ZOE
DIGITAL ENERGY

# Whitepaper European VPP & Energy Storage Development

2025.8

# Preface

Between 2022 and 2025, the European electricity market is undergoing a profound transformation driven by multiple factors, including a surge in electricity demand, large-scale deployment of renewable energy, and the lessons learned from the 2022 energy crisis. Faced with these challenges, policymakers in the EU and the UK are actively adopting a series of directives, regulations, and guidelines aimed at building a smarter, more flexible, and consumer-concentric electricity system. These policies focus on strengthening load management, demand response (DR), and energy storage to ensure reliable and affordable electricity supply.

The UK's new Regulation 415, enacted in November 2024, has a profound impact on the commercial landscape of the electricity market by establishing the role of "Virtual Trading Party" (VTP). VTP allows independent aggregators to directly access the UK wholesale electricity market, transcending the previous limitations of the BM Balancing Mechanism (P334) and enabling the direct monetization of customer-side "behind-the-meter flexibility" (BTM). This mechanism not only provides new revenue streams for energy consumers but also aims to intensify competition among market participants and "force traditional, inflexible energy suppliers" to improve their operational and management capabilities. The common goal of these policies is to accelerate the rapid development of "behind-the-meter load flexibility management," establishing VPPs as a key form of aggregation for distributed energy resources (DERs), enabling them to play a central role in grid balancing, economic optimization, and decarbonization.

Commercial and industrial energy storage is a crucial asset for achieving behind-the-meter (BTM) flexibility. The BTM flexibility market encompasses a diverse set of revenue streams, and relying solely on single service revenue streams to cover investment costs is insufficient. This is crucial to understanding the profitability models of VPP and energy storage projects, and explains why aggregators play a key role in coordinating multiple value streams. This is the core business logic for achieving economic viability through VPP systems—"value stacking."

Based on this background, this article aims to provide a reference for software and hardware vendors, project developers, and partners in related fields. It will deeply analyze the latest regulatory developments in the European electricity market and the mechanisms of the behind-the-meter flexibility market, present the competitive

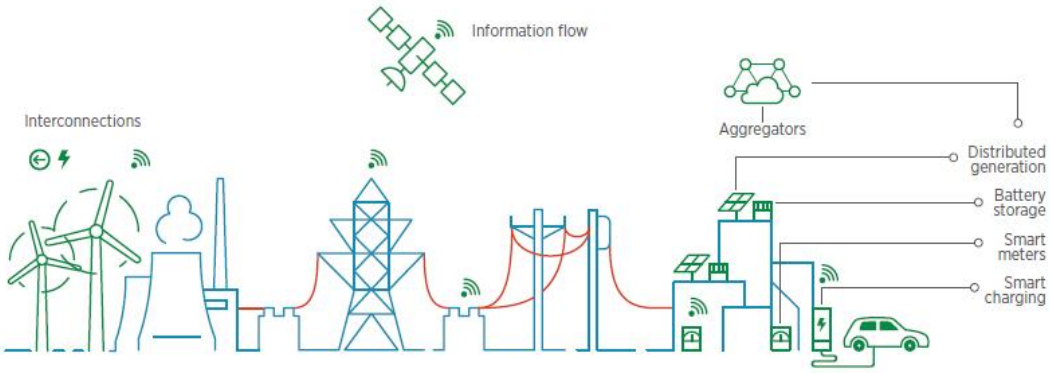
landscape of major VPP platforms, and explore how to select appropriate products and technologies to achieve optimal scheduling of distributed resources.

# Contents

# 1 VPP Market Overview

Power Grid Context: The century-old grid architecture was built on a fundamental assumption that centralized power generation could be efficiently delivered to passive distributed loads, with the belief this configuration offered optimal cost efficiency. However, over the past 10-20 years, transformative forces including rapid deployment of renewable energy (RES), market-driven reforms in the power sector, and accelerated electrification of transportation systems have fundamentally reshaped the industry landscape. These changes encompass not only surging demand from computing centers and EV adoption, but also deregulation of electricity markets and breakthroughs in smart grid technologies. To effectively address these evolving challenges, comprehensive energy management solutions requiring technological upgrades are now imperative.

Virtual power plant (VPP) has become the mainstream trend and form of smart grid technology in the world.




From：IRENA

## 1.1 BTM's flexibility is rapidly developing globally

With the rapid advancement of Global electricity market liberalization, behind-the-Meter (BTM) flexibility management for grid loads has gained increasing attention and support from both markets and power regulatory authorities. Virtual Power Plants (VPPs), as aggregators of distributed energy resources (DERs), play a pivotal role in managing and utilizing customer-side flexibility. These systems provide multiple value streams to the power grid and have experienced rapid global development.

- **The value of flexibility BTM**

The flexibility of the grid is usually derived from the flexibility from smart thermostats, heat pumps, buildings with energy management systems, and energy storage devices such as batteries. The aggregation of VPP can generate significant system benefits and customer benefits. These values are mainly reflected in the following aspects:

- **Improve the reliability and stability of the power grid**
  - VPPs balance power supply and demand and provide utility-grade grid services. They assist the operation of power systems by providing operational backup through load shedding and transfer.
  - VPP has significant advantages in addressing urgent grid challenges such as rapidly growing power demand.
  - VPP can also assist large-scale power systems in emergency control, such as maintaining system frequency standards through generator load shedding or load reduction

- **Realize economic optimization and market participation**

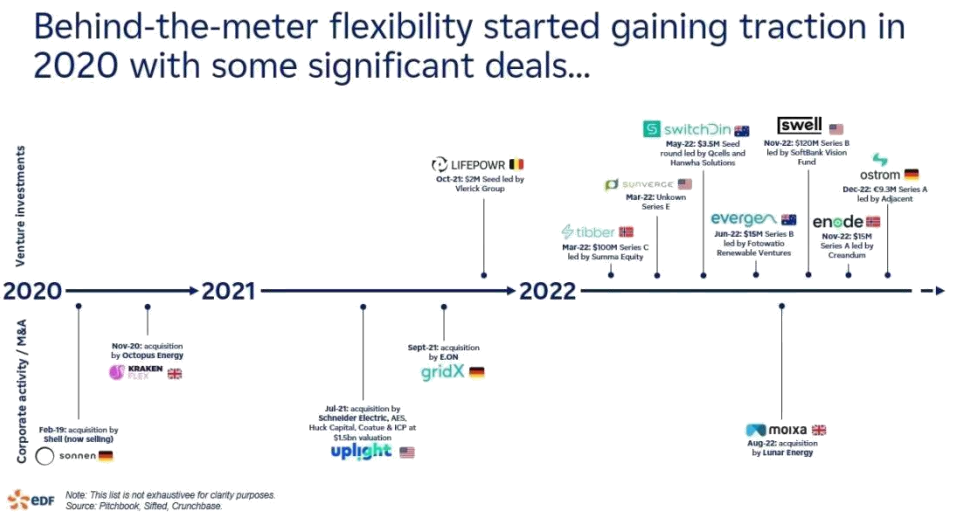
  - The VPP control process encompasses market-related issues (Commercial CVPP), performance and functional challenges (Technical TVPP), as well as their combined applications. Key components include network status monitoring, generation/demand information forecasting, bid pricing, electricity pricing mechanisms, DER protocols, fault diagnosis, generation/demand regulation, energy balance management, tariff updates, customer control systems, network stability maintenance, communication with other VPPs (OpenADR), meteorological station integration, and BESS energy storage management
    - VPP is particularly active in the balanced power ancillary services market, including automatic Frequency Restoration Reserve (aFRR) and manual Frequency Regulation Reserve (mFRR)
    - VPP is actively involved in the wholesale electricity market, including day-ahead market and intraday market. It can quickly transmit dynamic price signals to end users and support automated price response based regulation.

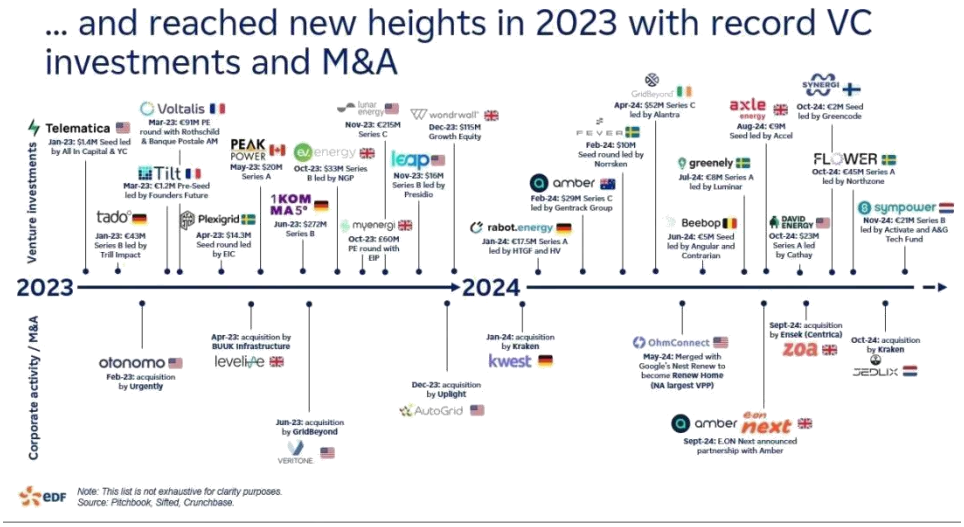
- **Promote decarbonization and integration of clean energy**

VPP operators can provide comprehensive energy services for DERs to help

absorb wind and solar power.

These market changes have also led to a boom in investment in customer-side flexibility for the energy Internet.




From：VC@EDF

The current energy Internet is experiencing two waves:

**2020–2025: Linking wholesale electricity prices to household end-user tariffs.**

**2025-2030: P415 BTM flexible market .**

The first wave: which saw the rise of Octopus.energy, valued at $15 billion, and OVO.energy, now the fourth largest energy company in the UK.

Which innovative companies will emerge from the second wave of flexibility? Let's wait and see.

# 2 European Policy Changes 2022-2025

Over the past three years (2022-2025), the European Union has intensified efforts to modernize electricity market regulations, aligning with its Green Deal commitments, climate goals, and lessons from the 2022 energy crisis. The European power grid is facing surging demand (projected to grow by approximately 60% by 2030) and a surge of volatile renewable energy sources (with wind and solar capacity expected to more than double by 2030). These trends require smarter load management —— balancing supply and demand through flexibility, demand response, and energy storage —— to ensure reliable and cost-effective electricity. Recent EU directives, regulations, and guidelines have introduced a new framework for demand-side flexibility, urging distribution system operators (DSOs) to become "smart grids" capable of proactively managing loads and distributed resources . Below are key policies affecting load management for utilities and technology providers since 2022.

## 2.1 Key EU directives and policies affecting load management

- **Power Market Design Reform (2023-2024)**

In 2023, the European Commission proposed a major reform to design the electricity market, which was adopted in 2024. The reform aims to enhance market flexibility and consumer protection by introducing peak-shaving products for system operators to curb demand during price surges. Additionally, it empowers demand-side resources by reducing bidding scales (100 kW or less in wholesale markets), enabling small power companies to participate. Distribution System Operators (DSOs) must now consider operational costs when designing electricity prices, incentivizing them to procure flexible services (demand response) that reduce grid costs. Member states will regularly assess and report on flexibility needs (starting biennially from 2025) and set national targets to achieve non-fossil energy flexibility (demand response, energy storage) by 2026. These measures aim to accommodate more renewable energy through demand-side response and energy storage, marking a shift toward a more flexible, consumer-centric market. Reference link

- **Demand side flexible network specification (2022-2025)**

The European Union is developing specialized network regulations to coordinate demand-side responses across member states. In late 2022, regulators (ACER) and stakeholders drafted the Demand Response Framework Guidelines through public

consultation, establishing the foundation for EU-wide regulations. These network regulations, set to be implemented in 2025, will define standards for aggregation, energy storage, and demand reduction services. The initiative aims to remove remaining regulatory barriers, enabling demand-side resources to participate equally in balancing and capacity markets. A Demand Side Flexibility Expert Group has been convened to provide recommendations on policy and technical details. The guidelines will clarify how aggregators, smart charging (vehicle-to-grid) systems, and other flexibility providers can deliver services to transmission and distribution operators. Reference link

- **Renewable Energy and Energy Efficiency Directive (2023)**

The EU's "Fit for 55" legislative update includes revisions to the Renewable Energy Directive (RED) and Energy Efficiency Directive (EED), which will impact load management. The revised RED (2023) mandates smart control for new electricity-consuming assets: For example, EV charging infrastructure must support intelligent scheduling (referencing design points in the OCPP2.0.1 protocol), and even bidirectional charging (vehicle-to-grid) where applicable. Starting in 2024, all newly installed public EV charging stations in the EU must have smart charging capabilities to regulate loads. Meanwhile, the updated EED (2023) incorporates the "efficiency-first" principle, ensuring demand response competes equally with generation capacity when planning energy systems. It encourages dynamic pricing mechanisms (time-of-use rates, critical peak rates, etc.) to incentivize consumers to adjust their demand through rule-based strategies. Reference link

- **National assistance guidelines and flexibility support plans**

In January 2022, the European Union adopted the new Climate, Energy and Environment Aid Guidelines (CEEAG), designed to direct public funds toward achieving the Green Deal objectives. These guidelines explicitly permit support for non-fossil fuel flexible technologies (including demand response, battery, and other energy storage solutions) to balance power grids and reduce emissions. For instance, in 2023, the European Commission approved a €1.3 billion French initiative under CEEAG, aimed at incentivizing peak-hour demand response and energy storage capacity. Reference link

## 2.2 What flexibility on the table means for the market

The period from 2022 to 2025 marks a pivotal shift in EU energy regulation, positioning active load management and flexibility as core elements of power systems. From market design reforms to mandatory smart charging regulations, key directives and policies are reshaping how power companies operate and technology providers engage in the market. Distribution network operators are emerging as coordinators of flexibility, supported by new incentives but also challenged by infrastructure upgrades. Technology providers and integrators are become key participant in energy markets, fueling innovation and competition even as they must prove their solutions in a critical and safety-focused domain. From financial and operational perspectives, these changes hold significant implications: companies successfully integrating into these transformations can unlock new value (through cost reduction, service innovation, or public funding), while those slow to adapt risk higher risks and miss opportunities. The industry's overall impact presents both opportunities and challenges, but with clear strategic direction——The EU is building a power system where flexible demand and smart load management are as vital as generation. By actively responding to these regulations, companies in the sector can thrive in Europe's cleaner, more resilient energy future

**The UK P415 and P375 rules have a profound impact on the business pattern of electricity market**

The UK electricity market underwent profound transformations between 2022 and 2025, with the implementation of amendments P415 and P375 to the Balance and Settlement Code (BSC) being particularly pivotal. P415, effective November 2024, explicitly established the role of Virtual Trading Parties (VTPs), allowing independent aggregators to enter the UK wholesale electricity market for the first time – a significant expansion beyond their previous participation in the Balancing Mechanism (BM). This strategic shift facilitated the monetization of customer-side flexibility through the "deviation factor" mechanism. Complementing this, P375 was implemented in June 2022, permitting settlement using post-bounds independent asset meters to enable more refined flexibility trading.

The UK's VTP program maintains unique characteristics while sharing broader objectives with European power market entities like the Balanced Service Providers (BSP) and Balanced Responsibility Parties (BRP) under the European Transmission

System Operators (ENTSO-E) framework. While all three share the goal of integrating flexibility and ensuring system balance, the UK's VTP explicitly provides aggregators with access to wholesale markets to utilize customer flexibility – a pathway more clearly defined than those typically offered by broader European entities. The UK's VTP certification process is rigorous, involving Central Volume Allocation (CVA) and Supplier Volume Allocation (SVA) qualifications assessed by KPMG and approved by the Performance Assurance Committee (PAB), which has fostered the development of professional support services. Although research materials do not explicitly detail Global participation in VTP, the presence of non-UK companies in other BSC roles (e.g., EDF) suggests potential permission for foreign entities to engage in VTP activities.

Among them: Axle Energy Limited has been identified as a VTP, demonstrating its first-mover advantage and technical expertise in aggregating diversified and flexible assets through smart metering and asset metering, and active participation in regulatory initiatives

**Introduction to the flexibility of the UK electricity market**

- **The context of an evolving energy landscape**

The UK electricity market is undergoing a profound transformation, evolving into an intelligent and flexible energy system. The core drivers of this evolution include integrating growing intermittent renewable energy sources, managing grid congestion, and enhancing overall system stability and security. The traditional centralized power generation model is gradually being replaced by more decentralized systems, which necessitates the introduction of new market mechanisms to efficiently balance supply and demand in near real-time.

- **The role of aggregators in the UK wholesale market**

Aggregators play a pivotal role in this transformation. They pool small, distributed energy resources (DERs)——such as demand-side response from industrial and commercial consumers, smart devices like electric vehicle chargers and heat pumps, and energy storage units——to form a collective flexible source that serves the grid. Historically, these independent aggregators, known as Virtual Lenders (VLPs), were primarily involved in balancing mechanisms (BM) where they responded to direct instructions from the national grid to maintain system balance.

The evolution of the aggregator role (from VLP to VTP) demonstrates that

broader policy objectives aim to unleash diverse sources of flexibility, shifting focus from large centralized power generation to distributed resources including consumer-side assets. This is crucial for achieving net-zero emission targets and ensuring system security amid the growing reliance on renewable energy

## 2.3 ELEXON: Market opportunities arising from P415 regulations

**BSC Amendment P415: Facilitate the entry of virtual trading parties (VTP) into the wholesale market**

- **The purpose and goal of P415**

The BSC Amendment P415, formally titled "Promoting Flexibility of Virtual Lead Scheduling in Accessing Wholesale Markets", represents a pivotal regulatory overhaul to the Balance and Settlement Code (BSC). This landmark change enables Virtual Lead Parties (VLPs) – independent aggregators – to directly participate in the UK wholesale electricity market. The initiative has created a new market entity: Virtual Trading Parties (VTPs), specifically designed for these aggregators. Fundamentally, it empowers electricity consumers to unlock value by selling their inherent flexibility to wholesale markets, breaking free from previous constraints of limited participation through suppliers or restricted access to balancing mechanisms (BM). Additionally, P415 introduces reciprocal compensation mechanisms to mitigate potential impacts on suppliers.

The fundamental premise of P415: For energy consumers whose upstream suppliers lack flexibility in on-site operations, VTP (Virtual Trading Party) enables direct connection to your equipment, allowing participation in wholesale electricity market arbitrage and unlocking operational flexibility. This mechanism will inevitably drive traditional rigid energy suppliers to enhance their operational efficiency amid intensifying competition. Industry forecasts indicate the BTM flexibility market will reach €580 million by 2025, with total scale projected to exceed €2.5 billion by 2035 (Source: EDF).

- **Implementation details and main impacts**

The P415 amendment was implemented on November 7, 2024 as part of the BSC November standard release. This revision is expected to primarily impact Virtual

Lead Parties (VLPs), existing BSC participants (particularly suppliers), and Elexon Company (BSCCo) managing the BSC. A key operational change is that VTPs can now trade "deviation quantities" —— the difference between expected and actual energy consumption over a 30-minute cycle – in wholesale markets (including day-ahead or intraday markets). This mechanism incentivizes load shifting, enabling consumers to reduce demand during high-cost periods and monetize their flexibility.

