The role of batteries towards carbon neutrality: How can distributed electricity storage contribute to balancing supply and demand in power markets as well as in power grids?

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1 Introduction

Both Japan and Germany recently declared their commitment to reach carbon-neutrality until 2050 and 2045 respectively. To achieve these goals, the expansion of renewable energy sources (RES) as well as their flexibility options is crucial. With the release of the 6th Basic Energy Plan in October 2021, the Japanese government increased its 2030 renewable production aim by more than 50 % (from 22-24 to 36-38 %). The new German government aims for 80 % renewable electricity production in 2030, as announced in November 2021.

Photovoltaic (PV) and wind power will play major roles in the design of the future energy system. Both place different demands on the energy system than fossil fuels due to their dependence on weather conditions and associated variability. It can be generally stated that the higher the share of PV and wind power in the electricity mix, the more flexibility options are needed to provide a constant and secure power supply.

Batteries can be deployed to increase the much-needed flexibility of the power system, amongst other flexibility options. They differ in storage capacity and their main purpose, often depending on their ownership. For example, home batteries are well established add-ons to home PV-systems in both Germany and Japan, but up to now they are mainly used for the maximization of self-consumption by private consumers. The same goes for batteries of battery electric vehicles (BEVs), where until now the only rationale for charging (or not-charging) is the consumers' demand. On the other side of the spectrum, large-scale storage systems deployed by energy providers are already used for different market and grid services as their main purpose.

Possible future applications for batteries include the pooling of home storage systems in a virtual power plant, which then provides electricity and storage capacity depending on the needs of the electricity market or grid. High hopes are also placed on the deployment of battery electric vehicles (BEVs). If their (dis-)charging behavior can be controlled in such a way that it is serving the market or grid, electric vehicles might have huge potential as flexibility options. This potential is increasingly researched and tested in Japan and Germany with the growth of annual EV sales in both countries.

Lastly, one has to keep in mind that the use of batteries is finite. After serving in an electric vehicle, batteries usually can be deployed for other, less demanding purposes. But at some point, they have to be recycled. Both Japan and Germany explore new business models for the so-called second-life use and recycling of batteries, which will become increasingly necessary especially with the spread of BEVs.

This study focuses on how distributed electricity storage can contribute to balancing supply and demand in power markets as well as in power grids. It has been structured as following:

- **Chapter 2** outlines the technical and system background on the integration of batteries into the grid. The current and potential uses of batteries for matching supply and demand and stabilizing the grid, as well as their potential for second-life uses and recycling needs are first be explored conceptually. After that, Japanese and German experiences and potentials with market- or system-serving battery functions are highlighted.

- **Chapter 3** starts with a general analysis on business models and regulatory frameworks needed for the further establishment of grid services by batteries. It then showcases novel business pilots and experiences in Japan and Germany, and presents studies on regulatory frameworks in both countries.
- **Chapter 4** conducts a comparison of German and Japanese potentials, business cases and regulatory frameworks.
- **Chapter 5** concludes and deduces future study/research needs on technology, policy intervention and business development.

2 Technology assessment

2.1 The current and potential uses of batteries for matching supply and demand and stabilizing the grid

Toward the achievement of carbon neutrality, the power generation, the building, and the transportation sector have been working on the program within each sector. There is a new development that technologies and services are converging from more than one segment in a cross-sectoral manner. This is called sector coupling or sector integration.

Some examples of sector integration will be introduced in the following chapters. They will elaborate the conceptual background of battery use for matching supply and demand as well as grid stabilization by investigating current and potential uses of electric vehicles (short EVs) with focus on battery electric vehicles (BEVs), building-integrated, and grid-integrated batteries.

2.1.1 Battery Electric Vehicles (BEV)

In the current phase of the mobility transition, passenger cars are estimated to be idle around 95 % of the time. At the same time, users of electric vehicles generally need only 10 % of the hours in a day for charging, which leaves at least 85 % of the time free for potentially providing flexibility services to homeowners or the grid/the market (Hildermeier et al. 2019). As a stationary battery storage installation is expected to boost the share of roof-top solar power that can be used in buildings, many users may wonder whether they can use EVs as quasi building-integrated storage when they do not use EVs for transportation. In addition to such private uses, BEV batteries could also be used for matching supply and demand and stabilizing the grid. In both cases, the flexibility in charging and discharging electricity to or from the batteries must not compromise their primary use: serving as the power source for the BEV to fulfill the users' mobility needs.

The potential use of BEVs for matching supply and demand and stabilizing the grid can be conceptualized by two stages: 1) flexible charging, where the vehicle owner is adapting his charging behavior to meet power market/grid needs and 2) vehicle-to-grid (V2G), where the vehicle is charged and discharged depending on power market/grid needs. In both stages, the charging/discharging is happening while also respecting the user's demand. The two approaches can be even further differentiated according to their scope (see Figure 1).

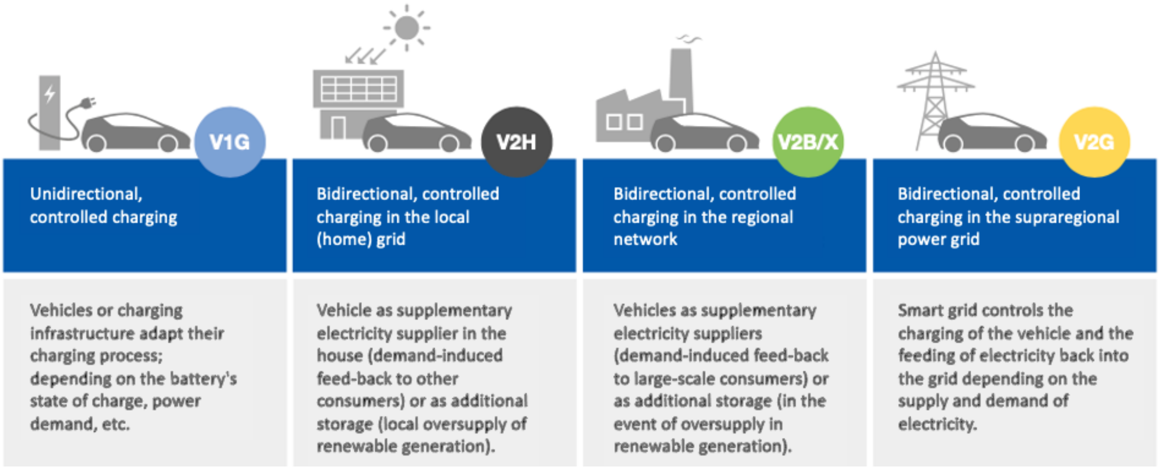


Figure 1: Concepts for connecting BEVs and the electricity grid. Source: VDE (2021), own translation.

1) Flexible charging (see V1G in Figure 1): Vehicles or charging infrastructure adapt their charging process, depending on the battery's state of charge, power demand, etc. Previous research highlights the benefits of strategic BEV integration, stating that smart BEV charging can integrate increasing amounts of renewable energy resources, increase utilization of the existing network infrastructure, lower the operating cost of BEVs, and minimize the need for new investment. There is a broad agreement that the grid can cope with integrating the anticipated growth in electric vehicles without issue, provided charging is managed. This means that users are provided with incentives to move their vehicle charging to off-peak hours, thus using the existing grid assets more efficiently (Hildermeier et al. 2019).

2) Vehicle-to-home (V2H): V2H comprises individual solutions for connecting the electrical systems behind the house connection point. The main focus here is on optimizing self-consumption. For example, during electricity production by means of a PV system, additional consumers are activated to absorb the surplus energy. These are primarily consumers that can be switched on at flexible times, such as heat pumps, water heating, or BEVs. The vehicle battery is used as a quasi-stationary intermediate storage unit, into which excess solar power from the roof panels of the house is fed and, if necessary, is also fed back into the house and to the consumers there.

BEVs battery capacities are usually larger than home battery storage capacities, so the use of V2H can store and supply more roof-top PV power. V2H users can also benefit from fast EV charging time by straight DC charging from roof-top PVs to EVs. The biggest obstacle to the use of V2H is the initial cost of the system installation, since a V2H converter costs 4,000-8,000 US $ excluding the installation cost. Many governments provide subsidies as much as half of V2H initial installation cost.

Figure 1 furthermore shows two stages of V2G application:

3) Vehicle-to-business/X (V2B/X): Another form of intelligent vehicle (battery) connection to producers, consumers and distributors of electrical energy would be the Vehicle-to-business coupling. It functions similarly to V2H, except that larger units, i.e., a company, are coupled with several vehicles.

4) Vehicle-to-grid (V2G): The completely flexible use of vehicles as energy storage devices within the framework of V2G applications describes the possibility of controlling vehicles with regard to the public power grid. The goals are the safe and grid-supporting integration of feeding (charging the battery) and feeding back (discharging) into an increasingly volatile energy system (grid service at the distribution grid level), system services for the transmission grid operator according to his specifications/needs and the marketing of the self-generated electricity (VDE 2021). From a technical point of view, all services that can be provided by home storage systems as described in the following chapter, could also be provided by EV batteries with the according technical standard.

In this context, it is important to note that not all BEVs are capable of the above described services today. The technical requirements for bidirectional charging must be considered in all components involved and the communication between them. For example, the two-way power supply with vehicles to buildings requires a V2H compatible EV and V2H converter. Most of the new BEV/PHEV models are V2H compatible, and there are good choices of V2H converters. On the vehicle side, there are two approaches for implementing bidirectionality, which differ according to where the current is converted from DC to AC voltage. This can take place either in the vehicle or in the charging station. Thus, depending on the charging technology, changes to the vehicle side or to the charging facility are necessary for the use of bidirectionality. These changes are associated with additional costs for the charging infrastructure or the vehicle side. In addition, the communication protocol standards currently used in the automotive industry for e.g., in Germany are not yet designed for bidirectional charging (NPM 2020).

2.1.2 Building-integrated batteries

In the following section, the residential use of stationary batteries, as well as their use in the commercial and industry sectors (C&I), will be further investigated. Figure 2 shows four stakeholder groups involved in the use of those batteries. The residential, C&I, and the utility group, and the assigned functions will be explored in chapter 2.1.2 and chapter 2.1.3. The first distinction between these groups can be made by looking at the question of ownership: Building-integrated batteries are owned by the building/facility owners and are at a first-place used to optimize their operations and energy costs. They have to be differentiated from batteries located in a building/facility or transformer station and owned and operated by a utility for optimizing its operations. Those would be counted under grid-integrated batteries (see chapter 2.1.3). The off-grid use of batteries will not be the subject of this study, due to its focus on-grid- and system-serving functions.

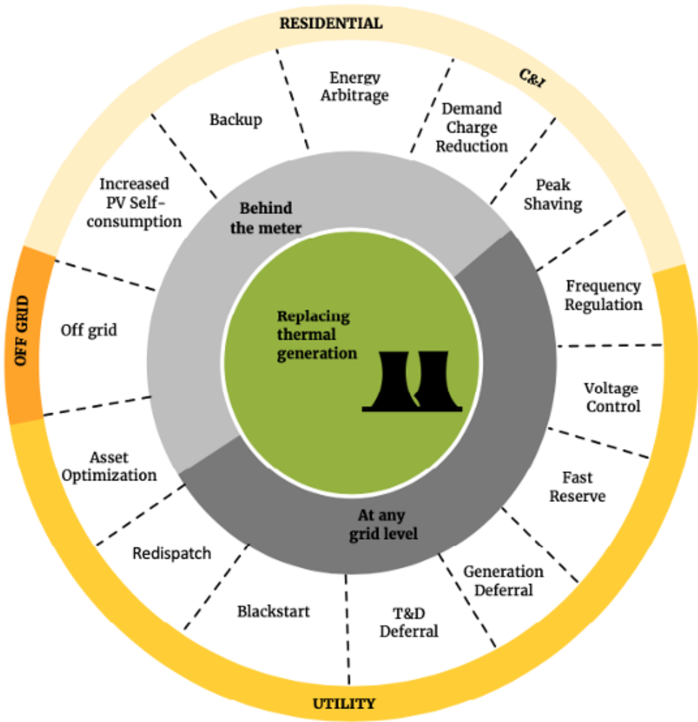


Figure 2: Batteries can provide up to 14 services to four stakeholder groups. Source: BEE (2016).

Grid- and system-serving functions of batteries

Batteries can contribute to matching supply and demand and stabilizing the grid when used in a grid- and system-serving manner (services under 'Utility' in Figure 2). According to BEE (2015), serving the grid or the system can be conceptualized as follows: Stationary batteries and other battery energy storage systems (BESS) show **grid-serving behavior** when they actively contribute to the stabilization and smooth operation of the electricity grid. The provision of services such as the provision of primary and secondary balancing power, the contribution to voltage maintenance and quality as well as to supply reconstruction are to be located in the area of grid serviceability.

As an extension of grid-serving behavior, a BESS **serves the whole system** when its operational behavior contributes to the overriding goal of making the energy system more flexible. This includes that its use optimally adapts the fluctuating renewable supply to the electricity demand and thus minimizes fluctuations in the residual load. This way, it serves both grid operation and matching supply and demand in the market/the system. The system-serving behavior of BESS requires a high degree of flexibility, communication, and interaction between the various system components.

In contrast to the grid- and system-*serving* behavior, BESS can also be used in a **grid- and system-*compatible*** manner. This means that they only fulfill the minimum requirements that ensure safe and reliable grid operation and the maintenance of the energy supply system.

The contribution of decentralized batteries for matching supply and demand and stabilizing the grid

For building-integrated batteries, these functions would come in addition to optimizing their energy bill and their PV self-consumption, in case they operate a PV plant (services under 'Residential' and C&I' in Figure 2). Building-integrated batteries are thus a technical option of Demand Response. For the building owner, such services would be secondary to the primary services expected from the battery, and may also contradict the operation patterns that would optimize its economy or utility, and therefore the necessary incentives for serving their own needs and those of the grid and system will need to be created (cf. chapter 3).

Currently, the main application case for building-integrated batteries is the charging and discharging to **increase the own consumption of self-generated PV power**. For example, in Germany, the electricity price of around 30 Eurocents/kWh can be saved by consuming self-generated power in residential PV systems of less than 10 kW, while selling these to the grid would earn just over 8 Eurocents/kWh (in case of EEG FiT for new PV home systems).

Although direct charging of the residual PV generation after self-consumption is a grid- and system-compatible in principle, it is not necessarily contributing to grid stability. Unregulated self-consumption-optimized operation of home storage systems (HSS) can lead to steep feed-in ramps for individual storage systems, which may pose a challenge to the grid (see Figure 3). Other modes of charging are delayed charging (with preset battery charge level), **peak shaving** (storage of power peaks), and forecast-based charging. They comprise the first aspects of grid-serving behavior. Forecast-based charging combines the different modes of operation and serves both self-consumption and grid operation. Therefore, it represents a basis for a system-serving battery driving mode.

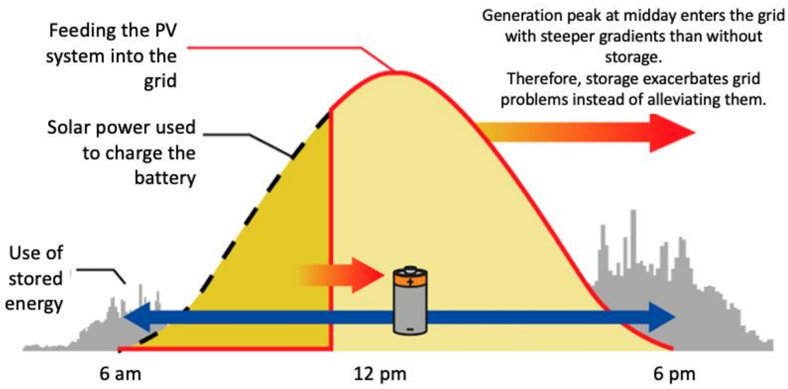


Figure 3: Unregulated self-consumption-optimized operation of home storage systems. Source: BEE (2020), own translation.

The service of **energy arbitrage** refers to power being purchased and stored when power prices are low and sold or used when it is higher. Using batteries as an arbitrage application helps to mitigate high electricity prices and to reduce potential low load conditions. Thereby, and within certain limits, batteries can also increase the secured power of fluctuating generators (Table 1: **contribution to secured power**). For example, power can be stored in cases where there is insufficient demand (commonly at night or at the weekends), coincident with large electricity production attributable to growing wind and solar generation capacity. Due to its advantages for both consumers and the grid, energy arbitrage can be considered a system-serving function.

Quite similar, but relevant only for C&I, is the possibility to reduce demand charges with batteries. Demand charges are additional fees that utilities charge non-residential customers for maintaining constant supply of electricity even at demand peaks. Most utility rates specify the maximum power demand a C&I customer is allowed to have in any given interval (usually 15 min.): exceeding the maximum power demand for consecutive months can result in being moved to a different rate with higher demand charges. **Demand charge reduction** refers to the reduction of power draw from the grid during specific time periods in order to reduce the demand charge component of the electricity bills. Lithium-ion batteries (LIBs) are a reliable solution for this purpose. Called upon at key times throughout the day, they are able to manage peak building loads.

Another service of batteries is **backup/uninterruptible power supply (UPS)**: For large industrial customers and datacenters, even the smallest variation in power quality resulting from grid instability can cost millions of euros in lost productivity. Batteries can provide backup power at multiple scales ranging from sub-second-level power quality for industrial operations to household backup when paired with onsite PV generation. Lithium-ion based technologies have evolved to a point where they can now deliver reliable backup power at a price point well below that of diesel generation sets when paired with a renewable generator. In the area of uninterruptible power supply, battery storage systems are now mature and state of the art (see Table 1).

Potential future uses for building-integrated batteries can outlined by an even more system-serving behavior. For example, **frequency regulation** ensures that the frequency of the grid is held within an acceptable tolerance band in order to avoid grid instability. In Germany and Europe this tolerance band lies between 49,8Hz and 50,2Hz. Due to their short reaction times in the millisecond range, battery storage systems are technically ideally suited for the provision of balancing energy up to the minute range (especially instantaneous reserve and primary balancing power). This is already used to some extent in the German balancing market (Ninomiya et al. 2019). In the future electricity system, batteries can increasingly provide balancing power that was previously mainly provided by conventional power plants.

2.1.3 Grid-integrated batteries

Grid-integrated batteries are owned by utilities, e.g. grid companies, generators, or suppliers with their generation. They exclusively provide the ‘Utility’ services in Figure 2.

The current and potential market- and system-serving functions of grid-integrated batteries can be outlined by flexible charging and discharging, respecting power market/grid needs. In its study on decentralized energy storage, the German Renewable Energy Federation (BEE 2015) assessed the technical and economic feasibility of possible applications of battery storage for the integration of renewable energies. Table 1 gives an overview of the results.

Table 1: Possible applications of battery storage for the integration of renewable energies into the electricity system and assessment of their technical and economic feasibility. Source: according to BEE (2015).

Possible applications of battery storage				
System services	Security of supply and reconstruction	Contribution to secured power		
		Uninterruptible power supply		*
		Black start capability		
	Voltage maintenance and quality	Provision of reactive power		
		Provision of short circuit power		
	Frequency maintenance through active power control	transient	Instantaneous reserve	**
		Control and reserve power	Primary control power	
			Secondary control power	
			Tertiary control power	
			Long-term reserve	**
	Grid operation management	Gradient control (ramping)		
		Network congestion management		
Generation Balancing	Future markets			
	Spot markets			

Technically feasible and economically viable — Technically feasible, economic viability to be examined — Not economically feasible

* Only Lead-acid battery
** Still to be examined in case of Redox-Flow-Battery

The contribution of grid-integrated batteries for matching supply and demand, stabilizing the grid

Blackstart: A blackstart-capable power plant is suitable for rebuilding the supply system on an island basis after a supply collapse (blackout) and without external support. BESS can be black-started if designed accordingly and can thus contribute to the reconstruction of supply. With (decentralized) battery storage, wind farms, gas turbines and combined heat and power plants can also be upgraded to black start capability.

Voltage control: Grid operators must ensure that the voltage remains within permissible bandwidths and that their operating resources are not overloaded. To achieve this, four measures, in particular, can be taken technically with BESS: Provision of reactive power and reactive power compensation, provision of short-circuit power (fault ride-through), storage, and release of active power for voltage maintenance, and the local stabilization of fluctuating renewable feed-in. The provision of short-circuit power can also be undertaken by building-integrated batteries but would require the pooling of more than one battery.

Frequency regulation (including fast reserve), which was already mentioned in the prior chapter, can also be provided by grid-integrated batteries.

Grid operation management (e.g. Redispatch and Asset Optimization): BESS can have a grid-relieving effect by reducing the maximum electricity demand and absorbing steep gradients in the residual load. In the future, batteries can be used in the distribution grid at overloaded grid points in order to alleviate the bottleneck situation and, for example, prevent renewable generators from being shut down. Energy storage can help the grid operator avoid the redispatching process when batteries are deployed downstream of the congested area. So-called "grid boosters" can store power downstream of the congestion point during non-congested periods and dispatching that electricity during periods of congestion. The use of batteries for this purpose may be even more economical in the future than the curtailment in special cases. At present, battery storage does not yet play a significant role here.

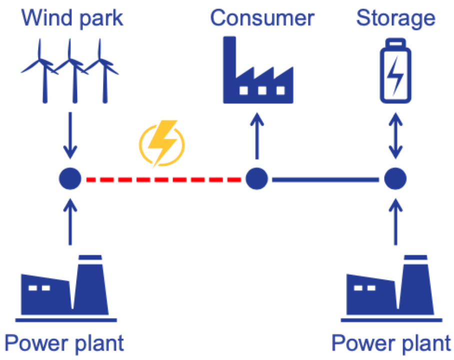


Figure 4: Illustration of a grid congestion point that could be addressed by batteries (so-called "grid boosters"). Source: DENA/Team Consult 2020.

Generation balancing on spot markets: The participation of BESS in the electricity markets is technically possible and, with further cost degression, will probably become interesting especially for short-term compensation of the forecast errors of wind and PV feed-in on the intraday spot market of the electricity exchange and in over-the-counter trading. But from today's perspective, the use of BESS on the conventional electricity markets is not yet worthwhile.

