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Digitalization and the Energy Transition: Virtual Power Plants and Blockchain

Report on analysis in Japanese FY 2018:
The role and status of Virtual Power Plants and blockchain technology

Part 1 of the GJETC Study on Digitalization and the Energy Transition

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Content

1. Introduction: The role of digitalization for the energy transition and the subject of this paper

Digitalization in the energy system is progressing rapidly with the spread of artificial intelligence (AI), such as software tools to optimize demand and weather forecasts, and internet of things (IoT) technologies, including smart meters and secure data communication systems such as blockchain. As a result of the development, virtual power plants (VPP) are being put into practice in some countries, and a peer-to-peer (P2P) energy trading utilising blockchain technology is being started to demonstrate.

In terms of VPP, Germany has already entered into a commercial stage, while it is still in a demonstration stage in Japan. Hence, Japan could learn from Germany on the business model of the German VPP, the structure of the electricity market and the policy framework for VPPs. Regarding the energy business utilising digital technology such as P2P, it is also meaningful to learn from the empirical examples ongoing in Germany.

On the other hand, since 2010, Japan has been promoting the efficient use of energy by introducing concepts and technologies such as home energy management system (HEMS) and zero-emission house (ZEH) for the residential sector, building energy management system (BEMS) and zero-emission building (ZEB) for commercial buildings, and community energy management system (CEMS) for communities. Consequently, Japan has a high standard of technological accumulation in the field of energy management systems at individual facility. Germany could learn from such examples of EMS in Japan. As Japan and Germany are highly industrialized countries with advanced technological capabilities, conducting the cooperative survey on this topic is worthwhile for both countries.

Against this background, this paper concentrates on two main subjects, making use of existing literature and selected interviews:

1. Virtual Power Plants (VPP) and their possibilities for improving balance between supply and demand through both wholesale markets (day-ahead, intraday) and ancillary services markets.
2. Blockchain technologies and their use in the energy sector.

Further uses and results of digitalization in the energy sector are planned as subjects of analysis for the second year of this cooperative study.

2. VPP and blockchain: their role and status in Germany

In Germany, the energy market legislation and regulation in combination with the renewable energy legislation have been instrumental in creating business opportunities for VPPs. The renewable energy law, EEG, has been requiring larger plants to market their power in the power exchange for several years. The wholesale market, in turn, is based on the energy market legislation (EnWG, see below). A first major business for VPP was, therefore, to pool medium-sized renewable energy sources (RES) generators and offer selling their power in the wholesale market (day-ahead market) as a service to fulfil this legal requirement. However, particularly for biomass and hydro power plants, their flexibility allows the pool to both maximise revenues by selling when power is more expensive in the day-ahead market, and to operate in the reserve control power market that has been required by the energy market legislation since around 2010, as well as in the intraday market for balancing energy that developed in parallel. Therefore, in addition to RES generators, VPP nowadays also include gas-fired CHP, battery storage, emergency gensets, and demand response.

In contrast to VPP, blockchain technology has only very recently been tested in Germany, as a way to enable direct power purchasing agreements between generators and consumers of electricity. There is no legislation or regulation yet, so these are pilot projects that may be possible with experimental exceptions from regulations. Their motivation is either to facilitate the direct marketing of power from RES plants that are beyond the period, in which they are entitled to receive the feed-in tariff (FIT), or to facilitate mutual exchange of power between owners of small PV plants and batteries. One pilot scheme is aiming at reducing network congestions between Northern and Southern Germany through using these batteries.

We first present some more information on energy market legislation and regulation as well as on energy markets, before we discuss the status and impact of VPPs and blockchain in Germany.

2.1 Energy market legislation and regulation

Since the unbundling legislation (Energiewirtschaftsgesetz, EnWG, Energy Industry Act, http://www.gesetze-im-internet.de/enwg_2005/index.html, i.e. the German electricity and gas supply industry law), all energy companies including Stadtwerke above a certain size (at least 100,000 customers connected to the distribution network, for electricity and gas each; §7) were forced to legally unbundle their network assets and operations as a distribution system operator (DSO) from the competitive generation and supply business, i.e. to create separate companies. The smaller companies need to provide unbundling in operation and accounting (§6).

In the area of one DSO or transmission system operator (TSO), many suppliers are now competing for customers. The totality of customers of one supplier in a TSO area and their total electricity demand are called a Bilanzkreis (balancing group). If one customer has more than one supplier, he or she will be allocated to only one balancing group. The respective company (Bilanzkreisverantwortlicher, i.e. balancing responsible party; this can be a supplier—that is the usual case—or also an aggregator) is responsible for balancing supply and demand for all these customers at any time. The TSO will perform the Clearing for each balancing group in its area in each 15-minute period, i.e. (1) monitor the difference between actual demand and demand forecast in the balancing group and (2) settle imbalances through balancing energy (this type of balancing energy being called Ausgleichsenergie in German) that will balance the difference, imposing or paying the uniform price (reBAP, see chapter 2.3) for that energy to the balancing responsible party. For the resulting overall total of balancing energy across all balancing responsible parties in the network area, the TSO has to purchase or sell this energy in the reserve control market for this uniform price resulting from the markets (see chapter 2.3). The reserve control and balancing energy market is one of the markets VPPs in Germany are operating in.

It may be cheaper for balancing responsible parties to reduce imbalances between the actual supply or demand and their forecast from the day before by purchasing or selling power during the day, until the last 15-minute period before the actual period. This is the **Intraday market**, organised in intervals of 15 minutes. This is another one of the markets that VPPs in Germany operate in.

The balancing responsible party has to deposit securities guaranteeing its ability to pay the Ausgleichsenergie.

The EnWG also requires the TSOs to purchase **reserve control / balancing power** via competitive tendering to reduce prices, and provides the basic rules for the reserve control / balancing power markets. These markets concern both capacity and energy, for settlement of imbalances at the TSO system level. Capacity costs will be included in the grid fees, while energy costs will be paid by/to balancing group responsibles in total.

The EnWG contains the basic rules. In some cases, regulations (Verordnungen in German) specify the details. Examples are regulations on non-discriminatory access to the grid (Netzzugangsverordnung) and on the fees for using the grid (Netzentgeltverordnung).

There are no explicit regulations for the wholesale market (day-ahead, intraday, futures) in the law.

The law (§22 EnWG) also requires TSOs to create a joint internet platform (regelleistung.net) for the tendering schemes for reserve control / balancing power.

Recent changes

In 2017, there were regulatory changes, especially at the European level, which will have an impact on the electricity wholesale and balancing energy markets in the medium term. The "Guideline on Electricity Balancing", adopted in March 2017, provides for the introduction of platforms for the replacement of all types of control energy. As the first project to implement this Directive, 19 transmission system operators have started a project to operate a common minute reserve platform.

The revised EU internal market directive has been passed in 2019 and will now have to be transposed into national law.