- **Relationship with virtual lead parties (VLPs) and balancing mechanisms**

Prior to the implementation of P415, VLPs were restricted to participating in the Balancing Mechanism (BM). The VLP role itself was established following the December 2019 BSC amendment P344 "broader access", which granted independent aggregators their first-ever authorization to enter the BM. P415 represents an expansion of VLP capabilities, enabling them to register as VTPs and access broader wholesale markets, thereby diversifying revenue streams for flexibility.

The implementation of P415 represents a pivotal step in market liberalization, enabling independent aggregators to interact directly with wholesale markets. This reduces reliance on traditional suppliers as the sole market channel for consumer flexibility, thereby fostering greater competition and potentially lowering costs for consumers. The reciprocal compensation mechanism serves as a critical design element that ensures existing market participants (suppliers) receive "full compensation," effectively mitigating potential negative incentives for suppliers to support VTP activities.

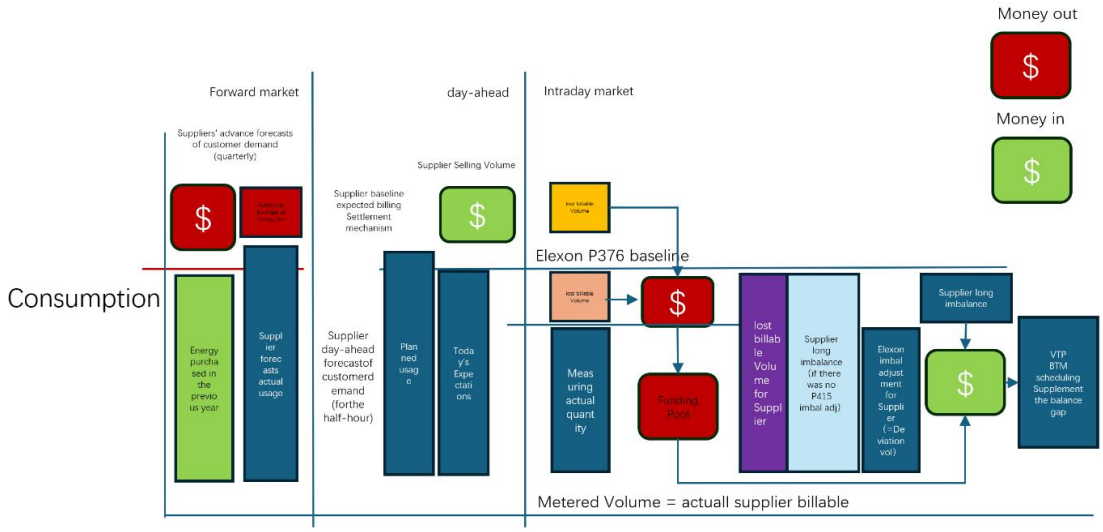
Market rule-making is an iterative and interconnected process. P444 (regarding supplier compensation for BM transactions) and P415 are considered concurrently, with P444 aiming to leverage the functionalities developed in P415. The proposal of P465 seeks to amend the provisions concerning credit coverage requirements for virtual transaction parties in the legal text of P415.

## 2.4 The role of virtual trading parties (VTP) in the UK

### Definition and scope of VTP activities

A Virtual Trading Party (VTP) is defined as an aggregator registered with the Supplier Volume Allocation (SVA) for a 30-minute metering system. Its primary purpose is to enable independent aggregators to trade customer flexibility in wholesale markets. VTPs can specifically engage in wholesale market activities,

meaning they may sell "deviation volumes" (reduced demand compared to baseline levels) to day-ahead or intraday markets.




The establishment of VTP roles formalizes and expands the scope of independent aggregators, recognizing their unique contributions to market efficiency and flexibility. By allowing VTPs to focus on wholesale market activities, it creates a specialized category of market participants that promotes greater innovation and efficiency in flexible aggregation and trading.

VTP Business Model

## 2.5 Access requirements and qualification certification process

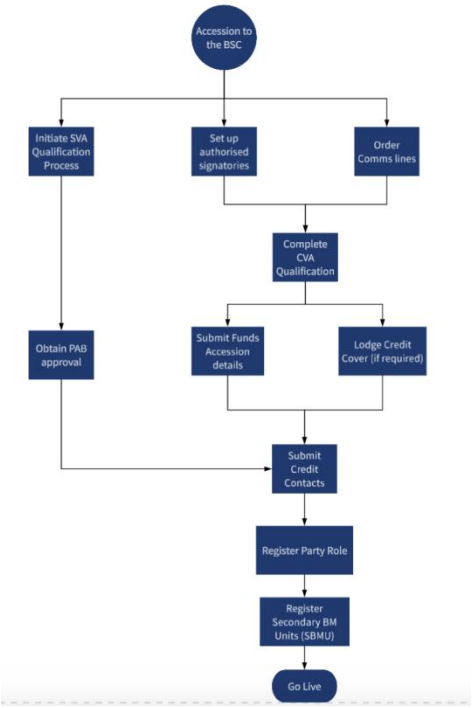
### 2.5.1 Mandatory qualifications

To qualify for VTP, a company needs to be qualified for both **Central Volume Allocation" (CVA)** and **Supplier Volume Allocation (SVA)**,.

- CVA qualification: Proof that VTP is capable of sending and receiving specific communications to and from the BSC agent. Enegen will work with Elexon to perform the required CVA tests.
- SVA qualification: Ensure that VTP understands the obligations and activities of the BSC and can maintain a certain level of performance. The qualification process is designed to ensure that the organization's systems and processes comply with BSC requirements and good practices, and do not create risks for settlement.

### 2.5.2 Detailed steps for market access

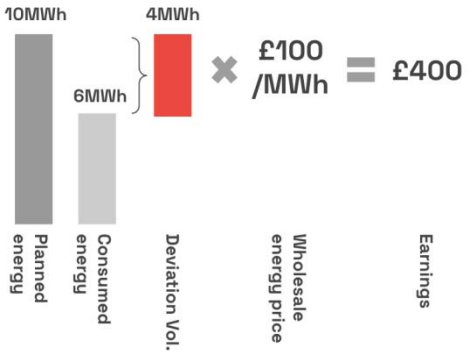
The process begins with the formal registration of intent through a letter of intent. Elexon's market access team then provides access to the Kinnect self-service portal, which provides a guided and simplified market access process including digital forms and data access. Reference link




From：elexon

The fundamental premise of P415: If you're an energy consumer and your supplier lacks flexibility in on-site operations, VTP can directly connect your equipment to participate in wholesale electricity market arbitrage. It's reasonable to assume that these traditionally rigid energy suppliers might enhance their competitive edge as market competition intensifies. This is precisely where P415 brings hope.

Under such market-driven and incentivized conditions, innovative companies like Axle Energy emerge.




Schematic diagram of income From：AXLE

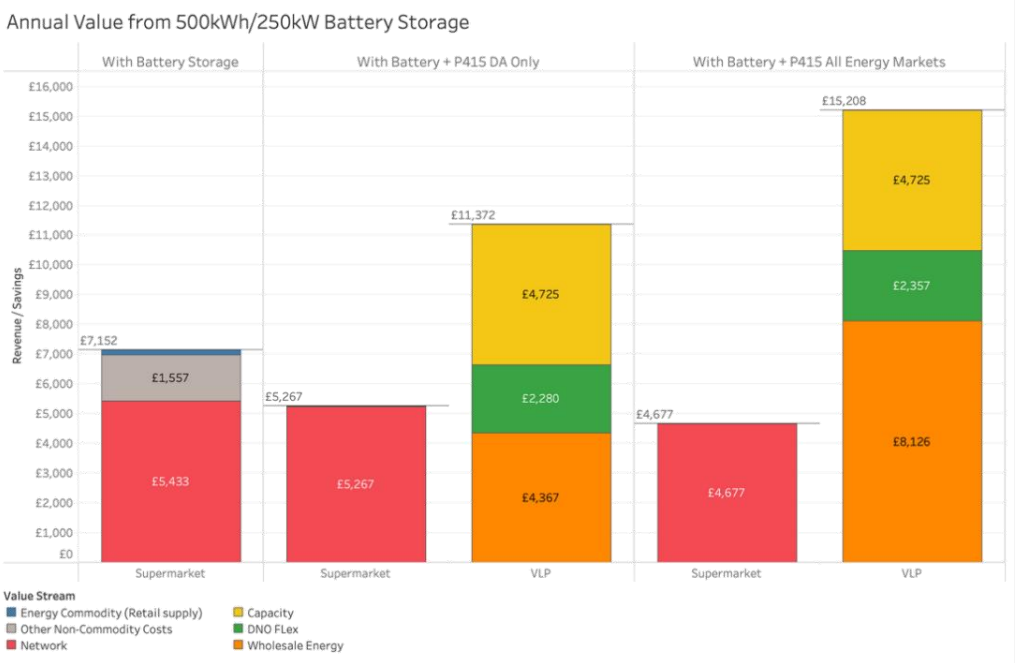
Table 2: UK Virtual Trading Party (VTP) qualification requirements

| Category of request | Specific requirements/standards | Description/Purpose | Involves an organization/process |
|---|---|---|---|
| Mandatory qualifications | Central Volume Allocation (CVA) qualification | Demonstrate the ability of VTP to communicate with BSC agents for specific communications | Elexon performed a CVA test |
| | Supplier Volume Allocation (SVA) qualification | Ensure that VTP understands the obligations and activities of BSC and maintains a certain level of performance | Elexon is responsible for performance assurance activities |
| Market access steps | Registration intention | Complete the formal registration by filling in the letter of intent to start the market access process | The Elexon market access team provides the Kinnect self-service portal |

| | | | |
|---|---|---|---|
| Qualification assessment | Self-evaluation document (SAD) submitted | Demonstrate that the applicant has sound systems, tested software and documented business processes to fulfill VTP obligations | Audit representative Elexon conducted the assessment |
| | Approved by the Performance Assurance Committee (PAB) | Finally, self-assessment is approved to ensure compliance with BSC requirements | Performance Assurance Committee (PAB) |
| Operational requirements | Sound systems and business processes | Ensure that VTP is able to perform its obligations and is properly tested and documented 10 | Internal development and testing by the applicant is subject to audit evaluation |
| Financial obligations | admission | £ 500 to cover the administrative costs of entering the market | Pay to Elexon |
| | Monthly basic fee | £250 + VAT/month, once eligible | Pay to Elexon |
| | credit guarantee | Sufficient collateral is deposited to cover the debt of a trading imbalance that may arise within 29 days after the settlement date | Decided by VTP according to the characteristics of the transaction, subject to the amendment P465 |

### 2.5.3 P415 potential revenue opportunities for flexible assets

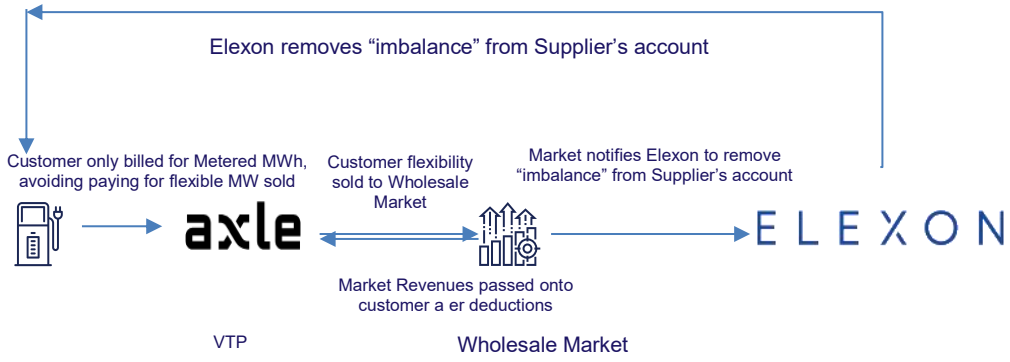
According to the objective value analysis by a third party, it can be seen that the energy storage benefits of P415 can basically double, and the highest energy storage benefits can be more . Detailed link




From：Gridcog

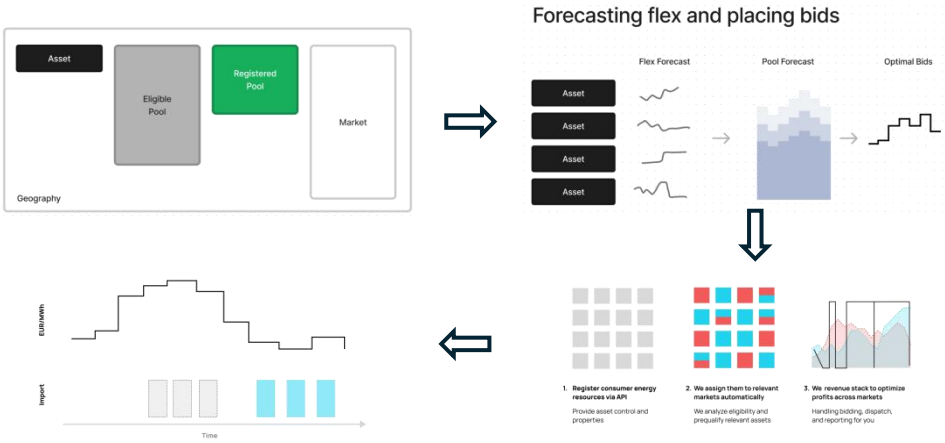
### 2.5.4 Axle Energy: A Benchmark Case for P415

Axle manages the entire process for its partners, such as Pod Point, a P415 participant, from user and asset registration, bidding, scheduling to settlement.




Axle also holds trading licenses for EPEX SPOT and Nord Pool:

- The Axle participates uniquely in both smart metering and asset metering, which relies on the meter to achieve "half an hour settlement", and the asset meter complies with the CoP11 standard;
- Axle Energy has introduced the P483 amendment to address the current 30-minute interval limitation of electricity meters, aiming to better align with the spot market's 5-minute trading frequency. The existing P375 regulation currently restricts the full implementation of P415 for residential consumers. This demonstrates that initial amendments typically require subsequent improvements or supplementary changes to fully achieve their objectives or resolve unforeseen consequences. It also highlights the ongoing evolution of electricity markets, necessitating continuous strategic adjustments and adaptability.




From：AXLE

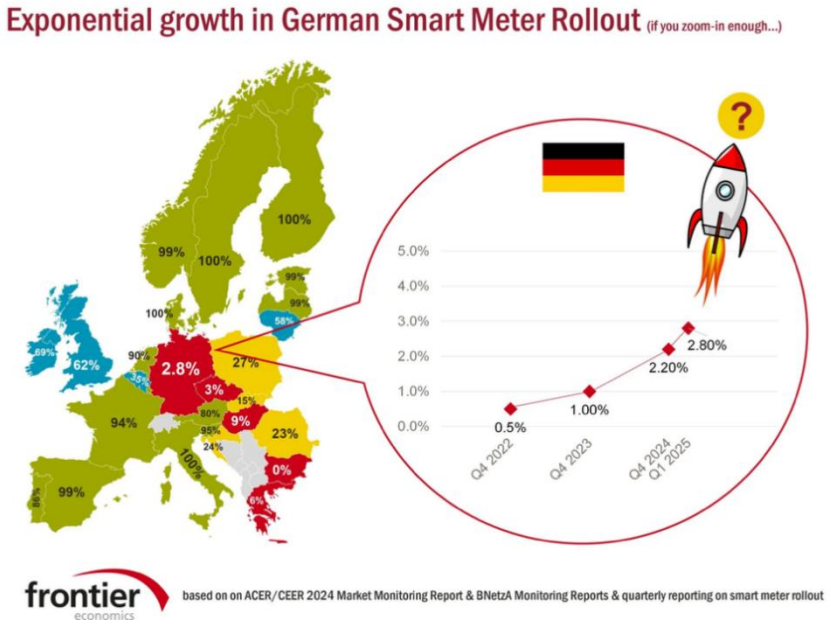
# 3 Introduction to the European BTM power flexibility market

The penetration rates of smart meters in Europe can be used to assess the deployment rates of dynamic pricing and BTM meter flexibility. Germany has the lowest penetration rate at 2.8%. The entry into force of Article 14a of Germany's Energy Industry Act (EnWG) on January 1, 2024, marks the regulatory launch of smart energy implementation. Power suppliers must provide dynamic pricing packages by January 1, 2025.

Core content:

- Controllable consumption devices: Article 14a of the Energy Industry Act (EnWG) allows flexible control of equipment such as heat pumps, energy storage systems and EV charging stations to achieve grid stability and integration of renewable energy.
- Forward-looking: Article 14a EnWG is a step towards a decentralized and smart energy system in which consumption follows production and sustainable behaviour is rewarded.
- Dynamic grid fees: Consumers can reduce grid costs through grid-friendly behaviors, such as shifting electricity consumption to off-peak hours. "Zeitvariable Netzentgelt" (Module 3)
- Technical requirements: Smart meters, control units and optional home energy Hems management systems are essential to take full advantage of the benefits of the law.

Device connection protocol: EEbus has become the mainstream device connection protocol specified in this article.




From：[linkedin]

The EU Regulation EU/2024/1711 establishes dynamic electricity pricing mechanisms, requiring member states to incorporate these provisions into national legislation by January 17,2025. Nordic countries including Finland, Italy, and Spain have demonstrated compliance through implementing dynamic tariff contracts linked to wholesale and spot market prices, reflecting either heightened market readiness or more proactive regulatory measures.

Dynamic pricing contracts have become commonplace in Northern Europe. Norway stands out with 64% of consumers signing spot index contracts, demonstrating strong preference for market-linked pricing. This high penetration rate stems from several national-specific factors: notably, the exceptionally high adoption rates of heat pumps and electric vehicles (EVs). In Spain, approximately 35% of residential consumers have signed dynamic time-of-use contracts, a figure that "far exceeds the European average."

Dynamic pricing enables consumers to better understand and control their energy usage and associated costs. This transparency, particularly under transmission-based dynamic pricing mechanisms, fosters stronger trust between suppliers and consumers. In regions with high adoption of dynamic pricing, the BTM (Behind-the-Meter) post-metering flexible power market has become increasingly vital. The development of flexible assets significantly enhances grid stability and stimulates activity in wholesale markets.

# 4 Major active participants in the VPP European market from 2022 to 2025


Note: (Among them, ABB, Siemens, Schneider, Next Kraftwerke, EnelX, EDF,E.ON and other well-known enterprises are not repeated here)

## 4.1 Octopus Energy & Kraken

Octopus Energy was founded in the UK at the end of 2015, establishing a global reputation through its pioneering role in energy technology and exceptional customer service. The company has now set up branches or joint ventures in over 28 countries worldwide, positioning itself as one of the world's leading VPP (Virtual Power Plant) providers. With a current valuation of $15 billion, Octopus Energy is preparing to spin off Kraken for an IPO listing.

Kraken positions itself as the world's only proven end-to-end operating system for utility digital transformation. It aims to provide an integrated solution that covers the core business processes of energy retailers.

