NAVIGANT
RESEARCH

WHITE PAPER

Transforming Markets for VPPs in Europe

Flexibility and Trading Use Cases Grow in Sophistication and Scale

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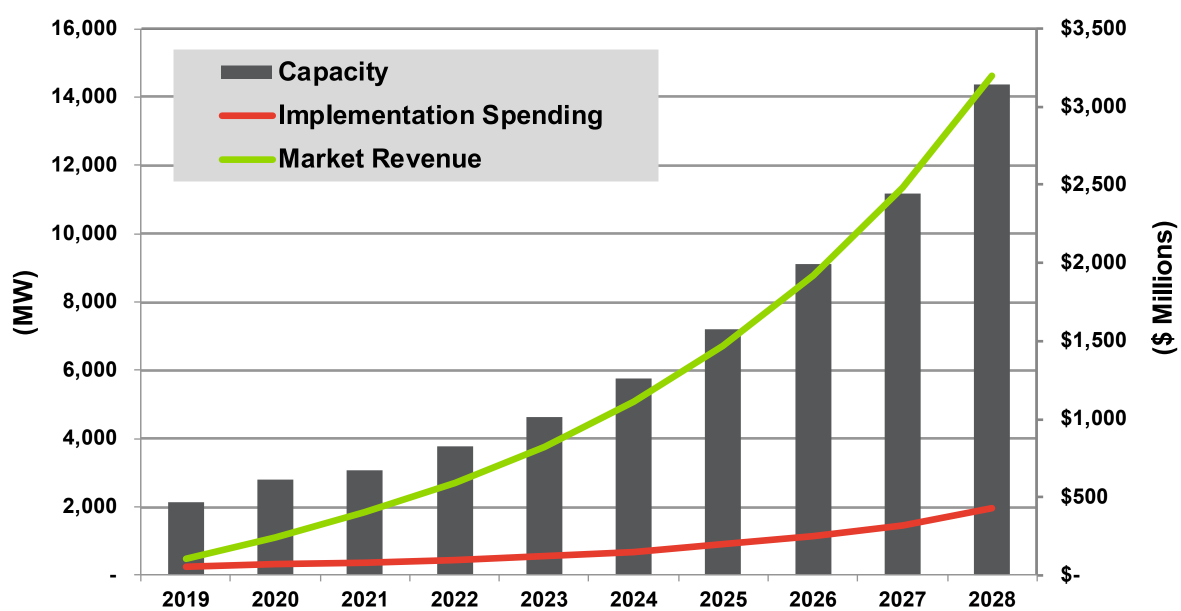
Section 1
EXECUTIVE SUMMARY

1.1 Europe and VPPs: Flexibility and Trading Innovations

Europe is pushing the envelope on the virtual power plant (VPP) concept. The continent is adapting platforms to provide new, more sophisticated capabilities to maximize the value of flexibility. At the same time, it is opening doors to new value streams linked to creative ancillary service markets and real-time energy trading.

Historically, the European VPP market centered around renewable energy integration. The tightly connected countries in the European Union (and the UK) have an advanced market integration that is taking VPP platforms into a more sophisticated direction, stacking complex use cases. These use cases are vital contributors to the continent reaching its climate and economic efficiency goals and targets. Perhaps the key distinguishing feature of Europe's VPP market is the use of advanced software platforms to enable smart energy trading. As a result, this region is proving exciting new possibilities to examine how VPPs can balance the grid, provide economic value exchanges between prosumers and the larger grid, and usher in commercially viable forms of transactive energy.

Chart 1-1. Annual Total VPP Capacity, Implementation Spending and Market Revenues, Europe: 2019-2028



(Source: Navigant Research)

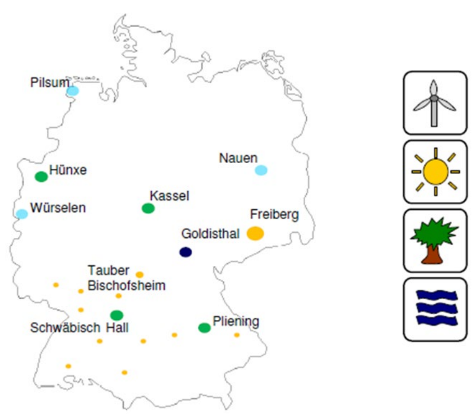
Section 2
EARLY EUROPEAN EXPERIMENTS SET STAGE FOR NEXT GENERATION VPPS

