop the Strategic Energy Plans based (section 2.1) in order to formulate long-term and comprehensive energy strategies.

The Electricity Business Act

The Electricity Business Act is the central act for electricity market regulation and defines the general structure, roles, competencies and obligations. It also serves to protect the interests of electricity consumers, to achieve the sound development of electricity businesses through adequate management, to ensure public safety and to promote environmental protection by regulating the construction, maintenance and operation of electricity facilities.

The Electricity Business Act was revised in 2015 in order to accommodate electricity market reforms. The last step of this reform is planned for 2020, when electricity companies must legally unbundle their generation, transmission and distribution, and retail divisions. In discussion for 2020 is also abolishment of regulated retail tariffs.

The Electricity Business Act in its current form poses substantial challenges for renewables integration. Firstly, grid access is still granted on a "first-come, first-served" basis, giving priority to existing generators already connected to the grid and guaranteeing them transmission capacity corresponding to their maximum generating output. This basically negates priority access for renewables. Furthermore, the capacity set aside for the already connected generators is calculated very generously, on the assumption that all their generation facilities are at maximal operation (including nuclear power plants idled after the Fukushima disaster); additionally, a certain portion of capacity for use in emergencies is set aside (which again is determined very generously). This “maximum generating output rule” is currently under discussion, since only in the rarest of cases, it corresponds to the actual output.

Secondly, granting grid connection to renewable energies is based on the connectable amount. The connectable amount is roughly determined by the maximum amount of solar and wind which can be connected to grid so that when renewables production is high (while thermal generation is kept at minimum *and* pumped storage is being used to absorb renewable power), the output restriction from the FIT-entitled generators does not exceed 30 days or 360 hours for solar PV and 720 hours for wind generators. Generally, the available connectable amount is too low. This holds especially true for solar power, where the installed capacity in most areas already exceeds the connectable amount (FES 2018). In Hokkaido, Tohoku and Kyushu, for example, the connectable amount has been exceeded by existing solar capacity by a factor of two. Hokkaido Electric Power has exceeded the connectable amount for wind power (FES 2018). As a consequence, feed-in from the respective renewable energy power into the grid has been restricted until the power grid has been expanded.

Thirdly, grid operators are not obliged to expand the grid in order to provide the necessary capacities for the expansion of renewable energies. When the grid expansion plans are laid out, a separate tender is carried out by the OCCTO in order to recoup the expansion costs. Here, renewable generators bid for a share of the newly created grid connection capacity. What this means in practice is that the connectable amount and bidding for grid access rather than the FIT scheme effectively determines the rate of renewables deployment in Japan (Matschoss, Iinuma 2017)

This framework has been criticised in Japan and abroad as an impediment for integration of renewables, and changes are foreseen. The 5th Strategic Energy Plan already stipulates that grid connection based on the connectable amount is to be replaced by the Japanese version of Connect & Manage, designed by the OCCTO. This new approach is intended to integrate the maximum amount of renewables possible into the existing grid and at the same time minimise the increase in electricity prices by reducing the need for grid upgrades. It works by first replacing the existing grid emergency capacity allocation method with the n-1 principle, thus freeing up technically available transmission capacities. Secondly, instead of offering the renewable generators what is called a “firm connection” where their feed-in can only be restricted for 30 days or 360 hours for solar PV and 720 hours for wind (see above), it offers them to connect and sell whatever amount of power the grid is able to accept. Third, choices on grid expansion under Connect & Manage are made based on cost-to-benefit assessment (FEPC 2018).

The Electricity Business Act also covers the technical standards and data security regulations for smart meters. Japan’s Electrotechnical Standards and Codes Committee (JESC) published in 2016 the Smart Meter System Security Guidelines and Power Controls System Security Guidelines. Both sets of guidelines are incorporated into The Electricity Business Act and thus mandatory for electric utilities and grid operators. A set of auditing guidelines were developed by the Japan Information Security Audit Association, and in 2016 internal audits had to be conducted by utilities and grid operators in order to address their cybersecurity concerns (Sasakawa Peace Foundation USA 2017).

Renewable Energy Act

Another relevant act is The Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities, also known as the Renewable Energy Act or the FIT Act. It defines renewable energy as solar power, wind power, hydropower, geothermal heat and biomass. In addition, it regulates the FIT scheme. The act is to be reviewed by the end of 2020. The review will take into account current discussions on how renewable energy can become an important energy source without the financial support provided by the FIT system, i.e. via a tendering system for electricity from large renewable power installations, and on how policies promoting renewable energy can be restructured.

With FY2017, the FIT scheme has undergone an important change: the fixed premium has been replaced with a reverse auction system (also called FIT tenders, not to be confused with the separate tendering for grid connection mentioned above).

Legislation relevant for smart grids

No legislation exists in Japan dedicated explicitly addressing smart grids. Instead, smart grids are covered in other strategic and legislative acts, for example those addressing disaster prevention, spatial planning, industrial and energy policies etc. (section 2.1). Some relevant aspects are also covered in the Electricity Business Act, such as that P2P power trading is not allowed.