In addition to the possible application cases shown in Table 1, BEE (2016) also mentions the following system-serving functions of grid-integrated batteries:

Transmission and Distribution upgrade deferral (T&D deferral): Energy storage is deployed in the transmission system to 1) defer the equipment upgrades of T&D due to the increase in power demand or to 2) extend the life of T&D equipment. Energy storage systems provide economical alternatives to developing new infrastructure (substations and feeders), which poses challenges concerning local communities, future demand growth, capital investment, and massive time requirement.

Power generation deferral: Batteries can be configured to provide peak demand and entirely avoid utility investments in peak power generation or diesel and gas peak generation units. For peaking purposes, generators are run at 70-80 % of capacity and ramped up or down depending on the grid needs. Putting in storage would enable such plants to be run closer to full capacity, which is a significant cost saving that is critical in countries which have strong growth in electricity demand. Electricity storage is a compelling alternative to ramping up and down existing plants or using expensive and rarely used peaker plants.

2.2 The potentials for a 'second life' of BEV batteries

Along with increasing EV deployment, there will be many used EVs and used EV batteries by 2030. In Europe, Japan, and the United States, policymakers and automobile industries are carefully designing the EV battery production capacity. There is a significant interest in securing key materials to manufacture batteries, and used EV batteries recycling is regarded as a promising potential. Before recycling, used EV batteries are also considered for potential re-use as stationary battery storage, such as grid-integrated battery storage (LSS) as well as other uses with fewer loads, such as a battery-powered forklift or a backup battery of street lights.

Despite these interests in second life and recycling of EV batteries, there are few business experiences with used EV batteries due to a short history of actual EV models deployment in the market. Little is known about the actual used EV batteries conditions, and the used EV battery collection process is yet to be developed in many countries.

Many automobiles manufacturers recommend battery replacement when the battery shows degradation as much as less than 70% of the initial capacity after 8 years of use or 160,000 km mileages. In Nissan Leaf case, the new car shows 12-segmented bars in the fully charged condition, and the segment indicator loss means a battery degradation. 11 bars out of 12 is equal to 85% of initial capacity, and 9 bars out of 12 is equal to 73%, which is regarded as the signal of battery replacement. Many users may keep using degraded batteries due to a high replacement cost. The battery replacement cost of Nissan Leaf (40 kWh model) is just over 900,000 JPY.

If EV users keep using the battery too long beyond the recommended limit, such used batteries may not have a second use life, and they will just go to a recycling process. There is also a concerning reality, that many used EVs are exported, sometimes under unauthorized channels. As in the case of Japan, the number of used EVs exported is significantly larger than the industry-wide collected used EV batteries (shown in Figure 5).

Most of the used EV batteries re-use and recycling technologies are already available. Many automobile manufacturers have already conducted demonstration projects, and they understand the challenges in making the re-use/recycling business commercially viable. The first challenge is the cost of remaining health valuations, the process is very time-consuming even with the original battery manufacturers. Then, there is the second challenge that the used battery must be fully discharged and be re-configured for the second application, which is also time-consuming and costly.

Because of these higher costs with the health valuation and the re-configuration, the second use application with smaller capacities, such as a home battery storage or a battery-powered forklift, may not be able to compete with new battery use. In larger capacity applications, such as grid-integrated battery storage, variations of battery module conditions can be acceptable as long as the system-wide performance is being achieved. It is widely acknowledged that the re-use and recycling of used EV batteries may need cooperation with original auto manufacturers/battery manufacturers, because the battery health assessment and the battery operational management are highly confidential and competitive technologies.

Another barrier, which is preventing business development, is a lack of regulation of EV battery re-use and recycling and a lack of information/discussion of EV battery re-use and recycling. That may gradually change, when discussions and interests on EV battery standardization grow during 2022 after European Union proposed legislation on EV batteries in December 2020.

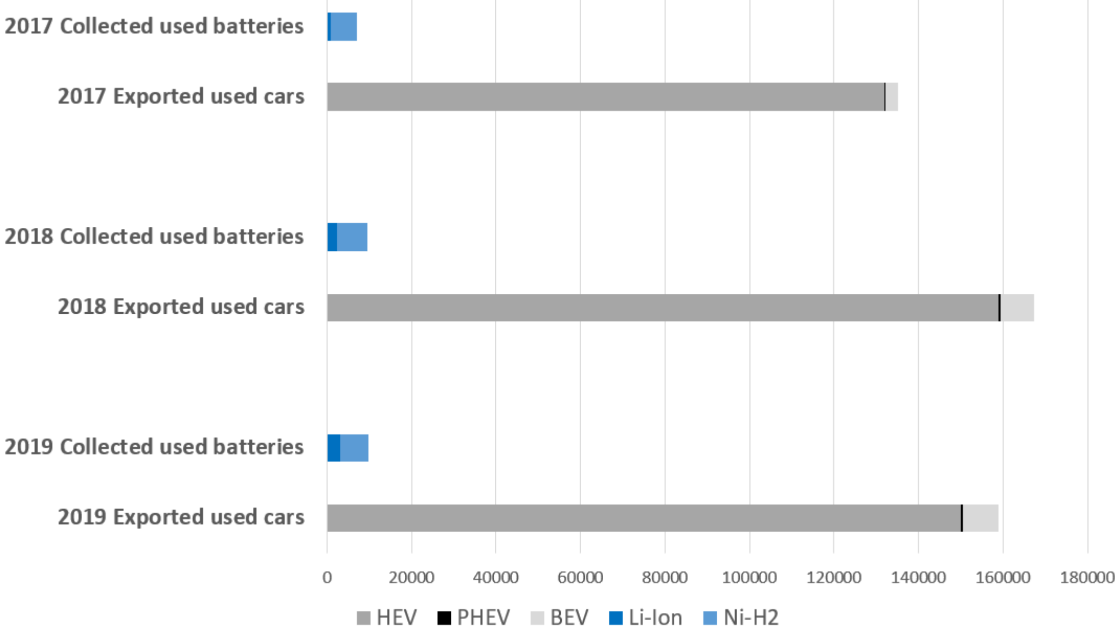


Figure 5: Comparison of the number of collected used EV batteries and the number of exported EVs in Japan (2017,2018,2019).

2.3 Recycling needs

Large-scale recycling infrastructures will be needed to ensure that the valuable but often toxic materials contained in lithium-ion batteries (LIBs) are not wasted and left for future generations to deal with. Besides the alleviation of toxicity, safety, and contamination risks, further economic and environmental drivers for recycling LIBs are the reduction of the carbon footprint of BEVs, the reduction of BEV costs, the reduction of reliance on mineral extraction, the reduction of reliance on specific suppliers of materials, and the generation of local economic activity (Beaudet et al. 2020).

The recycling of LIBs, which are used for BEVs as well as home storage systems, can be divided into the two stages of components removal and cell recycling. In contrast to portable batteries, LIBs for electric vehicles consist to a large extent (up to approx. 40 % of their weight) of add-on components such as battery casing, cables, battery management systems, various screws, plastic parts, etc. The first step of recycling a LIB is to properly remove it from the passenger cars. Due to the high-voltage batteries, only specially trained electrotechnical personnel may be used for this work. The LIBs can now be transported as hazardous goods to dismantling facilities. Depending on the process, LIBs may be discharged, and components such as casings (steel/plastic/aluminum), cables (copper), battery management systems (printed circuit board scrap) etc. are removed by specially trained personnel using small tools. These components can be fed to existing, conventional recycling plants.

The cell modules can consist of different cell compositions. Most LIBs recently produced are either based on nickel, manganese and cobalt (NMC cells) or nickel cobalt aluminum (NCA cells). The modules are separated and securely packaged and transported to a recycling plant. As with portable LIBs, pyrometallurgical (use of high temperatures), pyrolytic (thermochemical treatment) or mechanical processes are usually used in the next step for the further treatment of cell modules of EVs, depending on the process or company (Öko-Institut 2020, see also Figure 6).

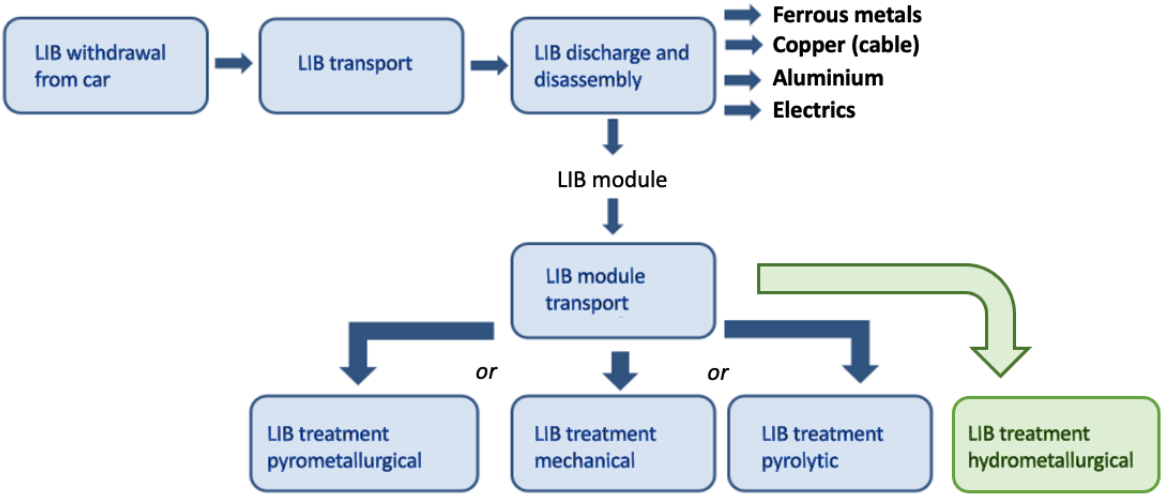


Figure 6: Scheme of removal, unloading, dismantling and subsequent treatment step of LIBs from electromobility. Source: Öko-Institut 2020, own translation and with modification.

One of the biggest challenges in the various recycling processes is the control of thermal runaway (TR) and the high fire load of a LIB. Fire incidents are repeatedly reported in connection with LIBs. These are caused by heating or mechanical damage to a cell, internal pressure build-up, a bursting of the cell, its subsequent self-ignition and the combustion of cell electrolytes and plastics. The TR of a lithium-ion cell can lead to particularly rapid and large fire events if there are many lithium-ion cells in a dense room. Therefore, all areas of the recycling industry where LIBs are collected, transported, stored and handled must be organized and technically equipped in such a way, that the TR of a cell can be detected as quickly as possible and countermeasures can be initiated or the extent of damage can be kept as low as possible (Öko-Institut 2020).

2.4 Germany: Existing experiences and potentials

This chapter starts with an overview of the development of stationary BESS in Germany as of 2020 and the development of the BEV market. Possible scenarios for 2030 and beyond will be explored. We will then go on presenting existing experiences and potentials in Germany in the field of stationary batteries, EV batteries, and second life/recycling.

Detailed information about the markets for home storage systems (HSS), industrial storage systems (ISS), and large-scale storage systems (LSS) in Germany is provided by Figgener et al. (2021). Concerning the market for HSS, the growth of the last few years continued in 2019. Approximately 60,000 new HSS, with a total battery power of around 250 MW and storage capacity of 490 MWh, were installed in 2019. This adds up to a total of 185,000 HSS, with a power of about 750 MW and a storage capacity of 1,420 MWh by the end of 2019. By May 2020, the new database of the German Federal Network Agency, “MaStR”, showed over 90,000 HSS registrations in total and is growing continuously. The market for HSS is dominated by domestic producers. Three of four HSS sold in 2020 have been produced either by one of the German companies Sonnen, E3/DC, and SENEC or the Chinese company BYD (EUPD Research 2020). The average net storage price for an HSS was estimated to be around 700 Euro per kWh in 2020. Compared to 2017, the price has dropped by more than 20 % (EUPD Research 2020, cited in PV magazine 2021) and is expected to decrease even further due to falling prices for LIBs. Since the beginning of 2013, it has been possible to finance HSS via a promotional loan. The German federal promotional bank (KfW) offered low-interest loans with a repayment subsidy. However, the KfW "Renewable Energy Storage" funding programme was discontinued in 2018. Interested households now have to resort to the programme "Renewable Energies - Standard" – a more general low-interest promotional loan for electricity and heat (KfW 2021).

Figgener et al. (2021) also give some insights into the ISS market, which thus far has mostly been uncharted. Approximately 700 ISS with storage capacities greater than 30 kWh have been registered. The registered ISS added up to a cumulative power of around 27 MW and storage capacity of over 57 MWh by the end of 2019. However, the current state of the ISS database still does not allow for comprehensive estimates of the overall German ISS market.

With respect to the LSS market, which includes mainly grid-integrated batteries, in 2019, only nine new LSS projects came into operation with a battery power of 54 MW and storage capacity of 62 MWh, indicating a strong decline in the market growth. The new and earlier installations add up to a total of 68 LSS in operation, with an accumulated power of 460 MW and a capacity of about 620 MWh. These mainly operate in the market of frequency containment reserve (FCR). The market environment for LSS has become more difficult in recent years. The expansion of battery storage is increasingly leading to a saturation of the market with falling FCR prices as a consequence. For example, while the average price per week for FCR in 2015 was still at 3,650 Euro/MW, this price fell to an average of 1,500 Euro/MW by the first half of 2019 (Tepe et al. 2021).

Although the Federal Government missed its proclaimed aim of one million BEVs in 2020, the number of all-electric cars in operation in Germany has picked up steam over the past decade and recently reached new heights. About 400,000 cars with electric drive systems were newly registered by customers in 2020, compared to 112,000 in the previous year, which results in an overall market share of 12.6 % in 2020 (Roland Berger 2021). The market for BEVs and electromobility, in general, is subject to extremely dynamic development. In 2019, 276,500 BEVs were produced in Europe at 17 locations in eight countries, including six in Germany. According to a study by the Chemnitz Automotive Institute CATI (2020), more than a fourfold increase compared to 2019 can already be expected by 2022. The study forecasts production of 1.2 million BEVs in Europe for 2022, and more than two million units for 2025. In 2020, Germany overtook France as a BEV production location for the first time. According to the study, this development will continue to gain momentum until 2025. The annual production of BEVs in Germany is expected to increase almost eightfold from 2019 to 2022 to around 600,000 vehicles and will rise further to over 1.1 million BEVs by 2025. A good 50 % of all BEVs produced in Europe could then be produced at German locations. This development is already much faster than that for hybrid vehicles, including plug-in hybrid vehicles.

2.4.1 The current and potential uses of batteries for matching supply and demand and stabilizing the grid in Germany

Experiences in Germany in the field of stationary batteries and EV batteries range from established business sectors, which will be shortly described in this chapter, to pilot projects, which will be further explored in chapter 3.2. This chapter also presents general trends and potentials.

Particularly regarding HSS and BEVs, Germany is still gaining experiences in pilot projects, while the typical use is for optimizing PV self-consumption, with the problems shown in Figure 3, and BEVs will just be charged whenever the user needs it.

One exemption is the case of HSS pooling, where there are some well-established ventures on the German market. For example, the producer of battery storage systems SENEC (formerly Deutsche Energieversorgung, DEV) offers a virtual electricity account, with which surplus electricity is “loaded” into the virtual “Senec. Cloud” and can be accessed free of charge in winter (SENEC 2021). Sonnen GmbH’s “Sonnen community” Virtual Power Plan (VPP) uses 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 (see also chapter 3.2 and Ninomiya et al. 2019).

In Germany, utility-scale LSS with an output in the range of several MW and capacities of several MWh are operating for several years. One example is the battery power plant of the municipal utility WEMAG, which was developed in cooperation with the battery system provider Younicos AG. With an output of 5 MW and a capacity of 5 MWh, the battery power plant provides positive and negative FCR. In addition, the system is able to take over transient tasks, such as the provision of short-circuit power, instantaneous reserve, and other services in grid operation management (BEE 2015).

Concerning stationary batteries in general, an annual expansion of around 10 to 30 GWh of storage could be necessary for the EU by 2035, depending on the speed of the expansion of renewable energies (Fraunhofer ISI 2020). In its recently published scenario, the Federation of German Industries (BDI 2021) assumes 21 GW of storage capacities in 2030 in Germany, compared to 10 GW in 2019. 12 GW thereof is supposed to be (not further specified) battery storage. According to the German government's grid development plan (NEP 2019), PV home storage alone could provide up to 10.1 GW of power by 2030.

In its coalition agreement from November 2021, the new German government proclaimed the aim of 15 million BEVs in 2030 and thereby enhanced the prior aim of up to 10 million (Federal Government 2019). Recent scenario studies suppose similar numbers of BEVs in 2030 (for example Agora et al. 2021, BDI 2021). BDI (2021) also expects an average EV battery capacity for passenger cars of 105 kWh in the upcoming years. The total storage capacity of all passenger BEVs in Germany could therefore amount to 1.575 TWh in 2030. In comparison: A study conducted by

Prognos et al. (2021) on behalf of the government in November 2021 estimated a gross electricity consumption of 658 TWh in 2030. Of this, around 44 TWh is accounted for by passenger cars, 7 TWh by light commercial vehicles and 17 TWh by heavy commercial vehicles. If the electricity consumption for buses and two-wheelers is also added, the total estimated electricity consumption for electromobility in 2030 will be around 70 TWh (excluding rail transport).

In its "Charging Infrastructure Master Plan", the German government previously had assumed up to 10 million electric vehicles in 2030 (Federal Government 2019). This would correspond to a charging capacity of 10 GW or 12.5 % of the assumed total load in the transmission grid for 2030 (80 GW). If the target of 15 million EVs already in 2030 is achieved, this capacity may increase to 15 GW.

These numbers may also represent an opportunity for flexibility and security of the electricity grid, should a large proportion of (domestic) connections be controllable in 2030 (VDE 2021).

2.4.2 The potentials of for a ‘second life’ of BEV batteries in Germany

In the relatively young market of electromobility in Germany, discarded traction batteries have not played a major role so far. This is about to change. According to typical ramp-up scenarios, the resulting capacity from discarded batteries could amount to 50 to 70 GWh annually in 2035. But the question remains open as to how large the proportion of batteries will be that is still powerful enough for further use in secondary applications, for it is still unclear today when and why the end of battery life is typically reached in the vehicle. The warranty conditions of the device manufacturers indicate that a claim for replacement exists when the range of the car drops to 70 to 80 % of the nominal range in less than ten years or 150,000 kilometers driven, for example. However, it is not yet possible to estimate what this means for vehicles over ten years old (which is quite the norm in Germany and the EU). Given the high expected costs of battery replacement and the typical value development of used cars, continued use until actual battery death, which may be well below 70 to 80 % of the nominal range, is quite conceivable, at least for private short-distance journeys. Such a battery would probably no longer meet the requirements of most secondary applications and could only be recycled (Fraunhofer ISI 2020).

Due to higher failure and replacement rates, as well as possibly also a higher fire risks, second-life batteries could disqualify for small and decentralized battery storage systems in particular. This would mean that the home storage market, which is growing strongly in Germany, would not be eligible for these batteries. Larger industrial or grid-serving storage systems, which are still rare today in Germany but could become much more relevant in the future, have a size that would allow the creation of redundant battery capacities and thus the occasional failure of individual battery modules. To be able to pay for this redundancy, second-life batteries would have to be correspondingly cheap (less than 50 % of the cost of a new battery) (ibid.).

Despite these concerns, there are several pilot projects for testing used EV batteries in stationary applications, cf. chapter 3.2.

2.4.3 Recycling needs in Germany

Powerful LIBs represent a large share of the market for both electric vehicles and home storage in Germany. In terms of the recycling process, LIBs currently fall under the category of "other batteries" within the EU law, for which a recycling rate of only 50 % of the average weight applies in the European Union (the new regulatory framework on batteries envisages a separate category for EV batteries, see chapter 3.2). Germany reports a collection rate of 48 % for discarded batteries in 2018 and a recycling efficiency for the category of other batteries of 84 %. Fraunhofer ISI (2020) estimated that by ensuring high collection rates and recovering 25-50 % of the lithium from discarded batteries, lithium from battery recycling could meet 10-30 % of the total annual demand by 2050. The EU proposes even higher recycling efficiency targets. According to its new regulatory framework, 70 % of lithium from batteries shall be recovered in 2030 (see chapter 3.2).

The number of discarded batteries ready for recycling in 2030 and beyond depends heavily on the (economic) efficiency of second-life applications for these batteries, and on when these applications reach their end of life. A scenario analysis conducted by Drabik and Rizos (2018) assumes that an average EV battery has a lifespan of 8 years within a vehicle and further 10 years within second-life applications. Based on these assumptions, the study forecasts about 1.1 million batteries reaching their end of life in 2030 within the EU. The authors furthermore calculate the recovery of valuable raw material from those batteries at different recycling efficiency rates. For example, the amount of recovered lithium from EV batteries could amount to 1.2 to 2.4 tonnes per year in 2030, with a recycling rate of 57 % and 94 % respectively. Cobalt (2.9 to 4.1 tonnes), nickel (10.6 to 13.5 tonnes), and aluminum (31.8 to 39.8 tonnes) are expected to have even higher recycling efficiency rates and according to material recovery in 2030.

Little is currently known about the economic viability of recycling LIBs from the automotive sector. Many processes in Germany are only operated on a small scale or are not specifically designed for these batteries. For dismantling, the yield is estimated at 210 to 240 euros per tonne of batteries, with half of the value going to the aluminum contained, a quarter to the steel, and another quarter to the recycling of copper. The actual cell recycling requires significantly more complex processes, for which no cost data is currently available from the industry in Germany. Furthermore, the economic viability of cell recycling depends on the chemical composition of the battery. For example, the metal value contained in lithium iron phosphate-based cells is less than half that of cells containing cobalt and nickel. In addition, the currently decreasing cobalt content in such batteries could make economic processing much more difficult in the future (Fraunhofer ISI 2020, see also chapter 3.1).