2.1 Market Design in Europe Shapes VPP Applications

The term virtual power plant (VPP) is constantly evolving. A project trumpeted as the world's first VPP has been operating for the German utility RWE since October 2008, aggregating the capacity of nine different hydroelectric plants ranging in size from 150 kW up to 1.1 MW, initially totaling 8.6 MW of VPP capacity. This VPP framework opened new power marketing channels for these facilities. These marketing channels would not have been viable if distributed energy resource (DER) assets were still operating as standalone systems, since contract commitments could be more easily met if these small facilities responded as a pool of hydro resources aggregated and optimized via software. The VPP expanded over time to include biogas, backup generators, combined heat and power (CHP), and wind to reach 200 MW in size today.

Germany is a leader in exploring how a VPP concept could help integrate large volumes of renewable energy. For example, another German VPP—the 23 MW regenerative combined power plant (RCPP)—was touted since it proved (in theory) that a country as large as Germany could rely completely on renewable energy resources for its power supply. A total of 36 wind, solar, biogas, CHP, and hydropower generators were operated as if a single power plant and supplied 24/7 power to the equivalent of 12,000 households.[1]

Figure 2-1. Regenerative Combined Power Plant in Germany



(Source: kombikraftwerk.de)

[1] Others have pointed out that this R&D project failed to account for grid congestion challenges that might frustrate this sort of VPP under real market conditions; limiting VPPs to common feeders is a more commercially viable approach.

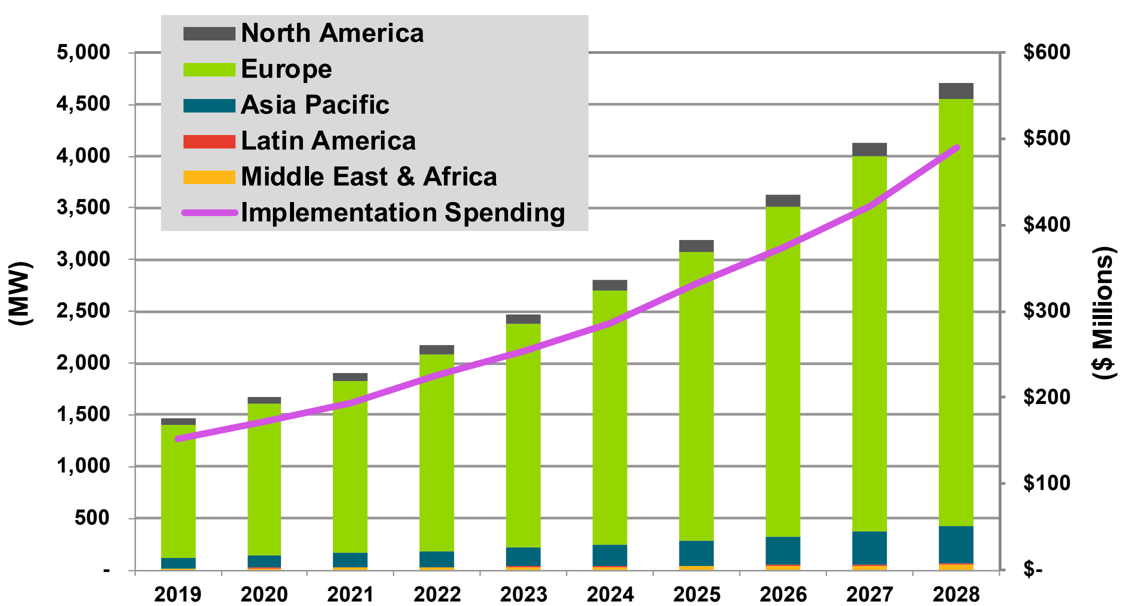
Today, the concept of a VPP is much more expansive. Europe lags the US in demand response (DR), largely due to the intense efficiency built into both residential and commercial and industrial buildings. However, the large fluctuations in solar and wind generation are providing incentives for aggregators, utilities, and grid operators to search more intensely for new balancing resources. This intense deep dive into potential assets on the demand side of the energy exchange ledger is tilting toward large industrial loads that can be economically harvested with the right software platform.

RWE is leading the way in next generation VPPs. It is working to maximize the value of new software platforms that address the technical details of managing pools of diverse assets into a VPP. RWE also plans to use software enhanced over time by machine learning to respond to the real-time needs of the power grid through energy trading.