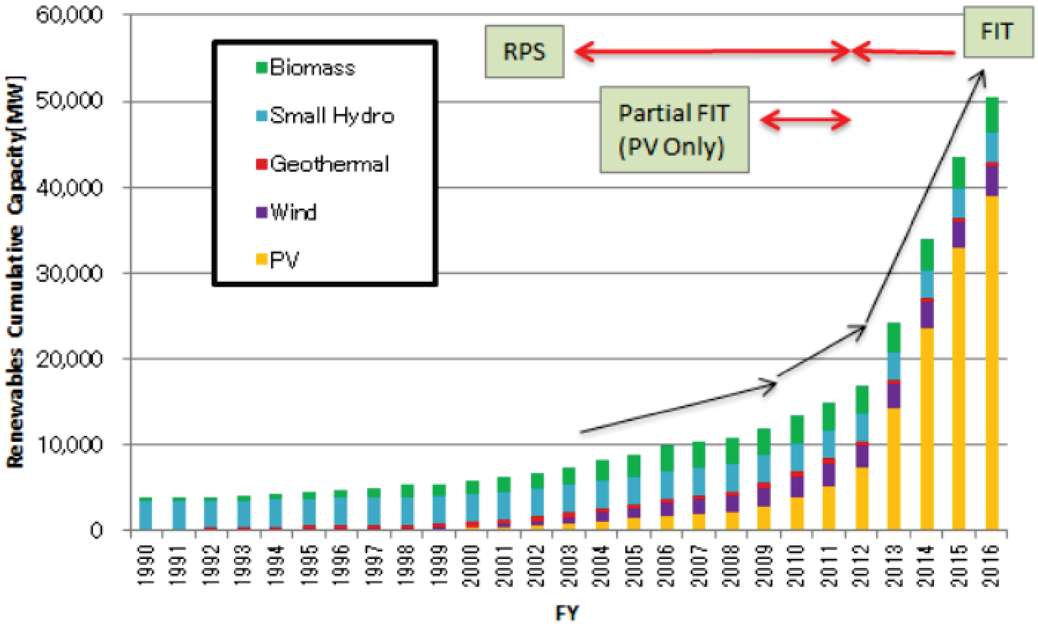
2.3 Status of renewable energy in Japan

As mentioned in section 2.1, the 5th Strategic Energy Plan from 2018 states that renewables are to assume a central role in Japan's future power mix. The 22 – 24% share in the power generation mix in 2030 are to be provided by 64 GW of solar and 10 GW of wind capacities (The Government of Japan 2018; REI, Agora Energiewende 2019). This is generally considered an unambitious target, especially in regard to wind power, where Japan's total technical potential is estimated at around 1,600 GW (JETRO 2015). The Japanese Photovoltaic Energy Association (JPEA) and Japan Wind Power Association (JWPA) have set themselves higher 2030 targets than the Government with 100 GW of solar PV and 36 GW of wind, respectively (Solar Journal 2018; Japan Wind Power Association 2014). The notion remains on the side of the Japanese Government that renewables are expensive and unreliable (The Government of Japan 2018). However, REI and Agora Energiewende (2019) come to conclusion that the power system stability can be maintained even at renewable energy shares exceeding the current 2030 Government target.

The first subsidy for residential PV was introduced in 1993 in the form of the Renewable Portfolio Standard (RPS) under which electricity retailers were obligated to supply a certain share of power from renewable energy (IEA 2016a). It was replaced in July 2012 by the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities (section 2.2) (REI 2017a). Much like similar schemes in other countries, including the Germany's *Erneuerbaren-Energie-Gesetz* (EEG) levy, the FIT's role was to jump-start private investment into renewable energy power sources. The FIT provided a comparatively high power purchase tariff for solar PV with a 20-year obligatory purchase period, and no cap on the purchase volume (Yamaguchi Mitsune 2014).

The general consensus regarding the FIT scheme is that it has been a success in terms of spurring the deployment of renewables. This holds especially true for solar PV, which went from 7.3 GW installed capacity in 2012 to 42 MW at the end of financial year 2016 (FES 2018), thus surpassing Germany with 41 GW. Wind and biomass capacities increased only marginally in the same timeframe, from 2.6 to 3.4 GW and from 3.3 to 4.1 GW, respectively. The capacities of geothermal and small hydro remained unchanged.

Figure 3: Installed renewable electricity sources capacities in Japan



Source: FES (2018)

Before the introduction of FIT, most PV systems were residential with capacities below 10 kW. By the end of FY2016, their share fell to 25%, as the newly added PV capacities consisted mostly of large-scale non-residential systems. The share of systems with capacities up to 1 MW increased to about 45% and those exceeding 1 MW to about 30% (FES 2018).

Despite its success in terms of renewables deployment, the FIT scheme has experienced its fair share of difficulties. At the beginning, it offered very high tariffs for PV projects in the first year they came online. This led to many projects being rushed through accreditation process by the investors without taking proper care of the funding or preparation of land, which often led to difficulties with project completion (FES 2018). In addition, the large quantities of solar power installed have led to substantial increases in electricity prices, with a lock-in effect for two decades (Yamaguchi Mitsune 2014). Third, despite the tariff price being decreased twice, and the scheme ultimately switching to a reverse auction system with FY2017, the tariffs per kilowatt hour remain high in Japan; they were about 2.5 times as high as in Germany in 2017 (PV Magazine 2018).

In addition, even after a project has been completed, there are major obstacles it faces before it can start feeding power in the Japanese grid and receive compensation under the FIT scheme (see section 2.2, The Electricity Business Act, for more details).

2.4 Smart grid research and demonstration projects, initiatives, platforms, partnerships

Many projects, initiatives and platforms have been established to promote smart grids and renewable energy integration. Many of them receive support by the Japanese ministries and national agencies. In the following sections, a selection is presented.

Japan Smart Community Alliance

The Japan Smart Community Alliance (JSCA) was established in April 2010 with the aim of overcoming the obstacles individual organizations were facing through collaboration of the public and private sectors. JSCA has a wide range of members from various private enterprises and organizations, including public service corporations, universities and local municipalities. In the beginning of 2019, the number of members stood at 259. Many activities of JSCA are international, e.g. an international strategy working group and an international standardisation working group. JSCA has also signed memoranda of understanding with similar organisations in other countries like e.g. Korea.

Japan Stadtwerke Network

Against the backdrop of the Fukushima Daiichi nuclear accident and its far-reaching consequences for the Japanese electricity supply, many municipalities are particularly concerned with ensuring a reliable and resilient energy supply to the region. The Japan Stadtwerke Network (JSWNW) was established by Japanese municipalities in September 2017 to pursue this objective. It aims to foster information exchange and to facilitate establishment of further *Stadtwerke* in Japan. Generally, the JSWNW offers support in a wide range of areas, from organising study trips to joint procurement activities, and also offers support with financial planning. Currently, the network counts 32 local municipalities as members. In Japan, the primary goal of setting up a municipal *Stadtwerk* is to supply the municipality or region with energy, especially electricity (Wagner et. al 2018), as well as securing the independence of the regional finance.