- **End-to-end system integration:** The Kraken platform integrates customer information systems (CIS), billing, customer relationship management (CRM), communications, and potentially metering data management (MDM) functions. Designed specifically for the energy industry, the platform aims to automate critical links in the supply chain.

- **Billing and Payment:** The platform automates billing processes and more. 5. Supports energy retailers in launching innovative smart pricing products. For example, in the Australian market, Kraken can process and manage billing and settlement based on 5-minute intervals.
- **Customer Management and Experience:** Kraken's design philosophy centers on customer-centricity. It has helped Octopus Energy secure industry-leading customer service ratings for eight consecutive years, with claims of achieving five-star customer satisfaction. The platform provides self-service capabilities while leveraging AI tools like "Magic Ink" to assist customer service operations, including drafting over 40% of digital communications and summarizing customer interaction data. Kraken's goal is to help clients reduce service costs by 40%.
- **On-site Service Optimization:** A hallmark of the Kraken platform, it integrates advanced on-site service management capabilities through Mapbox's geospatial technologies (including Matrix API, Directions API, Geocoding API, Isochron API) and an AI-powered optimization engine. This enables intelligent task allocation (e.g., smart meter installation, EV charging station maintenance) based on real-time traffic conditions, engineers' geographical locations, availability, and expertise, while optimizing routes and dynamically adjusting scheduling plans. The platform reportedly supports Octopus Energy's over 3,500 field engineers in executing tens of thousands of tasks daily. Reported efficiency gains include: reducing daily driving time by 300 hours, completing 150,000 additional service appointments annually, increasing urban operation efficiency by 88%, cutting CO2 emissions by 600 tons per year, and significantly improving engineer utilization rates (e.g., from 69% to 78% in Scotland).
- **Product Innovation and Market Launch Speed:** Kraken's agile operating system enables Octopus Energy to consistently deliver market-leading consumer-centric products at rapid deployment. Key implementations include: Intelligent Octopus Go (large-scale smart EV charging packages), Saving Sessions (massive demand response programs), Octopus Tracker, Agile Octopus (dynamic electricity pricing tracking wholesale market or hourly rates), Fan Club (discounted electricity rates powered by local wind power generation), and Zero Bills (integrated home energy solutions designed for net-zero electricity bills).
- **Cross-departmental operational efficiency:** Kraken empowers energy

companies' diverse teams with tailored solutions. Marketing teams can leverage it to identify and respond to market trends; procurement teams gain precise demand forecasting capabilities; field service teams execute engineering tasks while accessing comprehensive customer account information; customer service teams benefit from AI-powered tools.

Kraken's platform offers a broader scope, extending beyond core energy retail operations (billing, CRM, flexibility) to include physical equipment installation, maintenance, and field personnel scheduling. This makes it particularly attractive for vertically integrated utility companies with large field service teams or those managing installation projects for massive smart devices like smart meters, EV charging stations, and heat pumps, as it provides comprehensive end-to-end efficiency improvement potential.

**Technology and architecture**

Kraken platform technology architecture selection:

- **Cloud Native Architecture:** Kraken is a cloud native platform built entirely on Amazon Web Services (AWS). Its scalable, cloud-based architecture supports continuous deployment and ensures the platform's resilience and agility.
- **Hierarchical Python Monolithic Architecture:** Unlike Kaluza's microservices architecture, Kraken's core platform is a monolithic Python application. To manage the complexity of this codebase containing nearly 28,000 modules, Kraken employs a meticulously designed hierarchical structure. This architecture logically divides the codebase into distinct layers: Core-> Territory-> Client. Dependencies are strictly restricted to flow from upper to lower layers (e.g., clients can depend on territory and core layers but not vice versa). This hierarchy is enforced through an automated tool called Import Linter. The design aims to limit the impact radius of changes, preventing modifications targeting specific clients or territories from accidentally affecting other components. It also enables managing differentiated requirements for different client instances within the same codebase ("same yet different").
- **AI/Machine Learning Integration:** AI and ML technologies are deeply integrated into the Kraken platform to automate every link in the energy supply chain. Key applications include: AI-driven on-site service optimization (smart scheduling, route planning), AI-assisted customer service ("Magic Ink" for

drafting emails and summarizing interactions), ML-based demand forecasting (also utilized in KrakenFlex), and optimization algorithms for flexible services (such as smart charging and demand response).

- **Data processing capabilities:** The Kraken platform needs to handle massive amounts of data. For example, the Intelligent Octopus Go product alone processes over 100 million readings daily. The platform provides deep data access through APIs, enabling data analysis and customized customer experiences.
- **Scalability and Adaptability:** Kraken has demonstrated exceptional scalability, currently managing over 60 million customer accounts globally and more than 40 GW of power generation/storage assets. Its cloud-native architecture inherently supports scalability. While operating as a monolithic system, its layered design enhances manageability. Kraken's successful expansion into other utility sectors like water and telecommunications further validates the adaptability of its architecture.
- **Potential Limitations of Architectural Design:** While layered design aims to mitigate issues inherent in monolithic architectures, it still faces fundamental challenges. For instance, implementing control inversion patterns (such as Inversion of Control) for cross-layer interactions may introduce localized code complexity. Moreover, since modifications at higher layers (client/region layers) are easier and riskier to implement, developers might develop specialized code at these levels instead of building common functionalities into core layers. This approach often results in bloated high-level architectures that lack modular simplicity.

**Flexibility and DER management (KrakenFlex)**

The key component of the KrakenFlex platform that handles distributed energy resource (DER) management and provides flexibility services.

- **KrakenFlex:** Developed from Upside Energy, a smart grid software company acquired by Octopus Energy in 2020, KrakenFlex is a cloud-based platform that leverages AI and ML technologies to control and optimize distributed energy resources (DER) for energy supply-demand matching. As part of Kraken's complete ecosystem, KrakenFlex specializes in the integration and management of DER systems.

- **Device Connectivity:** KrakenFlex manages various consumer-side energy devices, including electric vehicles (EVs) and charging stations. It connects a large number of EVs (for example, over 160,000 connected via Intelligent Octopus Go), heat pumps, home photovoltaic systems, and smart thermostats. To expand its connectivity reach, Kraken has partnered with API aggregation service provider Enode to connect more brands of DER through Enode's APIs.
- **Optimization Capabilities:** KrakenFlex employs AI and machine learning algorithms to optimize energy usage based on electricity price signals, grid conditions, and customer preferences. For example, it coordinates EV charging during periods with the lowest electricity prices and most green energy availability. Beyond consumer-side devices, KrakenFlex also optimizes the operation and trading of large-scale power generation and storage assets such as wind farms and grid-level batteries.
- **Demand response and flexibility services:** KrakenFlex supports a variety of flexibility applications:
  - Smart Electricity Pricing: A series of innovative electricity pricing products from Octopus Energy, such as Intelligent Octopus Go (optimized EV charging, aggregating over 700 MW of flexibility), Agile Octopus (based on real-time electricity prices every half hour) and Octopus Tracker (tracking wholesale market prices).
  - Demand Response Program: Successfully operated the large-scale demand response program "Saving Sessions". In this initiative, over 1.5 million users participated by actively reducing electricity consumption during peak hours to earn rewards (paying £5.1 million in incentives during the 2023-24 winter season), cumulatively transferring 2 GWh of electricity. The Kraken platform was able to swiftly send out activity invitations to millions of customers and complete settlements within a short timeframe.
  - Grid balancing services: Kraken aggregates flexible renewable energy resources (DER) – including over 700 MW from Intelligent Octopus Go – and sells them to grid operators through grid balancing mechanisms, thereby generating additional revenue streams. The platform also manages geographically-based pricing zones to incentivize users to reduce peak demand in specific areas.

Octopus Energy has built the complete technology platform through a series of technology capability acquisitions:

Configurable (2020): Smart grid software that integrates heat pumps and electric vehicle charging to expand the New Zealand market.

Upside Energy (2020): Data science and AI expertise to enhance smart grid technology, manage solar panels and EV charging stations, which are eventually integrated into the internal Krakenfield system.

Depsys (2022): Provides energy network operator analysis and real-time monitoring technology.

RED (2022): Heat pump manufacturer, expanding hardware capabilities.

Sennen (2023): Real-time monitoring of large-scale renewable energy projects (wind farm operation and management).

Kwest (2024): Manage heat pump and smart meter installation software.

Jedlix (2024): A leading provider of smart EV charging solutions to enhance Kraken's flexible demand management capabilities.

Energetiq (2024): Australian energy bill reconciliation software company, enhancing the market reconciliation capability.

Invest in renewable energy: Acquire Octopus Renewables, invest in wind and solar projects, and support the Xlinks undersea cable project

## 4.2 OVO Energy&Kaluza

Founded in 2019, Kaluza is an internal static technology company of OVO Energy to address the urgent growth of traditional energy IT systems

Kaluza maintains close ties with OVO Energy. The Kaluza platform serves as the core technological backbone for OVO Energy's operations, with senior executives including founder Stephen Fitzpatrick and chairman Justin King also serving on Kaluza's advisory board. As part of the OVO Group, Kaluza has been actively expanding external collaborations beyond its core services. In 2024, Australian energy giant AGL Energy announced a $150 million acquisition of Kaluza's 20% stake, valuing the platform at approximately $500 million. The deal includes plans to migrate over 4 million customers to Kaluza's system. Additionally, Kaluza partnered with Mitsubishi Corporation in Japan to establish Kaluza Japan, introducing its

technology to the Japanese market.

The Kaluza system is designed to provide an end-to-end integrated solution that replaces the complex technology stack of various independent systems (such as MDM, CIS, CRM, VPP, etc.) in the traditional energy retail sector and modernizes the so-called "meter-to-cash" (meter-to-cash) process.

- **Billing and Payment:** A core competency of the platform lies in automating billing processes through real-time data streams. It handles complex billing logic, such as OVO's "Charge Anytime" plan that separates charging costs for electric vehicles from household electricity usage while offering a specific low rate. The platform processes data with minute-level precision, minimizing manual intervention to ultimately generate streamlined and unified bills for customers.
- **Customer Management and Experience:** Kaluza emphasizes empowering customers through intuitive digital experiences. It clearly displays real-time energy usage data and relevant insights, helping customers understand their energy consumption and carbon footprint. The platform offers seamless self-service features, aiming to significantly increase customer self-service resolution rates (OVO's digital center claims a 80% self-service resolution rate, while Kaluza's official website states a 50% increase in customer self-service usage). By enhancing transparency and ease of use, Kaluza seeks to build customer trust, improve satisfaction and lifetime value, and reports a 34-point increase in Net Promoter Score (NPS) among millions of its customers.
- **Customer Service Tools and Efficiency:** To enhance the efficiency and quality of customer service centers, Kaluza has equipped agents with AI-powered "co-pilots". These tools combine simplified interfaces (claiming to reduce the number of systems agents need to navigate from 12 to 4 while providing a single intuitive interface) to help agents quickly understand customer issues and deliver personalized solutions. Reports indicate this has increased first-contact resolution rates (FCR) by 40%-44% and reduced average handling time (AHT) by over 30%. AI prompts also assist in continuously improving account health. The ultimate goal is to free agents from daily billing tasks, transforming them into energy consultants who promote low-carbon solutions to customers. The platform aims to more than double the number of customers each agent can serve.
- **Product Innovation and Market Launch Speed:** The Kaluza platform design empowers energy retailers to rapidly develop and launch new energy products

and services, particularly innovative packages centered around low-carbon technologies like electric vehicles, solar power, and battery storage. Its agile, cost-effective, and low-risk market deployment tools are said to reduce product launch timelines to just a few days. Notable examples include OVO, the early EV Everywhere package; Charge Anytime charging program integrating billing and smart optimization; Battery Boost for PV + Storage customers; Australia's OVO Free 3 (three hours of daily electricity free) and EV Control smart charging plan; as well as V2G/V2X projects collaborating with multiple automakers.

A defining feature of the Kaluza platform is its seamless integration of billing, customer management, and flexible services (such as DER optimization) into a single real-time system—a departure from traditional architectures where these functions were typically handled by separate, disconnected systems. Furthermore, its application of AI technology in customer service assistance demonstrates that the platform's strategy not only drives digital self-service but also aims to enhance the efficiency and value of human support through technological innovation, directing customer interactions toward more complex inquiries and value-added services.

The technical foundation of the Kaluza platform is its modern, future-oriented architecture design.

- Kaluza is a fully managed Software as a Service (SaaS) platform with cloud-native architecture. This means the platform is deployed in the cloud, with Kaluza handling infrastructure maintenance, scaling, and updates. It leverages mainstream public cloud platforms such as AWS and Google Cloud.
- Real-time Data Engine and Streaming Architecture: The platform's core architecture revolves around a real-time data engine. Utilizing Apache Kafka as its core technology, this engine delivers high-throughput, event-driven data stream processing. Real-time information from industry systems, customers, and smart devices—including smart meters, EV charging stations, and energy storage batteries—automatically updates the platform's data. This architecture breaks away from traditional batch processing models, enabling real-time data handling, analysis, and response capabilities. It provides the foundation for real-time billing, customer insights, and flexible services.
- Microservices Architecture: Kaluza employs a microservices architecture. In this framework, platform functionalities are decomposed into independent services that share a common data model to ensure consistency in data structures, while

maintaining decoupling between services. This design enables the platform to:

- Independent scaling: Individual services can be scaled horizontally or vertically as needed.
- Independent release: Individual services can be updated and deployed independently, speeding up the launch of new features.
- Regional adaptability: It is easier to make local adjustments according to the specific needs of different countries or regions.
- Fault isolation: The failure of a single service does not cause the whole system to fail, improving the resilience of the platform.
- Security Isolation: Helps isolate security threats and prevent their spread throughout the system. Kaluza's design aims to avoid the common bottlenecks and cascading failures found in monolithic architectures (Monolithic Architecture) and synchronous microservices (Synchronous Microservices) architectures.

AI/ML Integration: AI/ML technologies are extensively applied across all aspects of the platform. For instance, they enable automated operational processes (e.g., billing), provide intelligent support for customer service teams, drive optimization algorithms for DER systems (including smart charging and battery management), conduct energy forecasting, and collaborate with Mesh-AI to explore advanced analytics applications such as customer churn prediction.

## 4.3 Tibber

Tibber's smart energy solutions include virtual power plant (VPP) services for residential battery users and electric vehicles, along with its Grid Rewards program launched in the Netherlands, Sweden, and Norway. The company's go-e Power-up app automatically charges EVs during off-peak hours when electricity prices are lower. By integrating smart home systems and real-time data analytics, Tibber empowers users to reduce both costs and carbon emissions.

Tibber's flagship product is an AI-powered smart energy solution specifically designed for residential architecture. The platform provides real-time household energy consumption data and employs AI-driven algorithms to optimize electricity procurement, ensuring customers secure the most cost-effective power deals. A defining feature of Tibber's model is its software-centric approach over proprietary

hardware ownership, seamlessly integrating with third-party devices like thermostats and smart heat pumps for comprehensive energy consumption analytics. The company's core mission is to empower every household with simple yet affordable sustainable energy solutions through real-time data insights and precise control. It offers hourly billing plans with a 100% commitment to fossil fuel-free energy. Additionally, the Tibber Store serves as a retail hub for smart home devices—including EV charging stations and air-source heat pumps—complementing its software-driven services. This hardware-agnostic strategy enhances ecosystem flexibility by eliminating vendor lock-in risks, accelerating market adoption. As a software-first energy coordinator, Tibber enables intelligent energy management across diverse installed hardware systems.

Positioning itself as "the world's first fully digital energy company and platform", Tibber aims to revolutionize the energy industry. Its core competitive advantage lies in an innovative business model: Unlike traditional utilities that profit from increased energy consumption, Tibber provides renewable energy at purchase price while offering smart technologies to empower customers to proactively control and reduce energy usage. This unique approach fundamentally aligns the incentives of both customers and companies with energy efficiency and sustainability goals.

Tibber's innovative products have a number of compelling advantages, merit：

- Cost savings and optimization: The company's AI-powered optimization and dynamic pricing are designed to help customers slash their energy bills and overall energy consumption. For example, smart charging of electric vehicles through Tibber can save up to 50% on charging costs.
- Green Energy Focus: Tibber is committed to providing 100% fossil free energy and actively helping users shift their consumption to more environmentally friendly and affordable times to meet environmental goals.
- Digital First and user-friendly: The company has been praised for its "outstanding application" that provides a positive user experience (UI/UX), effective support, and real-time insight and control over energy use.
- Flexibility: The power agreement is characterized by no binding period, providing customers with greater freedom.

Open ecosystem: Tibber's vendor-agnostic EMS and its ability to integrate with a variety of third-party smart home devices promote an open and flexible energy

management ecosystem.

Tibber has strategically built key partnerships to expand its ecosystem and enhance its service offerings:

- Kiwigrid: Tibber is partnering with Germany's energy IoT leader Kiwigrid to build a new installer ecosystem. The collaboration will provide integrated energy systems including hardware, Energy Management System (EMS) platforms, smart meters, and dynamic pricing mechanisms, along with a "360-degree EMS" solution that optimizes energy efficiency from households to the market.
- Wallbox: Established an interoperability partnership with leading electric vehicle charging provider Wallbox, enabling EV drivers in the Netherlands and Sweden to use the Tibber app for smart charging and automatically start charging sessions when energy prices are lowest.
- Kostal: The partnership with inverter manufacturer Kostal aims to enable intelligent control and charging of various home storage systems.
- EEBUS e.V.: Tibber is a member of EEBUS e.V., which is the globally recognized German-led energy equipment communication standard, highlighting its commitment to ecosystem openness and interoperability.

Futurehome: Integration with Futurehome allows heating devices and temperature sensors to be controlled via the Tibber application.

As a private company, Tibber's exact market value remains undisclosed. However, it has secured a massive funding round of $177 million to $180 million and successfully completed a $100 million Series C financing, qualifying as a unicorn. Its investor portfolio is diverse and robust, including Balderton Capital, Summa Equity, Eight Roads Ventures, Nordea Bank, Altor Equity Partners, Eviny Ventures, and Schibsted Ventures. This demonstrates that venture capital firms and strategic corporate investors are confident in Tibber's disruptive business model and its potential to make a significant impact on the energy transition.

## 4.4 1KOMMA5°

1KOMMA5° has quickly become a major player in the new energy sector in Europe, focusing on integrated home energy solutions.

Headquartered in Hamburg, Germany, 1KOMMA5° was founded in 2021. Since

its establishment, the company has raised approximately 400 million euros in equity financing and secured an additional 150 million euros during its pre-IPO funding round in January 2025. With robust financial health, ample equity capital, strong profitability, and no debt obligations, the company demonstrates solid financial management and strong investor confidence, positioning it as a unicorn enterprise. Its major investors include Eurazeo, G2VP, eCAPITAL, BNP Paribas, Deutsche Bank, and Baden-Württembergische Bank.