2.2 Renewable energy act (Erneuerbare-Energien-Gesetz, EEG)

In 2011, the EEG was amended and now requires 'Direct marketing' (EEG-Direktvermarktung) for RES generators above 100 kW. These generators have to sell the power in the wholesale market, no longer to the TSO as it was before. They will then receive the 'market premium', i.e. the difference between the fixed FIT tariff they received before and the average monthly wholesale (day-ahead) market price (Referenzmarktwert des Börsenstrompreises). In addition, they receive the 'management premium' (Managementprämie) of 0.2 ct/kWh (biogas, hydro power, CHP units) or 0.4 ct/kWh (solar PV and wind) for voluntary 'direct marketing' for older EEG generators, and the same amount is also included in 'market premium' for newer EEG generators obliged to 'direct marketing'.

The justification for 'direct marketing' and 'management premium' has been: (1) experience in trading and direct control of plant allows to reduce imbalance between schedules and actual generation/demand: this will reduce the need for balancing energy / control reserve and the associated cost; (2) prepare EEG generators for time after FIT scheme ends (individually / in general).

In additon, for biogas generation units, there is the 'flexibility premium' (Flexibilitätsprämie/-zuschlag (§50 EEG); 130 € per kW for plants older than 1 August 2014 but only for additional capacity created after that date; 40 € per kW for plants that started operation on 1 August 2014 or later, for the full capacity) for units above 100 kW. However, the market premium (i.e., the difference between market price and the full value of the FIT) is only paid to biogas plants for up to 50% of full load hours per year (§44b EEG). This is to incentivise flexible production, particularly when market prices are high.

All of this has created a market for aggregators such as Next Kraftwerke, to offer the 'direct marketing' as a service to operators of medium-sized RES power plants. And the aggregated plants are then the basis for operating as a VPP so as to further optimise power market revenues.

Net metering in the strict sense (the same price for a kWh fed back into the grid as for one purchased via the grid) is not allowed in Germany. However, owners of PV plants < 10kW may use power directly for self-consumption without metering, so saving the price of a kWh purchased from the grid, including all taxes and levies.

2.3 Energy markets

Wholesale market

As a result of the legal unbundling, the competition for customers, and the balancing groups, in many utilities, even if still under one holding, the generation company or department will market all power in the power exchange (**day-ahead** and possibly **intraday**), while the supply business will purchase power in the exchange. Others, however, will directly use the power generated for the customers and aim to optimize both generation and supply in their balancing groups in this way.

For example, a VPP such as Next Kraftwerke offers power producers in its pool that can be scheduled (biogas, CHP based on natural gas), which they call 'Demand-oriented feed-in' ('bedarfsgerechte Einspeisung'; which means it is oriented to the demands, i.e. prices, of the wholesale market and trying to optimize revenues). In this case, the schedules for bidding in the wholesale market will be defined by Next Kraftwerke to optimize revenues based on their forecasting system.

As far as reserve control power is needed to settle imbalances in the system, it is the TSO's responsibility, based on the merit order list established in the reserve control markets (see below). The TSOs will also settle imbalances remaining for any balancing group responsible. The price for balancing energy is a uniform price for all TSO areas, in German "regelzonenübergreifender einheitlicher Bilanzausgleichsenergiepreis (reBAP)". It is based on the wholesale power price, but if prices for secondary or minute reserve are cheaper, they will be used (https://www.regelleistung.net/ext/static/rebap?lang=en and downloads on "Ermittlung reBAP und Umgang mit Korrekturen" in German).

Balancing market (Primary or FCR, Secondary or aFRR, Tertiary/Minute or mFRR reserve control markets)

The TSOs, in addition to the joint tendering platform for all reserve control markets required by the law (§22 EnWG), created a joint dispatch of balancing power, even with neighbour counties (Netzregelverbund).

The dispatch order is determined by the merit order list (MOL) that results from the tenderings. However, there may be justified deviations (https://www.regelleistung.net/ext/data/mol?lang=en).

There is no difference between power plants and demand response (DR) or VPP. There is a uniform market, both for wholesale power and balancing power/reserve control. Prequalification for the reserve control market will be valid for all TSO areas due to the joint tenders and consequent dispatch order (Netzregelverbund).

Capacity market and auctions

There is no capacity market other than the balancing / reserve capacity market in Germany.

(N.B. This is based on the interpretation that the auctions for new renewable energy generators under the EEG are not a capacity market.)

The only capacity auctions to date in Germany are those for RES power plants. Energy companies, e.g. Stadtwerke, who also operate their own VPP, may also participate in capacity auctions. In general, however, the VPP concept and business in Germany is seen distinct from the investment in new capacity: VPP optimise the use of *existing* capacities (which may have been built after a successful bid in an auction).

Ancillary service market

There is no market for other ancillary system services (such as voltage control, redispatch, restart of the network, congestion management), so the Next Kraftwerke pool does not (yet) contribute here. There are possibilities to reduce curtailment and redispatch demand with existing flexibilities. The regulatory framework to introduce a market for this currently does not exist.

Strategic reserve capacity

In Germany, mainly coal- or gas-fired power plants that would otherwise be shut down completely are moved to strategic reserve capacity (Netzreserve). VPP are not relevant for this market, although distributed energy resources (DERs) could achieve the goals more accurately according to VPP operators. However, the current design for the strategic reserve capacity indirectly excludes DERs.

2.4 Status and impact of VPP and blockchain

VPPs: status

Due to the legal, regulatory, and market environment in Germany, VPPs are now quite common and in full commercial operation in Germany. There are

- Two large independent VPP operators (Next Kraftwerke and Energy2Market) with a diverse portfolio of mostly independent or RES power producers, or power plant portfolios of small to medium-sized Stadtwerke,
- Larger existing utilities (private and municipal) pooling their own generation assets and possible those of their customers to a VPP,
- And some niche providers, such as Sonnen GmbH, a manufacturer of batteries connecting the rooftop PV power plants and batteries of its customers plus some wind and biogas plants to a VPP.

There is also commercial software, DER control box, and SCADA unit hardware available from various providers (including the large VPP operator Next Kraftwerke, offering it as a service to other VPP operators) that combines the forecasting, scheduling/dispatching, and real-time data communication and asset control functions needed.

For example, Next Kraftwerke currently (early 2019) has connected approx. 6,500 technical units with around 6,000 MW of capacity in Germany and six other EU member states. Out of these capacities, prequalification for the reserve control power markets is as follows: FCR: 57 MW (mostly flexible biogas CHPs, electrolysis, and batteries); aFRR: 922 MW; mFRR: 1,572 MW (FRR being mostly CHP and/or biogas).