Storage Battery Strategy Project Team

Based on its successful semiconductor and power cell industries, battery energy storage systems (ESS) are one of the focus areas of Japan’s industrial policy, in particular after the Fukushima disaster. METI announced its battery strategy in 2012 with the stated aim of reaching a worldwide market share of up to 50% until 2020. Large scale batteries are envisioned to represent just over one third of market volume (Tomita 2014). In 2012, METI also set up the Storage Battery Strategy Project Team in cooperation with

- the Commerce and Information Policy Bureau, responsible for battery industry and information policies;
- ANRE, responsible for overseeing energy policies; and
- the Manufacturing Industries Bureau, responsible for supervising industrial policies (application of storage batteries, next-generation vehicles).

The aim of the team was to set up and implement integrated battery policies, to create battery ESS market, to enhance industrial competitiveness and to reach international standardisation of relevant technologies (Tomita 2014).

Technology research and demonstration projects

While mostly initiated and co-financed by the ministries or government agencies, research and demonstration projects in Japan typically include Japanese companies. Their participation tends to be technology-focussed with a clear business aim, e.g. development of export technologies. Some of the technologies are already being tested abroad.

For example, Tokyo Electric Power Company (TEPCO) Power Grid, Tokyo Gas and the Industrial Technology Research Institute (ITRI) have agreed to jointly conduct a demonstration project to develop a next generation metering platform in the Shalun Green Energy Science City in China (Smart Energy International 2019a).

What is claimed to be the world's largest grid-connected battery ESS with 720 MWh storage capacity has been announced by Hokkaido Wind Energy Transmission, Mitsubishi Electric and Chiyoda. The project is funded by ANRE and is set to come online in 2023. With the help of an energy management system (EMS), batteries are used for managing the surplus wind power and helping power producers comply with Hokkaido's grid codes (Smart Energy International 2018).

NEDO has initiated the Next Generation Offshore HVDC System RD&D Project in order to connect offshore wind parks to the grid. The aim is to enable grid connection to wind farms by building multiple-terminal offshore DC transmission systems which connect offshore wind farms to the existing grid. As presented at the 2019 smart community summit in Tokyo, this project should be completed at the end of FY2019 (Kato 2019).

A V2G pilot project has been started by Chubu Electric Power, Toyota Tsusho and the U.S. company Nuvve. Nuvve's part in the project is to deploy its Grid Integrated Vehicle platform GIVe that enables electric vehicles to be used as power generation assets for frequency regulation. The project is funded by METI and ANRE. Its further aims are to develop a roadmap for increased use of V2G technologies, and to standardise electric vehicles as virtual power plants (Smart Energy International 2018a).

TEPCO in cooperation with Swiss-based company Landis+Gyr has implemented a project based on an internet of things (IoT) network, aiming to connect 30 million smart devices in TEPCO's supply area. With this project, TEPCO is modernising its grid and aims to improve customer services, i.e. by integration of home energy management systems (Smart Energy International 2019).

METI has also initiated the Sustainable Open Innovation Initiative. This programme is intended for utilities, grid operators and other stakeholders from the private sector which will receive government support to launch VPP projects. Technologies such as solar PV, demand response (DR), V2G, home- (HEMS) and building energy management systems (BEMS) are to be incorporated into VPPs. Apart from technology demonstration, the stated goals of the programme are development of new business models and public engagement (ESSJ 2018).

2.5 Status of smart technologies deployment in Japan

Smart communities

Four pilot smart communities have been established under METI's Demonstration of Next Generation Energy and Social System from 2010: Kansai Science City, Kitakyushu City, Toyota City and Yokohama City. These four smart communities are based on smart grid technologies used to optimise energy management, safely integrate renewable energy sources and achieve demand peak shift through dynamic pricing or demand response schemes (Wongbumru, Dewancker 2014). Further, Japanese smart communities focus not only on energy issues, but aim to increase stakeholders' involvement. To this end, not only the grid is to be made smart but also the demand-side applications in industry, commerce, business, mobility and households.

Apart from that, the Project for Promoting Introduction of Smart Communities has been under way since 2012 in the earthquake-hit areas in Tohoku. On 13 individual locations, aspects of smart communities such as community energy management systems (CEMS), control centres for distributed power generators, and smart energy systems have been implemented (JSCA 2015).

Smart metering

Smart meters rollout is one of the central measures in Japan's strategy for smart grids. According to the 4th strategic energy plan, all households and businesses are to be equipped with a smart meter by early 2020s, totalling 80 million smart meters (The Government of Japan 2014). The roll-out is implemented in a top-down manner. Acting on a mandate from the Government, major electric power companies have been deploying smart meters since 2012. TEPCO aims to install about 29 million smart meters by FY2020 and has reached the 20 million mark by March 2019 (Smart Energy International 2019). Based on this rapid smart meter deployment, Japan is widely considered a smart meter champion.

Power grid upgrade

The term "upgrade" is used here as umbrella for optimisation, reinforcement and expansion of both transmission and distribution power grid. As explained in the section 2.2, power grid upgrade has been lagging in Japan and is considered (in combination with the existing grid connection regulation based on connectable amount) the main cause for slow renewables uptake. Japan's efforts have been hampered by limited physical space for grid extensions and high costs.

Nevertheless, upgrading of interconnection capacities has been under way. The current interconnection between Japan's two frequency zones of 1.2 GW (section 1.3) is to be increased to 2.1 GW by FY2020 and to 3.0 GW by 2027, according to Electricity and Gas Market Surveillance Commission (2018).