1KOMMA5° provides a complete set of smart energy solutions, committed to achieving zero emission living in the home. Its main products and services include:

- Solar Modules and Power Generation Systems: The company provides all-black solar modules manufactured using the latest TOPCon technology, designed to achieve optimal energy production and longevity. It also offers proprietary hardware such as PowerHarvester batteries
- Heartbeat AI Management System: This proprietary AI-driven software serves as the core of its product ecosystem. By integrating with dynamic electricity pricing systems, it optimizes energy consumption during low-cost power periods to enable intelligent use of clean energy. Designed for compatibility with various inverters, charging solutions, and heat pumps, Heartbeat AI enhances its versatility and delivers greater value to customers.
- Virtual Power Plant (VPP) capabilities: Heartbeat AI allows connected systems to operate as virtual power plants, pooling and connecting customers' photovoltaic, electricity storage, heat pumps and charging points to the energy market to improve profitability.
- Heat pumps: 1KOMMA5° Heat pumps as part of their energy efficient home solutions emphasize their ability to reduce energy costs, increase home value and provide an environmentally friendly alternative to heating.
- Power storage: The company provides battery solutions that allow customers to use their own electricity even when solar power is not available.
- Electric car charging stations: These are designed to make it easier to use solar energy to charge electric cars.
- One-stop service: 1KOMMA5° Position itself as a one-stop convenience store for the purchase and installation of solar systems, charging stations and heat pumps, providing comprehensive services from consultation to installation and

maintenance.

Open platform strategy: The company plans to open the Heartbeat platform to all customers who own compatible heat pumps, heat storage units or wall-mounted boxes, and all manufacturers will have access.

## 4.5 Enpal

Enpal, a German private company headquartered in Berlin, specializes in providing solar energy solutions for homeowners. The company has delivered solar power services to over 90,000 German households. In April 2025, Enpal successfully completed a new round of financing totaling 110 million euros, with major investors including TPG, Equitix, Keppel Infrastructure Trust, VAERING, and Activate Capital Partners, securing robust financial backing.

Main products and services:

Enpal provides "integrated" solar solutions designed to make it easy and convenient for homeowners to use renewable energy. Its main products and services include:

- Solar power system: enables homeowners to produce their own electricity. Reduces the cost of electricity and increases the proportion of green electricity.
- Enpal battery (energy storage): Used to store self-generated solar energy for later use, enhancing energy independence.
- Enpal Wall-mounted BOX: An electric vehicle charger that can be used to charge an electric vehicle using solar energy.
- Enpal heat pumps: High-efficiency heat pumps for home heating, reducing dependence on fossil fuels.
- Enpal application: A component of its five-piece suite that may be used to monitor and manage solar energy systems.
- Flexible payment options: Customers can choose to buy or rent a solar system and offer an "€0 deposit" option.
- Guaranteed feed-in tariff: Double the feed-in tariff for surplus solar power over two years, at 16.4 cents per kilowatt-hour.

Enpal, through its stake in Flexa and alignment with Germany's dynamic electricity pricing policy, announced its official entry into the VPP sector in

November 2024. Flexa's VPP will leverage arbitrage opportunities through ultra-short-term trading. The network will focus on continuous-day market transactions within a 5-minute pricing interval. Enpal has also established deep collaboration with Entrix in energy storage and market linkage services.

## 4.6 ACCURE Battery Intelligence

ACCURE Battery Intelligence, a software company specializing in predictive battery analytics headquartered in Aachen, Germany, has secured substantial funding with four rounds of financing totaling $34.5 million. Its most recent round, the Series B funding round on February 12,2025, amounted to $16 million.

ACCURE Battery Intelligence delivers an AI-powered predictive analytics platform for battery systems, designed to optimize performance and safety across industries. Its flagship solutions include the Performance Manager, which provides insights into available energy reserves, weak modules, and system imbalances to guide efficient operations and maximize performance and availability. The Warranty Manager tracks Key Performance Indicators (KPIs) for Battery Energy Storage Systems (BESS), such as capacity, cycle life, and round-trip efficiency (RTE), to detect violations and validate claims. Digital commissioning services identify and resolve issues before BESS deployment, addressing potential oversights during field commissioning. Additionally, ACCURE launched PCS Analytics™ and Tasks™ in May 2025, tools that extend BESS uptime while streamlining operations and maintenance (O&M) processes. The competitive edge lies in its AI-driven predictive analytics, which leverages machine learning and cloud computing to transform complex battery data into actionable insights, providing weeks of lead time to resolve critical issues.

ACCURE claims to have "the most deployed and trusted predictive battery analytics platform in the world", supporting more than 15 GWh of real-time assets. This shows that professional software solutions have a strong market position.

ACCURE positions itself as "the global leader in AI-powered battery safety and performance solutions". Its core value proposition is "reducing risks, improving performance, and protecting investments throughout the battery journey". The company aims to simplify battery data complexity, making batteries safer, more reliable, and more sustainable.

## 4.7 Opoura

Opoura delivers comprehensive customized solutions for renewable energy applications. Its flagship SCADA software enables real-time monitoring, analytics, reporting, and control of renewable energy parks and portfolios. This solution ensures operational autonomy, supports hybrid portfolio management, optimizes asset lifecycle performance, and facilitates cross-brand data integration. The company also provides power plant control solutions featuring grid-compliant automation controllers for wind farms, solar PV systems, Battery Storing Energy Systems (BESS), PtX (Power-to-X) technologies, and hybrid configurations. For energy trading, Opoura offers flexible and future-ready software tailored for renewable portfolio owners and balancing responsibility parties (BRPs). Beyond software, the company delivers hardware and engineering services including SCADA system outsourcing, cabinet and server manufacturing covering full lifecycle from design to installation. Additionally, Opoura provides consulting services in power engineering and operational technology, along with specialized expertise to optimize power plant performance.

OPURA's development focuses on an independent, AI-powered battery analytics platform ACCURE, which directly addresses the inherent technical and financial risks in expanding complex battery systems, effectively transforming key pain points into high-value services. The company specializes in "predictive analytics" and "AI-based" solutions that directly tackle challenges posed by the complexity of battery chemistry, supplier diversity, and massive data volumes—challenges that manual or traditional monitoring struggles to handle. AI-driven predictive analytics are crucial for managing these complexities at scale, converting raw data into actionable intelligence that balances safety and profitability. Their value proposition is rooted in the belief that "deep insights from battery data can create safer, more profitable systems," with ACCURE dedicated to "extracting clear, timely intelligence from noise." This emphasis on data-driven clarity is vital for long-term asset management and investor confidence, as the ability to "verify annual capacity tests and gain deep insights into battery degradation" is invaluable.

Opura operates within a robust partner ecosystem serving diverse clients across the energy sector. Its client base includes Independent Power Producers (IPPs), Original Equipment Manufacturers (OEMs), Engineering, Procurement and

Construction (EPC) firms, utility companies, traders, and Transmission System Operators (TSOs). Notable clients include EDF, Uniper, RES, and EDP.

## 4.8 TWAICE

TWAICE is a battery data analytics company based in Munich, Germany. As of the end of 2023, TWAICE has raised a total of $75 million through six rounds of funding.

TWAICE provides a battery data analysis and management platform based on digital twin, providing a combination of hardware and software systems to analyze and manage battery data. Its main products include

Performance management: It provides insights into available energy, weak modules, and imbalances to guide effective operations and maximize performance and availability.

Warranty management: Help track battery Energy Storage System (BESS) warranty Key Performance Indicators (KPIs), such as capacity, cycle and round-trip efficiency (RTE), to detect violations and verify claims.

Digital commissioning: This service is designed to identify and resolve issues prior to the deployment of BESS, addressing issues that may be missed during field commissioning.

Business strategy planner: enables users to create scenarios and perform sensitivity analysis for different use cases to help identify the best operational strategies to maximize profits.

Penalty risk assessment: This tool makes it easier to understand and take action on the charging state (SoC) issue, thereby helping operators avoid costly fines.

TWAICE positions itself as a "green tech company" and "transformational climate technology leader", committed to accelerating the transition to green energy and emission-free mobility. Its core value proposition is to provide policymakers with accurate data to develop, manage, and optimize batteries, ensuring safety, performance, and lifetime value.

The competitive advantage is built on several key strengths. By leveraging digital twin technology to integrate field data with physical and data-driven battery models, it provides precise analysis and predictions of the "health status" of each

energy storage device. TWAICE possesses profound expertise in batteries, stemming from a research project at the Technical University of Munich, where its team brings over 300 years of collective battery experience. The company focuses on:

Predictive analytics empowers organizations to anticipate emerging demands and deliver innovative solutions with immediate practical value, while detecting thermal, resistive, and self-discharge anomalies before triggering alerts. TWAICE provides a holistic system view by integrating diverse data sources—including power conversion systems, substations, and market interfaces—into a cohesive platform for comprehensive insights. A key value proposition lies in its explicit objectives: maximizing revenue, reducing costs, and safeguarding long-term asset profitability through KPIs like "Available and Recoverable Energy" and monitoring features such as Return on Travel (RTE).

TWAICE's products offer multiple advantages, including enhanced availability and performance, early detection of safety issues, smarter data-driven operations, and robust tracking of warranties and guarantees. The software accelerates development timelines for Original Equipment Manufacturers (OEMs)while reducing operational costs for electric bus fleets. It also provides a holistic view of the entire battery system. However, the company faces inherent challenges related to battery data complexity, as data from different suppliers varies significantly in granularity and sampling frequency, making comprehensive analysis difficult. Managing such massive datasets requires substantial storage costs and computational power. Additionally, growing public awareness about batteries—including debates over their environmental impacts—may pose additional challenges. Operational issues like battery system imbalance could disrupt scheduled operations or lead to penalties.

TWAICE is recognized as the "global battery analysis leader" and has analyzed over 5 GWh of BESS with a portfolio of more than 68 projects.

TWAICE is dedicated to maximizing profitability and reducing risks for battery asset managers. By implementing features like warranty tracking and penalty risk assessment, the company transforms battery deployment into a critical financial driver that goes beyond technical specifications. Its products, including the "Warranty Manager" and "Penalty Risk Assessment" solutions, directly address key financial risks in the energy storage sector. In this capital-intensive industry, financial risks—including warranty violations, operational penalties, and unexpected performance declines—can significantly impact project viability. TWAICE's software effectively

mitigates these financial pain points, making battery investments safer, more reliable, and more attractive.

TWAICE collaborates with a diverse partner ecosystem to serve global clients, including leading battery operators and innovative enterprises. Its client portfolio spans multiple sectors such as utilities (Verbund, MN8, ju: niz energy, Global Power Generation, Apex Clean Energy, EDP Renewables), automotive OEMs (BMW, Mercedes-Benz, Audi), heavy-duty vehicle manufacturers (Epiroc), and energy storage integrators/asset owners (BayWa r.e., InterEnergy, Second Foundation, BW ESS, Vispiron, Enpal).

In terms of partnerships, TWAICE has established a joint venture with Germany's TUV Rheinland called Battery Quick Check GmbH. It also collaborates with The Mobility House and integrates with Modo Energy's financial platform. 97 further strategic alliances include collaborations with renovation specialist Pepper Motion and semiconductor company Analog Devices.

## 4.9 Tado°

Tado° GmbH, founded in September 2011 in Munich, Germany, has raised a total of $245 million through 10 funding rounds. Its most recent Series E financing, completed on March 18,2025, secured $32.7 million. Key investors include Target Partners, Shortcut Ventures, E.ON, Amazon, Total Energy Ventures, Energy Innovation Capital, Inven Capital, European Investment Bank, Next47, and IP Group.

The market penetration of Tado° products is remarkably high, with reported installations exceeding one million units. As of February 2022, the company announced that its smart thermostat sales in Europe had surpassed 2 million units, doubling within just two years—a clear indication of rapid adoption. By serving nearly one million households across Europe, Tado° has solidified its position as a leading force in smart heating and control systems for European homes.

Tado°'s key partnerships with major smart home platforms including Google Assistant, Amazon Alexa, Apple HomeKit, and Matter demonstrate its commitment to comprehensive system integration. The company has also established strategic collaborations with energy and installation firms, particularly in heat pump optimization, through a partnership with Panasonic. Its primary customer base consists of homeowners and residents seeking intelligent climate management for

heating and cooling systems. The products are distributed through over 30 utility companies and numerous leading retailers.

## 4.10 Flower

Flower was founded in 2020. Headquartered in Stockholm, Sweden, with a total of 130 employees, it has raised a total of $109 million in three rounds of financing. The latest round of financing was raised on November 1, 2024, raising $21.7 million led by Northzone

Flower provides cutting-edge software for forecasting, optimizing, and trading to enable energy assets to actively contribute to a stable energy system. This capability is critical to the operation of virtual power plants.

The main products and services include:

- Energy storage solutions: Provide comprehensive solutions for grid scale battery storage systems (BESS) and residential applications.
- Grid balancing services: Optimize the participation of asset owners in the energy market, enhance grid resilience and create additional revenue streams for asset owners.
- Renewable energy integration: Provide AI-driven energy optimization solutions tailored for solar and wind production.
- Demand response: A mechanism that encourages energy consumers to adjust their consumption patterns according to grid demand.
- Support services: With official approval from the Swedish Transmission System Operator (Svenska kraftnat), these essential services are provided for the maintenance of grid stability.

Flower positions itself as a key contributor to "unlocking the potential of tomorrow" through its focus on "flexible power." Its competitive edge lies in advanced software and statistical models, AI-driven optimization capabilities, and crucially, its approval from national Transmission System Operators (TSOs). This regulatory endorsement from transmission system operators establishes robust regulatory and trust barriers, validating the reliability and effectiveness of its solutions. The company aims to stabilize energy systems by enhancing predictability and flexibility. Its products offer advantages including increased participation of flexible

assets, enhanced grid resilience, and additional revenue streams for asset owners. They also support increased investment in renewable energy while reducing reliance on new infrastructure. Although specific disadvantages remain unspecified, potential challenges may include the inherent complexity of integrating diversified energy assets or intense competition in rapidly evolving markets. Beyond revenue growth and customer demographics, the product penetration rate remains unclear.

Flower serves a diverse client base, including energy consumers (through green baseload and demand response services), energy storage clients (targeting grid-scale BESS and residential solutions), and energy producers (solar and wind power customers). Notable clients and partners include Ellevio, one of Sweden's largest distribution system operators (DSOs), Monta (related to electric vehicle chargers), and Kungalv Municipality. Headquartered in Stockholm, Sweden, 23Flower primarily operates as a virtual power plant operator in Sweden.

The collaboration with Ellevio, a leading distribution system operator (DSO), and the formal approval from Sweden's transmission system operator Svenska kraftnat serve as critical validation of Flower's technology and reliability. The transmission system operator's endorsement demonstrates that Flower's solution meets the stringent operational and safety standards required for State Grid participation, creating a significant competitive advantage for new market entrants while establishing high entry barriers. Partnering with Ellevio validates the practical application and value of Flower's solutions in managing critical energy infrastructure, paving the way for broader adoption and expansion across the energy sector.

## 4.11 GridBeyond

Headquartered in London, UK, GridBeyond commenced commercial operations in 2010. The company has secured 10 funding rounds totaling over $100 million, with its most recent Series C financing of $55.3 million on April 16,2024, led by Alantra. Its main competitors include Autogrid, Voltus, and Franklin Energy.

The company provides a full range of services:

- For asset owners (front end of the meter-FTM): includes battery storage, co-location of battery storage and renewable energy, gas peaking and cogeneration, power purchase agreements and hedging, renewable energy optimization (wind, solar and hydro), and various software solutions.

- For energy users (BTM): includes carbon management, corporate PPA and hedging, demand side response, electric vehicles and fleet management, funding for battery storage, microgrids and solar, net zero path, process optimizers, software solutions and smart energy management systems.

GridBeyond positions itself as a "repeatedly awarded AI-powered energy service provider" and a global leader in grid edge asset management. Its competitive advantage stems from its advanced AI-driven platform and pioneering initiatives (such as developing the world's first hybrid battery and demand network), which have proven effective in creating new revenue streams and cost savings for asset owners and energy consumers while enhancing resilience and price volatility management. The company offers comprehensive solutions covering both FTM (First-Mover) and BTM assets, demonstrating broad market appeal. While specific weaknesses remain unaddressed, integrating diverse distributed energy resources (DER) and navigating complex regulatory environments across multiple international markets may present ongoing challenges. Currently operating a load portfolio exceeding 2.6 G watts, the company's target market penetration remains unclear.

GridBeyond has demonstrated an aggressive global expansion strategy, entering new markets including the United States (2020), Japan (2021), and Australia (2022), with plans to expand into other U.S. markets (CAISO, MISO, SPP) by 2023. The company has also diversified its service offerings, launching electric vehicle optimization solutions and SaaS services in 2023.

## 4.12 Piclo

Piclo operates an end-to-end marketplace that connects "flexible energy sellers" (such as electric vehicle and battery operators, along with distributed energy (DER) aggregators) with "flexible energy buyers" (including utilities, system operators, and energy retailers). Its core platform, Piclo Flex, supports the entire process of procuring, operating, and settling flexible energy services for system operators (SOs).

Key aspects of its business model include:

- Market as a Service: Piclo provides cloud-based platform and integrated service products that allow subscription of functional modules based on their flexibility needs and required degree of automation.
- Competitive auction: The platform facilitates competitive auctions for Flex

suppliers to bid for contracts, ensuring the best price.

- End-to-end solution: Piclo Flex covers the entire procurement process (creating competitions, screening participants, accepting bids), operations (monitoring asset availability, scheduling instructions) and settlement (post-scheduling measurement, verification, invoicing).
- Piclo exchange: This is a secondary market where users can buy and sell existing flexibility contracts, the first active market being GB's capacity market.
- Revenue: revenue from transactions facilitated by the platform, subscription revenue from platform modules, and potential market participation fees, customer support fees, and process automation fees (procurement and operations API).

Global Impact: Piclo operates across the United States, Europe (UK, Ireland, Italy, Portugal, Lithuania), and Australia. Currently, over 250 flexible power retailers including Octopus Energy, Enel X, and Sunrun have registered more than 350,000 assets, with the platform's flexible power capacity exceeding 30 gigawatts. Key buyers on Piclo's platform include NESO, National Grid, SP Energy Networks, Northern Powergrid, E-Distribuzione, E-Redes, and Powercor.

## 4.13 Cyber Grid

Cyber Grid is an Austrian energy technology company founded in 2010. On March 11,2022, Cyber Grid was acquired by EVN Group, one of the largest energy service providers in Europe. It has about 30 employees

Cyber Grid delivers the Cyber Noc integrated virtual power plant (VPP) solution, designed to enable seamless flexibility management and energy asset monetization. This cloud-based technology integrates diverse distributed energy resources—including renewable energy sources, battery storage systems (BESS), small hydropower stations, and electric vehicles (EVs)—into a unified large-scale entity that participates in energy markets.

Cyber Grid positions itself as a "full-spectrum solutions provider" dedicated to transforming energy flexibility into profits and advancing sustainable, decentralized grid development. The company's overarching vision is to make all generated, stored, and consumed energy renewable and flexible. Its strategic focus is to maximize customer profitability while accelerating broader energy transition efforts.