2.5 Japan: Existing experiences and potentials

2.5.1 Current status of grid-integrated large-scale storages deployment

Previously, in the vertically integrated electric power sectors, pumped storage power generations were responsible for large-scale power storage. Pumped storage power generation is reliable engineering with plenty of facilities with historical usage experiences, but there is scarcely a new facility due to the lack of new applicable location, mainly concerns from nature environmental effects. As the energy efficiency of pumped power generation is 70 %, an alternative to a large-scale storage facility is expected to achieve a similar efficiency. In the case of using battery storage, the total efficiency is the multiplication of "charging efficiency" and "discharging efficiency", so both of the battery storage efficiencies are expected to be as much as 80 %, which leaves the choice of available high-efficiency battery technology as LIBs and sodium–sulfur batteries (NaS).

METI (The Ministry of Economy, Trade, and Industry) conducted the technologies verification projects on grid-integrated large-scale battery storages, with the consideration of increasing renewable power generations which may result in instability of grid operations. The 4 years projects started in 2013, with the installation of newly developed battery technologies in power utilities' transformer substations. The projects validated the effectiveness of frequency fluctuation restoration, voltage adjustment, avoidance of renewables power restrictions, and the efficiency of battery storages.

Japan's power grid system is operated by nine regional power-grid operators. Among the nine grids, the Hokkaido Electric Power Company (HEPCO) grid is relatively smaller than those in main-island (Honshu) grids, and HEPCO grid interconnecting capacity with adjacent grid is also small. HEPCO's service area, Hokkaido Island, is suitable for renewable mega-size PV parks, onshore wind parks, and offshore wind farms. HEPCO recently experienced a few cases when frequency fluctuations reached the acceptable limit (0.3 Hz fluctuation from 50 Hz control), resulting in the curtailment of renewable power generations. Since 2015, HEPCO is demanding new mega-solar projects to install battery storage so that the output fluctuation from the PV parks can be controlled within 1 % fluctuation range of the Power Condition System (PCS) output capacity. The mandatory battery storage cost is borne by the mega-PV developer.

Table 2: Hokkaido Electric Power Co.: Mega-PV projects with mandatory battery storages (2016-). Source: METI/ANRE (2019)

Utility Scale Mega-PV Project	Solar Capacity	Battery Storage	Operation Start
Shin Hidaka Solar Park	21.0 MW	9.0 MWh	2018/5
Loop Nakashibetsu Solar	31.6 MW	14.45 MWh	2019/10
Suzuran Kushiro-cho Solar	92.2 MW	25.3 MWh	2020/2
Softbank Yakumo Solar Park	106.82 MW	27.8 MWh	2020/7
Softbank Tomatouabira Solar Park2	64.4 MW	19.0 MWh	2020/10

HEPCO is also demanding new onshore wind power developers to install a battery storage, but instead of having individual battery storages by project, HEPCO has called a joint battery storage investment at HEPCO's transformer substation (Table 3 HEPCO joint battery development with wind farm projects).

Table 3: Hokkaido Electric Power Co.: Minami Hayakita Battery Storage cost sharing with wind power projects. Source: METI (2021a).

Project Stages	Battery Capacity	Wind Power Capacity	Wind Power cost sharing
Stage 1-A (2019/2)	170 MW- 3 hours	162 MW	95 % of battery
Stage 1-B (in process)	780 MW- 4 hours	438 MW	90 % of battery

Stage 2 (2023/4-, TBC)	600 MW- 4 hours	400 MW	TBD

2.5.2 Estimated capacity of grid-integrated large-scale battery storage in 2030

According to the Basic Energy Plan formulated in October 2021 (BEP 2021), renewable is expected to be responsible for as much as 36-38 % of Japan's electricity supply in 2030. In addition to roof-top solar panels in houses and buildings, BEP 2021 expects the installation of mega-PV as much as 16.6 GW to 24.2 GW, 4.4 GW to 8.8 GW onshore wind power, and 1 GW to 5 GW offshore wind power. METI has not started the discussion on the storage planning to absorb the fluctuation of those renewable powers. Dispatchable power generations with coal and natural gas power generations may contribute for now, while BEP 2021 is planning to decrease coal power generations.

This study attempts an estimate of grid-integrated battery development scale with an assumption that a similar requirement with HEPCO's mega-solar and wind power will be implemented at a certain scale across the nation in 2030. This study assumes that 50% of the projects will be required battery storage installation. The study also assumes the required storage capacity from HEPCO cases, a 30 MWh battery per 100 MW PV capacity. With such assumptions, the annual deployment capacity of the grid-integrated large-scale power storage with mega-PV projects will be 277 MWh to 403 MWh (Table 4).

BEP 2021 estimates the potential for wind power generation is as much as 15.2 GW to 23.6 GW until 2030. BEP 2021 does not show the wind power growth path towards 2030, this study assumes the equally deployment of wind power generation towards 2030. METI does not show the wind power projects mapping or a possible requirement of battery storage. This study assumes that 50 % of wind power projects are subjected to the battery storage requirement again and the same capacity requirement as the mega-PV project, 30 MWh battery per 100 MW wind power capacity. With such assumptions, the annual deployment capacity of the grid-integrated large-scale power storage with wind power projects will be 90 MWh to 230 MWh (Table 4).

Combining the mega-PV projects and the wind power projects, installation battery capacity in 2030 will be 3.3 GWh to 5.7 GWh.

Table 4: Estimation of grid-integrated battery storage deployment in 2030. Source: METI (2021b).

（Assumptions）
- Basic Energy Plan 2021 resource planning is used to estimate mega-solar and wind power deployment.
- Assume a certain ratio of HEPCO battery installation requirement
- Assume 30MWh battery requirement per 100MW mega-solar or wind power capacity.

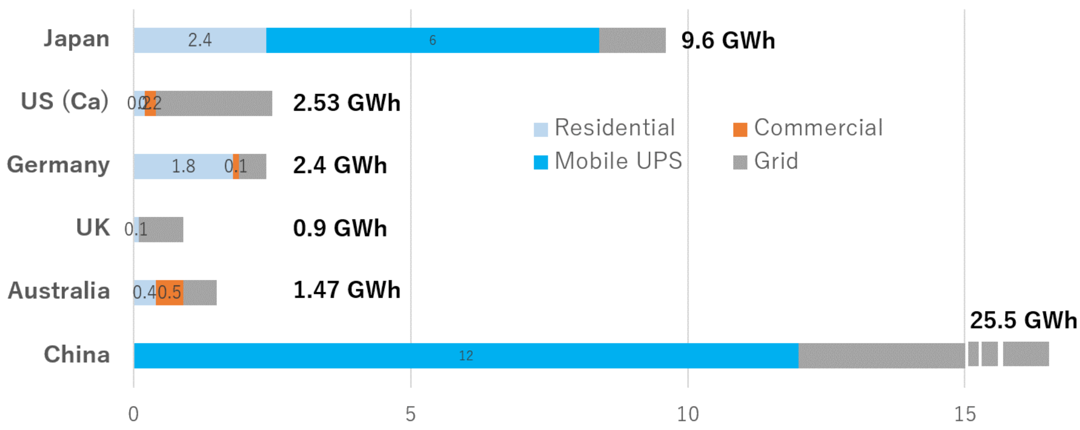
	Estimated New Installation Capacity in 2030 (GW) from BEP2021） *A	Battery Requirement Ratio (assumption)	Required battery Capacity per 100MW (assumption)	Estimated battery capacity by 2030	Annual Battery Installation (2022-2030) (MWh)
Mega Solar	16.6～24,2	50%	30MWh	2.49～3.63 GWh	277～403 MWh
Onshore Wind	4.4～8.8	50%	30MWh	0.66～1.32 GWh	73 ～147 MWh
Offshore Wind	1～5	50%	30MWh	0.15～0.75 GWh	17～83 MWh

(GW)	2019 Capacities + Submitted, to be operational	**2030 Capacities BEP2021**	2030 Capacity Previous BEP
PV	55.8 + 18.0	103.9～117.6	64
Rooftop	14.5 + 0.8	28.8～34.9	9
Mega-solar	41.3 + 17.2	**75.1～82.7**	55
Onshore Wind	4.2 + 4.9	**13.5～17.9**	9.2
Offshore Wind	0.01 + 0.7	**1.7～5.7**	0.8

総合資源エネルギー調査会 省エネルギー・新エネルギー分科会／電力・ガス事業分科会 再生可能エネルギー大量導入・次世代電力ネットワーク小委員会 中間整理（第4次） 2021/10/22
https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/pdf/20211022001_01.pdf

2.5.3 Current status of home storage and commercial/industrial storage

The cumulative amount of stationary storage batteries (for residential and commercial industries) introduced in Japan from 2010 to 2019 is 9.6 GWh, which is one of the highest in the world. The Japanese domestic market for stationary storage batteries is largely driven by LIBs used in the residential and the mobile phone tower UPS (Figure 7).



https://www.meti.go.jp/shingikai/energy_environment/storage_system/pdf/004_04_00.pdf
第4回 定置用蓄電システム普及拡大検討会　資源エネルギー庁　2021年2月2日

Figure 7: Cumulative capacities of installed battery storage (2010-2019). Source: METI/ANRE (2021).

Home battery storage: cost reduction and the distribution value-chain

With continuous works on the cost reduction by METI and the battery value chains, the average unit price per kWh of the battery system (excluding the installation cost) has been reduced by

36 % from 221,000 yen / kWh in 2015 to 140,000 yen / kWh in 2019 (Figure 8). METI has given a strong incentive to decrease the system cost by providing a generous subsidy for the purchase of battery storage, when the unit price is below the target unit price, set each year by METI.

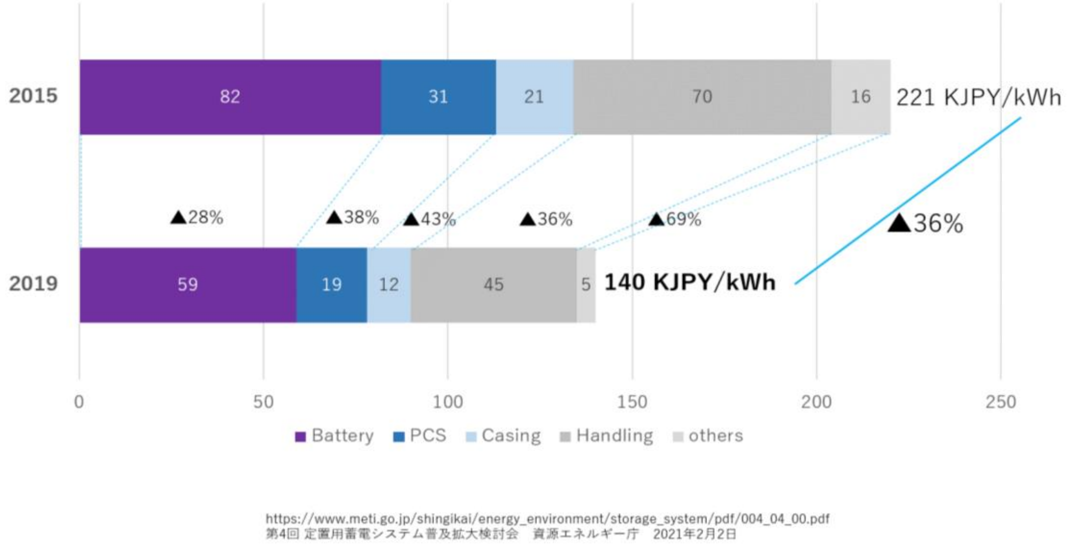


Figure 8: Cost reduction of residential battery storage from 2015 to 2019. Source: METI/ANRE (2021).

As for the price difference by the battery capacity, the larger the capacity, the lower the system price, but the construction cost varies greatly from project to project, and no difference due to the capacity is observed (Figure 9). The kWh unit price including the construction cost in 2019 was 180,000 yen / kWh.

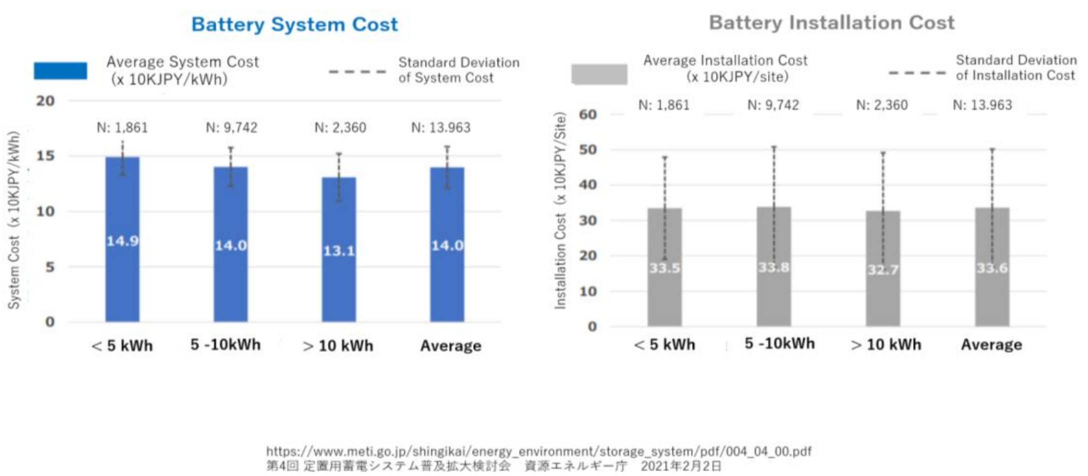


Figure 9: Average residential battery cost differences with battery capacity (2015-2019). Source: METI/ANRE (2021).

20 % of home storages are installed in new homes and 80 % are installed in existing homes. In the case of new home installation, the battery system will be delivered directly from the electricity storage manufacturer to the housing developers/housebuilders. In the case of an existing home

installation, a wholesaler is often placed between the electricity storage manufacturer and the construction company. The wholesaler bears the credit risk of the small and medium-sized construction company, and such a cost is incurred as the distribution cost (Figure 10).

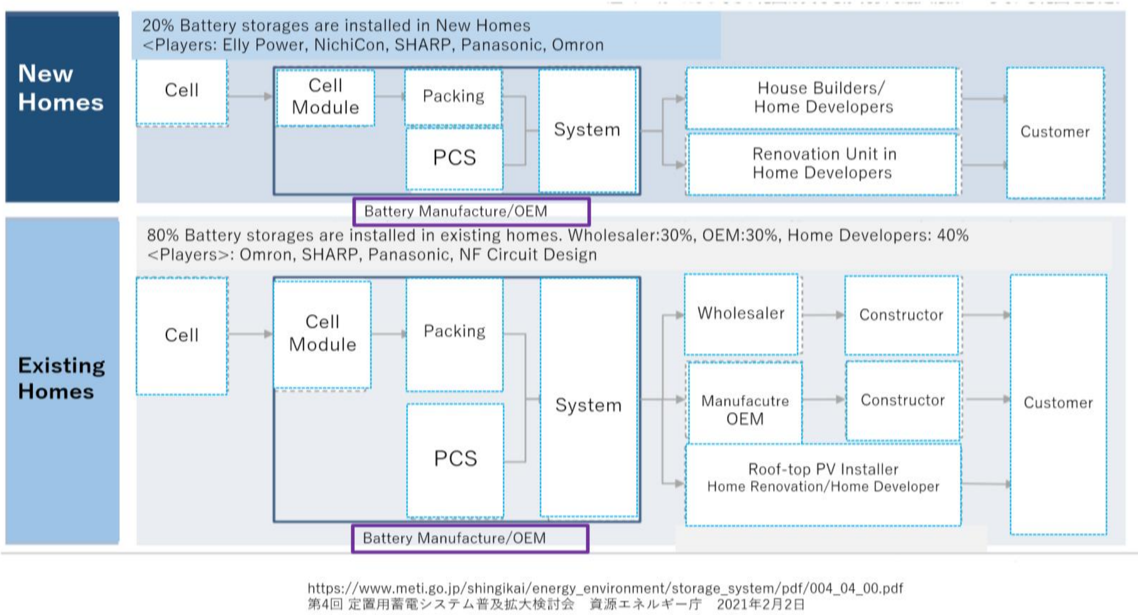


Figure 10: Residential battery market players and business structures in Japan. Source: METI/ANRE (2021).

Commercial/industrial battery storage: cost reduction and the distribution value-chain

Similar to a home storage, METI and the battery industry has worked on the cost reduction and the average unit price per kWh of the battery system (excluding installation construction costs) has decreased by 45 %, from 355,000 yen / kWh in 2015 to 195,000 yen / kWh in 2019 (Figure 11). The kWh unit price including the construction cost was 242,000 yen kWh.

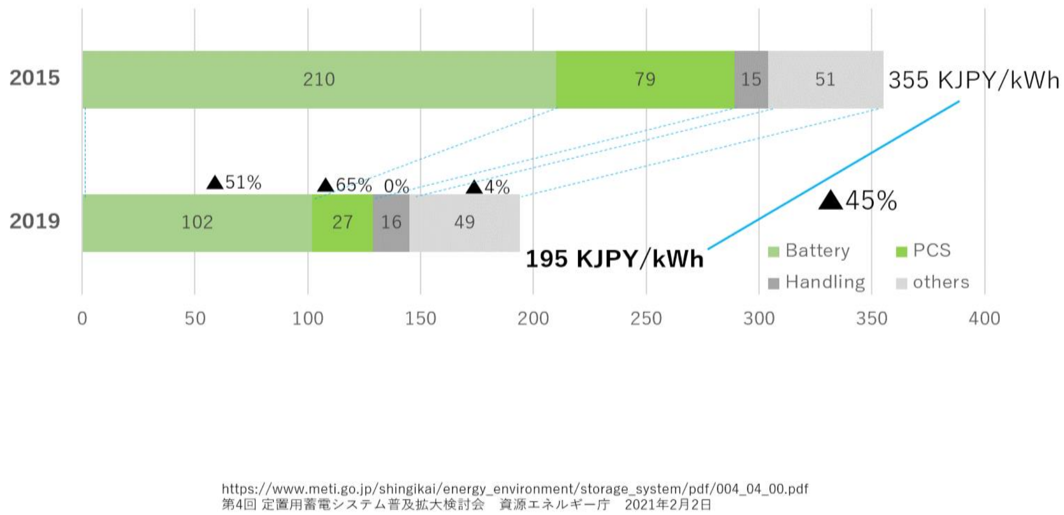


Figure 11: Cost reduction of commercial/industrial battery storage from 2015 to 2019. Source. METI/ANRE (2021).

The distribution channel for an industrial power storage, 100 kWh and more: the system integrators design the entire system, procures the PCS (Power Conditioning System), the battery, and installation. Major system integrators are NIHON GAISHI, Sumitomo Electric, GS Yuasa, Toshiba, LG Chemical, and Sumsung SDI.

The distribution channel for smaller commercial power storage systems, less than 100 kWh: battery manufacturers control system development and sales to users with the use of contractors for installation (Figure 12).

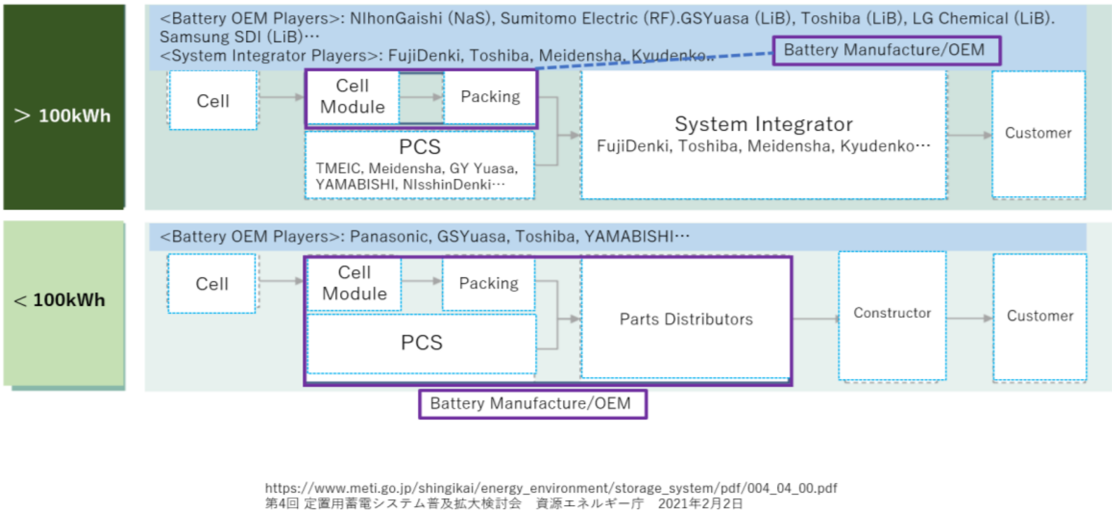


Figure 12: Commercial/industrial battery market players and business structures in Japan. Source. METI/ANRE (2021).

2.5.4 Estimated capacity of home storage/commercial and industrial storage in 2030

The current home/commercial-industrial batteries deployment is one of the outcomes of METI's Battery Strategy Project Team in 2012. The project highlighted the steady growth of stationary battery market and xEV battery market and it focused on the battery cost reduction by increasing product shipments. METI re-visited the battery storage strategy after the Japanese Government made announcement on the 2050 carbon neutrality target in October 2020. METI immediately started "The Subcommittee on stationary battery deployment strategy" in November 2020. The Subcommittee worked on the 2030 battery storage strategy, reflecting the new carbon neutral target and the possible new Energy Basic Plan. In February 2021, the Subcommittee published the roadmap of home storage/commercial-industrial storage 2030 targets on cost reduction and the shipments (METI 2021).

Home stationary battery

METI's home storage deployment priority and the Subcommittee's roadmap heavily focus on the maximum self-consumption of roof-top PV electricity.

METI and the Ministry of Land, Infrastructures, Transport and Tourism (MLIT) are jointly promoting the newly constructed homes to achieve Net Zero (ZEH: Zero Energy Home), and METI-

MLIT expects 60 % of newly constructed single-family homes achieve ZEH standard with roof-top PV by 2030. METI's battery Subcommittee set a target to install home batteries with roof-top PV in both newly constructed single-family homes and existing single-family homes. The maximum use of roof-top PV power is also reflecting the post-FIT (feed-in-tariff), which allowed higher-price purchase by utility scheme of surplus PV generations started in 2012. FIT purchase is gradually expiring from 2021 and METI is focusing on the maximum self-use of roof-top PV electricity.