The interconnections between the 10 regional EPCOs' service zones are typically weak as well, including to the northern island of Hokkaido where the best wind potentials are available (JWPA 2017). Their capacities are also being upgraded, especially between Tokyo and northern Honshu which is to go from the current 5.7 GW to 10.3 GW in 2027. The connection from northern Honshu to Hokkaido has also been increased from 0.6 GW to 0.9 GW in 2019 by a single high voltage direct current (HVDC) cable.

Grid-connected battery energy storage

Japan, with companies such as Panasonic and Toshiba, is considered one of the global leaders for the utility-scale battery energy storage systems. The 5th Strategic Energy Plan identifies batteries as key technology for achieving its energy policy goals, as well as an industrial policy priority.

This has indeed translated into deployment of stationary battery energy storage systems. According to IRENA (2017), Japan had about 300 MW of installed capacity in 2017, with only USA and Korea ahead of it. Batteries have seen deployment both behind-the-meter, where market is expected to increase further after many solar PV projects fall out of the FIT scheme after 20 years, and before-the-meter applications where they are used to store the excess renewable energy produced and sell it during peak hour to provide frequency regulation and act as spinning reserves. Some visible projects have been announced recently, for example the world's largest grid-connected battery ESS with 720 MWh storage (section 2.4).

Expansion of EV charging infrastructure

Japan is one of the world leaders in EV charging infrastructure[3]. Especially in terms of publicly available fast chargers, Japan with about 7,600 was second only to China in 2018 (IEA 2019a). There were also about 22,000 publicly available slow chargers in 2018. Japan has both high targets for EV infrastructure – the Government's goal is to have a fast charger every 15 km or within every 30-mile radius, although the absolute number of charging stations this translates into could not be found – and provides subsidies for EV chargers (IEA 2019a, Inside EVs 2018).

Demand response

METI opened the "Negawatt" market in 2017. The first auction for demand response (DR) was reported to net about 1GW of capacity from industrial and commercial power consumers. Demand Side Management (DSM) where households' demand reduction potentials are aggregated have been part of pilot projects but not yet commercialised.

It is generally considered that the DR potential is huge in Japan. Under the current rules, participation in DR market is voluntary, but when the Government responded in 2011 to the shutdown of the nuclear reactors in the TEPCO service zone by imposing an obligatory peak-load reduction on the industry, the peak-load was reduced by 15% (Takahashi 2013). Sasakawa Peace Foundation (2018) quotes another source which estimates that DR could reduce the national peak load by about 9%. The Government's target is a 6% reduction in peak demand in 2030.

Virtual power plants

In Japan, virtual power plants (VPPs) have been implemented as pilot and demonstration projects, but have not yet seen commercial deployment as they lack economic viability. Part of the reason is the current power market design. It limits business opportunities for front-of-the-meter VPP applications since the vertically integrated EPCOs essentially do not require much additional generation resources outside the system (Thomas et al. 2019). In addition, due to the relatively low share of renewable energy, high FIT tariffs and limited power market activities, business opportunities for bundling renewable power sources are low (Thomas et al. 2019). A gradual expiring of FIT scheme after 2019 in Japan, which forces producers of renewable energy to sell the power in the market, should bring about more favourable conditions for VPP. METI is supporting VPP demonstration projects (section 2.4).

[3] It has to be noted that this does not translate into EV sales as strong as might have been expected.

Blockchain technology

Blockchain applications in the power sector are not yet established in Japan. Part of the reason is that peer-to-peer (P2P) trading necessary for electricity sharing between prosumers is restricted under the Electricity Business Act, limiting the possibilities for blockchain applications . The answer of Japanese utilities (e.g. TEPCO) has been to participate in projects in other countries where no such restrictions exist, such as the UK, Australia, the Netherlands and Germany (Thomas et al. 2019). Several pilot projects have been under way since 2017.

Asian Super Grid

Under discussion since 2012 is the so-called Asian Super Grid, aiming to connect the electrical power transmission networks of China, South Korea, Mongolia, Russia and Japan. The idea was floated after the Great Eastern Earthquake by Masayoshi Son, the founder of the Japanese Renewable Energy Institute. Though technically feasible, several barriers like (national) legislative frameworks, diplomatic concerns etc. have so far hindered its implementation. The Renewable Energy Institute is developing the concept further and has proposed that the super grid be set up exclusively for renewable energy. Reports by the Asia International Grid Connection Study Group show the economic feasibility of the super grid and offer a prospective costs estimation and suggest possible routes (REI 2017b, REI 2018).

3 Stakeholders, public acceptance and new business models

3.1 Main stakeholders in smart grids and integration of renewables

While the Japanese Government has often been criticised for setting unambitious renewable energy targets and lacking strategies for renewables grid integration, it has taken initiative on other aspects of the energy transition, including smart grids, for example by initiating the four pilot smart communities and establishing an advanced cybersecurity framework (section 3.2).

As explained in the section 3.2, the general public is generally supportive of renewable energies, even if the opposition to renewables increased as power prices rose. Feldhof (2014) cites a research from Institute for Sustainable Energy Policies which found that there is support for 100% renewable power in many Japanese regions. With regard to smart communities, there is evidence that while the public does not engage extensively in governance processes, there has been no visible opposition to their implementation.

The 10 EPCOs power sector incumbents have generally responded positively to the changing environment in which they operate. Although they were generally slower than their competitors in terms of renewable power deployment (REI 2017) and continued to invest into fossil generators, they are among the world leaders in terms of smart meter roll-out and deployment of EV charging infrastructure, and have been keen to seek new partnerships and business opportunities.

In the private sector, 19 corporations were members of the global RE100 initiative in 2019. They addressed an open letter to the Japanese Government where they argue for a 50% share of renewables in the power mix by 2030 and 100% in the long term (The Climate Group 2019). They call for a wide alliance of stakeholders, including public authorities and the business community, to provide financing for the necessary infrastructure investments. Organised by Japan Climate Leaders' Partnership (JCLP) and supported by The Climate Group, signatories included corporations such as Konica Minolta, Sony, Fujitsu, Fujifilm, Ricoh and Apple.