The company's competitive edge stems from multiple strengths. Its proprietary VPP software Cyber Noc delivers cutting-edge solutions for managing and monetizing energy flexibility. A defining feature is its "multi-market and free bidding" capability, which seamlessly connects assets to various energy markets including the Federal Credit Reserve (FCR), Alternative Federal Reserve (aFRR), and Medium Federal Reserve (mFRR) markets, as well as re-scheduling services and both day-ahead and intraday markets. This functionality enables capitalization through "free bidding," potentially generating up to 30% additional revenue for clients. Cyber Grid promises rapid ROI and deployment, unlocking flexibility potential within 3-6 months.

The company provides a comprehensive service model encompassing Flexibility as a Service (FaaS), Software as a Service (SaaS), consulting, and R&D services. Its technology plays a vital role in accelerating the energy transition by enhancing the integration efficiency of existing power generation resources, energy storage systems, and renewable energy. Cyber Grid offers expert supervision and support, guiding clients through the entire process from initial consultation to seamless technical market integration. Cyber Noc has been recognized in the "Smart Integrated Energy" category of the 2024 Smarter E Awards, further demonstrating its innovative technology.

## 4.14 Kiwigrid

Headquartered in Dresden, Germany, Kiwigrid was founded in 2011 and currently employs 135 staff. The company has secured undisclosed funding through three rounds of financing, with investors including Innogy Venture Capital, HTGF, Aqton, Venture Out, LG, and Future Energy Ventures. Classified as a Series C entity, Kiwigrid has begun generating revenue. The involvement of strategic investors such as Germany's leading energy firm Innogy and global electronics giant LG holds significant strategic importance.

Kiwigrid is an energy ecosystem platform operator dedicated to optimizing energy systems and providing customers with efficient renewable energy management. As an IoT platform, it integrates various components within smart grids. At its core lies KiwiOS, an energy service platform that analyzes, visualizes, and optimizes energy flows. Building on KiwiOS, the company offers turnkey solutions tailored for two rapidly expanding market segments: home energy management and enterprise smart charging solutions. Their product suite includes specialized tools such as

Energy-Manager Rail (a communication protocol), Energy Service Gateway (for collecting smart meter data), Energy Manager Wall (for home energy management), and Installer Center (energy applications for installation teams and service personnel).

Kiwigrid positions itself as a Platform as a Service (PaaS) and Software as a Service (SaaS) provider, dedicated to driving industry convergence in decentralized energy. The company aims to empower businesses to effectively manage renewable energy and electric mobility solutions while achieving profitability. By integrating diverse distributed energy assets, the platform seeks to create a seamless experience for users.

Kiwigrid's competitive edge stems from multiple dimensions. Its integrated IoT platform KiwiOS seamlessly connects distributed energy producers, storage systems, smart metering solutions, consumer devices, and EV charging infrastructure. The flexible SaaS/PaaS model ensures scalability and adaptability. With decades of expertise in deploying tens of thousands of devices across over 100 successful projects, Kiwigrid has demonstrated strategic foresight by adopting Google Cloud and Kubernetes Engine as early as 2017. This technological commitment delivers exceptional deployment flexibility—reducing delivery cycles from days to hours—and enhances platform stability for rapid product launches. Such agility proves crucial in the fast-evolving decentralized energy market, enabling Kiwigrid to outpace competitors relying on legacy infrastructure. The company holds two patents, including "Method for Controlling Energy Distribution Systems," and has forged strategic partnerships like the Energy Systems Alliance with Solarwatt and Tibber to build a robust installer ecosystem.

Kiwigrid's products offer multiple advantages that help customers reduce energy costs, maximize self-sufficiency, and lower carbon footprints. For clients, the platform shortens time-to-market and reduces investment costs while enhancing transparency and control over energy production and consumption. Even without solar panels, the system optimizes energy systems through battery optimization with dynamic electricity pricing and Bosch heat pump cost control. Despite these benefits, the inherent complexity of IoT and energy systems presents ongoing challenges. Integrating diverse renewable energy sources and further decentralizing power, thermal, and transportation systems remains a complex task. Balancing user experience with economic benefits also poses challenges, much like managing Kubernetes logs.

Kiwigrid's key partners and clients include energy suppliers, installers such as Solarwatt and Tibber, along with technical collaborators like Bosch (Heat Pump). The company serves businesses seeking to manage decentralized energy systems and mobile electronic solutions. Reports indicate they have connected over 220,000 devices and successfully implemented more than 100 projects. This impressive scale demonstrates the widespread adoption of their products within specialized market segments.

## 4.15 Flexitricity

Flexitricity, a UK leader in demand response that optimizes flexible energy assets through its virtual power plant platform, was acquired by Quinbrook on September 14,2020. It is now part of Alpiq Group, Switzerland's leading electricity and energy services provider

Headquartered in Edinburgh, UK. The company operates mainly in the United Kingdom (GB) with approximately 116 employees.

Core offerings: Provides grid flexibility services (developed through collaboration with OVO Kaluza). Specializing in Demand Side Response (DSR) projects, the company has successfully integrated its first residential EV aggregation unit into the balancing mechanism. Its Virtual Power Plant (VPP) platform aggregates multiple sites including battery storage systems (BESS), co-located assets, and gas peaking plants. The company also offers power generation and operation maintenance services. Leveraging AI and advanced modeling technologies, it optimizes flexible energy assets for optimal performance.

Flexitricity's core business revolves around flexible energy and demand response services in the UK. The company operates a virtual power plant (VPP) with over 1 GW of capacity, aggregating diverse flexible energy loads from industrial, commercial, and public sector entities. This virtual power plant plays a vital role in real-time balancing electricity supply and demand for National Grid's Electricity System Operator (ESO). Their comprehensive services include market access (covering energy trading, balancing mechanisms, frequency response, capacity markets, and demand flexibility services), asset optimization, demand-side response, flexible O&M (operations and maintenance), and energy supply.

Flexitricity positions itself as a "flexible energy specialist" dedicated to

providing clarity in complex energy landscapes and maximizing revenue opportunities for flexible energy assets. The company's mission extends beyond generating revenue for clients; it is committed to reducing emissions, enhancing energy security, and making energy affordable for consumers across the UK.

Flexitricity is recognized as a pioneer and market leader in the UK's flexible energy sector, maintaining leadership in both production capacity and technical capabilities. With virtual power plants exceeding 1 GW in scale, it has the potential to significantly impact grid balance. By integrating proprietary AI and sophisticated algorithms with deep human expertise, Flexitricity delivers first-class performance and revenue streams through advanced technologies. The company provides comprehensive market access by operating 24/7 control rooms that leverage diverse flexible service and energy trading markets. Notably, it was the UK's first supplier to fully engage in demand response asset balancing mechanisms. Its core selling point lies in generating substantial revenue for industrial and commercial power users and generators through flexible trading, with prices in the balancing mechanism reaching up to £2,500 per megawatt-hour. Beyond economic benefits, Flexitricity's demand response solutions contribute significantly to environmental goals by providing low-carbon reserve energy, thereby helping reduce national $CO_2$ emissions and support the transition to a low-carbon energy system. Additionally, the company offers robust operations and maintenance (O&M) services for over 200 engines across 40 power stations, along with a dedicated portal providing customized information and detailed revenue tracking for clients.

Flexitricity's main partners include National Grid ESO, which sells grid balancing ancillary services to it. It also works with entities such as the Gresham House Energy Storage Fund, as well as regulators, system operators and various industry bodies.

## 4.16 Emsys

Headquartered in Oldenburg, Germany, Emsys is a provider of diversified smart grid solutions. Its VPP technology aims to help energy suppliers and direct marketers monitor, control and trade aggregated power production. It has received three rounds of funding, the total amount of which has not been disclosed

Energy & Meteo Systems offers a comprehensive range of products and services:

- Power Forecasting: The company delivers highly accurate and customizable solar and wind energy forecasts for individual plants, portfolio projects, and entire markets. Utilizing advanced systems like Solar Forecast (Suncast) and Wind Forecast (Previento), it optimizes weather model blending with real-time adjustments. A distinctive service includes real-time predictions of current solar output across multiple regions worldwide.
- Virtual Power Plant (VPP): Through emsys VPP GmbH, it provides a modular SaaS software suite that connects, coordinates, and monitors distributed generators, storage facilities, and controllable loads via a central intelligent control room. Three energy suppliers and distributors utilize VPP technology to monitor, remotely control, and profitably trade aggregated power generation
- Grid Management: emsys grid services GmbH provides the "Future Power Flow" IT platform, delivering intelligent solutions for grid operators. The platform facilitates Germany's implementation of Redispatch 2.0, preventing grid congestion and enhancing market communication. By processing massive data streams—including grid metrics, flexibility parameters, generation forecasts, and load predictions—it calculates optimal grid resource utilization while proactively identifying operational bottlenecks.

Energy & Meteo Systems is committed to delivering precise, reliable, and comprehensive renewable energy integration solutions. The company claims to predict approximately 50% of global wind power capacity and 40% of solar capacity, demonstrating exceptional forecasting accuracy. This high precision serves as a key selling point, directly helping clients reduce imbalance costs. The integrated service suite covers the entire renewable energy lifecycle from forecasting to virtual power dispatch (VPP) and grid management, offering holistic solutions. The "Future Power Flow" platform proactively identifies and manages grid congestion, surpassing passive measures to further solidify its market position. It specifically aligns with Germany's "Redispatch 2.0" requirements, providing crucial regulatory advantages. Additionally, the company emphasizes customer-centricity through customized data transmission, personalized communication, and round-the-clock support services.

The product's primary advantage lies in its ability to support the integration of inexhaustible carbon-free renewable energy, thereby enhancing grid stability and reducing customers' operational costs. Although renewable energy generation is inherently unstable due to weather influences, Emsys' advanced forecasting and

management software directly addresses this challenge. The high upfront costs of renewable energy projects represent a broader industry-wide challenge. While not a direct drawback of Emsys software, this factor may impact its service market.

The company boasts exceptional market penetration: It is projected to account for approximately 50% of global wind power installed capacity and 40% of solar capacity. Serving around 200 clients worldwide, it provides consulting services while having over 20 international grid operators relying on its forecasts. The company delivers millions of predictive datasets to clients across six continents. A notable example is Greek energy provider WATT+VOLT, which has partnered with German IT firms emsys VPP and energy & meteo systems to supply virtual power plant (VPP) and electricity forecasting services for its newly established aggregator division.

The company operates worldwide, serving clients on six continents: Europe, North America, South America, Asia, Africa and Australia.

## 4.17 Frequenz

Frequenz, a German tech startup founded in 2019 with 30 employees, secured its latest Series A funding round on October 6, 2022, raising $12.9 million. The investment was led by SET Ventures and 468 Capital, alongside industry leaders including CleanSpark, Xendee, and HOMER Energy. Specializing in developing groundbreaking AI solutions, the company operates through a B2B SaaS (Software as a Service) business model.

Core offerings: The company's flagship solutions focus on artificial intelligence (AI) technologies and open-source development platforms to accelerate the transition to 100% renewable energy. Its Edge Platform enables smart deployment, optimization, and operation of microgrids, while integrating AI, IoT, and battery storage technologies to streamline renewable energy production and procurement.

Frequenz's main product is an AI-based platform designed for grid management solutions. The platform aims to optimize energy flows, balance supply and demand, and facilitate the integration of multiple energy sources within complex grid infrastructure.

Frequenz positions itself as a provider of cutting-edge AI-driven solutions for critical grid challenges. Its competitive advantage, or moat, likely stems from proprietary AI algorithms and advanced software capabilities that enable real-time

optimization and automation of power grids. By focusing on "grid management solutions," Frequenz directly addresses the growing demand in the energy transition: ensuring grid stability and efficiency while absorbing increasing amounts of variable renewable energy. Although specific product pros and cons are not explicitly detailed, its AI-centric approach promises benefits like enhanced efficiency, increased automation, and improved grid stability. For new entrants, potential challenges include building market trust with more established competitors and achieving widespread product penetration, particularly without concrete pricing strategies currently available.

## 4.18 Enspired

Enspired, a Vienna-based Austrian company founded in 2020 with a team of over 50 members, provides AI-powered short-term energy trading platforms and VPP solutions to maximize the value of energy assets. The company has successfully raised a total of $36.2 million through two funding rounds, with its most recent milestone being the $27.5 million Series B financing on May 14,2024. This round was led by Zouk Capital, with participation from Emerald Technology Ventures, 360 Capital Partners, PUSH, Banpu NEXT, and Vopak Ventures.

Enspired specializes in energy asset trading. The company provides AI solutions designed to optimize power portfolios, offering direct market access through electricity trading services that leverage advanced data analytics, self-learning models, and cutting-edge technologies. Enspired focuses on short-term and continuous-day trading within the energy market.

The company positions itself as a key enabler of efficient and profitable energy transactions, especially in an increasingly complex and volatile energy market. Its goal is to help energy asset owners and traders maximize the value of their flexible assets in a dynamic market.

Enspired's competitive edge, or "moat," is built on several key pillars. Their AI-driven solutions and self-learning models enable instant market response, crucial for successful day trading. The use of algorithmic trading is considered vital for systematically generating profits in volatile intraday markets. The inherent complexity and high costs of implementing such advanced technology create significant entry barriers for competitors. Additionally, Enspired's service provider model helps clients overcome challenges related to market access, software integration, and data

management, effectively lowering the threshold for engaging in these complex markets. Their algorithmic trading features round-the-clock operation, eliminating the need for clients to maintain dedicated trading desks, enabling continuous optimization. The company also holds a patent application titled "System for Controlling Charging and/or Discharging Power of at least one Energy Storage Device," further solidifying its technological defensive capabilities.

The core strength of Enspired's products lies in generating higher profits through enhanced efficiency and dynamic market responsiveness. Their solutions optimize assets to boost clients' profit margins and overall profitability. By providing round-the-clock algorithmic trading, the platform reduces operational burdens and costs associated with maintaining internal trading desks. Furthermore, their service model streamlines market access for clients, simplifying complex energy transactions. At the heart of Enspired's strategy is its AI-driven algorithmic trading focused on short-term energy markets, enabling them to capitalize on renewable energy's increasing intermittency. As more wind and solar power integrates into grids, intraday price fluctuations grow both in frequency and magnitude – precisely what their technology is designed to harness for profit. This directly addresses a key challenge of the energy transition: managing and profiting from renewable energy volatility.

Enspired's main clients are energy asset operators and e-commerce sellers, and its heavy asset investors include Zouk Capital, Emerald Technology Ventures, 360 Capital Partners, Banpu NEXT and Vopak Ventures, among other well-known companies, which have established strong strategic partnerships with each other.

It operates mainly in Europe. When it comes to European power exchanges such as EPEX SPOT and Nord Pool, these exchanges generally use algorithmic trading, which shows that the company is highly focused on the European market.

Market adoption analysis demonstrates Enspired's solutions have gained strong market acceptance. In 2021,55% of EPEX SPOT transactions were automated, compared to nearly 60% on Nord Pool in 2020. Recognized as a leader in the field, Enspired tops the rankings among three active competitors on Tracxn. The high proportion of automated trading on EPEX highlights the maturity and widespread acceptance of Enspired's AI-driven solutions in the market.

## 4.19 Axle Energy

Founded in late 2023, Axle Energy is now a fully compliant UK P415-certified Virtual Trading Party （ VTP ） service provider. The company has raised $10.6 million through two funding rounds, with its most recent seed round on August 1, 2024, securing $8.98 million. This funding was led by global venture capital firm Accel, with participation from Picus Capital, Eka Ventures, and Google for Startups.

Axle Energy is a European company specializing in energy flexibility solutions, providing market access through integrated systems. The company develops energy software designed to directly connect household energy devices—including electric vehicles (EVs), heating systems, and home batteries—to electricity markets. By offering connectivity, management, and monetization options, their software enables transformative energy usage that optimizes electricity bills. Essentially functioning as "virtual power lines," Axle's solutions create seamless connections between household energy devices and broader electricity markets.

The company positions itself as a key enabler of grid decarbonization by unlocking the inherent flexibility of residential energy devices. Axle's goal is to become the "Stripe of energy," meaning its strategic focus is on seamless, API-driven integration and monetizing energy flexibility.

Axle Energy's competitive edge stems from its software-defined flexibility, enabling seamless integration and optimization of diverse home energy devices to participate in the grid. A key selling point lies in monetizing this flexibility, allowing energy providers and hardware manufacturers to generate revenue from residential energy assets. For consumers, the solution significantly reduces costs by shifting usage to periods with the lowest electricity prices and most eco-friendly energy sources, potentially cutting household bills by over 25%. The "Energy Stripe" positioning also emphasizes API-first methodology, facilitating seamless integration for Original Equipment Manufacturers (OEMs)and energy suppliers. Furthermore, the platform leverages machine learning to predict energy demand, enhancing its optimization capabilities. The "Energy Stripe" positioning underscores Stripe's strategic vision to become the foundational layer for energy flexibility, mirroring how Stripe revolutionized online payments. This business model focuses on high-throughput, low-friction API transactions, which could create powerful network effects. As more connected devices and partners join the platform, its value will

multiply exponentially.

The advantages of Axel Energy's products include significant cost savings for households, enhanced grid integration of renewable energy, reduced emissions, and improved grid stability. It provides a single integrated solution to access Europe's flexible energy market. The company's business spans energy storage and V2G applications

Country of operation: Headquartered in London, UK. Operations in Europe, including the United Kingdom, Austria, France, Germany, Finland and Belgium.

## 4.20 Entrix

Headquartered in Munich, Germany, it was founded in 2021 and has 76 employees. It is financing but details are unknown.

Entrix delivers an AI-powered trading platform that dynamically markets battery storage across energy markets. As a specialized grid-scale battery storage optimization and trading solution, the company provides cutting-edge technologies and services to boost power generation through grid-scale battery storage and renewable energy storage solutions.

Entrix positions itself as a market leader in optimizing grid-scale battery storage, aiming to accelerate the transition to a clean energy future. Its mission is to maximize the efficient use of green energy and ensure the reliability of future energy systems. The company's competitive edge stems from its AI platform, which enables dynamic marketing and optimization of battery storage. Entrix claims to deliver market-leading performance through a comprehensive approach that maximizes energy asset utilization. Their advanced technology provides valuable services for asset owners and investors. The company also emphasizes its expert team, actively seeking top talent to join its mission. Focusing on "dynamic marketing of battery storage across various energy markets," Entrix employs a sophisticated revenue overlay strategy. This approach goes beyond single-market focus (e.g., wholesale energy) by optimizing across multiple revenue streams including frequency regulation, capacity markets, and arbitrage, thereby maximizing the profitability of battery assets and creating a complex, hard-to-replicate competitive advantage.

The core strengths of the Entrix product suite include optimizing energy asset value, accelerating the clean energy transition, and ensuring the reliability of future

energy systems. Their solutions enable effective utilization of green energy. However, the inherent complexities of real-time trading across different energy markets and the evolving regulatory landscape may pose significant challenges. Competition from other optimization platforms like Limejump also adds to these considerations.

Entrix has deep cooperation with leading enterprises such as Enpal and Pelion Green Future.

## 4.21 Eliq

Headquartered in Gothenburg, Sweden, Eliq was founded in 2015. As of 2025, the company has 61 employees and has secured a total of €19 million in funding since its inception, with its most recent round being a €10 million Series A financing in November 2023. This funding round saw continued investment from existing investor Inven Capital, along with new strategic investors Axpo and Valkea (Fortum's investment arm).