2.2 Moving from Supply-Side to Mixed Asset VPP Frameworks

Unlike North America, which built initial VPP use cases on the back of DR programs, Europe's focus has tended to lean on supply-side resources. Given the enormous growth in renewable energy generation—the majority of which flows directly into wholesale markets under feed-in tariff contracts—the VPP market is quickly shifting to tap more diverse assets. As Chart 2-1 illustrates, Europe owns the supply-side VPP market, which is expected to continue growing over the next 10 years. However, the continent is more focused on the orchestration of large wholesale renewable energy fleets than DER-based VPP projects. The mixed asset model remains the primary driver for innovation in VPPs.

Chart 2-1. Supply-Side VPP Capacity and Implementation Spending, World Markets: 2019-2028



(Source: Navigant Research)

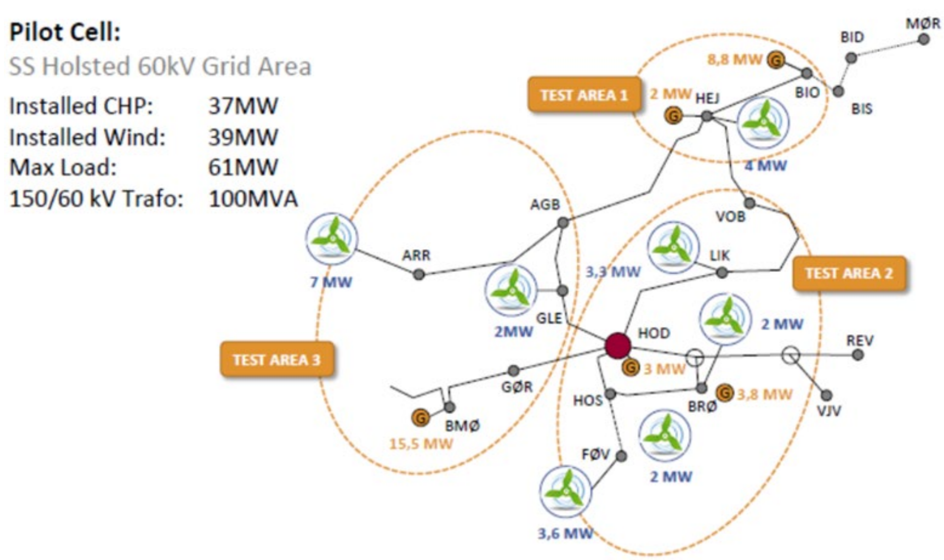
2.3 Unpacking VPP Use Cases with Enhanced Control Platforms

Though Europe's foray into VPPs has been focused on renewable energy integration, a handful of projects highlight pioneering efforts to integrate other DER assets (including both CHP and EVs) into VPPs, and to layer VPP functionality on top of microgrid topologies. Two R&D experiments in Denmark showcase how VPPs can provide a combination of grid services that will be increasingly important as Europe moves to meet its aggressive renewable energy targets.

2.3.1 Cell Controller Project

The Cell Controller Project consists of distributed wind and CHP units owned by farmers and village heating districts, and was operated by Energinet.dk, the transmission operator for Denmark. Since so many different parties own these assets, this project was one of the most advanced forays into what a distributed energy future could look like. The goal was to provide services, such as voltage regulation at the local level, in each cell (each discrete microgrid). Testing was successfully completed in 2012, validating all key VPP operational solutions. With software and controls, the Danish grid operator Energenit.dk was able to optimize the coordination of distributed wind and CHP facilities to create a VPP that helped set the stage for the country's aggressive renewable energy goals. Multiple non-utility owners can create a series of microgrids (i.e., cells) that can island and work at an enterprise level as a VPP. The project concluded in 2012 and served as a basis for Denmark's plan to allow renewables to provide 100% of its electricity, thermal, and transportation energy by 2050.

Figure 2-2. Denmark's Cell Controller VPP Demonstration Project



(Source: Spirae)

2.3.2 Island of Bornholm

The VPP system on the Island of Bornholm is another large microgrid demonstration that represents more than 112 MW of peak capacity capable of islanding from the main grid (the Nordic interconnected power system). Under normal conditions, the system has a high penetration of wind and some solar power. When islanded, it depends significantly on fossil fuel generation. Still, the VPP/microgrid project set a goal to obtain 76% of its total electricity from renewables by 2025. The testing period for VPP applications, such as DR from residential electric heating systems and heat pumps in 2,000 homes, concluded in June 2019. At that point, the island's DER mix included the following: 29 MW of wind power, 16 MW of combined heat and power, 6.5 MW of solar PV, 2 MW of biogas, 34 MW of diesel, and 25 MW of oil-fired steam generation. The latter serves as backup resources. Plans also include the development of two large solar PV farms. One of the key lessons learned from this living lab is the need for standardized protocols to move beyond simple on-off systems, shifting to greater flexibility in load management.