Larger Stadtwerke usually operate CHP plants, which provide more flexibility than e.g. wind or solar PV plants anyway. The district heating network itself can buffer some heat, so these plants can participate in the reserve control power market. Recently, they increasingly add large heat storage tanks to increase this flexibility, and often in combination with immersion electric heaters in order to be able to use power for heat generation when power exchange prices are very low or even negative.

The electricity generated by combined heat and power can thus be offered flexibly to maximise revenue in the day-ahead market, used for optimization in intraday trading on the power exchange, or offered in the reserve power market. Furthermore, Stadtwerke can use the flexibility in power generation in CHP plants enabled by heat storage for balancing group optimization without trading for their own balancing group, by ramping power generation up and down to meet demand of the electricity customers in real time, even if it deviates from the schedule. This will allow them to avoid purchasing or selling power in the intraday market or to take balancing energy from the TSO. A regional flexibility market (i.e. at DSO scale; however, that is currently only feasible in demonstration projects such as the SINTEG programme) offers another sales opportunity for the flexibility of the virtual power plant.

VPPs: Impact

The prices particularly for secondary and tertiary/minute control power in Germany have reduced quite a lot during recent years. This is likely to be an impact of the introduction of a market for this type of ancillary services and partly also of the VPP activities, so it is a proof that the introduction of VPPs has had the intended effect.

Next Kraftwerke states that the balancing quality of VPP is better than for large power plants.

Biomass power plants incl. biogas have obtained prequalification for capacities of between 1.6 and 2.5 GW for the four types of secondary control reserve (aFRR+: 1.59 GW; aFRR-: 1.98 GW) and tertiary/minute control reserve (mFRR+: 1.85 GW; mFRR-: 2.46 GW) (50 Hertz et al. 2018); and even for 0.03 GW of primary control reserve (FCR). Data for other CHP plants are not available; most of them are included in the Gas category of Figure 1. Demand response / DSM is now also taking a certain share in control reserve: FCR: 0.08 GW; aFRR+: 0.54 GW; aFRR-: 0.66 GW; mFRR+: 0.88 GW; mFRR-: 0.84 GW. Among other new sources for grid flexibility and stability, 0.25 GW of batteries are prequalified for FCR and 0.1 GW of wind power plants for mFRR-. There is a pilot phase ongoing for prequalification of wind. However, due to the low prices for control reserve, experts state that there is currently no business case for this.

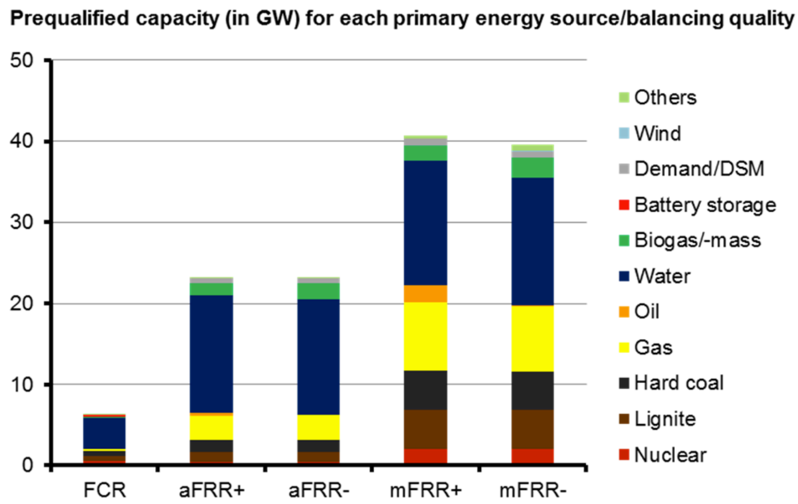

Figure 1: Prequalified capacity (in GW) for each primary energy source/balancing quality in Germany

Source: 50Hertz et al. 2018

For CHP plants to provide flexibility, heat storage is important. Between 2012 and 2016, the capacity of large heat storage facilities in Germany more than doubled, from 8 GWh_{th} to 20 GWh_{th}. A research project (grant no./ FKZ 03ET1188A) found a total potential of ca. 88 GWh_{th} for installation of heat storage facilities in district heating in Germany (BINE 2018b).

Estimating an average ratio of 0.6 units of electricity generation for 1 unit of heat generation in CHP facilities, this may allow the shifting of electricity generation in the time range of several hours to a few days of up to around 12 GWh_{el} for the heat storage existing in 2016, and up to around 53 GWh_{el} for the total potential. This compares to pumped storage hydro capacities existing in Germany of 40 GWh_{el} (Deutscher Bundestag 2017).

However, due to the low prices in the balancing power market, mainly “low-hanging fruit” have been included in VPPs to date, i.e. CHP (natural gas and biogas/biomass), non-CHP biogas/biomass, and some storage facilities.

The challenge is to create a favourable framework for other renewable energies, particularly solar PV and wind, and all the storage options and more of demand response. This could be achieved through better frameworks for the control reserve market, regional flexibility markets (at DSO level), waiving fees for electricity that is stored, making capacity payments for plants in demand response depend on system peaks instead of individual facility peaks, distinguishing grid fees between conditional and unconditional use of the grid, or through financial incentives for investments in storage, possibly through auctions similar to the EEG.

Currently, a number of pilot projects now examine such frameworks as well as integrating other types of technical units into VPPs, such as PV and wind power plants as well as thermal consumers (e.g. swimming pools, cold stores, night storage heaters) and electric storage (e.g. electric cars), in the example of Stadtwerke Iserlohn and University of Wuppertal. As another example, TSO Amprion recently prequalified a Nissan Leaf electric car for FCR.

However, looking further into the future of the decarbonised energy system that Germany is aiming for, VPPs from exclusively DERs, i.e. renewables, storage, DR and other flexibilities will need to completely meet the load at any times. Two studies (the "Kombikraftwerk" studies; Mackensen et al. 2008; Knorr et al. 2014) already demonstrated the feasibility of this several years ago.

Blockchain – status and impact

Blockchain is a very recent technology in the energy field. There are currently several pilot projects in Germany, including:

- Sonnen GmbH's "Sonnen community" VPP, using blockchain to track and bill the mutual exchange of power between the several thousand owners of small PV plants and batteries aggregated in the VPP. They also cooperate with TSO TenneT in a pilot project that aims to reduce network congestions by using the batteries to take up excess power or provide it to markets with a lack of power.
- Wuppertaler Stadtwerke have been testing the "Tal.Markt" since 2018, facilitating the direct marketing of power from local RES plants that are beyond the period, in which they are entitled to receive the FIT, to the utility's electricity customers. No information on the success is available.

However, since either a traditional quarter-of-an-hour load metering (required for customers using more than 100 MWh/year) and real-time data transmission, or a smart meter is the precondition for using blockchain, and smart meters will only be introduced from 2019 in Germany, many experts expect that the blockchain technology will see wider use first in markets involving these larger customers and power producers, so as to make power transactions cheaper. In addition, P2P power trading may also be implemented using other transaction technologies than blockchain.