Eliq demonstrates significant competitive advantages through its white-label platform that enables energy suppliers to rapidly develop and deploy digital energy solutions. The platform's core differentiator lies in its ability to transform complex energy data into actionable insights for customers. 16 By prioritizing customer engagement and optimizing end-user experiences, Eliq empowers utilities to effectively adapt to the evolving digital energy consumer landscape. As an API-powered energy platform, Eliq serves 10 million connected end-users while managing over 100 billion energy data points.

The advantages of Eliq products include accelerating the broader energy transition, helping users avoid energy waste, and achieving long-term savings. For customers, the platform significantly enhances marketing and sales efficiency by driving customer conversions, increasing monthly active users, influencing behavioral changes, and boosting purchases. This ultimately leads to substantial reductions in energy costs and carbon emissions. However, in the rapidly evolving technological landscape, challenges include inherent complexities in automation, scalability, and reliability. The European utility industry itself is undergoing rapid transformation due to the proliferation of electric vehicles, rooftop solar panels, energy storage solutions, and other connected home appliances. Eliq has developed an energy monitoring and white-label tool platform designed to improve daily energy efficiency. This platform excels at converting massive amounts of energy data into valuable customer insights,

thereby accelerating the energy transition. Eliq helps energy customers make informed green energy choices and provides energy efficiency and optimization services. Their core product is the home energy efficiency platform.

Eliq's main partners and customers include energy companies and utilities, as well as banks and global smart home suppliers. Specific strategic partners mentioned include TotalEnergies, Schneider Electric, Fortum, and KBC.

## 4.22 Rabot Energy

Rabot Energy is a company located in Hamburg, Germany. Founded: 2021, with 105 employees, Rabot Energy has raised a total of $25.1 million from investors including HTGF, HV Capital, 9900 Capital, All Iron, CNI (Stockholm), Arsago Alternative Capital Management, Yabeo, etc.

Focusing on renewable energy system integration and developing a dynamic electricity pricing platform, aiming to help environmentally conscious households and electric car owners save money and reduce their carbon footprint. Fuse Energy (UN) is also positioned similarly to Aelx Energy.

Rabot Energy, a German-based independent energy provider in Hamburg, delivers dynamic electricity pricing to both residential and commercial customers. Their pricing model is based on daily wholesale electricity rates, enabling clients to benefit from cost fluctuations in the energy market. The company's platform leverages real-time electricity market data to optimize charging schedules for electric vehicles. By utilizing 100% renewable energy, Rabot Energy empowers customers to monitor and optimize their power consumption through a dedicated app, driving sustainability and cost savings. The app allows customization of personal preferences while providing continuous reports on electricity usage patterns and associated costs.

Rabot Energy positions itself as a platform designed to help environmentally conscious households and EV owners save money while reducing their carbon footprint. The company aims to simplify vehicle ownership through smart charging automation. Its core value proposition lies in providing dynamic electricity pricing based on daily wholesale rates, positioning it as a disruptor in the traditional energy retail market. This model directly addresses consumers' needs for cost savings and control during periods of energy price volatility, while promoting renewable energy integration by incentivizing consumption during peak green energy supply periods.

The company's competitive edge stems from its dynamic electricity pricing model that directly links customer rates to wholesale prices, delivering potential cost efficiency. Committed to 100% renewable energy use, it aligns with growing environmental consciousness. A dedicated mobile app empowers users with real-time monitoring, optimization tools, and customization options, enhancing control and engagement. The platform's ability to optimize EV charging schedules based on market data stands as a key feature for electric vehicle owners. Equipped with robust automated data extraction pipelines integrating multiple sources, the company provides actionable insights into marketing effectiveness and conversion channels. This unified data infrastructure eliminates technical bottlenecks, empowering marketing teams to conduct self-service analytics.

The advantages of Rabot Energy's products include enabling customers to enjoy low costs while contributing to a more environmentally friendly power grid. By optimizing electricity consumption, it promotes sustainability and cost savings. The application allows users to control energy usage and costs. Automated data pipelines ensure reliable and flexible data flow, thereby enhancing marketing effectiveness. Although specific drawbacks are not explicitly stated, reliance on dynamic pricing means the amount of savings customers save depends on market fluctuations, which may create uncertainty for some users. The mobile application-centric approach may not appeal to all demographics.

Rabot Energy primarily serves private households and businesses seeking dynamic electricity pricing. Partnering with 173tech, they have developed data infrastructure and sophisticated modeling systems for cross-account acquisition channels. The company's recent acquisition of 1&1 Energy marks a significant milestone, as 1&1 Energy specializes in residential and commercial power supply services.

Rabot Energy faces tremendous opportunities, especially in a market where dynamic electricity pricing and renewable energy applications are growing. With the increasing adoption of electric vehicles, there is also growing demand for smart charging solutions.

## 4.23 Moost

MOOST AG, headquartered in LaPersville-Jona, Switzerland, is a small startup.

Moost's flagship product is an AI-powered home energy management solution. This platform delivers personalized, actionable insights designed to help households optimize energy consumption. By transforming raw data from connected devices into proactive alerts, Moost empowers users to monitor key metrics and patterns, detect critical anomalies, and identify potential energy-saving opportunities.

Moost's technology is powered by its "intelligent algorithms" that perform pattern recognition, anomaly detection, and predictive analytics. The "Advanced Rule Engine" ensures messaging consistency, while the "No-Coding Editor" enables customers to customize use cases without extensive IT involvement. The platform also provides performance monitoring and analytics, along with "Progressive Home Analysis" to ensure data relevance for each household. A key design feature is seamless cloud-to-cloud integration with existing client systems, allowing data conversion and messaging to be seamlessly transferred to customers' current messaging platforms or preferred endpoints.

Moost positions its products as "smart home energy management systems." The company aims to empower end users by helping them control energy usage, provide assurance, offer progress feedback, and motivate them to achieve greater energy savings. Its core value proposition focuses on fostering long-term user engagement through personalized, action-oriented insights delivered near real-time via existing applications (without requiring additional apps) and multiple channels including push notifications, in-app messages, wall-mounted tablets, and email.

Moost's competitive edge stems from multiple dimensions. By leveraging proprietary AI and algorithms for pattern recognition, anomaly detection, and predictive analytics, it has established a significant technological barrier against competitors. The platform's unique capability to deliver "100% personalized" services and actionable insights sets it apart from generic data aggregation platforms by effectively driving user behavior transformation. Its seamless integration features further reduce friction for potential B2B clients, streamline adoption processes, and minimize implementation challenges. Moost also benefits from robust research partnerships, including collaborations with iHomeLab – a world-leading research institution in smart building machine learning – and support from Switzerland's innovation agency Innosuisse. These partnerships provide a solid foundation for continuous innovation while maintaining Moost's leadership in energy management technology

The Moost recommendation system is integrated into existing E.ON intelligent control applications and works closely with E.ON.

## 4.24 Relienergy

ReLi Energy is a German software company specializing in battery technology optimization. Headquartered in Darmstadt, Germany, ReLi Energy is a small startup with investors including InnoEnergy, Free Electrons, The Migrant Accelerator, Fit 4 Start and Hessian AI

ReLi Energy's flagship solution is a software-driven framework designed to enhance the performance of stationary energy storage systems, particularly optimizing lithium-ion battery operations. This technology delivers measurable benefits including up to 35% extended battery life and up to 70% reduced energy costs for users. These breakthroughs are achieved through sophisticated integration of advanced analytics, precise modeling, and operational optimization strategies. The company's mission is to "maximize energy storage efficiency, prolong battery lifespan, and boost profitability" by "fully unlocking batteries' potential". Its technical roadmap highlights innovations like the "Battery Cost API" and "Battery Data Gateway", advocating a modular, API-driven approach to enable seamless integration with other energy management systems.

ReLi Energy positions itself as the nexus of sustainability and innovation. Its mission is to reduce the environmental impact of lithium-ion batteries while combining economic benefits with sustainable development goals. The company aims to "take climate action to the next level."

ReLi Energy's competitive edge stems from its proprietary technologies. Its "innovative software solutions" leverage "advanced analytics, precise modeling, and operational optimization strategies" to form its core competitive barriers. Quantifiable benefits like "up to 35% extended battery life" and "up to 70% reduced energy costs" offer strong value propositions for potential customers. Additionally, four pending patents related to "battery optimization control systems and methods" demonstrate its independent intellectual property rights, safeguarding its innovative achievements. The company's explicit commitment to "reducing the environmental footprint of lithium-ion batteries" aligns with the growing market demand for sustainable solutions, further enhancing its market appeal.

## 4.25 allye

Headquartered in London, UK, Allye Energy is a startup specializing in AI-powered energy storage solutions. With a lean team, the company aims to help businesses overcome grid challenges through smart, future-ready energy management. By integrating AI software with innovative battery storage technologies, they empower utilities to maximize power output, upgrade constrained grid infrastructure, and reduce energy costs.

Their solutions are designed to be modular and mobile, providing flexibility for a variety of applications, including on-grid and off-grid use, buffer storage and peak shaving.

Product lines include:

- MAX300: Positioned as a "commercial power unit", the device is modular and mobile, designed to achieve high performance and flexibility for commercial applications.
- MAX1000: The system provides "industrial-grade power" with high capacity and high power storage suitable for demanding industrial environments. Collins Earthworks is the first customer of MAX1000.
- MegaMAX Series: These systems integrate three MAX300 structures with inherent redundancy, a liquid-cooled thermal management system, and a complex AI-driven control system for real-time decision making and frequency regulation.

Allye Energy also emphasizes sustainability by reusing high-quality electric vehicle battery packs in its systems, which helps reduce carbon footprints. Supported by leading clean technology investors, the company aims to help businesses save money, generate revenue, and accelerate the deployment of power solutions while benefiting the environment.

Key aspects of product positioning include:

- Artificial intelligence-driven energy management: The system uses artificial intelligence to predict energy demand, optimize usage patterns and continuously learn from consumption data.
- Mobility and Modularity: The solution is highly adaptable to a variety of applications, whether grid-connected or off-grid, buffer storage or peak shaving.

They are available in both mobile and fixed options with modular design for seamless expansion.

- High performance: The system is carefully designed for maximum efficiency, maximizing the kilowatt-hour (kWh) of storage, and extending system life through advanced power management.
- The environmental and cost advantages of electric vehicle battery reuse: A key differentiator lies in their utilization of recycled EV batteries. Reports indicate these batteries can reduce embedded carbon emissions by 40% or more compared to other short-term energy storage systems, while cutting embedded $CO_2$ emissions by 60%, making them approximately 2.5 times more cost-effective. This dual advantage of sustainability and cost efficiency delivers a compelling value proposition.
- Energy Storage AWS Vision: Allye's mission is to coordinate community battery networks and create a new market worth approximately $1 trillion in virtual energy storage and digital energy services. This will establish it as a scalable cloud-based energy management platform. The company aims to install 10,000 MAX devices by 2030, achieving an installed capacity of 3GWh

Allye Energy has established partnerships and client relationships with several renowned enterprises. Its business partners include Jaguar Land Rover, Roadchef, Aerovolt, OnBio, and Horizon Plant. Collins Earthworks served as the pioneering partner and first client of MAX1000, collaborating in the field of building electrification. Other clients include SSE and EON.

## 4.26 Fever Energy

Fever Energy, founded in Stockholm, Sweden, is a small startup that has raised a total of $12.4 million through two rounds of funding. Its main investors include General Catalyst, La Famiglia and Norrsken VC.

Fever Energy's core product is a platform designed to help utilities deploy smarter energy solutions. This platform enables utilities to rapidly, securely, and comprehensively deliver modern energy services. Its key feature is the Virtual Power Plant (VPP) platform, which aggregates, coordinates, and optimizes various distributed energy resources (DER). A critical technical characteristic lies in its hardware-agnostic and software-defined design, allowing seamless integration with

diverse energy assets regardless of manufacturer.

The platform supports a variety of asset types, including:

- Solar (photovoltaic) installations
- electric vehicle （EV）
- Battery Energy Storage Systems (BESS), including utility-scale batteries and home batteries
- Electric car charging pile 4

Fever Energy offers two main optimization engines:

- Post-meter assets: These are mainly focused on on-site optimization strategies such as peak shaving, time-sharing management and smart charging.

Instrument front assets: These provide opportunities to obtain market profitable services, including spot price arbitrage and ancillary services.

Fever Energy's core business objective is to help utilities increase revenue and reduce customer churn by providing advanced flexibility programs, electric vehicle services, and demand-side innovations. The platform is designed to rapidly launch and scale these products.

Key aspects of its market positioning include:

- Utility-Centric approach: The company focuses on helping utilities modernize their customer service and make effective use of DER.
- Real economic benefits: Fever Energy aims to deliver quantifiable improvements for the utility, including a 6% increase in revenue from new business lines (expected to double within three years) and a up to 50% reduction in the attrition rate of digital native providers.
- Accelerating service deployment: Utilities using the Fever Energy platform can roll out new services five times faster than their competitors because they focus on customer service rather than technical complexity.
- Comprehensive Asset Management: The platform aggregates all distributed energy assets into a seamless VPP, enabling utilities to have full control over their flexible capacity.

Fever Energy's core competitive advantages stem from its platform's hardware-agnostic and software-defined architecture. This design delivers exceptional

flexibility while eliminating integration barriers for utilities operating across multiple existing infrastructure systems. The company's unique profit-sharing model establishes direct financial alignment with clients, creating compelling incentives for adoption and long-term partnerships. The founding team's background at tech giants like iZettle and Spotify underscores their expertise in scaling network-driven businesses and delivering market-disrupting solutions through software innovation. Their capability to integrate with any existing or future distributed energy (DER) systems provides universal compatibility, while the profit-sharing mechanism minimizes risks for utilities, making adoption more accessible. Major utility clients include Varberg Energi, Vattenfall, and Greenely.

## 4.27 Tilt

Tilt Energy, founded in 2023 and headquartered in Paris, France, is a small startup. As a European AI-driven platform, it optimizes power consumption by connecting assets to the flexible market, aiming to achieve decarbonization, competitive, and resilient grids. Its investors include Daphni, Founders Future, Innov'Up Leader Pia, Microsoft France, and AFI Ventures (Paris).

Tilt Energy's main product is an AI platform that predicts, coordinates, and monetizes electricity consumption by connecting assets to the flexibility market. The technology's core goal is to leverage electrical flexibility without compromising end-user usage or comfort.

The platform provides solutions in three main areas:

- Consumption forecasting algorithm: The forecasting model predicts the power demand pattern.
- Automatic aggregation and orchestration of DER: Systematic management and coordination of distributed energy resources.
- Monetization of the flexible market: Participation in the energy market can generate revenue from flexible consumption.

The company's software is designed to help control electricity consumption across France

Key aspects include:

- RTE Certified Operator: Tilt Energy is an RTE-certified demand response

operator and balancing agent. This certification marks its high level of trust and operational competence in the European energy market.

- Expertise: Their predictive model is trained on thousands of load curves across distributed assets, demonstrating a complex, data-driven approach to energy management.
- 100% Software-based Solution: The platform is completely software-based, technology universal, and compatible with all types of brands and devices. This gives it broad applicability and easy integration with a variety of energy ecosystems.
- No capital expenditure for customers: The solution can be seamlessly integrated with existing assets and APIs at no cost and without upfront investment, making it attractive to potential customers.

Tilt Energy's core competitive advantage lies in the advanced forecasting and orchestration capabilities of its AI platform. The complexity of this technology makes it possible to precisely manage and monetize energy flexibility.

Tilt Energy serves three main customer groups:

- Energy consumers: Owners, operators or users of commercial buildings seeking to monetize power flexibility, generate revenue and reduce their carbon footprint.
- Energy managers: Including engineering firms, ESCO and BMS operators who are building flexibility into contracts to enhance low-carbon impact and improve customer satisfaction.
- Practical applications: Suppliers, distributors, and other utilities want to provide embedded flexibility services and access to consumption forecasts.

Major customers or partners: Carrefour, RTE, Advizeo, Westfield, Siplec, Caisse des Depots, Les Mousquetaires, Microsoft, Alliander, Gaz Europeen, Schneider, etc

## 4.28 podero

Podero GmbH, founded in 2022 and headquartered in Vienna, Austria, is a small startup. On June 1, 2024, it secured its latest seed funding round led by Planet A Ventures, with Systemiq Capital participating as a co-investor. Existing investors Pale Blue Dot and Push Ventures also joined the funding.

Podero's primary product is a device control and energy flexibility platform. The

platform is a fully integrated suite designed to provide device flexibility for smart power contracts. Its core business focus is to help utilities and energy companies manage residential device fleets and monetize them.

The functions of the platform are mainly divided into three aspects:

- Guidance: This platform connects, monitors, and controls consumer devices, allowing customers to log into their devices and manage preference settings. Podero handles the technical details of device control while maximizing user comfort. The platform is compatible with various devices including heat pumps, air conditioners, electric vehicles (EVs), wall-mounted charging stations, inverters, and battery storage systems.
- Trade: Podero automatically guides aggregated equipment clusters based on market activities to optimize procurement, sales, and grid balance. By intelligently controlling these clusters to fulfill trading responsibilities, it optimizes spot market procurement, reduces imbalance cost risks, and provides balanced energy to ensure grid stability.

Unified Platform: This platform enables flexible startup, management, and integration of devices. Utility companies can deploy Podero's white-label applications to activate smart device control within just 10 minutes. The platform also provides a console for managing users and device groups, along with partner APIs that seamlessly integrate with existing utility software systems (including backend systems, transactional platforms, ERP, and customer support).

Podero positions itself as a platform that empowers utilities to unlock "next-generation energy solutions". By bridging consumption with market opportunities, the company transforms small-scale energy assets into competitive market players, delivering cost savings for both utilities and their customers without compromising comfort. The firm also emphasizes empowering consumers through automated processes and transparent workflows to control electricity usage, reduce financial burdens, and decrease carbon emissions.

Key aspects of its market positioning include:

- Full device integration: Podero integrates more than 1,500 devices from more than 50 manufacturers, covering a wide range of areas from electric vehicles to heat pumps.
- Quick Start and Integration: The platform offers a "soft start in 10 minutes"

feature, using its white-label components to save utilities up to 90% of integration time.

- Transaction support: Provides comprehensive support for optimizing procurement, sales and grid balance by automatically directing aggregated equipment groups based on market activities.
- Scalability: Built as a cloud native platform, it is designed to scale safely to millions of devices.

  High uptime: The reported historical platform uptime is 99.98%.

Podero has earned the trust of leading utility companies including TotalEnergies, oekostrom, E.ON, Kelag, Vereinigte Stadtwerke, Fokus Energie and STW. Its partnership with E.ON, serving 49 million customers, demonstrates the platform's potential to achieve large-scale coverage and significant market impact.

## 4.29 CyberGrid

CyberGrid is an Austrian energy technology company founded in 2010. CyberGrid focuses on virtual power plant (VPP) solutions and flexibility management, aiming to facilitate the transition to a sustainable, decentralized energy grid.