3.2 Public debate, acceptance and the issue of data security

The topic of renewable energy has gained visibility after the Fukushima disaster in 2011. Prior to the release of the 4th Strategic Energy Plan in 2014, METI invited the public to comment on the proposal and received about 19,000 replied within the first month. Renewable energy in the general sense enjoys high support from the Japanese population. Most literature sources link the public acceptance for renewable energies to preconditions such as nature conservation, transparency regarding large projects and involvement of local stakeholders (FES 2018). Nevertheless, opposition to renewable energy started to increase with the Shinzo Abe Government on the grounds of high electricity costs, with suggestions that this would put pressure on low-income households and potentially make energy intensive business less competitive (Kameyama 2015).

As this is the case in many countries, it makes sense to differentiate between the acceptance for renewables in the general sense and the acceptance by people who are directly affected by the renewable energy projects. For the population directly affected, acceptance problems are much more common, especially in case of larger wind turbines. Some projects have been met with massive local opposition. Deterioration of the landscape, sleep disturbances due to noise and the low financial benefits are typically cited as grounds for opposition.

With regard to smart communities, Granier and Kudo (2015) studied citizen participation in Kitakyushu city, one of the four pilot smart communities selected in 2010 by the Japanese Government. The study finds that while there was no meaningful dissent towards the project, the citizens generally did not actively participate in the governance processes. One possible explanation is that they generally lacked the specific knowledge about ICT and energy technologies. While the early Japanese smart grid projects focused predominantly on energy, later smart community projects were targeted at *"energy issues, participation and lifestyle innovation"*.

The Kitakyushu city project apparently enjoyed a great deal of trust on the side of the residents as well, as they often agreed to their energy-related data being collected and analysed (Granier and Kudo 2015). Generally, information on public debate about data security in the context of smart grids in Japan is scarce, and this topic is not considered very controversial in Japan. One possible explanation is that Japan's measures for ensuring protection against cyberattacks are considered to be some of the most advanced in the world (section 2.2).

Apart from that, the Japan Electricity Information Sharing and Analysis Center (JE-ISAC) was established in 2017 with the task of ensuring cybersecurity in Japan's energy sector and watch over sharing of sensitive information among the authorised parties: the 10 EPCOs and other large-scale power generation companies, OCCTO, METI, the National Center of Incident Readiness and Strategy for Cybersecurity (NISC), and their European (European Energy-ISAC) and American (Electricity-ISAC) counterparts (Sasakawa peace foundation USA 2017).

3.3 New business models and opportunities in the power market

Vehicle-to-grid and vehicle-to-home

Wide-scale commercialisation of V2G and V2H systems is envisioned in Japan. V2H in the role of an emergency power system for buildings has already been commercialised after the Fukushima disaster (NEV 2018). A V2G-based use case which uses battery electric vehicles (BEV) or plug-in hybrids (PHEV) for frequency regulation to stabilise the grid is currently being tested in pilot projects. First V2G projects such as the Grid Integrated Vehicle platform GIVe (section 2.4) have already been deployed in Japan.

Demand Response

As mentioned, the Negawatt market opened in 2017. Since then, a yearly auction is held where bids for DR capacity are placed. Utilities then pay an annual sum, typically in the range of 3,000 to 5,000 yen (25 – 42 EUR) per kW, to aggregators to act as intermediaries and get the end consumers to reduce their load when called upon. The aggregator uses a portion of this to compensate both, the end consumer and the utility, since its revenue is decreased by the lowered power consumption. Since peak load is reduced, the generator (which in Japan often also acts as the retailer) can avoid investments into expansion of generation, transmission or distribution capacities.

Under the vision that METI has presented under the Sustainable Open Innovation Initiative (section 2.4), DR and other smart technologies might be aggregated into VPPs in the future. Indeed, EnergyPool, a VPP aggregator, has reportedly reached agreement for DR aggregation with Tokyo Electric Power Grid and Kansai Electric Power Company (IZES, JEPIC 2014).

For the time being, aggregating DR capacities from households has been prohibitively cost-intensive in Japan due to high level of dispersion and relatively small incentives per participant. Sasakawa Peace Foundation USA (2018) suggests that Including the utilities and retailers to act as intermediaries, since they already possess user data and have established communication channels, might be able to overcome this issue in the future.

Virtual power plants

Other sources (Nimoya et al. 2019, unpublished) have come to conclusion that while virtual power plants (VPP) are not be economically viable at present in Japan, this might change in 2020 with the completion of power market unbundling, as transmission and distribution companies will be forced to find flexible generation sources on the market.

Nevertheless, projects incorporating VPPs are already beginning to emerge. For example, a large behind-the-meter VPP was announced earlier in 2019 that will aggregate 10,000 distributed energy assets. The power they generate will be sold in the Japanese wholesale market. At first, only batteries are to be used, however, other distributed energy assets like solar, electric vehicle chargers and smart home thermostats can be integrated later on. The Japanese energy services and trading company ENERES acts as project developer and provides the batteries to the households with no upfront costs (Energy Storage News 2018). The Government provides financial backing for the project.

Blockchain applications

Minna-Denryoku, an electricity retailer, uses blockchain to keep record of the power it buys and sells. Information such as when and where the power was produced is onto the digital ledger recorded every 30 minutes. The goal is to improve the matching of power supply and demand and to provide the exact amount of electricity the customer demands. This solution has been successful on the market and MinnaDenryoku's services are popular in Japan.

Another project, the Digital Grid Corporation, is a spin-off from the Tokyo University and is developing a Blockchain application called Digital Grid Controller to accurately record technical, financial and environmental characteristics of power flows and feed them to an online trading platform. P2P trading is foreseen to be in the future.