3. VPP and blockchain: their role and status in Japan

3.1 VPP and blockchain: Status in Japan

In contrast to Germany, in Japan, VPPs have not been commercialised yet. Although a number of VPP projects have been implemented, all of them are still in a demonstration stage. Several reasons can be given for this situation where VPP is undeveloped. First of all, a market reform of the existing electricity supply system is underway, allowing traditional 10 electricity utilities, called General Electric Unities, GEUs, still being vertically integrated[1], but which are scheduled to be legally unbundled in 2020[2]. Therefore, at the present stage, there is little business opportunity for VPP since the vertically integrated power system essentially does not require much additional resources outside the system. Second, the share of VRE was 6.5% in 2017, which is significantly lower compared to Germany's VRE share in power generation of 22.7% in the same year. IEA (2018) states that the phase of VRE integration and system flexibility for Japan is 2 whereas Germany is in Phase 3. This difference may explain the contrasted situations for VPP development between the two countries since the higher VRE share inevitably requires more flexibility resources including VPP.

Thirdly, very generous FIT tariffs set for renewable power plants strongly prevent power producers from marketing their power in the market. Hence, little opportunity is left for VPP to aggregate renewable power resources. Fourthly, related to the first point, electricity markets in Japan have not well developed compared to Germany since the vertical integrated electricity supply system does not necessarily require market trading. As the retail market was gradually liberalized since 2000, a wholesale market, JEPX, was established in 2004, which is only the existing electricity market in the country. Balancing, ancillary and capacity markets do not exist but are planned to be established in 2021.

However, the above described situations are anticipated to change dramatically in the near future. As mentioned, a legal unbundling of the existing vertically integrated power utilities, GEUs, will be concluded by April 2020. Then, the unbundled T&D companies will be required to find flexible power resources in the power markets to balance their power systems, which will no longer be vertically integrated. Corresponding to this legal unbundling, as mentioned just above, the balancing market and the capacity market are planned to be established in the same or the following year.

In addition, there is no doubt that the share of VRE will increase as Japanese government clearly states that renewables are to be main power resources in the 5th Strategic Energy Plan adopted in 2018. An increase in flexibility of the electricity grid has been already a crucial issue in the southern large island, Kyushu, which is in Phase 3 according to IEA (2018) with more than 8GW of solar PV installed against 16 GW of peak demand in summer, where curtailment of solar PV generation has repeatedly taken place during the low demand periods. It was the first occasion of

[1] Although the retail sector was fully liberalised in 2016, most of the generation and transmission/distribution sectors are still tightly integrated.

[2] An only exception is TEPCO who was unbundled into generation, T&D and retail companies in 2017.

curtailment of VRE in the main islands of Japan, which is expected to increase progressively not only in Kyushu, but also in other main islands this year onwards.

Furthermore, from November 2019, an entitlement to receive the generous FIT comes to the end one after another as 10 years has passed since 2009 when the FIT scheme was introduced for residential solar PV less than 10kW. It is estimated that around 2GW of solar PV will be out of FIT in FY2019 and this number will be nearly 7GW in 2023. This implies that a large volume of solar PV generated electricity after the lapse of their FIT entitlement will need to be either sold at the electricity market or consumed themselves, or possibly directly shared with other consumers. In any cases, the solar PV owners need to consider how to maximise their benefit from generated power by the existing solar PV, which is unnecessary in the present secure FIT environment.

All these suggest that VPP is likely to be attractive for flexible resources in the near future in Japan, particularly after 2020 when the electricity market reform is completed. For T&D companies, VPP could increase their options of flexibility resources and an aggregation of power generated from solar PV under VPP could secure the control of the power systems with large volume of solar PV. At the same time, for solar PV owners after the lapse their FIT entitlement, they could sell their generated power to the market through VPP by which they could optimise their benefits.

In anticipation of such positive prospects of VPP, a number of pilot or demonstration VPP projects have been developed over the past years. Particularly, the demonstration projects conducted by METI, who aims to develop at least 50 MW capacity of VPP by 2020, are considered as a main stream in this field in Japan. In the next section below, the TEPCO VPP project, one of such demonstration projects, will be examined.

Regarding to blockchain technology, the status in Japan is similar to Germany but even in lesser development. Since 2017, several pilot projects have been implemented in a very limited scale since P2P trading, electricity sharing between prosumers, is restricted by the Electricity Business law, meaning electricity can only be supplied by a registered legal entity, not by an individual household or an individual. Having this circumstance, some of GEUs such as TEPCO acquire a stake of venture capital firms in Germany and other oversees countries where P2P trading with blockchain technology can be tested in the real field.

3.2 TEPCO[3] VPP demonstration project

VPP is defined as a control technology to aggregate distributed energy resources (DERs) such as power generation plants, energy storage, electricity appliances using ICT as if it works as a power station against electricity grid by dispatching electricity and demand control. The TEPCO project is characterised by a substantially large number of small-scale DERs at the end-users, demand side, within the VPP. This character is commonly observed among other VPP demonstration projects led by METI such as KEPCO model. TEPCO VPP model has connected a large number of residential and industrial batteries, air conditioners, gas CHP plants and lighting facilities. In total, the VPP project has 12.4 MW of total capacity with thousands individual DERs. These DERs are

[3] To be accurate, this should be referred as TEPCO HD. However, TEPCO is used here for simplicity. This section is mainly based upon TEPCO (2018).

individually controlled by HEMS (Home Energy Management System), BEMS (Building Energy Management System), FEMS (Factory Management System) within their located boundaries to optimise their energy usage. The HEMS, BEMS and FEMS are connected to the resource aggregators and the aggregation coordinators. Such optimisation of DERs and EMS at each demand side appears to be a distinct feature of the VPP model in Japan in comparison to the German cases.

An average capacity of the DERs is around 6 kW, which is highly contrasted to the case of Germany. For instance, as already described, Next Kraftwerke has connected to approximately 6,500 DERs with 6,000MW of total capacity meaning that an average capacity of the individual DERs is around 920 kW, which is more than 150 times larger than the TEPCO model. In addition, none of renewable energy resources has been connected to the model, making a clear difference from the Germany model.

The DERs are aggregated by 9-11 resource aggregators respectively, which are further aggregated by an aggregation coordinator which is TEPCO in this model. The expected functions of the aggregation coordinator are an aggregation of the DERs from each of the 9-11 resource aggregators to be dispatched to the balancing and the capacity markets as reliable resources, and continuous management of availability of contourable DERs. The wholesale market is also their targeted market in the future.