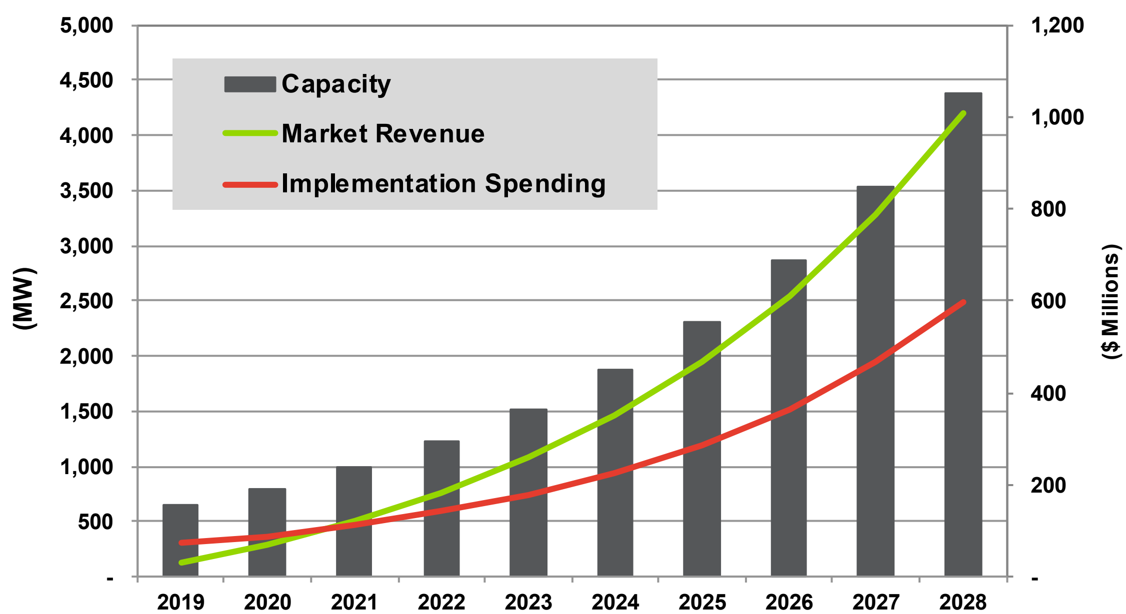
The primary purpose of this demonstration is to test flexible capacity and ways to control consumption through price signals in a load shifting and DR-type model. It is also testing the ability of EVs to provide grid services. A vehicle-to-grid (V2G) demonstration will simulate a full-scale penetration of EVs on Bornholm to assess how the fleet can be integrated into the grid. It will also deploy a small real-world pilot project with as many as 50 Nissan PEVs on Bornholm, using a V2G platform that enables EV batteries to store and resell unused energy back to the local grid. At present, 22 EVs on Bornholm Island are testing this concept in the small pilot. A larger fleet of PEVs could potentially provide peak shaving and balancing services to the grid. EVs offer several components and services of value to any VPP aggregation. These include last resort stationary storage services, loads that (if curtailed or modulated) represent DR resources, and loads coupled with energy storage for optimized DR firming and flexible capacity. It is this latter use case that has achieved the greatest market adoption.

Section 3
EXPANDING VPP MARKETS BEYOND COUNTRY BORDERS

3.1 Early Pioneers Give Way to New Market Opportunities

The VPP platform is agile; its attributes are being tested and expanded upon in Europe. Although the names of products, services, and markets are different across each regional market, they tend to have strikingly similar requirements for market participation. Germany is the largest and most mature VPP market, it leads the region in current deployments and is expected to continue holding that position over the next decade. Germany is anticipated to capture about one-third of the total VPP market's annual capacity by 2028, reaching approximately $1 billion in annual market revenue and over 4,000 MW of incremental annual capacity additions. The world's largest VPP traces back to 2009 and has grown to over 4,500 MW in size; it is expanding in stages across the entire European continent. With its Eurocentric focus on energy trading, technologies used for financial transactions, tracking, and settlements are setting the stage for future VPPs throughout Europe.