CyberGrid delivers the CyberNoc integrated virtual power plant (VPP) solution, designed to enable seamless flexibility management and energy asset monetization. This cloud-based technology integrates diverse distributed energy resources—including renewable energy sources, battery storage systems (BESS), small hydropower stations, and electric vehicles (EVs)—into a unified large-scale entity that participates in energy markets.

CyberGrid positions itself as a "full-spectrum solutions provider" dedicated to transforming energy flexibility into profits and advancing sustainable, decentralized grid development. The company's overarching vision is to make all generated, stored, and consumed energy renewable and flexible. Their strategic focus is to maximize customer profitability while accelerating the broader energy transition.

CyberGrid's competitive edge stems from multiple strengths. Its proprietary VPP software CyberNoc delivers cutting-edge solutions for managing and monetizing energy flexibility. A defining feature is its "multi-market and free bidding" capability, which seamlessly connects assets to various energy markets including feed-in tariffs (FCR), ancillary feed-in tariffs (aFRR), and market-based feed-in tariffs (mFRR), as

well as re-scheduling services and both day-ahead and intraday markets. This mechanism enables capitalization through "free bidding," potentially generating up to 30% additional revenue for clients. CyberGrid promises rapid ROI and deployment, claiming to unlock flexibility potential within 3-6 months. The company offers a comprehensive service model encompassing Flexibility as a Service (FaaS), Software as a Service (SaaS), consulting, and R&D support. By enhancing integration efficiency across existing power generation resources, energy storage systems, and renewable energy sources, its technology plays a pivotal role in accelerating the energy transition. CyberGrid provides expert oversight and support, guiding clients through initial consultations to seamless technical market connections. CyberNoc's recognition in the 2024 Smarter E Awards' "Smart Integrated Energy" category further validates its innovative capabilities.

## 4.30 Rebase.energy

Headquartered in Sweden and founded in 2018, the company currently employs 8 to 10 people. The company focuses on deep technical expertise in energy modeling and data science rather than a rapid expansion strategy for a wide range of consumer products.

Rebase.energy Develop energy simulation and optimization software. Its core products provide data and tools designed to evaluate and optimize distributed energy systems. The company operates as an API-first platform for energy forecasting and optimization. It offers a comprehensive toolkit for processing data from various sources (such as data centers) to support energy prediction and optimization applications, including integration with useful datasets and computational tools.

The company positions its product as "the easiest way to create, deploy and monitor energy forecasting models on a large scale." Its mission is to empower innovators accelerating the energy transition and build the world's first open collaborative energy modeling platform.

Rebase.energy's competitive edge is rooted in both technological and strategic dimensions. Its "API-first" philosophy ensures all functionalities are accessible through APIs, enabling seamless data interoperability and easy integration with existing systems. The open-source toolkit empowers users to rapidly develop and deploy machine learning algorithms. For energy traders, the platform leverages multiple weather forecasting models to significantly enhance accuracy while reducing

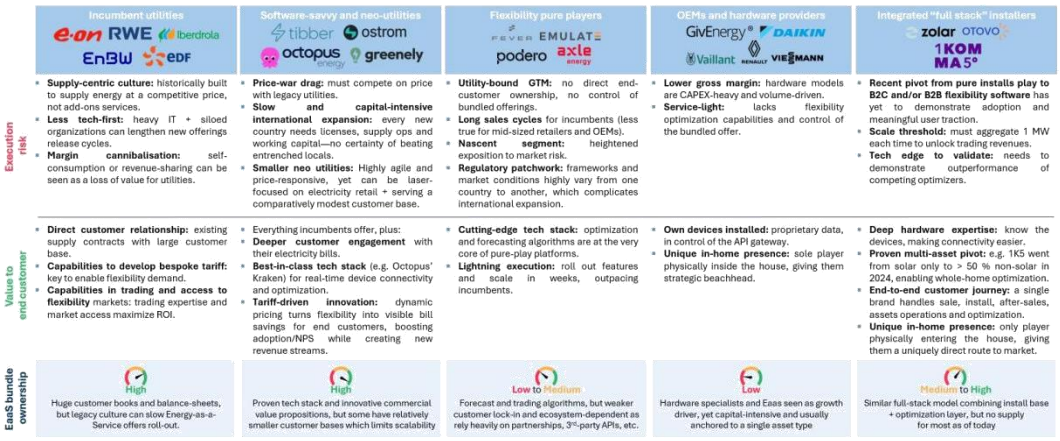
imbalance costs. Furthermore, the company strictly adheres to industry standards, complying with the Wind Energy Task Force's (IEA Task 36) wind power forecasting specifications, and plans to adopt more industry-specific standards, particularly in building energy modeling. The team's strong technical expertise in energy and data science—harnessing insights from both industrial and academic sectors—further solidifies its competitive position. By fostering developer adoption and ecosystem development through its "API-first" approach and open-source toolkit, Rebase.energy establishes robust competitive advantages. Through improved tool accessibility and integrability, the platform can become the de facto standard for energy modeling, cultivate a thriving user and developer community, thereby enhancing its value and making it difficult for competitors to replace.

Rebase.energy's key partners and clients include energy companies and energy traders. Its major investors encompass Third Derivative, Bentley iTwin Ventures, and Plug and Play Tech Center. The company also collaborates with the International Energy Agency's Wind Energy Task Force 36 and integrates with various data platforms such as Bazefield, Greenbyte, SFTP, Google BigQuery, and ActiveMQ.

In market applications, Rebase.energy processes over 20,000 forecasts daily and handles more than 200 GB of weather data each day. The massive volume of daily weather forecasts and processed data demonstrates the platform's robust operational scale and practical value. Such high activity levels indicate that the system is powerful and performs exceptionally well, capable of meeting the demands of complex energy markets.

## 4.31 Summary of European BTM power flexibility business models

Summary: BTM flexibility startups are exploring diverse customer engagement strategies. Some leverage large-scale assets like heat pumps, photovoltaic systems, and battery storage solutions (e.g., ENPAL, 1KOMMA5), while others like Tibber and Rabot focus on power supply optimization through existing hardware infrastructure.




From：VC@EDF

Among them, Piclo operates an end-to-end flexible secondary exchange that has garnered significant attention. Currently operating a flexible capacity of 30 GW, this demonstrates the extremely high ceiling of the BTM flexibility market. Financially, Piclo adopts a dual revenue model: it collects service fees from distribution system operators (DSOs) based on the income of flexible service providers (FSPs), and earns transaction fees from secondary market transactions facilitated by Piclo Exchange. The company's successful private placement in August 2024 reflects investors' strong confidence in its business model and growth trajectory.

Outside of this, AXLE represents the role of a pure flexibility VTP service provider. In the future, as the national electricity market gradually follows the UK P415 scheme, there will be clear market growth space and business opportunities.

## 4.32 Summary of trends in related industries of BTM flexibility market in the next three years

### Battery Energy Storage System (BESS)

Battery Energy Storage Systems (BESS) form the cornerstone of BTM's operational flexibility. Europe's total operational battery capacity is projected to expand to 61.1 GWh by the end of 2024, with an additional 21.9 GWh added that year alone. Notably, the combined operational capacity across all 27 EU member states currently stands at 49.1GWh. Looking ahead, BESS is expected to experience significant growth, with capacity projected to increase sixfold to nearly 120 GWh by 2029, bringing Europe's total capacity to 400 GWh (334 GWh for the 27 EU member states). Information link

**Demand response (DR) and virtual power plant (VPP)**

Demand response (DR) and virtual power plants (VPP) are crucial for monetizing BTM flexibility. In 2024, the European VPP market was valued at $1.5 billion, projected to grow to $1.81 billion by 2025, with a compound annual growth rate (CAGR) of 21.3% from 2025 to 2030. Within the VPP market, demand response accounted for 48.1% of dominant revenue share in 2024. Information link

The broader European Demand Side Management (DSM) market, encompassing Distributed Energy Resources (DR), is projected to grow from an estimated $18.9 billion in 2024 to $21.4 billion by 2025, and is expected to reach $54.6 billion by 2034 at a compound annual growth rate (CAGR) of 11%. Notably, the demand response component within DSM alone is projected to exceed $150 billion by 2034. The expansion of Virtual Power Plants (VPPs) is primarily driven by three key factors: increasing integration of renewable energy sources, growing demands for grid flexibility and stability, and the widespread adoption of smart grid technologies across Europe.

# 5 How energy storage +VPP manufacturers meet the relevant legal and regulatory requirements for safety in Europe

## 5.1 SaaS software platform

- **General Data Protection Regulation (GDPR)**

Core Requirements: Providers must prevent the transfer of personal data to countries or regions outside the European Economic Area (EEA) and ensure compliance with the GDPR's international data transfer provisions. Default Privacy Protection (Privacy by Design and Default): SaaS platforms must prioritize privacy protection as a core design principle. This requires embedding data protection measures into platform design and operations from the outset, rather than implementing them post-launch. Comprehensive protocols must be established to enable real-time detection and response to data breaches, with mandatory notification of affected customers and regulatory authorities within 72 hours as mandated by the GDPR. This necessitates continuous monitoring capabilities and emergency response

plans for SaaS providers.

Implementation of technical and organizational measures: These measures are typically aligned with frameworks such as ISO 27001. Theoretically, meeting ISO 27001 already satisfies the basic requirements. Currently, there is no unified EU-level official "GDPR certification" institution for SaaS services. As a compliance certification, listed companies are currently undergoing compliance audits by accounting firms. The burden of proof for GDPR compliance primarily falls on SaaS providers. This requires enterprises to maintain detailed records and be able to demonstrate at any time that privacy principles have been integrated into their operations and products. Such internal documentation will serve as primary evidence when facing regulatory reviews or client due diligence.

Cost: 60~80WRMB (annual compliance audit fee is calculated by man-days (6~10W)

Penalties for violations: Violations will face severe financial penalties, up to 4% of global annual turnover or 20 million euros (whichever is higher).

- **ISO/IEC 27001:2022：**

The ISO/IEC 27001 certification is globally recognized to meet the most fundamental security audit requirements. For European SaaS providers, seeking SOC 2 certification on top of ISO 27001 certification aims to evaluate the effectiveness of cybersecurity controls implemented by service organizations to protect customer data.

Cost: European recognized certification bodies: BSI, SGS, Bureau Veritas, Intertek, TUV Rheinland, DNV, etc

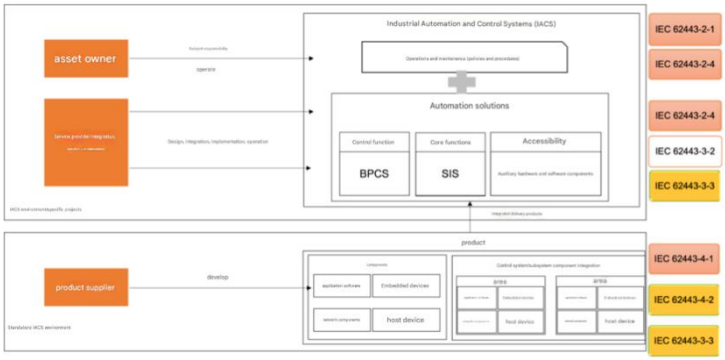
When SaaS services interact with critical infrastructure (especially in the energy sector), their security requirements will increase significantly.

## 5.2 Equipment and EMS software

IEC 62443: Industrial Automation and Control Systems (IACS) safety standard, designed to meet the requirements of the European Cyber Resilience Act (CRA). Officially published in the EU Official Journal on November 20,2024, it is scheduled to take effect in December 2024, followed by a 21-month transition period. (There will be some operational flexibility during this transitional phase.)

Hardware gateway device section:

The hardware equipment needs to meet IEC 62443-4-1 (system, firmware, etc.) and IEC 62443-4-2 (basic components, network drivers, etc.), which can be met by purchasing commercial hardware equipment.




**IEC 62443 for NIS2 and CRA**

| Security topic | NIS2 | CRA | IEC 62443-4-1 | IEC 62443-4-2 |
|---|---|---|---|---|
| Risk management | √ | √ | √ | √ |
| Incident response | √ | √ | √ | √ |
| Security measures | √ | √ | √ | √ |
| Supply chain security | √ | √ | √ | √ |
| Secure Product development | - | √ | √ | - |
| Technical security requirements | - | √ | - | √ |
| Vulnerability management | √ | √ | √ | √ |
| Compliance and certification | √ | √ | √ | √ |
| Network security and resilience | √ | - | √ | √ |
| Information sharing with the authorities | √ | √ | n.A | n.A |
| Monitoring and logging | √ | - | √ | √ |
| User awareness and training | √ | - | √ | - |
| Data protection and confidentiality | √ | - | - | √ |


From：zhihu /MOXA

The device application software shall comply with IEC 62443-3-2 and IEC 62443-3-3 and the equipment shall meet the security architecture for SaaS and IACS interaction.

In the future, it will be required to meet the CRA certification. Among them, RCA will be fully effective by February 2027.

Access to the grid system requires similar NIS2 vendor level authentication requirements.

Main certification bodies: Applus+, TUV Rheinland, SGS, etc

# 6 The relationship between energy storage and the BTM behind-the-meter flexibility market

The BTM flexibility market isn't a single formal market, but rather a collection of value streams encompassing customer bill savings, wholesale energy markets, ancillary services, and network support. The economic viability of BTM energy storage depends on the ability to "stack" these diverse revenue streams, as revenue from a single service is often insufficient to justify the initial investment. This value stacking is enabled by a new class of market participants : Aggregators , who leverage virtual power plant (VPP) software platforms to coordinate a large number of BTM assets, including batteries, heat pumps, V2G electric vehicles , and smart loads.

Looking ahead, the BTM flexibility market has a promising trajectory. Driven by declining battery costs, the rapid growth of electric vehicles with vehicle-to-grid (V2G) potential, and progressive policy reforms, the pool of flexible BTM resources is poised to expand significantly. Leveraging this distributed capacity is not only an opportunity but also a necessity for energy storage companies to support a reliable, cost-effective, and resilient grid that supports a future with a high renewable energy share. The core challenge facing policymakers, utilities, and innovators is to create market structures, regulatory frameworks, and business models that can fully unlock the value of these assets and benefit all energy users .

The main investors in BTM are owners or energy contract managers. The following services are the main drivers for end customers to adopt BTM storage because they create value directly in the user's electricity bill or through enhanced reliability.

**Demand Charge Management and Peak Shaving** : For commercial and industrial (C&I) customers, utility bills often include significant "demand charges," calculated based on the highest peak electricity usage (measured in kilowatts (kW)) during the billing period. BTM batteries can significantly reduce these charges by discharging during a facility's peak usage hours, effectively "shaving" peak demand from the utility. This is often the most profitable customer-side application.

**Dynamic electricity pricing and energy arbitrage** : Support for time-of-use (TOU) pricing and dynamic wholesale electricity pricing, where the price of electricity (per kilowatt-hour, kWh) varies by time of day (30-minute intervals) .

BTM allows users to engage in retail energy arbitrage: charging batteries when electricity is cheap (such as at night or midday when solar power is plentiful) and discharging them for on-site use when grid electricity is expensive (such as during the evening peak).

**Solar Self-Consumption** : For customers with on-site solar PV systems, batteries are essential for maximizing the value of their investment. Excess solar energy generated during the day can be stored in batteries rather than exported to the grid, often at a lower credit rate. This stored energy can then be used at night, reducing the need to purchase high-priced electricity from the utility. This is becoming increasingly important as lucrative net metering policies are phased out .

**Backup power and resiliency** : BTM energy storage systems provide critical resiliency by providing power during grid outages. For businesses, this ensures operational continuity, avoiding costly downtime and product loss. For homes, it keeps essential appliances like lighting, refrigeration, and medical equipment running. This reliability has tangible economic value and is a key driver of investment.

Through the aggregation of VPP or VTP service providers , BTM assets can participate in the formal electricity market and provide services that support the entire power grid.

- **Wholesale electricity market arbitrage:** Aggregated BTM batteries can directly participate in the wholesale electricity market operated by grid operators. They can buy ( charge ) when wholesale electricity prices are very low or even negative (due to excess renewable energy supply) and sell (discharge) when prices are high. Price volatility and spreads in wholesale markets are typically much higher than retail electricity prices, potentially leading to significantly higher returns .
- **Ancillary Services:** These are specialized services that grid operators require to maintain the real-time stability and security of the power system. Batteries' fast response time makes them ideal for providing a variety of high-value ancillary services:
  - Frequency regulation: This involves making minute, second-by-second adjustments to power output (injection or absorption) to maintain the grid frequency at a target frequency (e.g., 50 Hz or 60 Hz). This is the most technically demanding service, yet also one of the most profitable for

batteries. While the overall market size for frequency regulation is small compared to the energy market, it can be a major revenue source for storage assets.

- Operational reserves: This service involves keeping spare capacity that can be quickly dispatched if a large power plant or transmission line suddenly fails, helping to prevent a wider blackout.
- Voltage Support: BTM assets can help manage the end-of-line voltage levels of local distribution networks by injecting or absorbing reactive power , which is critical to maintaining power quality, especially in areas with high solar penetration.

- **Capacity services:** In regions with organized capacity markets (such as the UK or PJM in the US), aggregated BTM assets are paid simply for providing power during periods of system stress (typically the hottest or coldest days of the year). These payments help ensure long-term resource adequacy for the entire system. 21
- **Delayed Investment :** Utilities can purchase aggregated BTM assets to provide targeted regional load reduction in congested areas of the grid. By reducing peak demand at specific substations or feeders, these BTM assets can delay or entirely avoid utilities investing in expensive traditional infrastructure upgrades, such as new transformers or transmission lines.

To achieve the above-mentioned value aggregation goals, energy storage requires

**the "brain" of the system : VPP system or DERMS software**

At the heart of the BTM flexibility ecosystem lies advanced software that acts as its central nervous system: a virtual power plant (VPP) platform and a distributed energy resource management system (DERMS). These systems provide the intelligence layer needed to transform a fleet of dispersed BTM devices into a coordinated, value-generating asset.

Key features of these software platforms include:

- **Connectivity and control:** Software must establish secure, two-way communications with a variety of distributed energy resources (DERs) from different manufacturers. For residential assets like electric vehicles and smart thermostats, this is increasingly accomplished through cloud-to-cloud application programming interfaces (APIs), avoiding the cost and complexity of installing

proprietary hardware in every home.