The demonstration activities in this VPP project so far have solely focused on technical aspects, particularly connectivity between the DERs, the resource aggregators and the aggregation coordinator, and reactivity of the DERs corresponding to the dispatch signal from the T/DSO ensuring reliability to meet the expected qualification required as tertiary control reserve (TCR) , secondary control reserve (SCR) in the future balancing market. TCR would require an on-line controlled reaction of at least 1MW resource capacity at 10% accuracy within 15 minutes over 4 hours duration. Similarly, SCR requires an on-line controlled reaction of at least 1MW resource capacity at 10% accuracy within 5 minutes over 4 hours duration. Although the possibility of participation into primary control reserve (PCR) can be considered, TCR and SCR have been set as primary targets. Over the past years, a series of reactivity tests have been conducted repeatedly which have proven the VPP model can sufficiently meet the requirement for TCL with 89% of successful rate on an average. At present, the reactivity tests are conducted to examine if the VPP model can react to SCR and even PCR corresponding to a dispatch signal within a few seconds. It is expected that the VPP project continues to pursue the technical aspects to increase its reliability as a flexible resource. An optimal control of dispatching DERs corresponding to the price of the wholesale market will also be examined in this model.

Apart from the technical aspect, the economic feasibility has not been considered in the VPP project. This is partly because neither a balancing market nor a capacity market has established yet, which makes it difficult to test the marketability of the VPP model. As a result, market structure, policy and regulation, which can significantly affect the economic feasibility of the VPP model, are largely left for further consideration. These aspects also need to be investigated to implement VPP model in Japan.

4. VPP: the role and status in the US

4.1 VPP: Status in the US

In the US, VPPs seem to be uncommon and few cases are actually commercialised. Like Japan, described above, this is also contrasted to the case of Germany. Several reasons can be given for this uncommon status of VPP in the US. Firstly, the power pool model adopted by the US regulation prevents ISO/RTO from utilising VPP in a full scale as flexible resource. This is because that ISO/RTO can directly control the existing power plants under the power pool model, which are much easier flexibility resources available for ISO/RTO rather than VPP. To put it simply, ISO/RTO does not need VPP as a flexibility resource since they have enough directly controllable flexibility resources from the existing power plants. Germany, and Japan also, have a different power market model, the balancing group model (BG model), under which TSO has to acquire flexibility resources through the market where a VPP could potentially participate if it is reliable dispatchable resource. Second, the share of VRE in generated power is 7.8% in the US in 2017, which is marginally higher than Japan's 6.5%, but substantially lower than 22.7% of Germany in the same year. IEA (2018) states that the phase of VRE integration and system flexibility for the US as nation is 2,[4] the same as Japan, whereas Germany is in Phase 3. The relatively lower VRE ratio in the US implies that flexibility resources like VPP have not been urgently required at this moment, except for some states such as California where the VRE share was 19% in 2017. Thirdly, a net metering scheme, commonly adopted in many states in the US, creates a disincentive for solar PV owners to join VPP, since net metering gives itself enough benefits to them and not any more. These regulations have brought about the environment where VPP is not widely commercialised in the US.

Nonetheless, we have selected 2 case studies, one is ConEdison's VPP project from New York and the other is PG&E's SSP programme from California. In fact, it was revealed that both of VPP projects were demonstration projects and are no longer implemented for reasons explained in the below sections.

4.2 ConEdison Clean VPP project in New York[5]

ConEdison, originally founded in 1823 as the New York Gas Light Company, is one of the largest private utility companies in the US who provides electricity, gas and steam service to more than 3 million customers in New York City, Westchester County and New York. ConEdison's VPP model, known as Clean VPP, was planned as a demonstration project under REV (Reforming the Energy Vision) by the State of New York since 2015 and currently temporally suspended due to regulatory matter and residential acceptance.

In this model, ConEdison would partner with SunPower and Sunverge. SunPower, founded in 1985, a subsidiary company of Total Solar, has provided solar PV system more than 30 years. Sunverge, founded in 2009, provides a distributed energy storage/management appliance plus batteries,

[4] This is for the nationwide. Individual states, namely Texas and California are in Phase 3 respectively.

[5] This section is largely based upon ConEdison (2015a) (2015b) and State of New York (2015).

called the Sunverge Solar Integration System (SIS), power electronics and system management software running in the cloud. SunPower, in partnership with Sunverge, provides a platform, Network Operation Center (NOC), that aggregates control of individual residential resources into the VPP. The total aggregated DERs capacity of this VPP model would be 1.8 MW capacity and 4.0 MWh of stored energy capacity installed approximately 150 households. SunPower and Sunverge jointly offer their solar and battery system to residential customers and develop an advanced control platform to aggregate the distributed resources into a single, dispatchable capacity and energy resources (see Figure 3).

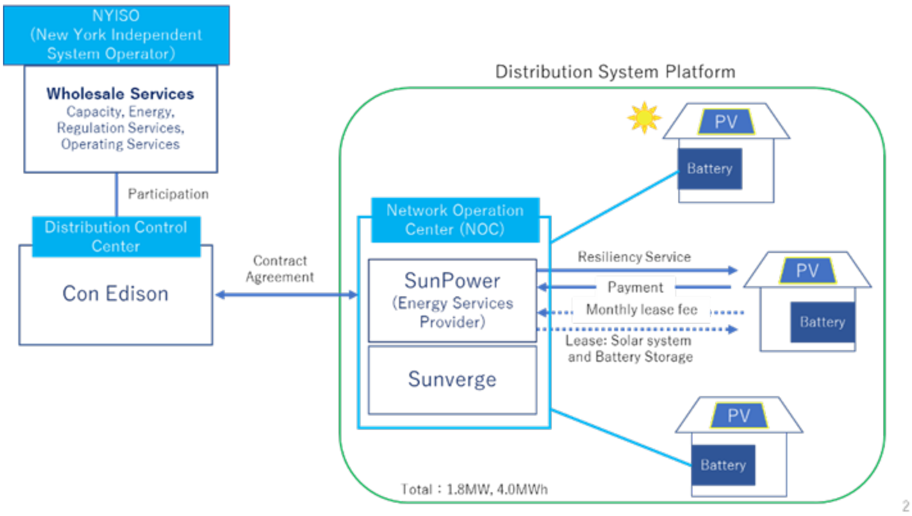

Figure 2: Overall picture of ConEdison Clean VPP

Source: Authors' own figure

The Network Operation Center (NOC) provides aggregated control of individual residential resources, converting them into the VPP, resulting in grid-scale impact and benefits to Con Edison and its customers. SunPower is an experienced solar technology provider that delivers solar PV system, providing project financing, engineering, procurement, and construction services for the VPP project. In addition, it would handle customer acquisition, site inspection, design, and installation services. Con Edison, for the duration of the VPP project, owns and operates the fleet of energy storage assets.

The VPP demonstration project includes the establishment of communications from SunPower's Network Operations Center (NOC) to each customer's energy storage system. In addition, communication in the form of data transfer and VPP control between Con Edison's Distribution Control Center and the NOC would be established. Once established, Con Edison would explore how hundreds of residential DERs can be aggregated into grid operations to provide firm capacity for participation and monetisation in competitive capacity and energy markets, NYISO wholesale markets and demand response programs.