Chart 3-1. VPP Annual Capacity, Implementation Spending and Market Revenues, Germany: 2019-2028



(Source: Navigant Research)

3.1.1 Case Study: UK

While Germany is the VPP market leader in Europe, the UK is the other hotspot when it comes to fully commercialized ventures and projects. The UK has always been a bit of an outsider; it embraced forms of electricity deregulation well before other nations and continents, first establishing open markets back in the 1990s.

VPPs mesh well with UK market reforms that fully embrace deregulation, flexibility, and variable renewable energy generation. From projects large to small, VPPs are emerging from a variety of vendors, attracting companies throughout the continent. The UK is a hotspot for VPP innovation. Its projects range from 1 GW from Statkraft, a Nordic energy company that is combining energy storage with natural gas generation, to another VPP of just 4 MW that uses resources in 250 homes and 100 schools and other buildings. Along with private sector vendors and out-of-country arms of utilities now deregulated, distribution network operators are also moving forward with VPP projects.

For example, UK Power Networks is launching a series of VPPs to substitute for traditional grid reinforcements. It is creating 25 flexibility first zones across three service areas in London, the southeast, and east of England. Aggregating rooftop solar PV systems paired with onsite batteries, these resources will be called upon to discharge electricity into the regional grid to relieve peaking power needs. In exchange, participating prosumers will be paid by the network operator. Though limited to 40 homes in the London zone at the outset, it is evidence that the UK is moving forward with the VPP concept at both wholesale and retail levels of energy production and consumption. Short-term contracts are being let for this winter and through 2021, with providers also having an option to bid for longer-term contracts as long as 4 years.

3.1.2 Markets in Eastern Europe Are Also Opening Up

Many utilities and energy companies start by developing a VPP solution with the help of software innovators in their primary country of operation, but with an eye toward future applications in other EU markets. These software vendors can often incorporate lessons learned from other global markets into their platforms, exploring diverse flexibility resources that may differ by type or scale in different markets but share fundamental control characteristics that help informed VPP offerings. Navigant Research, a Guidehouse company, believes the entire global market—including Europe—is marching toward the mixed asset model. The twist to the VPP model in Europe revolves around linkages to active energy trading, the sheer volume of the market (and renewable capacity, including large wholesale offshore wind farms), and sophisticated load management resources given the continent’s legacy of embedded efficiency in buildings and industrial processes.

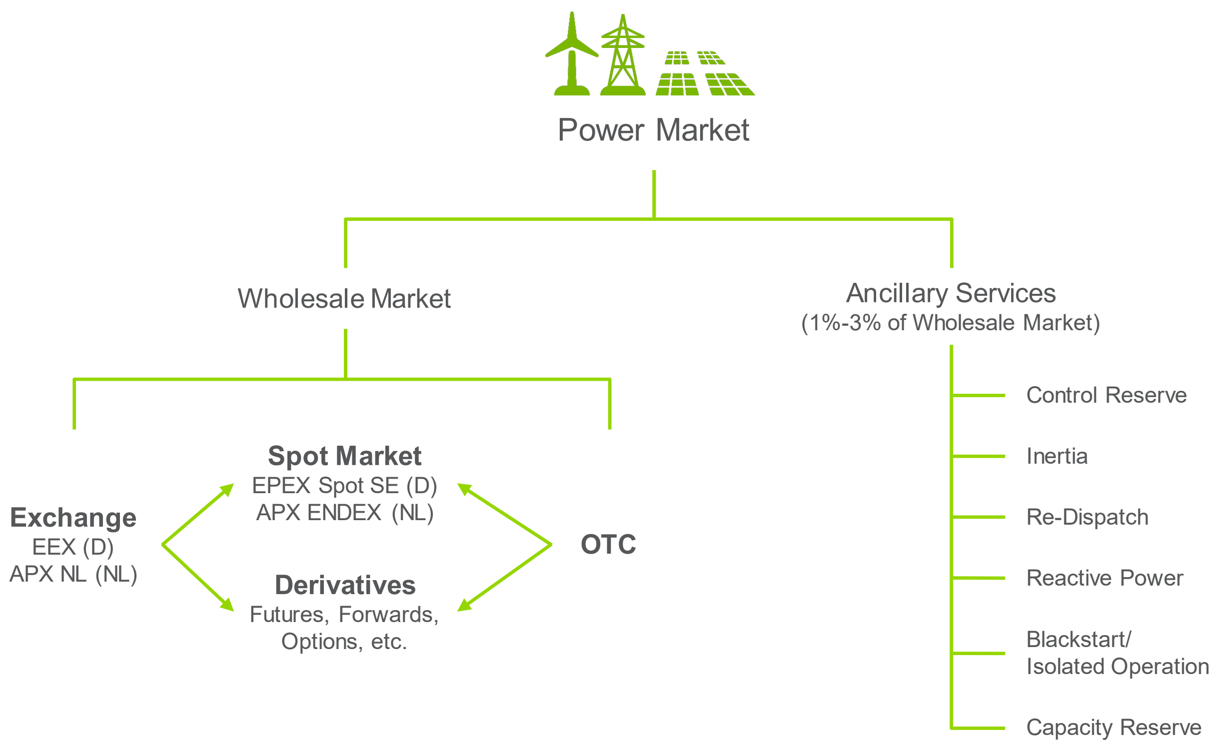
An emerging market for VPPs lies in Eastern Europe both in the north (Estonia) and to the south (Poland). Renewable capacity in Eastern Europe has traditionally lagged Western Europe. In these markets, less efficient industries represent harvestable loads not generally available throughout the rest of the continent. Deregulation of these markets is now taking hold, so customers, utilities, and regulators are aligned in seeking new forms of flexibility, exploring the VPP model based on lessons learned in pioneer markets such as Germany and the UK.