Newly constructed single-family home deployment: METI's Subcommittee set a target of home storage penetration of 40 % in the newly constructed single-family homes in 2030. The current penetration is 9 %, which is equal to 26,000 units. The number of home storage deployments in 2030 will be as much as 84,000 units, 40 % of MLIT's estimate of the newly constructed single-family homes, 210,000 (Figure 13). The total newly built single-family homes with home batteries by 2030 is estimated as much as 550,000 units.

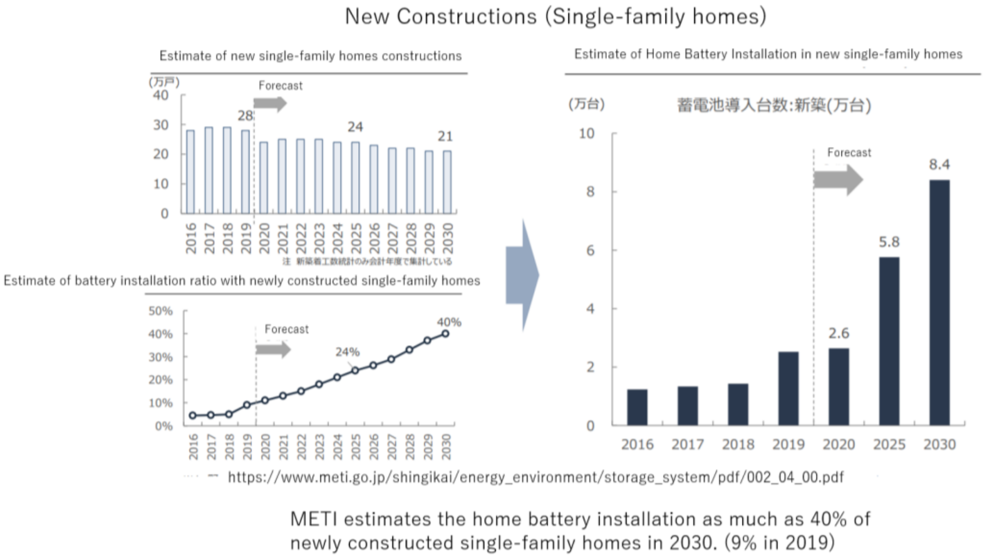


Figure 13: Home storages 2030 deployment plan, new constructed homes (METI's The Subcommittee on stationary battery deployment strategy). METI/ANRE (2020).

Existing single-family homes deployment: In existing single-family homes, METI targets (a) a home storage installation to homes already installed roof-top PV, and (b) a home storage installation to homes adding roof-top PV and a home storage. As of 2020, the home battery storage deployment in existing single-family homes is 120,000 units.

(a) The rate of installation of a home storage to roof-top PV-installed homes is currently 1.9 % (as of 2019), and METI expects the rate will increase to 3.2 % as early as 2025.

(b) The rate of installation of a home storage with new roof-top PV installation is currently 1.3 % (as of 2019) and METI expects the rate will increase to 2.7 % as early as 2030.

With these targets, the number of single-family homes with home storage installation in 2030 will be as much as 240,000 units (Figure 14). With this target, the total home storage batteries deployment in existing single-family homes by 2030 is estimated as much as 1.8 million units (METI 2020).

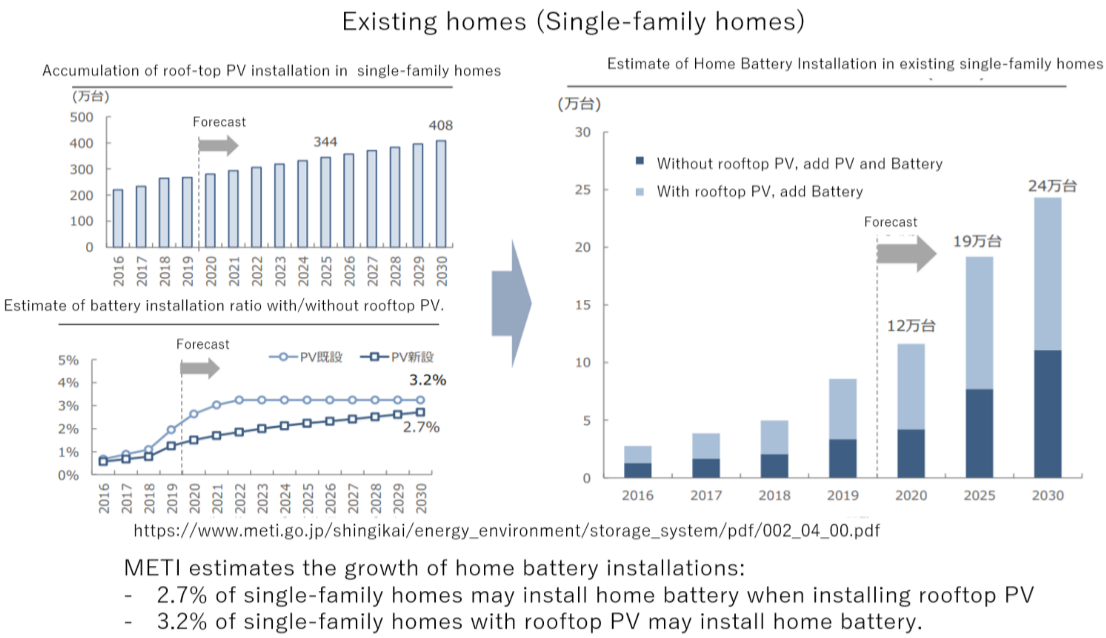


Figure 14: Home storages 2030 deployment plan, existing homes (METI's The Subcommittee on stationary battery deployment strategy). Source: METI/ANRE (2020).

This study assumes that the average capacity of the home storage is 7 kWh, the installed capacity of the home battery storages in 2030 will be 2.41 GWh and the total installed capacity of the home battery storages by 2030 will be 18 GWh.

METI's Subcommittee set a 2030 target reduction of home storage to achieve the above deployment target. The economic benefit of home storage installation is calculated by the self-use of rooftop PV electricity, replacing the purchase of electricity from utilities or power retailers. The target cost of the home storage is 70,000 JPY/kWh including the installation cost, reflecting the home storage investment being recovered by self-use of roof-top PV electricity within 10 years. The 2020 target cost is 187,000 JPY/kWh.

Commercial/industrial storage deployment

METI's Subcommittee expects a certain rate of installing commercial/industrial size storages to existing buildings and facilities, targeting four sectors, (1) Local governments and municipal facilities and buildings, (2) Retail Stores, (3) Hospitals, and (4) Manufacturing factories (with 30 or more employees). Table 5 shows the potentials of these buildings and facilities. The storage introduction rate is estimated to be (1) 30 % for local governments and municipals, (2) 10 % for stores, (3) 10 % for hospitals, and (4) 1 % for factories. Estimated average storage capacities are (1) as 15 kWh, (2) as 25 kWh, (3) as 30 kWh, and (4) as 1,000 kWh, respectively. The Subcommittee used (1) the average size of storages received selected municipals subsidies while it used the typical storage product capacities for (2), (3), (4) users (Table 5).

Table 5: Commercial/industrial storage 2030 deployment plan (METI's The Subcommittee on stationary battery deployment strategy). Source. METI/ANRE (2021a).

METI's The Committee of Stationary Battery Deployment Strategy estimated the commercial/industrial battery storage deployment potential.
https://www.meti.go.jp/shingikai/energy_environment/storage_system/pdf/003_04_00.pdf (2021/1/19)

Sectors	Buildings and Facilities	Numbers of Buildings	Ratio of Battery Installation	Battery Capacity	Installation Potentials
Local Government and Municipals	Municipal Buildings, School, Community Hall, Public Libraries	230,000	30%	15 kWh	1.035 GWh
Stores	Department Store, Convenient Store Appliance retailors Drug Stores Home Center Supermarket Gas Station	130,000	10%	25 kWh	0.325 GWh
Hospitals	Clinic and Hospital, Dentist, Veterenarian	184,000	1%	30 kWh	0.552 GWh
Factories	Food Processing, Manufacturing (textile, pulp, paper, plastic, rubber, leather, metal...) Steel, Non-Steel, Machinery (general, production, office, transport, agricultural...) Electronics Devices and Appliances...	46,000	1%	1,000 kWh	0.46 GWh
					2.372 GWh

With these assumptions used by the Subcommittee, the accumulated deployment capacities of commercial and industrial storages by 2030 are 2.372 GWh. Assuming that the annual deployment is constant, the annual deployment capacity of the commercial and industrial storage in 2030 is 0.26 GWh/year.

METI's committee sets a target price reduction of commercial/industrial batteries with the financial benefit from demand-charge savings. The 2030 target price is 50,000 JPY/kWh including the installation cost, reflecting the battery investment being recovered within 8 years. METI's committee previously used a target price per output capacity as KW, but it is replaced by the storage capacity kWh, reflecting the longer duration use.

2.5.5 Current status of EV-V2H market

To utilize EVs and PHEVs as home storages, V2H conversion stations are required for both EV/PHEV charging from the grid and EV/PHEV discharging to the grid. There are not many BEV models capable of V2H in Japan, and the price is higher than equivalent models with an internal combustion engine, and affordable EV models are yet available as of December 2021 (Table 6).

Table 6: Available BEVs with V2H function (Japan, December 2021).

Make/Model	Battery Capacity	Mileage per Charge (WLTP)	Price (JPY)	Size (L x W x H: mm)	Weight (kg)
Nissan LEAF / e+X	62 kWh	458 km	4,417,600	4,480 x 1,790 x 1,565	1,670
Honda e (*1)		283 km	4,510,000	3,895 x 1,750 x 1,510	1,519
Mazda MX-30EV (*2)	35.5 kWk	281 km	4,510,000	4,395 x 1,795 x 1,565	1,650
Subaru Solterra (*3)	71.4 kWh	530 km	5,000,000	4,690 × 1,860 × 1,650	1,930
Peugeot E208	50 kWh	403 km	4,260,000	4,095 x 1,745 x 1,465	1,490
Tesla Model 3 Standard Range	54 kWh	448 km	4,290,000	4,694 x 1,849 x 1,443	1,684
Audi e-tron 50 quattro		316 km	9,330,000	4,900 x 1,935 x 1,630	2,400
Mercedec EQC	80 kWh	400 km	10,800,000	4,770 x 1,885 x 1,625	2,470
Tesla Model S Performance	100 kWh	590 km	12,810,000	4,979 x 1,964 x 1,445	2,241

*1: next batch release date unknown, *2: Pre-order, 2022 delivery, *3: Delivery as early as 2022


NISSAN Leaf


HONDA e


Subaru Solterra

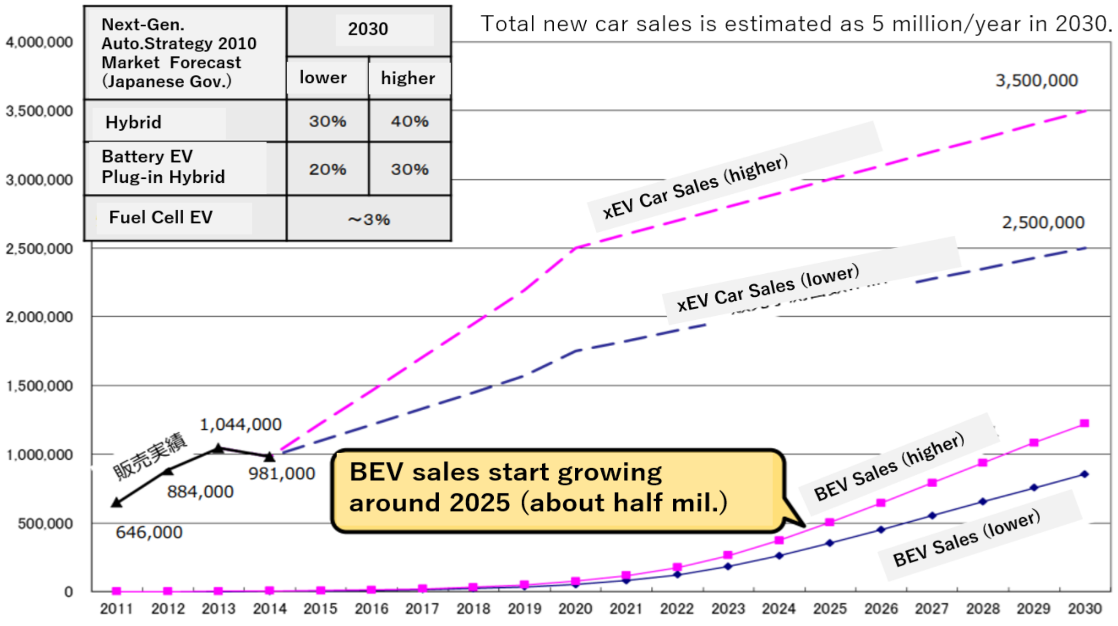
Nissan LEAF sales started in 2010, and the cumulative total of 100,000 units was sold in the Japanese market by December 2020 (the worldwide sales are 300,000). Tesla Model 3 may become the next choice in the Japanese BEV market, but Tesla market share is very small in Japan compared with the worldwide Tesla sales exceeding 1.5 million in March 2021.

Hybrid vehicles have been very popular in Japan for more than a decade, but plug-in hybrid models are limited and less popular.

2.5.6 Estimated capacity of EV battery storage shipments in 2030

Thousands of reports indicate the massive growth of mobility electrification and the EVs market and there are study reports indicating the use of EVs battery storages in the buildings. METI has high hope of using EV battery storages in buildings and grid balancing, but METI has yet to introduce target numbers of EVs deployment even in the latest BEP 2021. In this study, we used two publicly available EV deployments scenarios (passenger car only) to estimate the size of EV battery storage shipments in 2030.

In April 2019, METI's Next Generation Automotive Study Group used the “2030 next-generation automobile penetration forecast” from the Next Generation Automotive Study Group meeting in April 2010. The forecast predicts 50-70 % of new car sales will become next-generation cars, including hybrid, plug-in hybrid, battery EV, fuel cell EV, and clean diesel. Each type represents the share as much as 30-40 % by hybrid, 20-30 % by battery EV and plug-in hybrid, 3 % by fuel cell, and 5-10 % by clean diesel. In September 2019, The Japan Automotive Manufacturing Association (JAMA) predicts the number of next-generation vehicle penetration in 2030 in METI’s Next Generation Automotive Study Group meeting. While JAMA’s presentation was the forecast of EVs battery disposal and recycling, JAMA used the 2010's Next Generation Automotive Study Group forecast. In this JAMA’s presentation, the numbers of battery vehicles sales in 2030 are 1.45-3.82 million with hybrid and 0.966-1.933 million with battery EV and plug-in hybrid (Figure 15).



産構審・中環審 合同会議資料(2018/9/4)
https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/haikibutsu_recycle/jidosha_wg/pdf/046_03_02.pdf

Figure 15: xEV new car sales forecast by Japan Automotive Manufactures association (2019). Source: METI/MOE (2018).

In January 2020, Boston Consulting released a research report on "A study on 2030 EVs market penetration, worldwide and Japan market". For the Japanese market, Boston Consulting forecasts the new generation vehicles penetration exceeds 40 % in 2025 and 55 % in 2030, among the 38 % share will be from Hybrid. This relatively large share reflects the exceptional hybrid cars share in the Japanese market. According to this forecast, the number of hybrid vehicles sales in 2030 is 2.003 million and the number of BEV / PHEV sales is 843,000 (Figure 16).

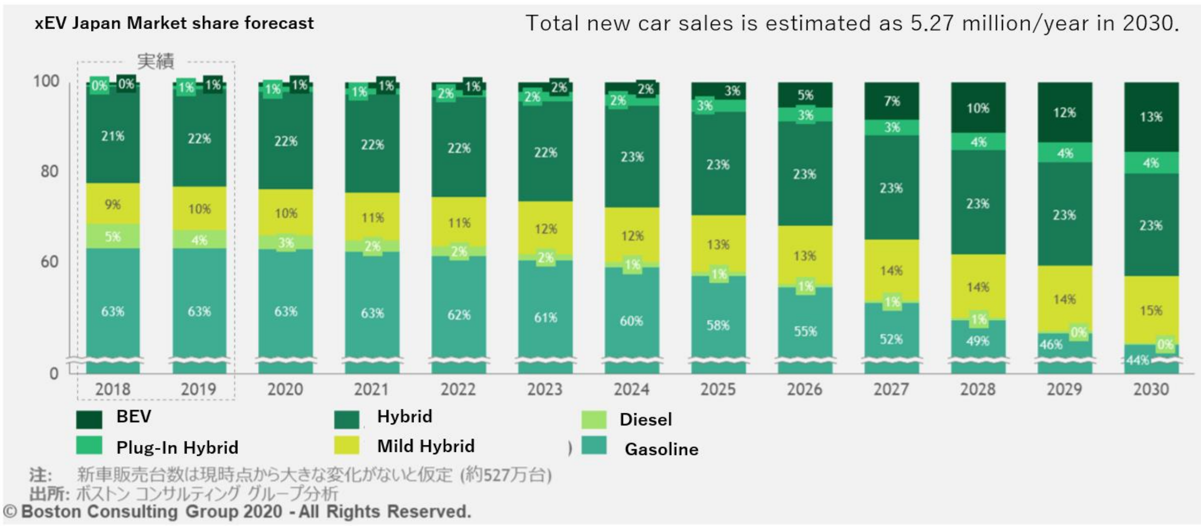


Figure 16: xEV new car sales forecast by Boston Consulting (2020). Source: Boston Consulting Group (2020).

The size of EV batteries should differ by manufacturers and models, and this study simplifies the battery capacities as 1 kWh per hybrid vehicle, 12 kWh per plug-in hybrid vehicle, and 55 kWh per Battery EV vehicle. The estimated shipment of EV batteries in 2030 is calculated as 50-75 GWh using JAMA's forecast and 41 GWh using the Boston Consulting forecast.

Hybrid cars battery capacity is relatively very small, as much as 1 kWh or less, the BEV battery shipment quantity is the dominant of EVs battery shipment. Both forecasts could represent rather conservative BEV market penetration, considering recent BEV market growth in China, Europe, and United States. Even this conservative estimate of EVs battery shipment suggests the importance of battery production capacity to meet 50-75 GWh in Japan by 2030, and the battery production investment decision should be made with the BEV market growth forecast.

2.5.7 Subsidies of stationary batteries and EV-V2H

There is a subsidy for purchasing EVs and PHEVs, but there is no stand-alone subsidy for stationary storage batteries. From 2019, METI and other agencies are trying to promote battery storage installation to post-FIT (feed-in-tariff) solar panel installed consumers. In 2009, METI started a strong promotion for solar panel installation (residential/commercial), and the solar-generated electricity was sold to utilities at a guaranteed premium price so that the solar panel investment could be recovered within 10 years. These fixed premium purchase arrangements started to become expired after 10 years, starting to show up in 2019. METI is strongly promoting adding battery storage to a solar panel installer so that they can use solar-generated carbon-free electricity as much as possible with a battery.

METI, Ministry of Environment (MOE) and major municipal government (Tokyo Metro included) are providing generous subsidies for adding storage batteries including EV/PHEV.

All of these subsidies demand two conditions, one is a target battery system cost must be below the METI's target price and the other condition is solar panel installation (existing or new installation). Details of subsidies are shown in Table 7.

Table 7: Subsidies for EVs, Batteries and V2H (Japan, FY2021 as of July).

Subsidies Project name	Ministry	Subsidy target	Subsidies Amount	Conditions
Clean Energy Vehicles Subsidy	METI	BEV PHEV FCV	2 KJPY x (Mileage per Charging – 200 km), Limit 600 KJPY per vehicle ※ Road Tax/ Vehicle Tax exemption also applicable	- Must to own more than 4 years
Pilot projects on Distributed Battery resources aggregation technologies	METI	Residential Battery Storage Com./Ind/ Battery Storage	RESIDENTIAL: 40 KJPY/kWh, < 1/3 System Cost COMMERCIAL/INDUSTRIAL: 70 KJPY/kWh, < 1/3 System Cost	- Must to have PV - Battery cost must be less than METI Target - Must participate VPP demonstration project
Storage Parity demonstration project	MOE	Residential Battery Storage Com./Ind. Battery Storage BEV, PHEV V2H Converter Station Roof Top Solar	RESIDENTIAL Battery: 20 KJPY/kW, < 1/5 Install Cost COMMERCIAL/INDUSTRIAL: 60 KJPY/kWh, < 1/3 Install Cost BEV/PHEV: 20 KJPY x (Battery kWh) /2 V2H : 1/2 total cost Roof Top Solar: 40 KJPY/kW,	- Must to have PV - Must not to use FIT or FIP contracts - Battery cost must be less than MOE target (install cost included) RES 165 KJPY/kWh COM 210 KJP/kWh
Roof-top PV self consumption promotion Subsidy	Tokyo Metro	Residential Battery Storage	70 KJPY/kWh, <1/2 System Cost Limit 420 KJPY/Unit	- Must to have PV - Battery cost must be less than 170 KJPY/kWh - Agree to provide usage, charging/discharging data to Tokyo Metro

3 Business cases and regulatory frameworks needed

3.1 General analysis on business models and regulatory frameworks

In this section, a general analysis on business models and regulatory frameworks will be conducted. The cases are grouped into three subchapters, due to overlapping challenges and opportunities for businesses and common regulatory framework needs: 1) the case of BEVs, 2) the case of building- and grid-integrated batteries and 3) using BEV batteries in building- or grid-integrated larger stacks, other reuses, and recycling.

3.1.1 The case of Battery Electric Vehicles (BEV)

This chapter provides first indicators for business models and framework conditions needed to promote grid-serving charging and discharging behavior of BEVs. Hildemeier et al (2019) conducted a qualitative review of policies for EV grid integration in the EU and U.S. markets. They identified three measures for ensuring EVs are integrated beneficially into the grid, which are: 1) cost-reflective pricing, 2) smart technology and 3) smart infrastructure.