Corresponding to the development of the VPP model, NYISO has set the roadmap to change its market structure to enhance the participation of DERs. Based on the roadmap, NYISO has published the "Distributed Energy Resources Market Design Proposal" in 2017, with which NYISO will permit DERs to participate in the wholesale, capacity and ancillary market for the first time ever. Specifically, the participation categories of DADRP (Day-ahead demand response program) and DSASP (Demand side ancillary service: scheduled in Day-ahead and real time ancillary market) would be replaced by "Behind-the-Meter Net Generation" which is comparable to a generation plant. This implies that DERs aggregated by VPP are expected to be more reliable and dispatchable resources as much as a generation plant rather than a "day-ahead schedule" resource.

It is, however, unfortunate that this VPP model has been temporally suspended since early 2017 due to not enough number of households having signed for installation of the Sunverge Solar Integration System (SIS), which finally resulted in a termination of the contract between ConEdison and Sunpower. There are two reasons for this. First, the cost of SIS was somewhat too high beyond the range of households' willingness to pay for receiving resiliency service. Second, an approval by New York City to install SIS in buildings was a lengthy process, which was much longer than initially scheduled. Nevertheless, ConEdicon shows their intention to continue running this model in the future.

The total capacity of DERs, 1.8 MW, in this model is significantly smaller than the Germany case such as Next Kraftwerke, which has 6,000 MW. In this context, it is important to recall that this VPP model was initiated as the REV demonstration project by the state of New York to seek how to aggregate DERs (solar PV with battery) associated with resiliency service, grid stabilisation and monetisation of DERs by participation to the wholesale market. In other words, this demonstration model was highly characterised by policy driven development and was not fully designed in a commercial basis. The cost issue of SIS, which is the cost issue of battery and is one of the reasons for the suspension of the project, represents a lack of consideration for the economic feasibility.

4.3 PG&E SSP programme in California

PG&E is one of three private utilities (IOU) in California; the other two are SCE (Southern California Edison) and SD&G (San Diego Gas & Electric). PG&E is providing 5.2 million households with gas and electricity in most of the northern part of California. PG&E's Supply Side Pilot program was a DR programme[6] implemented during 2015-17 period which was sponsored by PG&E. The primary objectives of this pilot DR programme are to test DERs participant interest and capabilities of wholesale market participation and to identify and work through wholesale market integration issues.

Olivine has a key role in this programme shown at the centre of Figure 4. Olivine is a DER aggregator connected with solar PV, DR resources, EV and battery storage to offer grid services and certified as a scheduling coordinator by CAISO who can participate in the CAISO market. In this particular programme, Olivine plays a role of an interface between the CAISO market and DER aggregators. Though this role of Olivine may look similar to an aggregation coordinator in the Japanese TECPO case, it should be stressed that their role here is not only coordination of various resource aggregators like in the Japanese TEPCO case, but also participation to the CAISO market.

[6] This is a DR programme, not a VPP programme. However, this can also be considered as a VPP programme since batteries are aggregated as DERs which potentially can dispatch electricity into the market.

Olivine employed its own DER management platform to control DERs, which is integrated with the CAISO market.

An aggregation of DERs in this model is done by DER aggregators shown on the left-hand side in Figure 4 who control each DERs corresponding to schedule notification. Among three companies who worked as the DERs aggregator in this programme, only one company, Stem, is known and the other two companies are unknown. Stem is a private company, founded in 2009, providing energy management service and DR with battery storage and IT system.

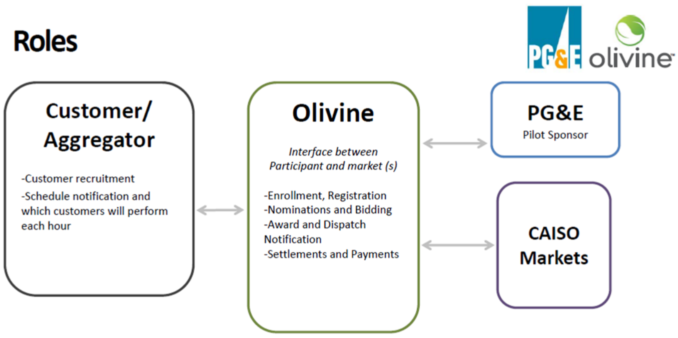

Figure 3: Overall structure of PG&E SSP

Source: Olivine (2016)

In this programme, as DERs aggregator, Stem manages the battery storage operation installed in various their customers, one of which was Adobe's office building with 162kW/180kWh battery to provide DERs according to the dispatch notification from Olivine. Apart from this Adobe's battery, HVAC, EV and solar PV are included in the DERs within this model, but their detailed information is not publicly available. Yet the total DERs capacity of this VPP model could be much smaller than the case of Germany, as already repeatedly pointed out before.

Each DERs within this model, Stem, can participate, through Olivine, into the CAISO day ahead market, real time market, and ancillary service market. They can choose to either self-consume or sale to the market. During the 2015-16 period, PG&E/Olivine's SSP made 6780 bids into the day-ahead CAISO market, which resulted in 872 awards, and 882 bids into the real-time market (e.g. balancing market) but no award was given there. In addition, DERs can receive a capacity payment of up to USD 10 per month from PG&E. Therefore, in this model, each DER can benefit from, not only electricity cost saving, but also revenue from the CAISO market and the capacity payment. However, it was found that there was little initial interest in providing ancillary service, such as non-spinning reserve with 500 kW capacity at minimum, as the benefit was not compelling enough to justify the current investment cost for installation of required equipment to provide such service.

The EMS in this model called "Stem's intelligent energy storage systems" which are installed in the buildings of customers like Adobe's San Francisco campus to automatically decrease energy costs, storing energy when costs are low and deploying when high. By participating in the CAISO market, Adobe is turning its Stem system into a revenue stream. Stem sets its price target and then its predictive software automatically accepts market bids and dispatches available power to the grid. Stem collected extensive data during successful day-ahead bidding at six customer sites for more than a year to enhance forecasting and refine automation. Accurately forecasting customer energy use is critical to ensure systems can be used both for decreasing energy costs at the customer site as well as participating in energy markets. Olivine's platform serves as the critical link for DERs such as those managed by Stem to participate in open energy markets.

As seen from the end-user's view point, the owner of DERs, Adobe, already benefits from Stem's energy storage system to store energy when retail electricity price is low and to self-consume such energy stored when the price is high. Since electricity consumers in the commercial sector in California are being charged a substantially higher rate of electricity price, called demand charge, corresponding to their individual peak demand, they are encouraged to reduce the peak demand by, for instance, an installation of battery storage. This fact implies that this VPP model can highly depend upon a particular business environment where electricity retail prices are set at intentionally high levels to reduce peak demand, which is in favour of installation of battery storage, like in California. It is worth recalling that California has a range of rigorous energy policies to promote renewable energy and associated technologies. California has the largest energy storage market in the US.