Section 4
LINKING ENERGY TRADING TO GRID RELIABILITY VIA VPPS

4.1 Europe Leads the Way on Leveraging VPP Platforms for Energy Trading

Automated energy trading is increasingly part of the VPP market in Europe. Germany is a leader in this space. Increased VPP-related trading activity is also opening up in the Netherlands, Belgium, the Nordic countries, and across certain Italian energy retailers. The UK is also a VPP hotspot. It is becoming more and more active on rapid energy trading opportunities due to the increased competitiveness of the market and the need for the established players (such as incumbent utilities) to provide innovative and compelling offers to their clients and to sign up new customers. Each country has its own reasons for increasing the need for a VPP solution, whether the driver is new regulations, government strategies, aggressive renewable energy targets, or EV charging. Figure 4-1 provides the framework in which VPPs operate, with an increased focus on ancillary services that represent a small fraction of the total market, but highly valuable grid services.

Figure 4-1. Classic Deregulated Market Structure for VPPs in Europe



(Source: Navigant Research)

4.1.1 Tapping Diverse Flexibility Resources for Economic Optimization

VPPs fill the need for flexibility as Europe scales up its renewable energy and DER portfolios. The beauty of the VPP platform, however, is not limited to flexibility. The full suite of grid services necessary for moving power grids fully into the 21st century is among the functionality upgrades being incorporated into VPPs: aggregation, control, scalability, and real-time active resource and grid management. From a high level perspective, the VPP solution is also seen as bringing digital transformation and cloud-based software solutions into commercial and industrial sites that seek greater efficiencies and new revenue streams from existing or new energy assets.

Since VPPs allow for the management of generation, energy storage, and customer load, they can aggregate flexibility resources across the entire pool of potential DER assets. This aggregation enables the determination of market offers, optimization of reserve capacity, and scheduling of mixed asset portfolios to meet a real-time market commitment or power grid need. The trend of relying upon a constraint-based approach for flexibility and control of DER assets is a technical item of note. These constraints typically fall into three categories:

- **Technical:** Minimum/maximum power limits, on-off times, and ramp rates)
- **Participation:** Opt outs due to unplanned outages or non-participation and blackouts due to planned outages or maintenance
- **Other Business Constraints:** Such as maximum activations per time period

4.1.2 Market Reforms Could Open up New VPP Use Cases

Europe is moving in the right direction on the VPP front. Nevertheless, experience in other global markets could inform regulators to fine-tune market structures to ensure the broadest participation among the universe of potential DER assets. Among the reforms that could accelerate VPP markets are the following:

- Modify market rules to allow participants to offer smaller bid volumes, for example, lowering the threshold to 100 kW instead of 5 MW.
- Allow aggregation of smaller generators to participate as flexibility resources and allow more diverse types of DER to participate in the provision of market services, including controllable loads and energy storage.