A successful trial for blockchain-enabled P2P power trading has been carried out by the company called Power Ledger in partnership with TEPCO in Osaka.

EPCOs

While new companies have entered the Japanese power market, either moving in from abroad or being newly created (IZES, JEPIC 2017), the 10 EPCOs which currently dominate the power market will remain key players even after the unbundling is completed in 2020. It is therefore worth looking what the changing business environment might mean for them. The

Renewable energy institute (REI 2017) provides an overview of challenges and opportunities they may face (selection based on relevance):

- **Expansion of VRES portfolio**. The viability of higher VRES shares is creating a downward pressure on power generation costs and forcing the power generators to integrate renewable generation into their portfolios. Not only solar but the often overlooked offshore wind potential might drive this trend in Japan. The EPCOs and their generation successors could choose to either develop their own projects or acquire existing ones[4].
- **Rooftop solar PV systems installations.** Rooftop solar is achieving price parity with the power coming out of the socket. EPCOs and their power generation successors could provide the technical know-how, financing and existing customer relationships to supply a potentially vast Japanese market with rooftop solar PV systems.
- **EV charging infrastructure expansion**. If the Government target for 2030 of 20 – 30% sales of EVs is to be achieved, the charging infrastructure will have to be vastly expanded. Again, due to their size and market position, EPCO should be in the pole position to profit from this (IEA 2019a).
- **Energy services** are increasing in importance as the need for efficient use of energy grows. At the same time, smart meter rollout enables them to become more sophisticated and diverse. EPCOs and their generation successors have the opportunity to provide advisory, equipment implementation, financing and demand response management.
- **Grid connection charges** might represent an increased revenue flow for the EPCOs and their distribution successors since decentralised power sources and V2H/V2G electric mobility all connect to the distribution network.
- **Operating interconnectors between the 10 current EPCO areas** could increase for the EPCOs and their transmission successors since the power flows should increase; at the same time, new interconnectors have to be built which might result in drop utilisation factors, representing a challenge to profitability.
- **Green power tariffs and PPA**. As the share of renewables increases in Japan, power retailers might offer green tariffs, i.e. supplying exclusively renewable power to their customers, as well as closing Power Purchasing Agreements (PPAs) with companies willing to switch to 100% renewable power supply.

[4] While in Japan, these economics are somewhat hampered by the atypically high wind and solar LCOE and the connectable amount limiting the renewables grid connection (chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**), the Renewable Energy Institute (2017) nevertheless sees the need for the EPCOs to invest in renewables.

4 The global context and comparison to Germany

4.1 Legislative measures

As discussed in section 2.2, the current Japanese Electricity Business Act presents unique challenges to renewables. Due to the technical constrains of the existing power grid, connectable amount and tendering for grid access, the uptake of renewable power has been lagging. The major change foreseen is the implementation of the Japanese version of Connect & Manage which will free up existing grid capacity and allow more of the already completed projects to come online, albeit with certain restrictions in terms of feed-in quantities and FIT payment (section 2.2). While this does not eliminate the need for grid expansion in the long term, it should help meliorate the current bottleneck.

Germany, like Japan, has switched from a fixed FIT system to a reverse auction system in 2017. In contrast to Japan, Germany has guaranteed and priority grid access for renewable energy where the grid operator closest to the generation site has to upgrade its grid if necessary and where power from renewables has priority before conventional generators in case of grid congestion (Ecofys, consentec, bbg 2018). While this system is more supportive for integration of renewables than the current Japanese system, it hasn't been without its challenges, e.g. there are no incentives for the owner of renewable generators to choose a project site favourable from the perspective of the grid. The costs for the grid expansion are carried by the end-consumers via grid charges, and these have been rising. In response to this and other challenges, the Government has limited further deployment of wind power in certain regions (Bundesnetzagentur 2017).

Indeed, the rising grid charges have been an often polemicized topic in Germany. In 2019, the grid charge is on average the highest cost component for households (BDEW 2019). The maximum grid charge that operators are allowed to charge to end consumers falls under authority of the *Bundesnetzagentur*. Agora Energiewende, a leading German energy policy think tank, criticised the lacking transparency of the procedure to determine these maximum charges.

The second major legislative change foreseen in Japan is the finalisation of the power market liberalisation in 2020 which will introduce the unbundling of generation from the transmission and generation segments. However, since that will be legal rather than ownership unbundling, the incentives for the new companies to continue to cooperate with one another (albeit illegally) will continue to exist. Fears have been expressed that in practice, fair third-party access to the power grid cannot be taken for granted.

In Germany, the power market liberalisation started in 1998 and ended with a combination of legal and ownership unbundling from 2010 to 2012. Two of the four previously integrated companies sold off their transmission segments completely (E.ON and Vattenfall); RWE kept a 25% share in the newly created transmission entity, and EnBW is the sole owner of its transmission daughter (Abbeg 2016). In contrast to transmission, distribution networks were not subject to unbundling obligation, and the "big four" maintain a strong presence in this segment, even as the overall number of distribution networks operators has reached around 900. The landscape has changed again recently as E.ON and RWE swapped some of their business divisions in order to consolidate their respective market positions. Although the EU competition authorities greenlighted the deal, concerns remain that end consumers will bear the costs of reduced competition.

Nevertheless, the power market liberalisation in Germany and generally in the EU is viewed as having been necessary and successful. Especially in the generation segment, it promoted diversity of suppliers, and renewable power production increased higher than in countries without a liberalised power market (Agentur für Erneuerbare Energien 2018).

From the perspective of smart grids, the status of P2P and possibilities of blockchain implementation are also relevant. As mentioned in section 2.5, direct P2P trading is restricted in Japan. While Germany has seen a number of blockchain-enabled projects, their legal situation is complex from the legislative standpoint and depends on the specific model. Apart from energy-related acts, blockchain applications underlie privacy and data security legislation (dena 2019). Direct P2P trading between prosumers without third-party support, either with or without the use of blockchain, it is not possible due to technical and supply reliability-related which have to be met by anyone selling power directly to households (RAILS 2018).