5. VPP and blockchain: Germany, Japan, and the USA in comparison

Table 1 summarises the above VPP case studies in Germany, Japan and the US.

Table 1: A summary of VPP case studies in Germany, Japan and the US

	Germany	Japan	US
Status	Fully commercialised (e.g. Next Kraftwerke, Energy2Market, various Stadtwerke)	Demonstration stage (most projects are financially supported by METI)	Demonstration stage (some are self-financed by utilities such as ConEdison and PG&E)
Purpose	Commercial business; also a number of pilot projects to test new uses of VPP and new types of technical units	Development of technical aspects of VPP let by government	Seeking new business models under new regulatory framework
Market targeted	Wholesale market, balancing market (FCR, SCR, TCR); Tests for regional flexibility markets	Wholesale market Balancing market (FCR, SCR, TCR) Capacity market	Wholesale market, balancing market, ancillary market (NYISO, CAISO)
Total capacity of DERs in case studies	6,500 MW (Next Kraftwerke)	12.4MW (TEPCO)	1.8 MW (ConEdison) 162KW (PG&E)
FIT/net metering/ RPS for RES	-Mandatory direct marketing of RES for medium to large producers, but entitlement to 'market premium' making up the difference to FIT level -fixed FIT for smaller producers; no net metering but auto-consumption behind the meter for small PV plants - Gradual expiring of FIT / premium entitlement for older producers after 2019	Gradual expiring of FIT entitlement after 2019, but majority are still receiving FIT over the next decade	-Net Metering at most of the states incl. NY and CA -Utility scale RES is under RPS in NY and CA, but not for small to medium DERs
Electricity market system	Balancing group model where TSOs have to purchase control reserve energy from the market	Balancing group model where, potentially TSOs have to purchase control reserve energy from the market	Power pool model where ISO/RTO can directly control the flexible power plants, less incentive to purchase control reserve from the market
Electricity supply system	Legal unbundling completed	Vertically integrated, but legally unbundled in 2020	Unbundling completed (NY), Partially vertically integrated (CA)
Share of VRE in electricity production in 2017	22.7%	6.5%	7.8%
RES target	65% of gross electricity consumption in 2030	22-24% of electricity production in 2030 (in which 3.7-4.6% of biomass)	RPS targets in 2030 set at 50% (NY and CA)
IT system and EMS	- Optimised scheduling and bidding of aggregated DERs in day-ahead and intraday markets based on forecasts - Aggregation of DERs corresponding to dispatch signal	- Optimisation of energy usage within individual boundary where each DER is located - aggregation of DERs corresponding to dispatch signal	Aggregation of DERs corresponding to dispatch signal

The table highlights some of the notable differences between two groups, namely Germany and Japan/the US. The most distinct feature of Germany's VPP business model compared to Japan and the US is that it has already been successfully commercialised in a full scale of operation with a large amount of trading volume in the electricity market. In contrast, any commercialised VPP models as much as a Germany's scale have been found neither in Japan nor the US. Most of the projects found in Japan and the US are in a demonstration stage or a pilot stage, none of which have been proved as commercially successful yet.

Several reasons can be given for the difference between Germany and Japan/the US:

- A remarkably higher share of VRE in Germany, 22.7% of electricity production in 2017 in contrast to 6.5% of Japan and 7.8% of the US in the same year, has encouraged the TSOs to utilise VPP as a flexible resource available in the wholesale market and the balancing market.
- The electricity market and relevant regulatory framework have been reformed in Germany in a way that has been favourable for VPPs. This has the following two main elements.
  (1) In response to the higher share of VRE, Germany has aimed to prepare RES power plants for the market post the current FIT regime and simultaneously to create a business opportunity for VPP, by setting up a series of policies for energy market and renewable energy. Particularly a direct marketing obligation for RE, initially introduced by EEG 2010 in place of an entitlement to directly receive the FIT, has strongly encouraged the medium-sized RES power plants to join the VPP and to receive a service from the VPP aggregators.
  (2) A balancing group model for the power market adopted in Germany creates a higher incentive for TSOs to purchase energy and balancing resource from the market. Still, the reserve control market was first created by legislation in Germany; before, control reserve was completely in the hands of TSOs. In contrast, a power pool model adopted in the US brings far less incentive to the ISO/RTO to do so, since they can directly control the existing grid-connected flexible power plants as necessary. However, the power pool model may make it easier to include demand response and regional potentials in the wholesale markets, through capacity mechanisms. In fact, Japan has a similar power market system to Germany, which is a balancing group model, suggesting that there would be higher potentials for VPP in the future.
- In Japan, RES power producers still are under the FIT scheme, and there is no control reserve (balancing) market yet. This may easily explain why the TEPCO VPP pilot project in Japan includes batteries and demand response but no RES power producers. However, the first producers will soon not receive the FIT anymore, and the control reserve/ balancing market is expected to be introduced in 2021. This may also create opportunities either for VPP including RES power plants, batteries, and demand response, or for P2P sales of power from RES power plants, if regulation enables this and market conditions are favourable.
- In addition, US states such as California allow net metering, which does not expire like the FIT scheme for PV plants in Germany and Japan and creates no incentive for selling power in the market.
- A technical precondition for also allowing smaller RES producers and consumers with batteries or demand response to participate in the market through VPPs, which provide the minimum capacity required for prequalification by market place operators through the aggregation, or for P2P marketing, are a general roll-out of smart meters and their communication gateways at least to these market actors, or a dedicated metering and communication device installed by the VPP operators.

- For batteries and DR, there is also the need to use individual EMS to optimize the use of batteries and electricity-using systems providing DR. This is the case both for the TEPCO or Sonnen VPP cases, but also Next Kraftwerke should operate at least the connected batteries like this.

The scale of the capacity of DERs connected to the VPPs also presents a clear difference between Germany and Japan/the US. Next Kraftwerke, one of the largest VPP operators, has connected approximately 6,500 units with around 6,000 of capacity in Germany and several neighbour countries, which is a dramatically higher capacity than in the case of Japan, where the TEPCO pilot project has connected to DERs of 12.4 MW, and the cases of the US where the ConEdison case would connect to DERs of 1.8 MW and the PG&E case connected to DERs of 162 kW. Such a huge difference essentially reflects the fact that the German VPP case is fully commercialised, while the other cases from Japan and the US are still in a demonstration stage. However, it is worth noting that Germany has a large number of biomass/biogas power plants available for VPP, which can be operated flexibly in a much better controllable way compared to wind and solar PV. The share of electricity generated by biomass against the total amount of the electricity generated in 2017 was 8.7% in Germany, which is substantially higher than Japan's 1.7% and the US' 1.6% in the same year.