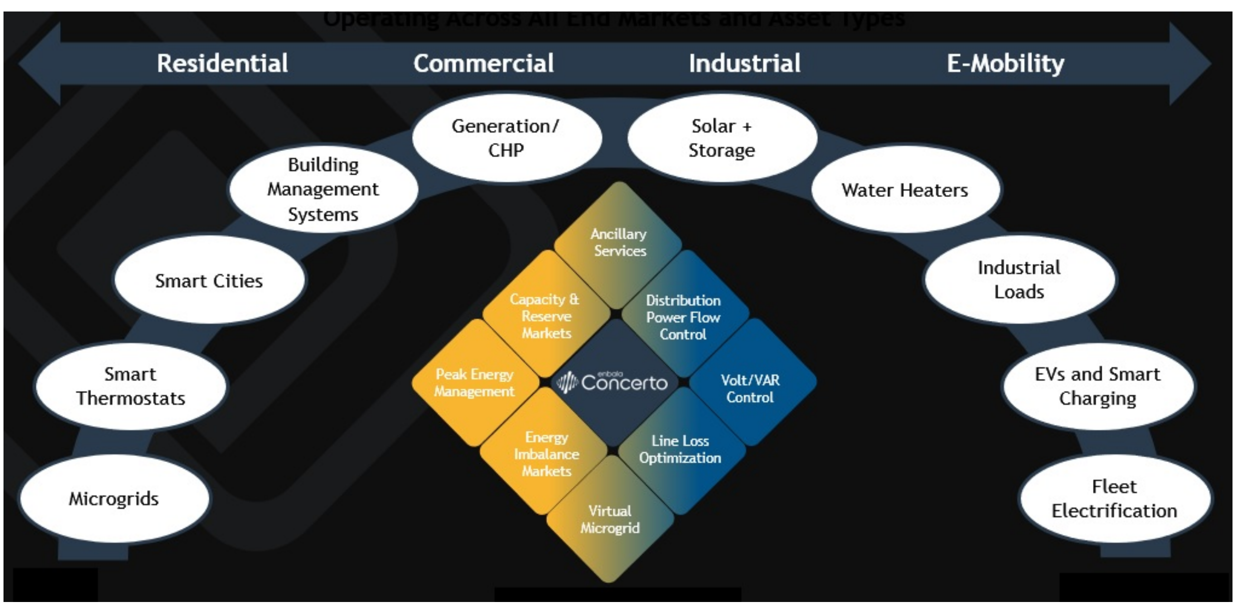
The challenges VPPs and other DER platform face as they bump up against remnants of the prior monopoly are among the other barriers to full mixed asset VPP commercialization in Europe. One impediment is that market participation rules often require a highly accurate meter to be placed on each large load. This requirement can drive up installation costs for each kilowatt of capacity registered into the market. In turn, this reduces the economic viability of including smaller generation, load, or energy storage assets into a VPP portfolio.

Another regulatory reform that could open markets in Europe to lower cost asset aggregations is adjusting how best to measure performance of a VPP. It is often best when markets rely upon an aggregated performance score rather than per asset performance scores, as the former approach reduces the probability of noncompliance. Europe could learn from the most active VPP markets in the US (the PJM control area) and seek to reduce the complexity of including demand side resources into a mixed asset VPP. Enbala was among the first participants to offer controllable loads into PJM for frequency regulation, which is necessary to keep grids in balance and has emerged as a classic VPP use case. The company enabled the participation of DR resources by designing metrics that include calculating (all in megawatts) a basepoint, upper control limit, and lower control limit for a chiller. It is not as easy to characterize demand resources in this way as it would be for a generator but capturing the grid value of diverse demand resources opens the door to state-of-the-art mixed asset VPPs.

4.1.3 How Advanced Platforms Enable Complex Value Stacking Use Cases

Platforms that once only addressed loads, generation, batteries, or EVs are now being asked to sense, aggregate, control, and respond to market signals for a growing list of grid services. Figure 4-2 highlights what is possible with a state-of-the-art platform spanning residential, commercial, and industrial prosumers. In an ideal world, VPP software platforms can stack complex use cases that include e-mobility services.