Cost-reflective pricing leverages the fluctuations in retail energy and network prices over the course of the day and night to encourage consumers to change how and when they charge their vehicles. An effective program will motivate consumers to change their charging behavior in a way that both lowers their costs and reduces power system costs. The current pricing models range from the simplest, time-of-use tariffs, to the most complex, real-time pricing. With time-of-use pricing, the utility sets different prices for different blocks of time. Real-time pricing, by contrast, changes according to the actual situation on the power grid over set intervals and thus requires smart metering. Table 8 gives examples of business models and experiences with the different pricing models in the context of BEV charging:

Table 8: Examples of time-varing rate design. Source: Hildermeier et al. (2019).

Tariff Design	Main Features	Prerequisites	User Experience
Two-period time-of-use tariff for energy (Spain)	80% discount for EV drivers charging during pre-defined night hours, at 0.03 €/kWh, compared to the day charge of around 0.16 €/kWh.	Simple binary meter.	A Nissan Leaf owner will save approximately 167 euros per year by charging the EV at the night tariff instead of the standard rate.
Octopus Agile (real-time pricing) (UK)	Tied to half-hourly day-ahead market, promotes renewable energy use and flexibility.	Smart meter, phone app, active participation of customers.	150 euros per year saved compared to standard tariff. Energy consumption shifted to low-demand hours.
Radius (Denmark)	Time-of-use network tariff with a surcharge for winter peak hours (5–8 pm) of 0.9 €/kWh, compared to standard rate of 0.35 €/kWh.	None, standard rate applicable to customers connected to low-voltage (households) and medium-voltage grid (commercial).	-

Smart technology is a critical resource for capturing the flexibility EVs can provide, especially when used in conjunction with smart pricing. Charging processes can even be automated if price and other data can be communicated. This feature is generally found only in more advanced programs. The goal is to enable consumers to make choices to reduce their bills without needing to constantly pay attention to the relevant technology. The following Table 9 provides examples of business models and experiences with different smart technologies in the context of BEV charging:

Table 9: Examples of smart technology development. Source: Hildermeier et al. (2019).

Technology	Main Features	Level of Consumer Intervention Required
Green Mountain Power (Vermont, U.S.)	Technology and pricing package; charging is controlled by utility and shifted to off-peak hours, includes an opt-out choice.	None. Utility supplies a seven-kilowatt charger free of charge to consumers who buy a new EV, and for a $10 monthly payment to consumers who already own one. The EV owner indicates when the vehicle is available.
Jedlix (NL)	Application assesses optimal charging profile, including grid capacity, sustainable energy availability, and energy prices, shifts charging to preferential hours.	Very low. Consumer only communicates travel times.
Maxem (NL)	Wall box/ application to integrate EV charging station, along with any self-generation (e.g., solar photovoltaic), and other uses and appliances (e.g., electrical heating) into a smart home or office building.	None to very low. Application monitors the electricity draw and feed-in for the different applications and implements smart EV charging to ensure safety (e.g., decreases EV charging if the home's demand is greater than its own production and network connection).
MyEnergi (UK)	Smart meter paired with application recognizes fuel source (for example, domestically produced solar energy) and directs it to EV charging.	Very low. User has option to manually determine charging time and mode.

Smart infrastructure refers to the strategic siting of EV charging infrastructure. More precisely, if the public or private infrastructure is carefully planned, it can serve mobility demands, take advantage of existing grid infrastructure and capacity, and provide balancing services. This powerful combination can substantially reduce the cost of integrating electric vehicles into the power system. The higher objective of this strategy is also to steer the time and location of EV charging to best serve consumers and the grid. The following Table 10 shows examples for smart infrastructure in the context of BEV charging.

Table 10: Examples for smart infrastructure deployment. Source: Hildermeier et al. (2019).

Infrastructure Solution	Main Features	Advantage for Grid Integration
Public park-and-charge programme (UK)	Convert street infrastructure such as light poles into 3–5 kW charging outlets.	Uses existing electrified infrastructure, reduces cost of installation from 8000 to 1000 pounds sterling, encourages off-peak use for parked cars, additional efficiency gain through shared infrastructure.
Study: public fast charging points along existing grid (San Francisco, U.S., and Ottawa, Canada)	Utility mapping tool identified more than 14,000 locations where fast charging points could be installed to provide every EV driver with a fast charger within a one-mile (1.6 km) radius. Identifies upgrade costs.	Joint energy and transport planning, use of existing infrastructure.
Transmission system operator mapping tool for highway fast	UK's transmission system operator, National Grid, studied 50 optimal locations for fast chargers (up to 350 kW)	Estimated cost 1 billion pounds, also avoids cost of building new infrastructure by linking

charging stations (UK)	along highways, allowing 90% of UK motorists to reach a location within 50 miles.	these locations to the high-voltage grid.
Battery-assisted charging for cars (Greenlots/Hawaii, U.S.); for ferries (Ampera, Electric Ferry, Norway)	Hawaii: battery-assisted fast charging infrastructure was built to avoid a more expensive connection to the grid; battery-electric ferry offers "fast charge" for ships ashore and slower charging when the ferry is not plugged in.	

Concerning vehicle-to-grid (V2G) applications, there is still a predominate uncertainty weather the bi-directional use of EV batteries is economically efficient for all parties. A meta-study conducted on behalf of the two German electricity and energy associations VDE and BDEW reviewed study results on the possibility of V2G system services (FGH 2018). It concludes that competing storage technologies (for e.g., pumped or compressed air storage) are more cost-effective for the provision of system services, so that the economic viability of vehicle-to-grid is not considered to be given so far. Should it nevertheless be possible to develop a business case for the provision of balancing power, a pooling of EVs similar to the pooling of HSS would probably be necessary to enable participation in the balancing power market.

3.1.2 The case of building- and grid-integrated batteries

There are various business models through which HSS, ISS and LSS can be used for grid services. According to ADB (2018), these business models range from service-contracting without owning the storage system to outright purchase of the stationary battery. The needs and preference of the service user will determine the specific option to be chosen, which will also depend on the regulatory framework. Table 11 is summarizing the different ownership models for building- and grid-integrated batteries. Batteries serving at the wholesale and substation level can be owned by utilities, independent power producers (IPPs), suppliers/vendors or energy service companies (ESCOs). Also, contracts with IPPs and load-serving entities for grid-supporting services are possible. Building-integrated batteries at the end-use customer can be owned by the customer, ESCOs, IPPs and utilities/load-serving entities (LSEs) and they can be part of utility programs.

Table 11: Energy storage ownership models. Source: ADB (2018).

Wholesale	Substation	End-Use Customer
Utility-owned	Utility-owned - Grid asset - Smart-grid asset	Consumer-owned
IPP-owned	IPP-owned	ESCO (with aggregator)-owned
Supplier-/Vendor-owned	ESCO-owned	IPP-owned
	IPP/LSE contract for grid support services	Utility (LSE)-owned
		Part of utility program

ESCO = energy service company, IPP = independent power producer, LSE = load-serving entity

Third-party ownership contracts generally include the following key terms:

- The off-taker holds the dispatch rights for charging and discharging the energy storage system.

- The seller earns a fixed capacity payment for each kW/month and a variable payment for operation and maintenance per MWh delivered.
- In return for the capacity payment, the seller provides assurance of a specified degree of availability of the plant.
- The seller provides an efficiency guarantee.

The economic viability of BESS projects depends on the cost of storage, network reinforcement cost and commercial services enabled by energy market design, as well as the availability of smart technologies and software. From these factors, policy developments needed to further promote stationary battery projects can be derived, which can roughly be described by removing barriers and creating a favorable investment and operation environment (see Table 12, last line). In addition, for BESS projects at the end-use consumer level, **cost-reflective pricing** is as important as for flexible BEV charging.

Table 12: Key factors affecting the viability of BESS projects. Source: ADB (2018).

Factor	Impact on Project Viability
Cost of storage	Battery costs, while falling, are still the most significant driver of project viability. Costs depend on the MW/MWh ratio of the battery. The terminal value at the end of the project's economic life also has a bearing, with a higher terminal value improving project economics.
Network reinforcement cost	Higher conventional network reinforcement costs increase the value of deploying storage as an alternative, improving project economics (and vice versa) for DSOs directly and for third-party projects with a contract for peak shaving with a DSO.
Commercial services / energy market design	Increased access to and higher value from the provision of commercial services (for example, ancillary service markets, the wholesale market, the capacity market) increase project revenue streams, improving project economics (and vice versa). It is generally accepted that value streams will need to be stacked to increase the economic viability of BESS projects.
Policy developments	Removing barriers to storage or creating a more favourable environment for investment and operation enhances the realizable value of a project, improving project economics (and vice versa).

3.1.3 Using BEV batteries in buildings or grid-integrated larger stacks, other re-uses, and recycling

Second use of EV batteries is often seen as an opportunity to delay disposal and recycling as well as an opportunity to generate value out of existing resources. But despite the potential of a 'second life' to be a good fit for several applications that are less demanding than an EV, there is currently no market for second-life batteries. Partly, that is because EV sales have been low until recently. A study conducted by Olssen et al. (2018) also found out that investors still hesitate when it comes to batteries' second life because of major uncertainties about battery composition, cost and its performance in different applications.

However, due to uncertainty about future battery volumes and chemistries, investments in recycling processes are not easily accomplished either. EV LIBs are made by many different manufacturers with many different constructions, which include variations in number and type of cell, physical shape and chemistry. LIBs are usually not labelled with their specific chemistry, so neither third-party battery refurbishers nor recycling actors know which kind of LIBs they receive. In addition, each LIB has a tailored management system (BMS) which regulates critical functions of the battery. This means that large costs are often associated with repurposing. Standardization of diagnostics, health monitoring, packing and labeling could simplify the process, but as common standards could interfere with competition between manufacturers this is a sensitive issue. Transport is another troublesome issue, as used LIBs can be considered to be hazardous waste. That means that transport is costly and highly regulated. Some logistics firms will not transport used LIBs, and air freight is not allowed at all. This is of course a problem for recycling as well as for second life.

Based on the above analysis, Olssen et al. (2018) describe four business concepts for the (future) reuse and recycling of BEV batteries. The "**Linear model: currently practiced recycling**" is the closest to the situation as it is today. The original equipment manufacturer (OEM) uses customized modules and packs for the first use in their cars. The close partnerships that the OEM has with dismantlers allows to collect almost all batteries for recycling after first use. Removal of the batteries from the EVs and unpacking (i.e., opening up the battery packs to separate the modules from other components and packing materials) can be performed by workshops certified by the OEM or by the dismantlers, before transport to recycling actors which perform recycling processes.

The "**Optimized recycling: state of the art recycling**" would require investments from the recycling actors in scalable and automated recycling processes. With close collaboration between the OEM and the recycling company, the recycling actor could then collect removed batteries from the cars after their first use, from workshops or dismantlers. In this scenario the recycling company performs both unpacking and recycling in an automated process which allows handling of large volumes of batteries with different designs.

The third model is the "**Circular model I: repair and refurbishing for second use in vehicle in the same or a new market + state of the art recycling**": After the first use in a vehicle, diagnostics are performed by workshops or dismantlers, to decide whether the batteries are in good condition and have capacity for reuse in a car. If that is the case, the OEM-certified workshop performs refurbishment and repair of the battery which is then placed in a car in the same or a new market (e.g., with less intensive driving demands).

The "**Circular model II: repackaging and second life in a different application + state of the art recycling**" would require the highest degree of collaboration among the different stakeholders in the value network, including the OEM, dismantlers, recycling actors and second-life actors. After the first use in a vehicle, an early diagnosis is performed by dismantlers to decide whether the batteries have capacity for reuse in a car, whether they are fit for refurbishment, repacking and transportation for use in second-life applications (e.g., home electricity storage), or if they should be recycled. Based on this decision, the battery may enter different flows. For a transition to a second life, the battery needs to be repacked and the BMS needs to be adjusted or even replaced, which are additional activities that need to be incorporated in the business model.

Concerning the framework conditions needed, Beaudet et al. (2020) identify three priorities for policymakers aiming at accelerating investments in battery reuse and recycling: 1. funding for Research and Development (R&D), 2. funding for pilot projects, and 3. market-pull measures to aid in establishing a favorable investment environment for LIB collection and recycling.

3.1.4 “Energy as a Service (EaaS)”

There is a growing expectation in the new business which provide V2H/V2B "As A Service". "As A Service" business cases are emerging in roof-top PVs and building energy efficiency: A service provider pays equipment/systems, installation, maintenances, and operations with monthly fees, and a few precedent players are providing V2H as a service. Both German and Japanese policies are going to promote ZEH (Zero Energy Home) standard houses and ZEB (Zero Energy Building) standard buildings, so we may expect more business cases in "Energy as a Service (EaaS)" with roof-top PVs and V2Hs/V2Bs.

There are business cases that provide roof-top PVs and home/commercial/industrial battery storage as an optional service of electricity supply, in Germany, Australia, the UK, and the United States. Service providers install roof-top PVs and home/commercial battery storage and they supply electricity by optimum use of PVs and batteries. In such a service, PVs and battery storage models are limited to the operators' specification and a service company needs additional monitoring and control system installation.

We can foresee that such EaaS providers may expand their menus in V2H/V2B service, but we need to understand that there are notable challenges in V2H/V2B-as-a-service compared with a home/commercial battery storage-as-a-service. The first challenge is the forecast of transportation use. While a home/commercial battery's primary function is to supply power to a building, the primary function of EVs is in transportation use and transportation use will largely vary by days, hours, and users. The second challenge is to understand EV battery management when EV battery charging/discharging with sustaining a battery’s life is in an EV manufacturer's technical competence domain.

EaaS providers control lightings/air conditioning as well as battery storage to balance the power demand and supply. The demand-supply is not necessarily balanced in a single home/building, the balance is usually managed in a balancing block with thousands of supply homes/buildings aggregation. Service providers use aggregated distributed resources as if they operate a utility-scale dispatch power generation to achieve the grid-scale demand-supply balancing known as a "Virtual Power Plant (VPP)" (see also Ninomiya et al. 2019). When using VPPs more competitively, service providers can expect additional revenues through providing capacities/reserves to an electricity grid operator. With increasing distributed resources and available digital technologies, the energy industry is expecting business growth in VPPs. In Japan, a series of VPP technologies evaluation projects have been carried out since 2015 and we see a precedent business case in Germany and UK by Sonnen.

The VPP business is preceded by examples of using demand response such as lighting/air conditioning controls, self-power generations, and home/commercial/industrial battery storage. With the deployment of EVs, more experiences with V2H/V2B with data analysis may help a VPP business to expand V2B/V2H resources.

3.2 Germany

The following section will explore pilot projects on the grid-serving integration of BEV and stationary batteries as well as the reuse and recycling of BEV batteries in Germany. It will furthermore discuss necessary framework conditions for the further promotion of those ventures and other businesses in the field of battery deployment and use, reuse and recycling.

3.2.1 Existing business pilots and experiences

Using BEV batteries for grid services

A number of pilot projects examine the integration of new types of technical units such as BEVs into VPPs and the grid. For example, TSO Amprion already prequalified a Nissan Leaf electric car for FCR (Ninomiya et al. 2019). Together with the German TSO TenneT and the technology company The Mobility House, Nissan has also completed a major vehicle-to-grid (V2G) pilot project in 2020. As a part of a **SINTEG showcase project** funded by the German Federal Ministry for Economic Affairs and Energy, the project investigated the potential of EV batteries to store locally produced electricity and feed it back into the grid to stabilize the power grid while increasing the use of renewable energy.

Within the project, the wind power available in the north of Germany was used by regional Nissan LEAF EVs, while electricity from fully PV-charged batteries in the south was fed back into the grid at the same time. Thereby, the use of renewable energy was increased and the need for wind power to be curtailed in the north was avoided. At the same time, the mobility and charging requirements of vehicle users were taken into account. These intelligent redistribution measures were controlled by software from The Mobility House, the ChargePilot intelligent charging and energy management system, which follows specifications from the TSO TenneT (TenneT 2020). This ChargePilot software was first used to enable flexible charging, but can also be used for vehicle-to-grid electricity feed-back. The project can serve as one example for the use of smart technology (see chapter 3.1.).

Another example is the **"i-rEzEPT" project**. It aims to demonstrate, by means of a field test, that electric mobility can be independently coupled with both electricity grids and real estate. Electromobility is to serve as a buffer storage for the respective building and also be available for the balancing energy market as primary balancing power. As part of the field test, Nissan has provided 13 PV system owners from all over Germany with a Nissan LEAF and a matching charging station. i-rEzEPT was launched by Nissan together with Bosch.IO and the Fraunhofer Institutes for Industrial Engineering (IAO) and for Manufacturing Technology and Advanced Materials (IFAM). The project is being funded by the Federal Ministry of Transport and Digital Infrastructure and is running until October 2021 (NOW 2021).

Using stationary batteries for grid services

The electricity provider **Sonnen** (see also chapter 2.4) recently developed a business model for PV plants that are excluded from EEG subsidy. In Germany, PV plants are supported for 20 years with fixed feed-in tariffs. After that period, they have to participate in the regular market, which is often costly, especially for small plants. Sonnen offers owners of EEG-excluded PV systems an economically attractive option for continued operation. The household does not have to take care of a direct marketer or technical and other requirements. Electricity that cannot be consumed by the household itself or by the so-called sonnenCommunity is marketed by Sonnen directly on the wholesale market at the currently valid price. Producers receive a profit share for participating in the VPP. In addition, each household receives an individual free electricity quantity from Sonnen, which can cover a large part of the annual electricity demand (Sonnen 2020).

In Germany, LSS have recently begun to be used to ensure black start capability. The proof of concept was successfully completed during an experiment in Schwerin in 2017. In this experiment, a BESS was used to start up a gas turbine and to gradually restore grid operation. In April 2019, the **Bordesholm energy storage** became operational. While its primary purpose is to provide FCR, it is also used to provide black start capability on a regular basis as well as islanding capability. The project successfully tested the continued operation of (parts of) the grid in case of outage of the main electricity source utilizing distributed electricity generation (DENA 2020).

The grid booster concept (see chapter 2.1, Figure 4) requires technologies which are not fully developed and available yet. However, TSOs in Germany are planning to develop and deploy grid boosters. For example, Transnet BW – a South German TSO – is planning a **grid booster facility** with a capacity of 250 MW. Two further German TSOs, Amprion and TenneT, are also planning grid boosters (DENA 2020).

BEV batteries reuse and recycling

Different projects explore the possibility of the second life of BEV batteries. In 2018, a joint venture between Daimler, The Mobility House and GETEC Group commissioned a LSS consisting of electric car battery modules in Elverlingsen, North Rhine-Westphalia. The **"living spare parts store"** with a total of 1,920 battery modules, an installed capacity of around 9 MW and an energy capacity of 9.8 MWh is available to the energy market for the provision of FCR. Its modular design enables the system to stabilize the power grid with fully automated, uninterrupted control power. Two further second-life storage systems with a total installed capacity of 20 MW (21 MWh) have also been realized by the consortium. They represent the largest fully operational second-life battery storage system in Germany with 1,878 vehicle batteries (The Mobility House 2018).

At one of these storage sites, in Lünen, the waste management company Remondis helped building a capacity of 13 MWh from 1,000 used car batteries. **The second-life use and recycling of batteries** is implemented in Lünen in the following way: The battery systems are manufactured and processed at ACCUmotive, a subsidiary of Daimler, which offers electric and plug-in hybrid vehicles. The installation and marketing of the stationary battery on the energy markets is carried out by The Mobility House and GETEC. At the end of the battery's life cycle, valuable raw materials will be returned to the cycle by Remondis in the future (Remondis 2021).

For the **"Second-Life Batteries" project in Hamburg**, the electricity supplier Vattenfall, the car manufacturer BMW and the technology company Bosch have connected around 2,600 used battery modules from more than 100 electric vehicles to form an electricity storage system. The facility in the Port of Hamburg has a size of 2 MW and a storage capacity of about 2.8 MWh and is used in the primary control energy market. Back in 2013, Vattenfall already launched two other second-life projects using BMW batteries with smaller capacities and other use cases. In Hamburg's HafenCity, used batteries were used as temporary storage for fast charging columns. In another application, self-consumption from the photovoltaic system located at Vattenfall's HafenCity heating plant was maximized by temporarily storing energy in these batteries during sunny periods with low electricity demand (Vattenfall 2018).

At the beginning of 2021, the Volkswagen Group launched its own **pilot plant for battery recycling**. In Salzgitter, 3,600 of the carmaker's LIBs can be recycled per year. If the battery is not given a second life or is reaching the end of its second life, Volkswagen will recycle it in the future. To do this, the individual components are first shredded, then the material is dried and sieved. This is how the so-called "black powder" is obtained. It contains the valuable raw materials nickel, manganese, cobalt and lithium. These then only have to be separated individually. Afterwards, they are immediately available for the production of new batteries. The pilot plant in Salzgitter is to be followed by other decentralized recycling plants in the next few years. The Volkswagen Group has set itself the long-term goal of recycling 97 percent of all raw materials (Volkswagen 2021).

The car manufacturer Audi and the materials technology company Umicore have developed **concepts for a closed cycle for components of high-voltage batteries**, which can then be used again and again. In a first step, Umicore and Audi determined the possible recycling rates for battery components such as cobalt, nickel and copper. The result was that more than 95 percent of these elements can be recovered and reused in the laboratory test (Umicore 2018). Based on these results, the partners developed concrete recycling concepts. The focus here is on the so-called closed-loop approach. In such a closed loop, valuable elements from batteries flow into new products at the end of their life cycle and are thus reused. The partners currently cooperate on a closed loop for cobalt and nickel. The recovered materials will be used in new battery cells (Umicore 2019).

Audi is furthermore cooperating in a second-life project with the social enterprise Africa Greentec, which is electrifying villages in Mali and Niger with decommissioned battery storage elements from Audi E-Tron cars (FR 2021).

The recycling companies Erlos and Duesenfeld offer **mobile reprocessing plants** for the recycling of car batteries. With mobile recycling containers from Duesenfeld, LIBs are crushed on site at collection points and the electrolyte is extracted without emissions. The smallest local processing finds space in two 40-foot containers. Thereby, valuable secondary raw materials such as ferrous and non-ferrous metals, the electrolyte and the black mass can be transported safely and efficiently to further processing under lower constraints and costs (Duesenfeld 2021).