4.2 Technical measures

Energy policy in Japan is always in a sense also industrial policy, and energy policy targets often include targets for shares of Japanese companies on the global market. Japan's Government provides massive support to new technologies: Japan ranked 5th globally in terms of GDP spend on RD&D in 2017 at over 3% (OECD 2019). However, Japan allocated in 2018 a larger proportion of its RD&D funding to nuclear technologies than to renewables and hydrogen combined. In Germany, the share of GDP spent on energy RD&D was just slightly lower than in Japan, but renewables were the single most supported category.

Japan is one of the leading countries in terms of experience with smart communities, with extensive know-how on technical implications and valuable insights into social aspects, including public acceptance. Nevertheless, the international microgrid market has been dominated by US firms, with Japanese companies like Hitachi or Toshiba quickly catch up[5]. In Germany, while the topic is not as high on agenda as in Japan, a recent project that mapped smart communities found that diverse initiatives are in place, with digitisation of administration, mobility, as well as energy and protecting the environment as their main foci (bitkom 2019).

Similar to Japan, expansion of the transmission grid, necessary to transport the power from the windy north of the country to the industrial south and west, has proved challenging in Germany. While the decision to go forward with the project has long been made, practical issues have delayed implementation, including lacking public acceptance. For example, finding exact routes for grid expansion hasn't been easy due to strong opposition from communities, initiatives and even federal states themselves (Thuringia filed a lawsuit against the *Bundesnetzagentur* in 2019 in order to force it to reconsider its proposal for alternative transmission line route) (ZfK 2019).

In terms of smart meter deployment, Japan with over 20 million installed is clearly ahead of Germany where the roll-out hasn't begun yet. Recently, only the second smart gateway was accredited by the German Federal Office for Information Security (BSI 2019). The high data security requirements for certification are seen as the main factor for lagging deployment. On

[5] https://apjjf.org/-Andrew-DeWit/4936/article.pdf

top of that, even after the threshold for obligatory smart meter installation is lowered from the current 10,000 kWh annual power consumption to 6,000 kWh in 2020, only about 7.5 million metering points will have to be equipped with smart meters. The low ambitions and lagging implementation have been criticised in Germany as being the Achilles heel of the efforts to digitise the power system. In global terms, China has deployed more smart meters than the rest of the countries combined, with US in distant second place, followed by Italy, Japan and Spain.

One important aspect for smart grids is energy storage. Since batteries are part of Japan's industrial policy and since its share of renewables is expected to rise, Japan is likely to remain an important market in the future. With increasing deployment of solar PV, decreasing FIT support and high electricity rates, the economics of storage could improve further. Germany, on the other hand, presently does not have world-leading battery producers and is also not expected to have a high demand for battery storage as it has cheaper options for providing flexibility to its power system (Agora Energiewende 2014). However, Germany, along with some other EU Member States, does intend to set up a strong domestic battery industry, as this technology is considered strategically important.

With regard to the EV charging infrastructure, Japan ranks fourth globally in terms of publicly available charging stations installed behind China, USA and the Netherlands with just under 30,000 chargers and just ahead of Germany with 25,700. However, as mentioned in section 2.5, Japan is second only to China in terms of fast chargers with about 7,600.

DR technology and market are still at an early stage in Japan, but the developments since 2017 have been encouraging. The US has the most developed market globally, while potential in Europe remains largely untapped (Respond, without year). Nevertheless, the European markets are opening and increase in DR capacity is expected. Germany has so far limited the participation of smaller generators with relatively high minimum capacity threshold for secondary and tertiary reserve markets (Arthur D. Little 2016). However, the DR potential in Germany is considered to be significant due to the country's energy intensive industries, and some of the potential is already being marketed (Stede 2016).

Similarly, VPP technologies and market are still in its infancy in Japan. North America is the biggest market for VPP. In Germany, VPP has entered a commercial stage and the legislative framework is providing good business opportunities. The VPP business started with pooling medium-sized renewable energy generators and selling the power in the wholesale market. Today, aggregators include RE generators, gas-fired CHP, battery storage, emergency power supply systems and demand response (Ninomiya, Schröder, Thomas 2019). Germany's Next Kraftwerke is one of the leading VPP companies in the world in terms of technology and has been active outside Germany as well.

4.3 Effects on the market

With further market liberalisation, generation and retail segments of the market are likely to see considerable changes. Completion of the unbundling process, improvement in the grid access for renewable power generators, and rising share of renewables will bring along increased need for flexibility, demand side management, demand response and other energy services. Electrification of transport and advent of hydrogen economy can potentially be strong future drivers of change in the Japanese power market.

Some changes can already be observed. Within the first year in the liberalised retail market, more than 400 new retail companies for electricity got the license to operate, and almost 3.8 million (about 6%) consumers switched from an EPCO to another retailer. Since then, the number of retailers has grown to 611 in 2019, and the number of households having switched the electricity provider to over 20%. Nevertheless, the 10 EPCOs remain dominant in the generation sector, having generated almost three quarters of all electricity in the first quarter of 2017 (JEPIC 2019).

It appears that the large Japanese energy suppliers are working hard to adapt to the changing power market and are not struggling excessively with new technologies. Perhaps the best example is TEPCO which invests in technologies that new market entrants could use to undermine its market dominance. Apart from setting an example for successfully managing a smart meter rollout, it has launched partnerships in areas ranging from offshore wind to blockchain. Some authors have argued TEPCO has truly grasped the gravity of changes lying ahead and is becoming a "*major leading force in the world's smart grid technology*" (HBS Business Review 2017).

Another important trend is rather coming from the bottom up. Modelled on their German counterparts, *Stadtwerke* and citizen energy cooperatives are being established in Japan. Typically public-private partnerships (PPPs), they have no easy task on the electricity market as they compete directly with established regional utilities. They often emphasize their local character and the principle of solidarity. They are primarily not profit-oriented and their revenues often at least partly flow back into local projects. The electricity prices they offer are often lower than those of incumbents, partly thanks to the introduction of smart grids and energy management systems which improve efficient use of electricity.