Figure 4-2. Expanding VPP Use Cases Span Market Segments



(Source: Enbala)

VPPs can only respond to precise grid needs if regulations allow them to do so. DR is perhaps the most extreme example of how new technology needs to be paired with new market designs. The aggregation of load to substitute for services was previously only provided by generators and requires explicit rules for market engagement by either state or federal regulators. The greatest challenge for regulatory treatment in this area may be for mixed asset VPPs. Why? They have characteristics that traditionally were treated separately, often in silos. VPPs instead look to treat these DER aggregations as systems of systems. The mix of resources ideally does not matter; the services that can be provided are what should be counted and compensated for. Utilities play a major role in this market transformation, as this is where many VPPs are incubated. Transparent interconnection rules, rational telemetry requirements, and coherent and stable subsidy schemes all contribute to a market environment conducive to VPPs.

Section 5
IS EUROPE TAKING VPPS TO THE NEXT LEVEL?

5.1 Pushing the Envelope on VPP Platform Innovation

Europe is on the brink of becoming the global VPP leader. Much work has been completed to align EU member states with an underlying framework of network codes and guidelines on topics such as transmission system operation, electricity balancing, and demand connections. These codes may seem like esoteric minutiae, but these are the nitty gritty details that guide countries to create markets that enable vendors to offer similar solutions across borders. Without such coordination and harmonization of protocols, the cost of VPP goes up and the timeline for deployments expands.

The work completed for EU member states is helping speed up the implementation of grid balancing services that are becoming standardized ancillary services (and include primary reserves, secondary reserves, tertiary reserves, and replacement reserves). With these requirements in place, once state-of-the art mixed asset VPPs take hold in a few country markets, such as Germany and the UK, their transactive energy models will likely be mimicked by other EU member countries that implement similar market structures as the early adopters.

5.2 Broadest Possible VPP Participation Due to Interconnected Country Markets

The VPP functions linked to balancing services are just one aspect of market developments in Europe. The European Power Exchange spot market also provides a key centralized structure to allow VPPs in member states for intra-day and day-ahead energy market participation. This single point of clearing bids allows VPPs to move beyond country boundaries and evolve into a regional solution with a footprint larger than any VPP market in the world, if measured by customer accounts or generation or load.

5.3 Future Opportunities for VPP Value to Grow

VPP platforms are likely to continue transforming. One twist to grid management now underway in Europe is that distribution network operators are being asked to become distribution system operators (DSOs), serving as a traffic cop for DER and energy trades at the distribution level of electricity service. This will ultimately lead to software platforms that can offer VPP capabilities on frequency and energy trading and active power management to solve voltage hotspots and other reliability concerns. Rather than extending investments in physical power plant-based assets, these DSOs may instead focus on squeezing value out of flexible resources that help balance the overall power grid. Though taking longer than some would hope, the shift from VPP to a DER management system appears inevitable over the long run. Interim steps currently underway include advanced distribution management systems providing data to localized markets in which VPPs can also play.

Section 6
ACRONYM AND ABBREVIATION LIST

CHP .... Combined Heat and Power

DER .... Distributed Energy Resources

DR .... Demand Response

EPEX .... European Power Exchange

EU .... European Union

EV .... Electric Vehicle

GW .... Gigawatt

kW .... Kilowatt

MW .... Megawatt

PV .... Photovoltaic

R&D .... Research and Development

RCPP .... Regenerative Combined Power Plant

UK .... United Kingdom

US .... United States

V2G .... Vehicle-to-Grid

VPP .... Virtual Power Plant

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Section 9
SCOPE OF STUDY

This white paper was commissioned by Enbala and focuses on the current and future potential VPP and DERMS market in Europe. This is the fourth and final in a four-part series exploring how new software control systems can show near-term value within the VPP market and sets the stage for additional applications under a DERMS framework. These white papers have been developed in parallel with updates to Navigant Research's overall market forecast of VPP segments. Navigant Research white papers are designed to be objective, third-party documents. As such, Navigant Research does not endorse any specific company or products.

SOURCES AND METHODOLOGY

Navigant Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Navigant Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Navigant Research's analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Navigant Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

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NOTES

CAGR refers to compound average annual growth rate, using the formula:

$$CAGR = (\text{End Year Value} \div \text{Start Year Value})^{(1/\text{steps})} - 1.$$

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2019 US dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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Note: Editing of this report was closed on November 26, 2019.

[2] On October 11, 2019, Guidehouse LLP completed its previously announced acquisition of Navigant Consulting Inc. In the months ahead, we will be working to integrate the Guidehouse and Navigant businesses. In furtherance of that effort, we recently renamed Navigant Consulting Inc. as Guidehouse Inc. We will continue to perform as proposed during and after this consolidation, using the same personnel and methods described in this report.