3.2.2 Studies on regulatory frameworks

Using BEV batteries for grid services

Based on their analysis (see chapter 3.1.1), Hildermeier et al. (2019) make the following suggestions for the European market und policy design to further promote the use of BEVs for grid services. Little of this has been implemented in Germany so far.

- Smart pricing should draw on **full flexibility** and provide EV users with fair prices for their services: According to Hildermeier et al. (2019), there are two crucial requirements for creating a suitable framework for dynamic pricing. First, it is critical that real-time energy prices are based on the full value of flexibility on the demand side. Second, electric vehicle users should be subject to fair retail tariffs for energy charges and network fees. This means that all users should reap the benefits of smart charging and, in equal measure, should bear their rightful share of the costs for uncontrolled charging.
- Leverage smart pricing with **responsive technology** to generate substantial benefits: Policymakers are able to maximize the benefits of time-varying pricing by ensuring responsive technology is broadly available to consumers. To this end, EU Member State have to comply with existing legislations on smart meter rollout thoroughly and swiftly, and revise standardization requirements to ensure broad distribution of market solutions. The UK, for example, is considering whether it should require all new, non-public EV charging infrastructure to have the ability to react to price signals.
- **Grid-friendly charging infrastructure** as a key to minimizing costs: In order to ensure future charging needs for different groups of EV users can be met, it is important to implement an integrated approach to energy and transport planning. Building codes should be revisited with a view toward facilitating vehicle charging at workplace and residential settings, including multifamily homes. It is also crucial to direct infrastructure funding in a way that bolsters the development of a competitive market for EV charging services. Municipalities can support this, for example, by including performance indicators in public tenders.

Using stationary batteries for grid services

The current German regulatory framework holds some challenges for the full deployment of batteries as grid-serving entities. First of all, the German energy law distinguishes between generation, consumption and transport and lacks a separate definition for storage facilities. Instead, batteries are classified as consumers when storing energy and as producers when discharging energy, which leads to a double burden: Generation is charged according to its own set of rules and consumption according to another one. This legal setup unsettles investors, all the more because at the same time, other governmental measures encourage them to invest in storage facilities (Tepe et al. 2021).

These challenges apply to LSS, ISS as well as households. In addition, a single HSS is currently not allowed to participate in the balancing energy market, as a minimum output of 1 MW for primary balancing power and 5 MW for secondary balancing and minute reserve power is prescribed. The remedy is to combine many small plants into a virtual large-scale storage facility (see also Ninomiya et al. 2019). The provision of balancing power from pooled, decentralized battery storage is already economically viable in Germany, although billing mechanisms and the distribution of grid and EEG levy costs are still open (BEE 2015). Based on an announcement in September 2019 in the “Klimaschutzprogramm 2030” by the German government, the energy storage operators of LSS should be exempted from the final consumer levies, although the classification as final consumer still holds (Federal Government 2019b).

Tepe et al. (2021) conducted a survey among 50 battery storage manufacturers, project developers, grid operators, consulting companies and research institutions during a battery storage expert forum of the German Federal Energy Storage Association in late 2020. They found that two-thirds of the participants at the expert forum cited "regulatory barriers" as the biggest obstacle to a wider use of battery storage in an industrial context. With regard to storage in general, they also named the "double burden of business models with taxes and levies", a "lack of legal and investment security overall" and the "excessive requirements for metering and billing concepts" as the greatest challenges for the economic operation of storage in Germany (see Figure 17).

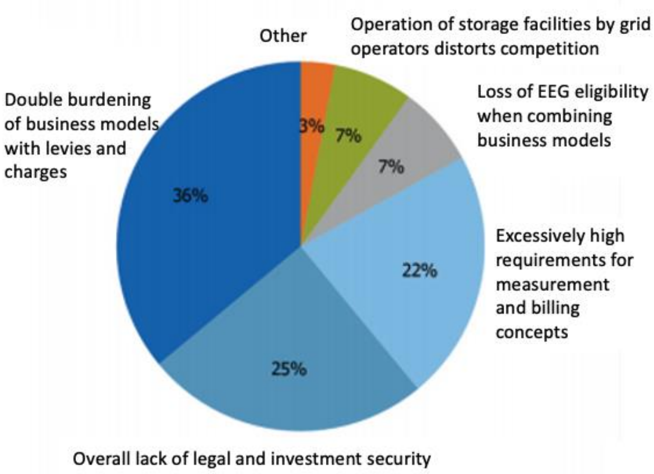


Figure 17: Survey of 50 experts on the greatest challenges for economic storage operation in Germany. Source: Tepe et al. 2021, own translation.

The EU Green Deal policy initiative and its concrete legislation address some of these challenges for investors and households. The Electricity Market Directive, which came into force at the beginning of the 2021, provides for a clear definition of energy storage systems. Its goal is to assign energy storage systems a clear role in the energy system and to unburden them of multiple or double levies, surcharges and taxes. In terms of state-induced costs, they must be on an equal footing with energy producers and consumers in the future (Tepe et al. 2021). An improvement in the regulatory framework for stationary energy storage in Germany is therefore to be expected.

BEV batteries reuse and recycling

The European Parliament currently works on a new regulatory framework for batteries (European Parliament 2021) in order to secure the sustainability and competitiveness of battery value chains. The Directive on batteries and accumulators, last amended in 2018, is the main legal act regulating batteries at EU level (Eur-lex 2018) and supposed to be preplaced by the new proposal. The innovations relevant for battery reuse and recycling are:

- The establishment of a new category of EV batteries, alongside the existing portable, automotive and industrial battery classes.
- Requirements to minimize the carbon footprint of EV batteries and rechargeable industrial batteries.

- A recycled content declaration requirement. Mandatory minimum levels of recycled content would be set for 2030 and 2035.
- Increased recycling efficiency targets for lead-acid batteries (recycling of 75 % by 2025, rising to 80 % by 2030) and new targets for LIBs (65 % by 2025, 70 % by 2030). The proposed regulation also envisages specific material recovery targets, namely 90 % for cobalt, copper, lead and nickel, and 35 % for lithium, to be achieved by the end of 2025. By 2030, the recovery levels should reach 95 % for cobalt, copper, lead and nickel, and 70 % for lithium.
- Requirements relating to the operations of repurposing and remanufacturing for a second life of industrial and EV batteries.
- Labelling and information requirements necessary for the identification of batteries and of their main characteristics. Rechargeable industrial batteries and EV batteries should contain a battery management system storing the information and data needed to determine the state of health and expected lifetime of batteries.
- Creation of a battery passport (i.e. electronic record) for each industrial battery and EV battery placed on the market or put into service.
- Development of minimum mandatory green public procurement criteria or targets.

Although those measures are about to solve some of the challenges described in chapter 3.1., there is still a need for further clarification. In a workshop with representatives from OEMs conducted by Olssen et al. (2018), legislation and responsibility were discussed as main issues to be clarified to stimulate more circular business models in battery reuse and recycling. In the EU, the actor that puts the battery on the market has producer responsibility, i.e., responsibility for providing a system for collection and recycling when the battery becomes waste. That responsibility can be transferred if the battery turns into a new product, with a new function or under a new brand. It is not always entirely clear which actor has the producer responsibility, and uncertainty about legal issues could discourage actors from engaging in second-life endeavours.

3.3 Japan

3.3.1 Study and demonstration for utilizing home/commercial batteries and EV batteries as distributed resources in Energy Resources Aggregation Business Development (ERAB) Projects

METI started the Virtual Power Plant demonstration project in 2016. The Energy Resources Aggregation Business (ERAB) demonstration project intends to remotely control distributed energy resources, such as home batteries, EV batteries, demand responses, and self-generations, as if the aggregated resources may function as a consolidated virtual power plant. The project includes evaluation of the remote control/operations under the grid operator's command, developing communication protocols and systems, and validating the remote-control technologies using real onsite pieces of equipment and systems. The project also tries to understand the barriers and challenges towards the business cases developments using virtual power plant controls.

3.3.1.1 The case of Battery Electric Vehicles (BEV): demonstrations of change in EV charging behaviours by use of dynamic electricity rates

Vehicle electrification has become one of the top priorities in many countries with the carbon-neutral target, and the electricity demand increased by EV charging will become an increasing challenge for most power businesses in the world. While EV charging is a big demand increase factor both in the total electricity usage as well as the load peak, there is a big chance to manage the charging schedule to avoid the power system load peak time. Increasing renewables and IoT controllable devices will introduce smart pricing power menus, reflecting the lower price when renewable sources are widely available or the higher price when the demand peaks with less renewable generations (Figure 18).

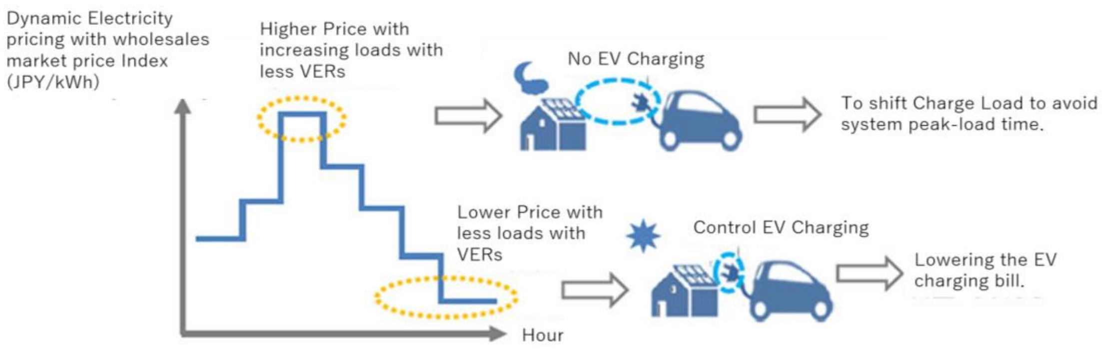


Figure 18: EV charging behaviour change program, Kansai VPP Consortium. Source: METI/ANRE (2019a).

Kansai VPP consortium had carried out a series of EV charging behaviour change tests, with a dynamic electricity price, reflecting the wholesales traded power price. The dynamic pricing has lower price tag during renewable electricity available hours, between 10 am and 2 pm. A typical daily charging result is shown in Figure 19, the hourly EV charging amount of controlled 32 EVs. When there is no dynamic pricing, most EVs are charged after 10 pm until the vehicles use starting from 7 am. When the dynamic pricing is introduced that the mid-day between 10 am and 2 pm electricity price is the lowest, EV users did change the charging hours. The program conducted the user's behaviour-based charging test as well as the automatically controlled charging test. In the former test, EV users received price information, and users decided when to charge their EVs, while in the latter test, EV users did not decide when to charge, the remote EV charging system decided when to charge. The tests showed behaviours change in both tests, shifting the charging time to less expensive hours. The latter test, using the smart remote charging system, had a larger cost-saving as well as fewer hassles for EV users.

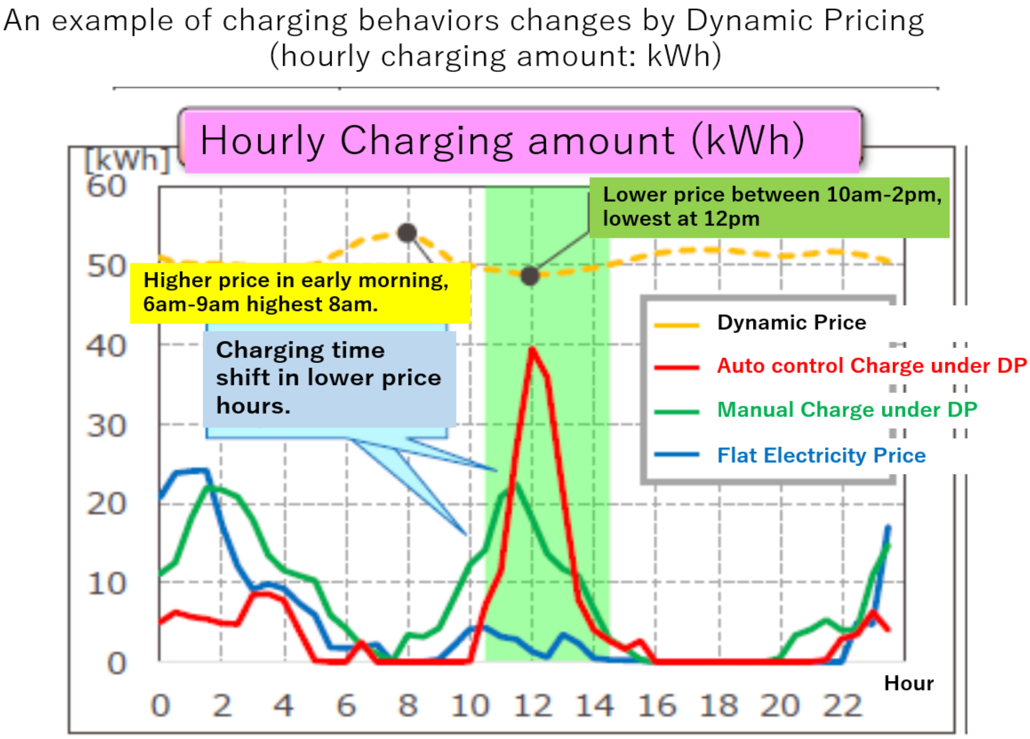


Figure 19: A typical result of Kansai VPP Consortium's EV charging behaviour change. Source: Kansai Electric Power Company (2021).

3.3.1.2 Using BEV batteries in buildings or grid-integrated demand-supply balancing: Demonstrations of the virtual power plant concept and the insights from the experiences of the project

A series of demonstration and validation field tests have been conducted under Program1 "Demonstration of the Virtual Power Plant Concept", including the communication-control technologies for the remote control, the implementation of remote control for various distributed resources, and metering issues. Field tests have been conducted with step-up test conditions reflecting actual grid resources service requirements. A few consortiums were developed, with the consortium leader, the Aggregation Coordinator, and several Resources Aggregators and Resources Providers.

Table 13 shows the largest consortium members in the "Kansai VPP Validation Project", and the schematic chart of the Kansai VPP Project is shown in Figure 20.

Table 13: Kansai VPP consortium, members and resources. Source: Kansai Electric Power Company (2021).

		Battery			Residential		Commercial		S Gen Fridge	EV	
		Res	Ind	Util	EQ	HMS	A/C	W P		Chg	V2H
AC	KANSAI Power			YES						YES	YES
R AG	Shikoku Power, Sharp,		YES								
	Mitsubishi Corp, Kyocera, Panasonic, LOOOP	YES									
	Enegate	YES			YES	YES	YES				YES
	Sumitomo Electric			YES			YES		YES	YES	
	Daihen, Kinden		YES				YES				
	Yokogawa, Hitachi, EON Delight, Fukushima Garay		YOK					YES	YOK		
	Hokuriku Power	YES	YES		YES	YES					YES
	NTT Smile Energy	YES			YES						YES
R PR	Sannshadednki, Sumitomo Corp, Delta Denshi, Nichikon, Benex, Yamabayashi, Elly Power	YES	YES	YES							
	ENEOS, Fuji Electric		YES	YES							
	Nihon Unisys	YES			YES						
	Idemitsu										YES

AC: Aggregator Coordinator, R AG: Resource Aggregator, R PR: Resource Providers
Battery: Residential/Industrial/Utility Scale, Residential Resources: EQ=Heat Pump Boiler, HMS: Home Management System, Commercial Demand Response:
A/C=Air Conditioner, WP: Water Pumps, Self Generation, Commercial Regrigerator, EV Charging, Vehicle to Home

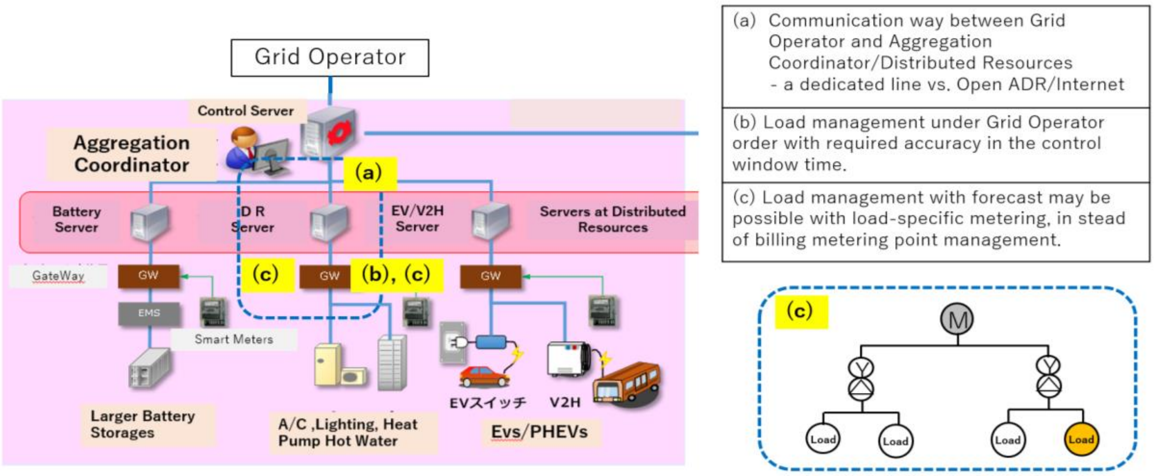


Figure 20: Kansai VPP Consortium, a schematic of resources aggregation as VPP. Source: Kansai Electric Power Company (2021).

Insights from the demonstration projects

(a) Development of communication standards, validation of the reliability of control by Open ADR and Internet line

In the case of large-scale power plant operation and communication with the power grid operator, the communication and the control use a dedicated line. In the Virtual Power Plant, such a dedicated line use across the numbers of smaller distributed resources is not economically feasible. The project validated the remote control and the communication by the use of widely available communication tools, such as high-speed internet. The communication protocols have been tested and the results showed acceptable reliability and accuracy.

(b) Reliable operation verification of resources under the grid operators' commands

Distributed resources need to be safely and accurately controlled by the grid operators' commands to contribute to the grid operation stability. The projects conducted a series of field tests under the RR-FIT service condition with providing negative demand responses.

(Table 14 shows the Type 3-2 RR-FIT (Replacement Reserve for FIT) service condition and Type 3-1 RR (Replacement Reserve) service condition)

Table 14: Control requirement under RR-FIT service and RR service (negative demand response). Source: Kansai Electric Power Company (2021).

	Type 3-2 (RR-FIT) Negative DR	Type 3-1 (RR) Negative DR
Control Change	Yes (3 changes in 3hrs window in the 2020 field tests.)	
Control Change Interval	30 min.	1 min.
Response Time	45 min.	15 min.
Duration Window	3 hours	
Reference Load	Aggregators nomination with 30mins resolution	
Control Accuracy Requirement	10% accuracy to reference load	
Minimum Load	> 1MW	
Nomination Schedule	Prior day, 3hrs data	Previous week Friday, one-week-3hrs data

Industrial battery: Most resources at stable loads showed an accurate forecast of the base reference load with successful control performances under the grid operators' commands. Among the field tests, there was a case at Load Site "C" with the load fluctuation exceeding the battery capacity, which brought a challenge of setting the base reference load. Most of the field tests used relatively large capacity reserve, which is not always available in much industrial battery installed customers. The tests also revealed a potential barrier to the RR-FIT service rule. The current RR-FIT application process requires an applied resource that should meet the control accuracy to be met in 5 minutes window, while the service only requires 30 minutes window control. Most of the resources showed accurate 30 minutes window control, using a minute resolution data communication. Such a 1-minute communication resolution is not good enough to maintain the accuracy in the 5 minutes control window, instead, it may require higher resolutions. This application approval process rule should be re-visited.

Home Batteries: In many cases, home batteries could not meet the RR-FIT service requirement. Most of the home batteries in the field operate as no discharging when roof-top PV generates electricity, and as maintaining the maximum storage level in the early evening when the rooftop PV power generations decrease. RR-FIT services are usually expected in early evening hours, while many home batteries do not by design discharge during those hours. This finding is not a technologies barrier, but the result gives insights that some resources may not be practically available.

EV batteries: EV batteries can become promising resources in RR-FIT services without compromising the EV transportation functions, as long as the EV use scheduling is accurately available. In that sense, commercial use EV vehicles scheduling should be available with reasonably good accuracy for the use of RR-FIT services, except the 3 hours consecutive use for RR-FIT services requirement can become a business barrier. The current RR-FIT service requires a single control resource should serve in an aggregation group for consecutive 3 hours. Smaller resources, such as EV batteries, are serving as an aggregated group, and there are enough aggregated resources while an individual resource can contribute less than 3 hours. The tests on the RR-FIT service also revealed the major challenge in the baseload reference nomination rule. TSS service rule requires a weekly reference load data to be submitted on the last day of the previous week, an entire weekly vehicle scheduling on the previous Friday tends to be less accurate in real business fields. RR-FIT service requires the daily reference load data submission on the previous day. Such one day ahead vehicle scheduling is more accurate and very manageable.

(c) Control metering points, the billing meter point vs. the control resource point metering

The field tests gave important lessons on the control metering point. The services transactions are made based on the resource control operation matching the control demand and the current services are procured by the smart-metering point electricity load (M in Figure 20). As shown in the schematic figure in Figure 20, the smart-metering point, which is the electricity purchase transaction measurement point can measure more than one equipment/system. When there is a larger fluctuating load or the roof-top PV is metered with a control device (resource), the smart-metering point measurement may have a large fluctuation of load, even if the control device perfectly matches the grid demand. Smaller home batteries, smaller commercial batteries, and smaller demand responses will be practically prevented from contributing to an aggregated resource as long as the service rule allows the control device load metering. It is also advised that uncertified metering techniques should be allowed to avoid the much higher cost of certified meters.

3.3.1.3 The Study and Demonstration Project (ERAB) programs between 2021 and 2023

The ERAB demonstration project continues a series of field testing to promote distributed energy resources use in new businesses. From 2021, the follow-up series of field tests are carried out, including these two tests.