While there are many parallels to the German concept, *Stadtwerke* in Japan have adapted to the specific context. The problem of an ageing society and shrinking population leads to a decline in local businesses, a shrinking local tax base, higher per-person energy consumption due to a larger number of single-person households, and ultimately to lower resilience to natural disasters (DeWit 2016).

Another trend in Japan is the self-consumption of energy in many cities where prosumers do not feed their self-generated regenerative electricity into the national grid but consume it themselves. In contrast to Germany, this is encouraged by the Government to promote resilience in case of an emergencies and to reduce the need for grid upgrades (DeWit 2016).

4.4 Public debate and acceptance

The situation with public acceptance for renewable energy in Japan is similar to that in Germany. Renewable energy generally enjoys high support among the German population, with concerns over affordability. In addition, the Japanese citizens seem to be more concerned that higher shares of renewables would endanger the stability of the system. What both countries have in common is rather frequent opposition from citizens to individual renewable energy and grid expansion projects which directly affect them. In Germany, protests, public campaigns and legal action by communities, civil initiatives and even local and state authorities are common.

While both countries have high data security standards for energy-related user data, the experience from the Kitakyushu city smart energy project where users would allow their data to be collected and analysed suggest that there is less concern in Japan with regard to this topic as in Germany.

5 Recommendations

In terms of their energy policy, Germany and Japan both share common features such as efforts to decarbonise the energy system, improve energy security and keep costs in check. At the same time, the context they find themselves in is vastly different. While Germany is part of the EU and surrounded by geopolitical allies, Japan is not part of any such closely-knit supranational entity, and close to some of its main competitors. There are parallels with regard to the countries' power systems - Germany has interconnections with 10 of its neighbours providing flexibility and market efficiency; Japan is an island in terms of its power grid. Japan currently finds itself in the 2nd phase of renewables integration according to IEA (2018) where only limited system measures are necessary; for Germany in phase 3, flexibility, grid expansion and grid congestion management are the central topics. Nevertheless, there are certain aspects of both countries' respective transition where they could profit from closer cooperation.

Despite Japan's envisioned shift from the current grid connection capacity allocation scheme to its version of Connect & Manage, this move will not eliminate the need for grid expansion in the future if the Government's 2030 renewable targets are pursued. Germany's experience with managing public acceptance for particular projects, congestion management and integrated planning approach could prove valuable to the Japanese. On the other hand, learning from Germany's experience could also help Japan avoid some of the same problems, for example having to restrict renewables deployment in certain areas due to lagging grid expansion (the so-called *Netzausbaugebiete*).

Some PV industry experts have also foreseen that in the future, falling prices of PV installations on one hand and persisting constrains for grid expansion on the other will make grid connection an increasingly valuable asset. This is already taking place in Japan where separate auctions are held for grid connection. PV plants would then typically be oversized in order to make most of the connection, and curtailment would become a permanent feature of system operation (Chase 2018). Japan's Connect & Manage approach essentially lays the foundation for this approach and might stay in place for longer time, even if grid expansion picks up pace. Care should however be taken that allocation of connection capacity is conducted transparently and fairly.

In the field of smart energy services and new business models, both Germany and Japan can learn from one other in specific areas. Japan has had a head start in smart meter deployment and it may be worth for Germany's regulators and companies to watch closely the Japanese experience with smart meter data sharing and security. Both countries have high security standards, whereas data security and privacy seems to be more a relevant issue in Germany.

Related to smart meters are the topics of demand response (DR), energy management systems and microgrids. Japan has seen impressive results from its obligatory peak reduction measures after the 2011 Fukushima disaster, and has made limited but generally positive experience with voluntary DR schemes. Both Japan and Germany share high DR potential due to strong presence of heavy industry, but which at present remains largely untapped. Information exchange between legislators, regulators and scientific institutions from both countries might prove fruitful and lead to better use of DR potentials. These same stakeholders from Japan might find relevant Germany's experience with its VPP market, which is at present much more diversified.

While Germany has seen initiatives in the field of microgrids, Japan has gathered more experience, including with regard to crucial aspects such as user approval and participation, different kind of energy management systems and data sharing. Although smart grids currently do not play such a central role in the *Energiewende*, these aspects are relevant in other contexts.

As has been noted in the past, Germany has a lower need for power grid-connected battery energy storage systems since it can find cheaper flexibility options via interconnections with neighbouring countries (Agora Energiewende 2014). However, Germany's industrial policy is shifting in favour of batteries, not least since its domestic carmakers have increasingly signalled their commitment to electric transportation. Japan already enjoys the position as one of the leading battery manufacturers. Although the European Battery Alliance has been formed and Toyota Tsusho Europe is already a member, if closer technology collaboration with Japanese battery manufacturers were possible, this could prove extremely valuable.

Blockchain applications in the energy sector are being tested in both Germany and Japan. Common to both countries is the complex legal situation with regard this technology, and direct P2P power trading without an intermediary is not possible. However, the concept is attractive and relevant for smart communities in Japan and perhaps as a way of incentivising the deployment of small power plants such as rooftop solar PV under a future regime of reduced or even absent subsidies in Germany.

This study has shown that smart grids and the technologies, business opportunities and user participation models they enable are crucial for overcoming many of the challenges Japan is facing as it tries to implement its 3E+S energy strategy. However, they should not be viewed as panacea or an end in itself. Ensuring not just minimum public acceptance for renewables but participation and wide dispersion of benefits, market access and fair competition which translate into improved efficiency and affordable energy prices, creating the necessary incentives for the environmentally advantageous energy sources, and pursuing a coherent industrial policy should be the top priorities for policymakers as they try to manage the intricacies of the energy transition.

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