This contrasting availability of biomass/biogas power plants as DERs in each of the countries could explain the difference between the capacities of renewable energy producers participating in the balancing power markets in the three countries to a large part. This may be proven by the fact that there is currently only a pilot project ongoing for prequalification of wind power to the control reserve market and no prequalification yet for PV, although wind power and PV could contribute to negative control reserve instead of just being curtailed by TSO, as it is currently done in case of imbalance between different TSO areas or between North and South Germany.

In terms of the electricity market, all three countries, Germany, Japan, and the US have developed or scheduled for introduction relatively similar wholesale markets, balancing power markets, and ancillary markets. Although the requirements for DERs to participate in the markets can be different in details, e.g. on minimum size of bids or conditions for prequalification to a market, and these may be decisive for the prospects of VPPs or types of DERs to participate in the markets, the setup of the markets as such does not seem to be a key aspect making a significant difference of the development of VPP between the countries. The only exception may be that the power pool model adopted in many US states creates a smaller incentive for TSOs to purchase balancing power from VPPs compared to the balancing group plus control reserve market model in Germany and Japan, as discussed above. Similarly, the technical features of IT systems and EMS employed in the VPP in the three countries do not appear to be considerably different.

In contrast to VPPs, the use of blockchain for energy metering and trading purposes is still limited to pilot projects in all three countries. An exception may be the VPP by Sonnen GmbH in Germany, which connects mostly homeowners with rooftop PV plants and batteries (Sonnen GmbH, recently purchased by Royal Dutch Shell, is actually a manufacturer of battery storage systems). However, it seems that only transactions within the VPP, i.e. between the facilities connected to the VPP and the aggregator, are blockchain-based.

6. Conclusions and outlook to further research

The case studies in the three countries and the comparison in chapter 5 have shown that the VPP business model may be largely dependent upon the regulatory framework on renewable energy resources (RES) and electricity supply system as well as electricity market system. These factors mainly give a significant impact on the status and purpose on the VPP examined in the case studies.

An existing generous RES supporting scheme such as a fixed FIT or net metering for RES clearly prevents RES producers from connecting to a VPP, which is currently observed in Japan and the US. The experience of Germany shows that a mandatory direct marketing of RES required by the law has a strong impact on the RES producers, which has created the market for the VPP aggregators, which is a basis for the VPP business model in the country. The VPPs now also include gas-fired CHP plants, demand response, and other resources such as gensets. In addition to this, in Germany, TSOs are legally required to purchase control reserve though the market so that VPP aggregators can offer their aggregated DERs to this market. In this context, Biomass/ biogas power plants are considered as indispensable resources for the large VPP such as Next Kraftwerke since they are as flexible as gas-fired power plants. A gradual expiring of FIT entitlement after 2019 in Japan, which requires RES producers to sell the power in the market by all means, would bring a favourable situation for VPP as occurred in Germany, although a majority of RES will remain under the FIT entitlement over the next decade.

The organisation of the electricity supply system is also an important factor for development of VPP. An unbundling of the traditional, vertically integrated power supply system establishes a fundamentally positive environment for market entry of new suppliers as seen in Germany. Similarly, an electricity market system also can bring about an impact on VPP development. The balancing group model adopted in Germany and Japan can be highly favourable for VPP in comparison to the power pool model adopted in the US. These findings imply that a positive environment for VPP can be expected in Japan, particularly after 2020 as the unbundling of the vertical integrated supply system is scheduled in that year.

Such positive prospects for VPP in Japan would be even enhanced by the fact that the share of VRE will increase, as the Japanese government has set a clear policy target that renewables are to be main power resources in the future. The higher share of VRE will obviously require an increase in flexibility of the grid, suggesting that VPPs would be one type of favourable flexible resources for the grid in the future. The capacities of each individual RES developed in Japan are generally much smaller than in Germany and the US, reflecting lesser availability of suitable lands for RES production with excessively higher population density. Thus, an aggregation of the small DERs via a VPP aggregator, rather than an individual DER, could create more valuable resources for flexibility for the grid in Japan, particularly when the share of VRE increases significantly in the future. The share of VRE seems to also be an important element to give a business opportunity for VPP to participate in flexibly matching supply to demand, as seen in Germany.

Compared to the factors explained above, including the existence of an electricity market, the *structure* of the electricity market does not seem to be a main cause of the difference between the VPP models, as the three countries have developed relatively similar markets. However, details on e.g. the minimum size of bids or conditions for prequalification to a market may be decisive for the prospects of VPPs or types of DERs to participate in the markets. Likewise, IT systems employed in VPP also seem to appear as an insignificant factor to explain the diversity between them. In fact, in Germany there are several providers of software systems for VPP operators.

However, it should be noted that the above explained outcomes from the case studies may considerably change in the future. This is because a full commercialisation of VPP has only been seen in Germany so far, implying that there is still substantial room left for further development of VPP in other countries that may bring very different consequences. For instance, at a matured stage, market structure and IT systems could make a substantial distinction between VPP models. Also in Germany, there exist further needs for VPP development. These include making better use of demand response, batteries – including in electric vehicles, and other flexibility options such as power-to-gas, power-to-heat, or power-to-fuel; improving the consideration of regional or local network constraints in the scheduling of DERs for the day-ahead and intraday markets as well as in their use as control reserve; prequalification of wind and PV plants for control reserve; and in general, improving the market conditions for DERs and VPPs further. Nevertheless, at this stage, it can be said that the regulatory framework on RES, the unbundling of the electricity supply system, and the existence of an electricity market system are the main factors to explain differences between VPP models in the three countries considered in this comparative study.

Regarding the use of blockchain technologies, the main conclusion from this analysis is that it is currently still unclear what their main use for the energy system could be in the near or further future. Will it be used to simplify transactions between actors already active in today's energy markets, and to reduce their cost? Or will it be used for increasing P2P energy trading, which in its ultimate form may fundamentally change the market by making each consumer and producer his or her own balancing group and balancing group responsible, thereby eliminating the need for energy suppliers and aggregators? The latter vision entails a large number of chances but also risks and questions on market rules, consumer protection, and hence regulation (PWC 2016). There is therefore the need for a lot of further research, development, demonstration, and policy analysis before broad-scale introduction of such new business concepts.

Outlook to further research

After having focussed on two special aspects of the use of digitalization for the energy transition—VPP and blockchain—due to the limited time available between the start of the study and the 6th GJETC meeting, we may take a broader or a more in-depth view in the second year of this study.

Further in-depth analysis could focus, e.g., on

- Peer-to-peer electricity trading / power purchasing agreements, e.g. using blockchain;
- Digital technology for P2P trading and its potential impact on the energy system;
- HEMS in Japan/Smart Home Systems in the EU, BEMS in Japan/BACS – Building automation and control systems in the EU, and other optimisation systems for individual premises, city districts, or even smart cities.

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