- More demonstrations of the dynamic pricing effect on the EV charging behaviours

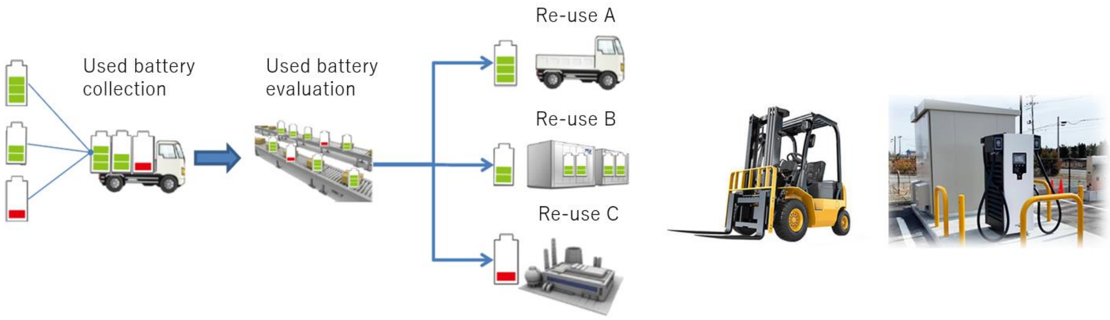
  Different types of dynamic pricing are introduced in the field tests, reflecting the wholesale market renewable power supply. The self-decision system with longer days with the actual wholesale market price is tested. The program is also developing new dynamic pricing along with the test use of apps, which will help EV users to understand the smart EV charging under the dynamic electricity pricing.

- Demonstration of more mixtures of aggregated resources

  The field test intends to understand the actual renewable power supply changes and the simulations on the supply-demand balancing with test-controlled aggregated resources. A different set of aggregated resources will be tested, including the discharge from battery resources and self-generations. Tests are also expected with the control requirements by the new services, Type2-2 FRR (Frequency Restoration Reserve) and Type2-1 S-FRR (Synchronized Frequency Restoration Reserve).

3.3.1.4 Experiences on battery ‘second life’ and recycling

Nissan Motor has been long working on technology and business trials on the re-use, re-purposing, and recycling of EV batteries. Nissan started selling their first BEV model, Leaf in 2010 and Nissan also launched a new business arm, FOR-R Energy jointly funded by Sumitomo Corporation. FOR-R has been working on the evaluation techniques of Leaf batteries, re-use as EV battery, re-purpose for less-demanding use, such as a forklift battery, a golf-cart battery, and a stationary battery. Before scraping the battery for material recycling, a used EV battery may be suitable as a backup/emergency stationary battery. Figure 21 shows business fields of EV battery re-use by FOR-R Energy. Mr. Makino, CEO of FOR-R Energy suggested challenges and business perspectives in BEV battery recycling in the media interview in 2021 (Xtech 2021). FOR-R started the re-use/recycling business in 2010, a month before Nissan launched the Leaf. Makino understood the re-use/recycling of BEV battery depends on how fast and accurate FOR-R can evaluate the remaining capacity. FOR-R could not advance in this technology, because there were no used Leaf batteries. It was around 2017 FOR-R started collecting the first batches of Leaf batteries. FOR-R built a reuse/recycling dedicated plant in 2018 and they started learning the battery evaluation. By then, FOR-R had tried several re-use applications, such as electric power forklifts, backup power for shelters and rail crossing bars, and street lights, using new batteries. After 11 years since the Leaf launch, Nissan and FOR-R are expecting to receive sizable used Leafs, as much as 2,000 units in 2022. FOR-R can evaluate the battery capacity in 4 hours, and they are working on the improvement. Mr. Makino told the media that he is not expecting the business growth soon. He said the re-use/recycling business growth will be in 5-10 years range, and the close work with Nissan is essential. Makino told that FOR-R has the second task in EV battery reuse and recycling, which is improvement of EV valuation in the used car market. It is widely known that the value of the first generation of Leafs dropped much faster than for conventional engine cars, as much as 60 % drop in the first year, and residual values could be low as 15 % after 4 years. Remaining battery capacity has been hardly known by most used car dealers and used Leafs have been unpopular in the second car market due to battery deteoration concerns. FOR-R and Nissan are trying to improve the Leaf’s residual values with transparent EV battery’s capacity valuation.



Re- Use: A	EVs, EV-Bus/Trucks
Re-Use : B	**Battery powered Forklift,** Battery powered Golf-cart Industrial Stationary Battery Storage **EV Charging Station Battery Storage**
Re-Use : C	Backup Emergency Power Supply (**Rail-Crossing, Street Lights**, Shelters, Medical Centers…)

http://www.cev-pc.or.jp/xev_kyougikai/xev_pdf/xev_kyougikai_wg02-1_about_WG.pdf
電動車活用社会推進協議会　車載用電池リユース促進WG　資料４　2019年12月25日　経済産業省　電動車活用社会推進協議会

Figure 21: BEV battery second-life use cases by Nissan-FOR-R ENERGY. Source: METI (2019), Nissan Motor Corporation (2021).

3.3.2 Regulatory framework

3.3.2.1 Japan pledged 2050 carbon neutrality, grid stability balancing resources will be required along with the increasing renewable generation and decreasing fossil-fuel generation

The Japanese government declared in October 2020 that it would aim to realize Carbon-Neutrality by 2050, and then-Prime Minister Suga announced the new 2030 GHG reduction target by 46 % reductions from 2013 at Leaders' Summit held in April 2021 (Suga also mentioned his determination to aim for a further 50 % reduction). To realize such pledges, discussions on the 6th Energy Basic Plan, which is the basis of energy policy, proceeded and the 6th Basic Energy Plan (BEP 2021) was published on October 22nd. BEP 2021 intends to introduce a large share of renewable energy power (36-38 %), and renewable energy and nuclear will become the two pillars of future power sources. The plan also proposes a significant and fast reduction of fossil fuel dependency (76 % in 2019 → 41 % in 2030) (Figure 22).

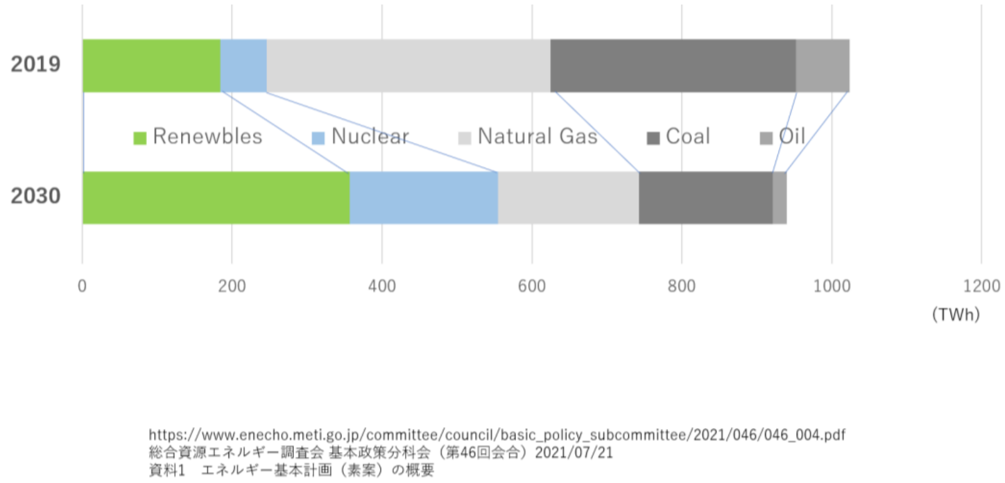


Figure 22: Renewable powers will increase towards 2030: Basic Energy 2021 (2021/10/22). METI (2021c)

Due to the increase in renewable energy use in recent years, METI and the electricity sector are already aware that the new electrical power system will require a substitute of supply stability measures, replacing fossil fuel thermal power plants, which so far have performed the function to maintain the demand-supply balance and the stability of power supply.

When the new balancing resource discussion started in 2018, the amount of renewable energy, especially Variable Renewable Energy (VRE) generation share was 6.3 % in Japan (2017). IEA Energy Outlook 2018 suggested the need for additional flexibility of power resources along with the increase of VRE generation shares by templating the 6 Phases (Figure 23) and 2018 Japan was corresponding to IEA-Phase 2: Draw on existing flexibility in the system (Kyushu had higher VRE ratio, corresponding Phase 3: Flexibility investment in all measures). The 2020 VRE ratio increased to 9.4 %, and it is now entering Phase 3, and the 6th Basic Energy Plan's renewable energy ratio of 36-38 %, in which the VRE ratio of generation, estimated at 53 %, corresponds to the later Phase 4. It is a more critical and urgent issue to prepare the flexibility measures than the initial discussion in 2018 because the VRE share will rapidly increase by the mid-2020s. METI intends to use available distributed energy resources for the demand-self balancing, including self-power generation, demand response with lighting-air conditioning-industrial processes, and the battery storages including EVs.

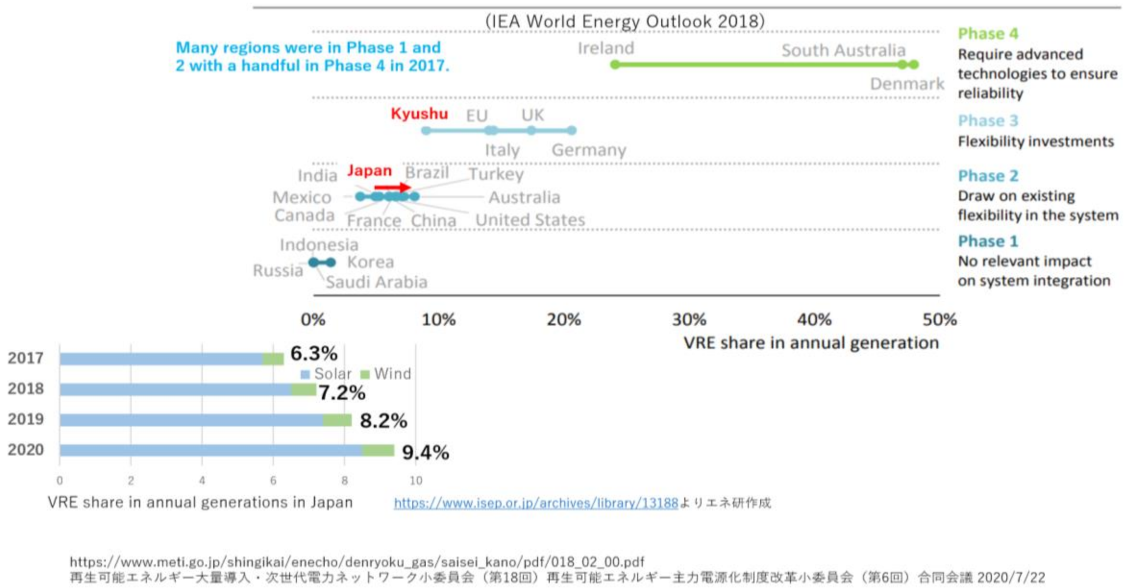


Figure 23: VRE share increase will require additional supply-demand balancing measures. Source: METI (2020a).

3.3.2.2 Green Growth Strategy (June 2021) includes "Mobility/ Battery" as one of the key growth areas toward carbon neutrality

The Japanese Government battery storage strategy is comprehensively described in "The Green Growth Strategy", revised with Action plans in June 2021. The Green Growth Strategy is an industrial policy which aims to create a positive cycle of economic growth and environmental protection. "Mobility/Battery" is one of the 14 sectors in the strategy.

Regarding Mobility electrification, Japan falls behind Europe and China in the widespread use of BEV and PHEV vehicles, in the first quarter of 2021, approximately 350,000 units in the EU (more than 1.5 times as many as in the same period of 2020) and approximately 11,000 units in Japan (20 % more than in the same period of 2020) were sold.

Japanese Government holds the position to use technology-neutral mobility development toward carbon neutrality, "electrically driven" vehicles should consist of electric vehicles, fuel cell vehicles, plug-in hybrid vehicles and hybrid vehicles. Each country and the market has a pathway to decarbonize the power generation as well as the economic status and the best-suited vehicle electrification is required to achieve the gross GHG emission reduction.

RoadMap, Action Plans: Automobile (related to electrifications and batteries):

- 100 % of new passenger vehicle sales being for vehicles that are electrically driven by 2035.
- Commercial vehicles, for light-duty vehicles (8 tons or less), 20-30 % of new vehicle sales to be electrified vehicles by 2030, and 100 % of new vehicle sales to be electrified vehicles and vehicles suitable for the use of decarbonized fuels such as synthetic fuels combined by 2040.

- Large vehicles (over 8 tons), 5,000 units of electrified vehicles in the 2020s, set to re-visit the target of 2040 by 2030, with the progress of hydrogen and synthetic fuels.
- Expanding the introduction of infrastructure. To install 150,000 charging points by 2030 the latest, including 10,000 quick chargers at gas service stations (SS), and 30,000 public quick chargers. To install 1,000 hydrogen stations by 2030.

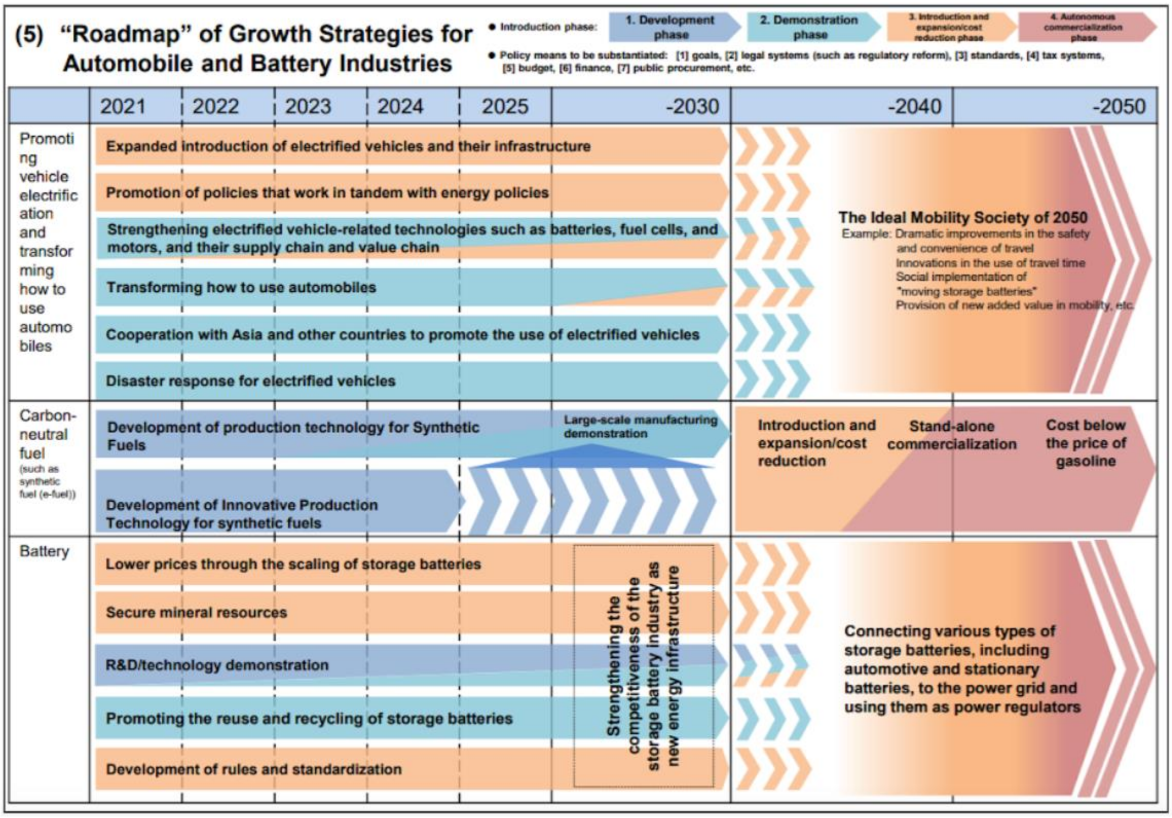
RoadMap, Action Plans: Batteries:
The market for on-board storage batteries is expected to grow with increasing electrification of automobiles, and the need for stationary storage batteries is also expected to expand. The storage batteries are also a "new energy infrastructure" that will play a key role in the advancement of carbon-free power sectors, with the increasing renewable energy.
The securing of storage batteries and the stabilization of supply chains are important issues when promoting electric vehicles. Electric vehicles need storage batteries with a capacity 50 to 100 times greater than that of hybrid vehicles, and 10 to 20 times greater than that of plug-in hybrid vehicles.
The Green Growth Strategy includes the battery production capacity increase target as well as securing the supply value chains of batteries.

- The domestic manufacturing capacity for automotive storage batteries will be increased to 100 GWh as early as possible by 2030.
- In addition, the aim is to achieve a cumulative introduction of approximately 24 GWh by 2030 (approximately 10 times the cumulative amount introduced by 2019) for household and commercial/industrial storage batteries in total.
- Lower prices through the scaling of storage batteries productions/sales
  - an onboard storage battery pack price of 10,000 yen/kWh or less
  - a household storage battery of 70,000 yen/kWh or less (including installation costs)
  - a commercial/industrial battery of 60,000 yen/kWh (including installation costs)
- Secure mineral resources.
- Promoting the reuse and recycling of storage batteries: R&D and technological demonstrations will be undertaken in order to reuse them as vehicle-mounted parts or stationary storage batteries if they can be reused after initial use, and to efficiently recover mineral resources if they can no longer be used. In addition, standardization and the institutional framework for promoting the reuse and recycling of storage batteries will be studied.
- Regulation development and standardization.

In order to promote the reuse of on-board storage batteries and their reuse as low-cost stationary storage batteries, Japan should work on international standardization of methods for evaluating the residual performance of storage battery packs and the performance and safety of stationary energy storage systems, including reused storage batteries.
Works are expected to increase in evaluating the value of stationary storage batteries toward the power grid supply and demand adjustment market (to be fully operational in 2024). In order to promote new businesses that utilize large-scale grid storage batteries, the positioning of grid storage businesses under the Electricity Business Act will be clarified, and the process of jointly

procuring grid storage batteries will be implemented in order to address the lack of short-term reserve capacity with increasing variable generations from renewable energy sources. Furthermore, in anticipation of the use of aggregated smaller storage batteries resources to adjust supply and demand, a new grid code for storage batteries use has to be developed.

Table 15: The Green Growth Strategy, Roadmap of "Automobile and Battery Industries" (June 2021). Source: METI (2021d).



3.3.2.3 Supply-Demand Balancing resource to be procured by creating the new reserve service market

Until the 2000s, regulated power utilities, that vertically integrating power generation, transmission/distribution, and retail supply, were responsible for maintaining the demand-supply balance and the power supply stability. They maintained the supply-demand balancing and the supply stability by operating their resources, such as thermal and pumped-storage hydro power plants. The deregulation of electricity retail supply began in 2000, and the market sectors were gradually opened for competition. The transmission/distribution business accounting separation was required in 2003, and the 2013 Power System Reform discussion eventually concluded the necessity of legal entity separation, which became effective in April 2020. The legally separated transmission-distribution grid operators (TDO) will take over the supply-demand balancing and supply stability. The reform demanded that TDO companies are responsible to maintain the supply stability, but the TDO companies do not own supply stability resources, they should use resources owned or secured by power generation companies and retail supply companies. TDOs currently make bilateral procurement contracts and METI plans to develop an open market where TDOs can procure balancing resources. METI and the industry have been working on the new balancing resource market, to allow efficient use of available balancing resources (Figure 24).

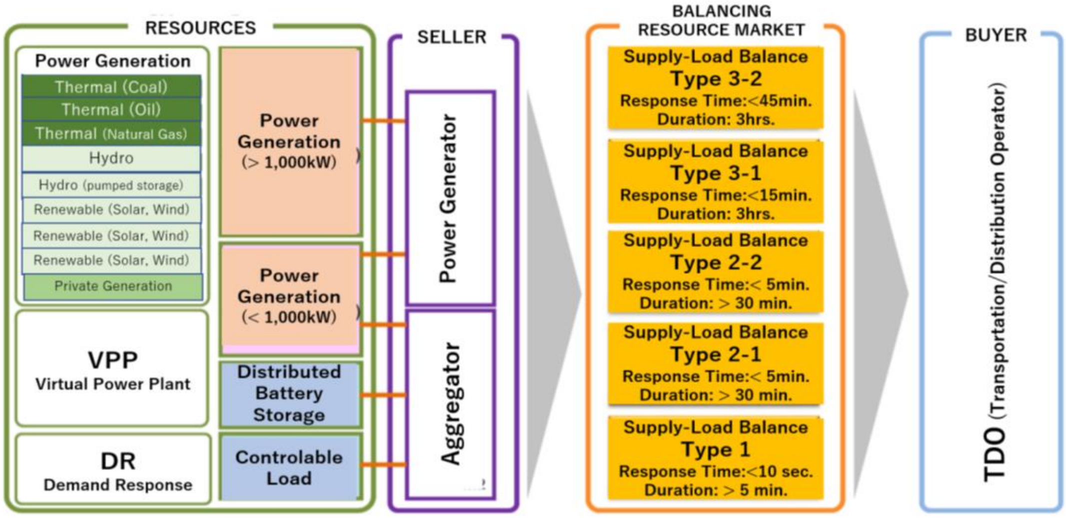


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Figure 24: Supply-Demand Balancing resource market proposal. Source: METI (2020b).

The proposed balancing resource market will have a series of balancing resource services, with different requirements (shown in Table 16). Type 3 service, maintaining the supply-demand balance, may start in 2022 and more critical grid-stability control resources, Type 2 and Type 1 services may start in 2024.

Table 16: Supply-Demand Balancing resources classification. Source. METI (2020b).

	Type 1 Frequency Containment Reserve (FCR)	Type 2-1 Synchronized Frequency Restoration Reserve (S-FRR)	Type 2-2 Frequency Restoration Reserve (FRR)	Type 3-1 Replacement Reserve (RR)	Type 3-2 Replacement Reserve for FIT (RR-FIT)
Calling events	Hourly fluctuations and unexpected supply failure	Hourly fluctuation and unexpected supply failure	Hourly fluctuation	Hourly fluctuation and unexpected supply failure	Fluctuating FIT renewables
Communication	Automation	Online-LFC	Online-EDC	Online-EDC	Online
Response Time Window	<10 sec.	< 5 min.	< 5 min.	< 15 min.	< 45 min.
Duration Time Window	> 5 mins.	> 30 min.	> 30 min.	Group Block (3 Hrs)	Group Block (3 Hrs)
Minimum Volume	5MW	5MW	5MW	5MW (dedicated online) 1MW (internet)	5MW (dedicated online) 1MW (internet)

https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/seido_kento/pdf/043_04_01.pdf
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3.3.2.4 METI and industries are working on EV utilization promotion and EV battery re-use

At the New Automobile Strategy Meeting in March 2019, METI officially set a goal of 100 % EVs sales by 2050. At the strategic meeting, attendants pointed that several strategies are necessary to accelerate the automotive electrification, including the development of battery supply chain, reducing risks by materials procurement, and establishing a method for evaluating the remaining performance of lithium-ion batteries.

In July 2019, METI established the "Electric Vehicle Utilization Promotion Council" in which industries such as electric power, logistics, and retail, as well as local governments, participate along with METI and automobile manufacturers. Two working groups were established, the "EV Utilization Promotion Working Group" which discusses the utilization of EVs in the event of a natural disaster, and the "Battery Reuse Working Group" which evaluates the performance of EV batteries.

The "EV Utilization Promotion Working Group" is working to encourage companies and local governments to employ and use EVs in an emergency, such as a temporary energy power supply to evacuation shelters, senior homes, and medical equipment power supply in the event of a power outage due to a natural disaster (storm, flooding, earthquake).

The "Battery Reuse Working Group" is working to establish the EV battery performance assessment standard, so that the EV battery can be re-used as another EV battery, other electrified mobility use, and stationary battery use, and less-demanding backup power battery. This working group found that the remaining performance evaluation standardization can help correctly evaluate used-EVs by reflecting the battery values in the next business use. The working group issued "Battery Performance Evaluation Guideline (1st Edition)" in June 2020. According to this guideline, the configuration, cell shape, and material of EV batteries differ from manufacturer to manufacturer, and excessive standardization may interfere with the manufacture competition. However, it is important to establish a trustful standardized battery performance evaluation method, and the guideline suggests using the relative performance ratio indicating what percentage of the initial performance of the battery is remaining, by using the government-(Ministry of Land, Infrastructure, Transport, and Tourism: MLIT) -authorized one-charge mileage comparison (by 10 % increments). The guideline expected the EV manufacturers to start employing this relative performance evaluation with 2022 model productions.

4 Comparison of German and Japanese potentials, business cases and regulatory frameworks

In this study, we conducted research on the policies and deployment status of storage batteries in Germany and Japan, seeking initial examples of the use of power grid-integrated batteries and building-integrated batteries but also battery-electric vehicles. The research has brought many findings, where there are many common perspectives and expectations between Germany and Japan toward storage battery use and deployment, while there are also differences in policy priorities and initial programs. With regard to the different types of batteries and the aspects of their use as flexibilities in electricity markets and grids, their 'second life', and recycling, we found the following facts:

- *Germany has more experiences with grid balancing/flexibility with LSS.*
  There are comparatively many large-scale power-grid-integrated battery storages used in Germany, reflecting the fact that variable electricity generation by photovoltaic and wind resources has exceeded 30 % of total power consumption, and the grid frequency control reserve and the demand-supply balancing resources are more imminent needs in Germany, while such grid frequency control reserve and the demand-supply balancing resources are less required in Japan with the variable electricity generation in Japan remaining as much as 10 %.
- *Germany and Japan are both expecting the increase of HSS to maximize the use of rooftop PV.*
  Japan has already implemented many commercial/industrial battery storages, with a long history of energy efficiency promotion and energy peak-shaving in the sector, and there are many on-site self-power generations and battery storages. In both countries, the market for home storage systems is growing too, but they are not yet widely used for grid flexibility and optimization purposes. In Germany, this is i.a. due to slow roll-out of smart meters.
- *Different policies in BEV deployment.*
  Regarding the battery electric vehicle (BEV) deployment, Germany is in the big movement of Transportation sector's electrification within EU-wide policy movement. The European Commission has proposed a new directive to ban internal combustion engine automobile sales by 2035, and the BEV sales in Germany have already exceeded 20 % of all new car sales in 2020. German experts in energy advise that the BEV's first contribution to the power grid is the flexible management of BEV charging load, avoiding the excessive stresses in the power grid operation and the investment that would be needed to strengthen the grid.
  The Japanese government and the automobile industry maintain the policy of automobile electrification without limiting to BEV but including hybrid cars. The BEV sales in Japan are not growing at the same pace as BEV sales in Europe and Germany.
- *Different approaches in the regulatory frameworks for BEV battery recycling.*

The European Commission has started the development of BEV battery recycling business chains with the proposed EU Battery Directive. Germany has experience on BEV battery recycling pilot projects with automobile manufactures and industrial recycling specialists. Japan is taking a different approach by allowing automobile and battery stakeholders to develop a voluntarily action guideline for the practice of evaluation of remaining capacitities of used EV batteries.

There are many findings from the research and they can be grouped in four types of status between Germany and Japan. They are:

A) "Two countries share the perspectives/expectations and they are in the same implementation status."
B) "Two countries share the perspectives/expectations, and Germany is ahead of Japan in implementation."
C) "Two countries share the perspectives/expectations, and Japan is ahead of Germany in implementation."
D) "Two countries share the perspectives/expectations, but there are differences in policy priorities/implementations."

Notable findings are shown below in the four types of comparison status.

A) Two countries share the perspectives/expectations and they are in the same implementation status.

- The deployment of Home Storage Batteries and Commercial/Industrial Storage Batteries focuses on benefits of battery storage users so far. There are barely cases where the initial expectation of storage battery implementation involves the grid-integrated use as a source of flexibility.
- Germany and Japan are both expecting the growth of home battery storage deployment in maximizing the roof-top PV generation use, as Feed-in-Tariff advantages over the grid purchase electricity is decreasing. To increase the home battery storage, the cost reduction of home battery storage will help the deployment pace uptake.
- Germany and Europe are increasing investment to secure the battery production capacities particularly for BEVs. In Japan, there will be fewer onboard batteries than in Europe because hybrid vehicles' onboard battery capacity is much less than BEV, however major Japanese automobile manufacturers are starting to invest in battery production capacity towards 2030.
- The experience with pooling of smaller battery storage (HSS or BEV) in both countries is rather low. There is only one viable business case in Germany on aggregating HSS as a VPP (see also B)). In Japan, a demonstration program on VPP has been found.
- For all of HSS, C/ISS, and BEV, both countries still need to develop the regulatory frameworks, in technical and economic terms, that will enable their widespread use as flexibility resources for the electricity markets and grids.
- Regulatory frameworks also need to be improved for second-life uses and recycling of batteries.

B) Two countries share the perspectives/expectations, and Germany is ahead of Japan in implementation

- As the variable electricity generation resources such as solar power and wind power increase and the thermal generations decrease, it is conceivable to use battery storage as a means of securing grid stability function and the supply-demand balancing function. A large-scale grid-integrated battery storage may play the first role in such an expectation due to lower investment and control costs, and there are already 68 grid-integrated battery storage systems that have been implemented in Germany, with a total storage capacity of 620 MWh (as of 2019). However, with the increase of large-scale grid integrated battery storage implementations, there are more available grid-stability reserves and the German reserve market is currently experiencing fewer values/payments in exchange for such reserve capacities.
- A few new business cases of aggregating home battery storage as a VPP have emerged in the German market, such as Sonnen. They are using aggregated home battery storage as an electricity supplier's tool, such as an imbalancing control measure or a balancing demand reserve in the wholesale market. The use of aggregated home battery storage for grid-integrated use in the active business case is hardly found in Germany yet.
- In Germany, a few major automobile manufacturers are working with industrial waste disposal companies in EV battery recycling pilot projects and they have started the discussion on EV battery recycling in 2030, when thousands of tons of wasted EV batteries will be waiting for recycling. In Japan, there has been practically only one BEV model in the market (Nissan Leaf) for more than a decade and the accumulated batteries from hybrid cars have been quietly disposed by either a car dealer or an industrial recycling specialist. Automobile manufacturers and the government have slowly started the discussions in a newly established "Used EV battery evaluation Council".
- It is still early to forecast the EV battery recycling business cases development, but experiences from Germany's EV battery recycling pilot projects indicate that the automobile manufactures may play major roles in the EV battery recycling business chains.

C) Two countries share the perspectives/expectations, and Japan is ahead of Germany in implementation

- In Japan, the deployment of commercial/industrial battery storage has progressed as much as accumulated deployment had reached 0.45 GWh at the end of 2019, and the Japanese government has developed the further deployment increase roadmap in commercial/industrial battery storage toward 2030 with 2.4 GWh target. Germany has slow progress in the deployment of commercial/industrial battery storage.
- In general, the development pathways for the installation and deployment of HSS and ISS in Japan are more defined than in Germany.
- Initial experiences from Japan's smaller distributed resources aggregation VPP project indicate that the commercial/industrial battery storage may have a high potential in an aggregated VPP business as long as there is a comfortably available reserve in the battery storage, which is not always the case in every industrial battery storage.

D) Two countries share the perspectives/expectations, but there are differences in policy priorities/implementations

- Securing the production capacity of EV storage batteries, especially lithium-ion batteries, by 2030 has been recognized as a task by both Germany and Japan, although the Japanese government and major Japanese manufacturers are siting new battery technologies other than lithium-ion. There is a strong position of the Japanese government that the battery storage policy does not limit to securing LIBs raw materials and the recycling of a LIBs.
- There is a general expectation on the EV battery evaluation standard and the battery performance measurement standard, but such an area is under severe technologies competition among car manufactures. In Europe, a draft amendment to the Storage Battery Directive has been published in late 2020, including life-cycle CO_2 footprints, environment labelling systems, and manufacturers' recycling obligations.
- BEVs sales are rapidly increasing in Germany exceeding 20 % of new car sales in 2020, and in 2021. The European Commission has proposed to ban the sale of new internal combustion engine vehicles, including PHEVs and hybrids, by 2035 (July 2021), and BEV sales and manufacturing are expected to increase sharply in European countries. On the other hand, Japan's share of new BEV vehicle sales in 2020 is only 0.6 %. In the new Green Growth Strategy (published in June 2021), Mobility/Battery is one of the 14 strategic growth fields and it sets a goal of 100 % electrified new car (passenger vehicles) sales by 2035 at the latest. The Japanese government is fully aware that the spread of BEVs in Japan is much slower than that in Europe and China. The Japanese government has considered the electricity source mixture transition period and also economic impact on the automobile industry, and the Japanese government maintains the position to consider electrified vehicles, not limited to BEVs, but including hybrid cars.
- In Germany, experts in energy systems are starting to look at the increasing BEV charging load effects on the local power grid, particularly at substation level. There is an expectation that EV batteries may contribute to the electricity demand-supply balancing and the grid stabilization reserve, but experts advise that the BEV's first contribution to the power grid is the flexible management of BEV charging load, avoiding excessive stress situations in the power grid operation and the investment that would be needed to strengthen the grid. The key considerations in the BEV charging load management are the "time" and "location" charging considerations, like promoting charging BEVs when there is plenty of solar/wind power generation and the careful development of public charging infrastructures considering the power grid capacity and the BEV users commuting routes.

  In Japan, one of the demonstration projects conducted a charging behavior change by introducing the time-dependent electricity rate, leading the BEV charging time during solar power generation peak hours, and the demonstration successfully lead BEV users to charge during lower rate hours. However, the charging stations deployment target in the Green Growth Strategy is the number of public charging stations by 2030, and little is considered with the charging load management or optimum charging infrastructures with power grid capacities.

- Regarding the re-use of EV batteries, initial pilot project scopes are different between Germany and Japan. In Germany, projects are trying to build larger stationary battery storages, LSS or ISS, while Japan's Nissan and FOR-R are trying to use second-life batteries in smaller applications, such as a less-demanding mobility or a backup battery of rail-crossing bars and street lights. The smaller application by Nissan and FOR-R seems challenging when many German and Japanese experts have indicated that secondary use for smaller batteries may be difficult due to the variations of remaining capacities. In both countries, the reuse/recycling projects are still in progress until the used EV batteries quantity grows. Even Nissan, one of the first BEV manufacturers, was able to only collect the first generation Leaf as much as 2,000 and that number does not match with an active reuse/recycling business. It is also worth noting on the comment by the FOR-R CEO that the evaluation of used EV battery is important for BEV manufactures in the sense of better residual valuation of upcoming new BEV models.

5 Conclusions and further research needs

Toward the realization of net-zero carbon targets, the increase of renewable power sources and the decrease of fossil-fuel power generation will require developing flexibility measures to balance supply and demand, and to provide a grid stability reserve. Battery storage, including the grid-integrated large-scale battery storage (LSS), the home/commercial/industrial stationary battery storage (HSS/ISS) and the BEV battery storage (BEV) is expected to contribute significantly to this task.

We have conducted wide research and study on the potential, business models, and policy measures in Germany and Japan. In addition to the above use cases of batteries, this covered the possibilities for a ‘second life’ of BEV batteries in other applications and the needs and options for recycling of batteries that have reached the end of their life. This chapter will summarize the learnings from the study and investigate further research/study needs.

5.1 Conclusions

We have studied three types of battery storage systems: Grid-integrated battery storage (LSS), Home and Commercial/Industrial battery storage (HSS/ISS), and BEV battery storage. Power utilities and suppliers install LSS for power supply and demand balancing as well as the power grid stability. HSS and ISS are installed by the users for their own merits, and the same is the case for BEV. The potential and the future need for utilizing HSS/ISS and BEV batteries for the market flexibility and power grid stability is well recognized, but the current examples of such uses are limited.

Germany is ahead of Japan with the installation of **LSS** as much as 620 MWh/460 MW by 68 units. Germany's renewable generation supply in 2020 has exceeded 42 %, while Japan's renewable generation supply was 21 % in 2020. Germany's fast renewable supply growth may require more LSS for the grid stability reserve. With these increasing LSS and other flexibility capacities as well as a better function of the intraday market, Germany is experiencing a decline in the grid-stability reserve market price. We are not sure whether the price decline is temporary, or the price decline will continue, while it is expected that the balancing reserve capacity need will continue to increase along with the solar/wind power supply increase.

HSS and ISS installations are increasing with the pursuit of users' own merits. With HSS, both German and Japanese users are in pursuit of maximum use of roof-top PV power generation, meaning the reduced purchase of electricity from the grid. With ISS, users intend to use battery power during the demand peak time to avoid over-payment of the demand charge throughout the year. Also, ISS are frequently used as backup power supply in industry processes.

In Japan, METI (Ministry of Economy, Trade, and Industry) and the HSS/ISS market players jointly worked to set the cost reduction target toward 2030. The study by METI did not include the possible merit of grid-stability values or the supply-demand balancing values.

The concept of aggregating many HSS and ISS and utilizing them like a **virtual power plant** (VPP) is widely recognized both in Germany and Japan. In Japan, METI has been conduction a demonstration project on VPP (Project ERAB: Energy Resources Aggregation Business) focusing on communication and remote-control technologies with many types of distributed resources. In Germany, there is a precedent case where Sonnen, an electric power supplier, is distributing Sonnen-produced home battery storage to customers and uses an aggregated supply capacity in the wholesale market as well as the demand-supply balancing measure. Such a case is in the early stage and not at the level of large commercial-scale deployment. The use of batteries for grid stability reserve capacity in Germany is predominantly supplied from increasing LSS, except for a few demonstration projects with HSS and BEVs.

There is a difference in the situation between Japan and Germany regarding **electric vehicle** deployment, which is the prerequisite for the utilization of BEV batteries for grid stability. BEV sales are growing rapidly in Germany and Europe. If Germany reaches its new target of 15 million BEVs on the road in 2030, the total storage capacity of all passenger BEVs in Germany may amount to 1.575 TWh and 15 GW by then. We want to highlight the insight from a study by Hildermeier et al. (2019) on the BEV market penetration and the power-grid effects. Hildermeier suggests that the first best contribution of BEV to the power grid is to manage the charging time and locations so that the BEV charging demands may not excessively give stresses to the local grid operation. This first contribution should be understood and recognized by involved players, including policymakers, before we also study BEV battery discharging (vehicle-to-grid) to enhance grid stability.

Regarding the **reuse** of BEV batteries, there are a few programs in Japan, with fewer electricity demand cases, such as forklifts, street lights, emergency power sources in shelters. However, literature reviews and interviews with experts, both in Germany and Japan, suggest the BEV batteries re-use in a smaller size, such as a Home Battery Storage, can be very challenging, due to the battery’s widely varying remaining capacity and the cost to value it.

Germany has conducted some large-scale BEV battery **recycling** demonstration projects, mostly conducted by auto-manufactures and industrial waste disposal companies. Olssen et al.'s study (2018), which is focusing on the business models of BEV battery recycling, suggests that the involvement of automobile manufacturers will be a major factor in BEV battery recycling and reuse.

Regarding **regulatory frameworks** to improve the conditions for using LSS, HSS/ISS and BEVs as a flexibility resource, we found:

- It is necessary to **remove any double charging** with levies, fees, or taxes of electricity during storage charging and discharging for feed-back to the grid, starting from **a clear definition of storage as an own element of the electricity system**. In the EU, this has been decided in the last revision of the electricity market directive but needs to be implemented in Germany. Removing any double charging may now happen soon with the 2022 revision of the renewable energy law (EEG). In Japan, the Strategic Policy Committee addressed the clarification of “LSS-Storage” business in the electricity power system. The

Committee suggests the "LSS-Storage" can be treated as "Generation" with safety responsibility consideratons. The Committee also suggests that the "LSS-Storage" should bear the transportation cost in discharge-portion and the storage-loss portion.

- As a technical precondition for the use as flexibility resources, stationary battery installations as well as BEVs and charging points will need **smart meters and submeters**. Although submeters may not need the full data protection and security, cost may still be a barrier for deployment especially in small-scale storage, such as HSS and BEV (dis-)charging (both private and public). Therefore, financial incentives for investment (grants, subsidized loans) are likely needed for some time. Although Japan is more advanced than Germany in the roll-out of smart meters, and technical demonstrations are ongoing in both countries, both Germany and Japan will need to develop the policy support and framework for mass-scale business cases further.
- In addition, **smart pricing** will also be needed to make flexible charging/discharging financially attractive, such as time of use tariffs enabled through the smart (sub-)metering. Both countries still have to stimulate the wider use of such incentives. The creation of a balancing reserve market in Germany has been very useful in this respect, and its ongoing introduction in Japan is expected to improve the framework for flexible use of batteries in similar ways.

Several steps will also be needed for improving the **regulatory framework for 'second life' and recycling**, including clear and operable standards for assessing the remaining capacity and quality of used batteries. We found that the industry and the policy makers are carefully working on the battery health assessment standard with understanding that battery management is in the highly competitive field in the industry. Germany may need to follow the Storage Battery Directive after approval of the European Commission proposal for amendment. Japan is rather taking a soft approach with industrial standard guidelines agreed by a voluntary working group.

5.2 Future study/research needs on technology, policy intervention and business development

We started this study to try to understand the current situations, potentials, new business models, and associated policies with the possible contribution of distributed battery storage to the grid stability capacity or the power supply-demand balancing measures. There are a few demonstration projects and precedent cases with using home/commercial/industrial battery storages for demand-supply balancing and grid stability reserve, but they are not in the stage of being commercially ready to deploy. There are studies on the use of such distributed battery storage to grid stability and the demand-supply balancing. We understand that EV charging infrastructure development is the essential twin of successful EV market development. Many policies target numbers of public charging stations, but Hildermeier's study (2019) points out the importance of information/data readiness of how/when/where BEV charging demands will affect power grid capacities and operations.

According to the German charging infrastructure masterplan from 2019, the total BEV charging demand in 2030 can amount to 1/8 of the total electricity demand when the BEV deployment exceeds 10 million. With the new government aim of 15 million BEVs in 2030, the demand is expected to increase even further. Therefore, it is important to note the following: When BEVs charge should reflect the renewable energy generation, where BEVs charge should reflect the power grid system capacity locations, thus the charging infrastructure should be developed accordingly with the consideration of BEV users' accessibility. It is important to recognize that the BEV charging system and behaviour should consider "time" and "location".

To develop the "time" and "location" conscious BEV charging infrastructures, data provision of power supply and the power grid capacity is essential. Such data can be highly useful for the development of time-dependent charging prices, the forecast of power demand-supply balancing, and the forecast of the grid stability reserve demand. These data and forecasting tools should therefore be developed further towards easy and cost-effective use.

Hildermeier et al. also make many recommendations on the BEV charging infrastructure development. Hildermeier suggests the importance of "smart charging technologies" and "smart charging infrastructures". The former includes a smart user interface, such as a smart application guiding optimum charging behaviour without hustling too much information on the dynamic price and the payment. The latter includes a building code update to mandate EV charging capacities, unconventional charging spots with street light poles, and road parking spaces. There is a need for further studies on these smart charging technologies and smart charging infrastructures. For example, future research could deepen the topic of BEV charging management with a comparison between Japan and Germany when it comes to framework conditions, infrastructure planning and business cases. In both countries, the effective technical and regulatory framework conditions, such as those mentioned in chapter 5.1, and business models need further study, testing, and development too.

To conclude, the potential of BEVs and also HSS and ISS for market balancing and grid stabilization may be enormous, but whether it is cost-effective in relation to other flexibility, will depend on the extra cost of controls for their flexible use for grid/system purposes, and the economic environment of markets and time-of-use or other smart power prices.

We may assume that in the future, BEV sales are going to increase even further, while it is still unsure to which extent this will continue to be the case for HSS with PV, and also for ISS for private cost optimization with/without PV. If so, the extra cost of flexibility will only be the cost of control and users' opportunity. Those two factors are still to be further researched and calculated, to better understand the size of the potential of these systems for market balancing and grid stabilization that may eventually become reality in the future to support decarbonization of power systems.

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