- **Forecasting and Aggregation:** The platform's primary function is to forecast the flexible capacity available across the entire asset portfolio. Leveraging machine learning and artificial intelligence, the platform predicts factors such as solar generation, building load, and electric vehicle charging behavior to determine how much dispatchable capacity can reliably be delivered to the grid at any given time.
- **Optimization and Dispatch:** This is the most critical function. The software runs complex algorithms to simultaneously optimize the dispatch of aggregated assets across multiple value streams (i.e., value stacking). It determines in real time whether using battery power to mitigate customer peak demand, sell energy to wholesale markets, or provide frequency regulation services is more valuable, while taking into account the operating constraints of the equipment and the preferences of the asset owner.
- **Measurement and Verification (M&V):** To be paid for grid services, virtual power plants (VPPs) must be able to accurately measure and verify the performance of their assets. This software provides the necessary data logging and reporting capabilities to settle financial transactions in energy markets.
- **Standard VPP application interconnection interface:** allows control systems and utility platforms to seamlessly interconnect with energy storage EMS systems, enabling commercial services on a larger scale.
  - OpenADR 2.0b or OpenADR 3.0
  - IEEE 2030.5

# 7 Some key descriptions of BTM flexible technology protocol:

## 7.1 OpenADR 3 protocol details

Demand response (DR) is transitioning from traditional event-based DR to continuous demand flexibility (DF). This shift is transforming multiple aspects of power asset-grid interaction: evolving from static DR events occurring only a few days a year to continuous flexibility implemented hourly daily, expanding from a small number of registered DR customers to all utility clients, and progressing from

limited devices like smart thermostats to all client equipment. This transformation may also render most system loads "flexible." Consequently, costly and cumbersome grid integration processes hinder the achievement of climate and power utility resilience objectives. There is a need for scalable DR solutions that are continuous and ubiquitous, enabling new functionalities for both customers and grids—such as cost-effective microgrid operations and maximizing all grid resources. Against this backdrop, the OpenADR protocol maximizes the integration of distributed renewable energy (DER) resources

The OpenADR 2.0b protocol was first released over a decade ago, with its technical foundations tracing back to earlier developments like the EMIX (OASIS 2012) and Energy Interop (OASIS 2015) formal mechanisms. While these frameworks enabled extensive and sophisticated interaction patterns, they also created challenges in understanding and implementing the standard itself. Despite these complexities, OpenADR 2.0b remains the most widely adopted demand response protocol globally to date.

OpenADR 3.0 represents the latest evolution of this protocol, meticulously designed with modern programming principles. Its primary goal is to simplify implementation while significantly lowering technical barriers for all participants. A key architectural shift in OpenADR 3.0 involves transitioning from the XML-based SOAP exchange protocol (characteristic of version 2.0) to a modern RESTful API architecture that utilizes JSON for data exchange

OpenADR 3.0 and OpenADR 2.0 are not backward compatible. The 3.0 version emphasizes architectural modernization (simplification and ease of use), designed to significantly lower technical barriers to entry, reduce overall implementation costs, and greatly enhance cross-deployment scalability. This simplification is particularly crucial for energy companies managing increasingly decentralized and distributed renewable energy resource (DER) landscapes, where expanding operations while ensuring compatibility and interoperability remains essential.

**Design scheme and positioning comparison differences:**

| respect | OpenADR 2.0 | OpenADR 3.0 |
|---|---|---|
| Protocol design | Based on SOAP/XML | Based on RESTful API/JSON |
| Implementation complexity | Complex, difficult to understand and implement | Simplify and lower the technical threshold |

| | | |
|---|---|---|
| target device | VEN is primarily in the cloud | Independent flexible load, building equipment, Internet of things equipment |
| security model | Usually mutual TLS (custom) | Only servers (VTN) require certificates and support OAuth and TLS 1.2 |
| message format | Older news style exchange format | Modern web service design is easier to use |
| Coexistence strategy | Widely used worldwide, no replacement plan | Supplement 2.0, no replacement, new VTN needs to be supported simultaneously |
| Enhanced functionality | Basic demand response function | Dynamic pricing, greenhouse gas signals, grid code adjustments, capacity management |

OpenADR 3.0 "is suitable for any device capable of Internet Protocol (IP) communication, as well as some new applications. It is suitable for basic scenarios such as allocating highly dynamic electricity prices. It is expected to become the dominant solution for demand response in a manageable short period of time.

The core of version 3.0 is a simple coordination model called "Market Dynamic Pricing and Capacity" – applicable both within customer sites and at the customer-grid interface. Equally crucial is the universal mechanism for conveying this information, which works across all contexts and scales. The OpenADR 3.0 released in late 2023 laid the foundation for implementing these mechanisms.

Some historical and contextual information:

The development of the DR communication protocol OpenADR aims to facilitate more standardized integration of related systems. DR was inherently designed for automation from its inception and is represented as " Continuous Pricing Mechanism" in OpenADR. Initially, DR was understood to encompass both price-based and event-driven coordination mechanisms. Another widely adopted protocol is IEEE 2030.5, which also supports many of the price-based and event-driven DR mechanisms implemented in OpenADR.

IEEE 2030.5 mainly follows and complies with the California Rule 21, while OpenADR mainly follows and complies with the California Title 24 (residential and commercial building construction program), but now IEEE 2030.5 is mainly used to manage equipment such as inverter PCS BESS, while other assets are relatively few in external expansion.

### 7.1.1 Key management elements

**capacity management**

Until recently, customer demand had kept grid capacity constraints primarily

driven by system peak loads, such as during hot summer months when numerous air conditioners operate simultaneously. This slow-growing issue can be addressed through targeted solutions. Today and in the future, two new indoor installations present fresh challenges for system capacity: excess photovoltaic power generated from on-site production and electric vehicle charging (which may also trigger peak demand for electrified heating).

Highly dynamic pricing reduces capacity constraints by shifting loads from peak high-price periods to off-peak low-price periods, particularly effective for transmission lines and medium-voltage networks. However, issues persist with localized capacity limitations such as individual feeders or transformers, even when reduced. Pricing can be partially location-based, but it appears unlikely to become ultra-localized. Nevertheless, capacity limits must still be maintained. Dynamic pricing may exacerbate capacity challenges, especially when renewable energy generation exceeds demand, causing low-cost power to peak during periods of reduced supply. Therefore, a capability management mechanism is essential.

The OpenADR 3.0 User Guide outlines two primary mechanisms: the continuous pricing mechanism and license-based capacity management. The optimal choice between these approaches requires further investigation and experimentation. However, certain mechanisms demonstrate clear merit. Without such mechanisms, utilities would face increasing demands to deny customers' load requests or incur substantial costs to expand capacity.

OpenADR 3.0 incorporates a second mechanism: permission-based capacity management, designed to address challenges in electric vehicle charging. This system enables customers to subscribe to capacity levels for typical usage scenarios (where high EV charging demand is not anticipated). Customers can charge based on their current consumption level relative to their subscription. For faster billing, customers may submit digital automated requests to utilities for additional capacity during specific periods. Requests might be approved, available but requiring payment (if peak local capacity occurs), or denied if no available capacity exists. The industry standard feature of regulating charging through meter status tracking to maintain compliance with specified limits is now widely adopted by multiple suppliers.

**Coordination architecture**

The coordination framework encompasses all mechanisms between customers and the power grid. This framework serves as an integrated system that coordinates

entities, their communication and control relationships, financial operations, and interaction patterns. Typically, specific organizations can participate in multiple systems simultaneously as defined by the coordination framework. Most coordination frameworks operate through a centralized mechanism.

- For DR, there are two emerging central architectures: VPP and highly dynamic pricing. Other approaches already in use include:
- Direct load control: Utilities directly change the behavior of customers' devices, such as by periodically turning them off during peak hours, or changing the level of operation (e.g., thermostat Settings).
- Event-based demand response: Utility plans customers to agree in advance to reduce load (compared to "normal days") within a specified period of time when requested.
- Time-limited variable pricing: Examples of this include time-of-use pricing and critical peak (or variable peak) pricing.
- Two-way trading energy: Customers provide consumers with most of these mechanisms in addition to two-way trading.

**Interactivity**

Interoperability refers to the capability of two or more devices or systems to successfully connect and exchange information to achieve intended outcomes, requiring minimal or no integration work. This is a critical issue in many power environments, ranging from mobile phone charging connectors to electric vehicle charging systems and AC power source plugs. IT systems demonstrate this even more clearly. For Demand Response (DR), interoperability involves several dimensions, such as:

- The structure of how the grid, customers and third parties are coordinated.
- DR is reflected in the tariff or in the optional plan.
- Which communication protocol to use.
- How to use the protocol.
- Whether the coordination is with the entire customer site or a single device.

Power grid entities have developed multiple models for selecting solutions across these dimensions. These differences make it challenging for manufacturers to integrate disaster recovery capabilities into their products and hinder utilities from

achieving widespread customer adoption of such features.

Demand response systems are hampered by conflicting mechanisms for addressing identical challenges, resulting in market fragmentation. The aggregation model exacerbates this issue through diverse grid-aggregator configurations and proprietary protocols between aggregators and devices. Furthermore, the multiplicity of functional control mechanisms employed in buildings complicates the development of standardized demand response controls.

OpenADR 3.0 is designed as a RESTful API, representing a modern IT architectural approach that prioritizes simplicity across multiple dimensions. This methodology facilitates the creation of standardized specifications using machine-readable files (in YAML format) to automatically generate most required software code. Such an approach reduces implementation time, minimizes errors, and simplifies updates to new versions. While YAML files are human-readable, they lack user-friendliness. Therefore, it is essential to define documentation in a more intuitive format that conveys the same information (along with additional details).

The third section of this standard features a comprehensive "User Guide" that provides examples of how to conduct common demand response activities. The core data model requires only three pages of text to describe. The primary structure of information transmission consists of events flowing to the Customer Demand Entity (DER) and reports returning from them. Both are composed of time intervals, each containing zero or multiple data elements. The overall structure of events (and reports) forms a program; electricity billing is an example of such a program. These constitute key structural concepts in OpenADR 3.0. Apart from the "program" itself, all other content represents adaptations of the same conceptual framework

The ability to communicate prices and coordinate capabilities is a core feature of OpenADR 3.0 capabilities, but the standard can do more, such as:

- Subscriptions, which allow the VTN to "push" data to the VTN (rather than having the VTN have to poll)
- Plan (or tariff) metadata
- The ability to locate events and reports to specific resources
- Complex reporting mechanisms, including arrays and data quality characteristics
- red alert

- Event-driven responsiveness enables seamless integration of CTA-2045 data tunneling modules (or devices). Despite these apparent complexities, devices without specific requirements don't need to implement them. Each device can implement only the subset of definitions tailored to its application.

**The basic data model of OpenADR 3.0:**

| Object name | major function | Key features/purpose | Relationship to other objects (brief description) |
|---|---|---|---|
| order | Define energy efficiency programs | Describe the demand response product metadata to enable structured management | Contains events, and VTN can manage multiple programs simultaneously |
| event | Describe in detail the specific actions or events that occurred within the program | Integrated selection to join/exit behavior, simplify participation management | It is a procedure and can specify reporting requirements |
| report | Sharing energy use data and related indicators | Provide data feedback in response to report requests for events | Generated by VEN and sent to VTN |
| subscribe to | Handle real-time update notifications | Push notifications are implemented through the Webhook mechanism | VTN pushes information to VEN |
| VEN | A device in a representative system | Receive VTN signals and manage their associated resources | Manage resources and interact with VTN |
| resource | A single asset managed by VEN | Has a unique name associated with its VEN | Managed by VEN |

**Technical solution differences:**

| Features/Aspects | OpenADR 2.0b | OpenADR 3.0 |
|---|---|---|
| API style | SOAP | REST |
| data format | XML | JSON |
| complexity | High (complex network architecture based on EMIX/Energy Interop) | Low (simpler code, core data model described in about 3 pages) |
| Target device/use case | Mainly cloud entities, utilities and aggregators | Independent flexible load, building equipment, Internet of things, consumer equipment |
| safety method | Custom/PKI (implicit) | OAuth/TLS 1.2 (standardized, widely accepted) |
| Message delivery style | Specific switching mode | VTN serves as a resource server for publishing information |
| Business logic separation | Business logic is often tightly coupled to the server | Business logic is clearly separated from the server |
| Level of certification | Single comprehensive certification level | Multiple authentication function sets (including very simple ones) |

**Open source integration chooses OpenLEADR (Rust)**

OpenLEADR, an open-source project under the LF Energy initiative, provides an implementation of the OpenADR protocol, including a Rust-based version of OpenADR 3.0. The choice of Rust as the development language for OpenLEADR 3.0 stems from its advantages in security, performance, and reliability, making it an ideal choice for critical infrastructure such as power grid systems. Detailed link.

### 7.1.2 Use cases and practical applications

**Dynamic pricing and load management**

OpenADR 3.0 streamlines the delivery of dynamic pricing signals to smart home appliances, industrial equipment, and commercial buildings, enabling faster adaptation to grid conditions. This innovation empowers consumers and businesses to optimize energy usage, reduce costs, and enhance grid resilience. By integrating with load management programs and dynamic pricing mechanisms, the standard makes participation easier for customers, driving broader adoption and improved energy efficiency. The OpenADR solution standardizes, automates, and simplifies demand response applications worldwide, transforming utilities into reliable and cost-effective resources while empowering customers with greater control over their energy future.

**Dynamic routing envelope**

- Concept: The Dynamic Operating Envelope (DOE) is a mechanism for communicating import and export constraints at network points for specific assets (such as HESS) that can change dynamically over time
- OpenADR 3.0 support: OpenADR 3.0 explicitly supports a dynamic running envelope mechanism based on constraints, which is useful for managing grid capacity, especially at high PV penetration.
- Function of EMS: For EMS, DOEs （dynamic operating envelopes, DOEs)can define the maximum power that can be drawn from or injected into the grid at any given time. This is crucial to prevent local grid congestion and ensure grid stability.
- Mechanism: The VTN sends a DOEs "program" or "event" with a time interval, specifying the allowed import and export power limits.
- EMS VEN logic: BESS EMS must continuously monitor these dynamic constraints and ensure that battery charging and discharging operations comply with requirements. If grid restrictions are more stringent and the grid's DOEs

priority is higher, arbitrage or demand response strategies will be covered or restricted.

Today, Australia is implementing a dynamic envelope mechanism to directly coordinate capacity management with customers. This system limits each customer's maximum output to the grid, enabling more users to access stable grid access. Originating from research (ARENA 2021), it is being deployed in Queensland (Energex 2024) and South Australia (SAPN 2024). The mechanism has been incorporated into Australia's IEEE 2030.5 standard (Energex 2023) for this purpose, and is also included in OpenADR 3.0 (OpenADR 2023). The mechanism operates with a one-way communication structure based on constraints. This design makes sense as it addresses highly correlated and predictable excess photovoltaic issues across all customers.

**Integrated with distributed energy (DER) and microgrids**

OpenADR 3.0 streamlines the process of transmitting real-time grid signals to micro-grids and distributed energy resources (DERs), enabling faster adjustments to energy input and output. As energy companies increasingly manage decentralized and distributed energy assets, OpenADR 3.0 plays a crucial role in expanding operations while ensuring compatibility and interoperability. It supports communication across all DER resources to regulate load patterns, energy inputs, and power characteristic variations of DER assets.

**Electric vehicle (EV), charging management**

As more electric vehicles hit the roads, managing charging demands effectively has become crucial to prevent grid overload. OpenADR 3.0 builds upon version 2.0b with enhanced integration methods, making smart and flexible EV charging deployment easier. This advancement enables equipment manufacturers and service providers to seamlessly integrate new features into customer products—including EV charging stations—making it simpler for businesses to add innovative solutions.

**Greenhouse gas (GHG) signals and grid code adjustments**

OpenADR 3.0 enhances capabilities for greenhouse gas signal transmission, grid code adjustment, and capacity management communications (e.g., dynamic operating envelopes). These features help the grid better adapt to the volatility of renewable energy and support more sustainable energy management practices.

**Capacity management communication**

OpenADR 3.0 supports two capacity management mechanisms between the grid and customers. This includes communication methods such as dynamic operating envelopes, which help utilities and aggregators manage grid capacity more effectively and improve the resilience and stability of the grid.

**Simple commands and event signals**

OpenADR 3.0 supports simple event signals that map load reduction levels from 1 to 3. Programs supporting only a single reduction level should be mapped to Level 1. For programs with multiple reduction levels, the minimum operational change should be mapped to Level 1, while load reduction values are progressively mapped to Levels 2 and 3 based on their degree of increase. Additionally, when deploying configuration file VEN, the payload can include BIDLoad and/or BIDPrice signals alongside SIMPLE signals. These signals represent set points and prices respectively, measured in actual power and monetary terms per kilowatt, respectively. This flexible signal mechanism enables OpenADR 3.0 to adapt to various demand response programs and market conditions.

OpenADR 3.0 supports a variety of event types, including:

- Price signals: Transmission of dynamic electricity prices. Can include current and forecast prices, such as hourly prices for 24 hours.
- Emergency alert: Independent sparse events for critical grid conditions.
- Capacity management / Dynamic Operational Envelope (DOE): Import/export restrictions for signal specific asset points.

  Demand response signal: generic demand response request.

## 7.2 The OCPP 2 protocol is described in detail

The OCPP 2.0.1 protocol is neither an incremental extension of OCPP 1.6 nor backward compatible with it, demonstrating fundamental transformations in core architecture and functional design. This update addresses market demands for more sophisticated charging station configurations, enhanced security, and superior customer experiences while maintaining cost-effective deployment scenarios. By introducing the innovative "device model" concept and unified "transaction processing" mechanism, OCPP 2.0.1 significantly improves network management efficiency, configure ability, and remote support capabilities for charging stations.

**Key points:**

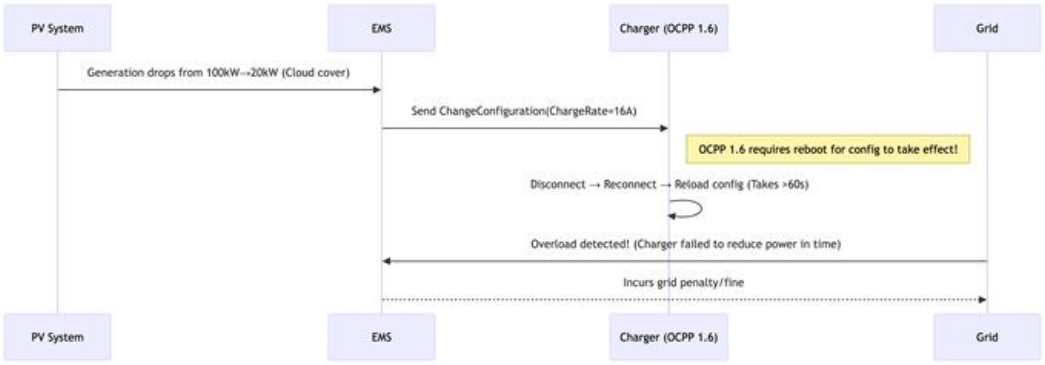
- Device Model: Introducing a new concept that dramatically improves the ability to configure, monitor, error report and inventory assets for complex charging stations, enabling plug and play and predictive maintenance.
- Unified Transaction Handling: All transaction-related functions are integrated into a single "Transaction Event" message, which simplifies CSMS's management of transaction data and supports configurable start/stop points for transactions.
- Full ISO 15118 support: Full support for ISO 15118-2 protocol, including plug-and-play authorization and advanced intelligent charging functions, laying the foundation for smarter electric vehicles to interact with charging stations.
- Enhanced security: The protocol's ability to resist cyber attacks is significantly improved by introducing strict security profiles, client certificate key management, secure firmware updates, and security event logging.
- Not backward compatible with 1.6, but compatible with future versions: OCPP 2.0.1 is not compatible with 1.6, but will serve as the basis for future OCPP versions (e.g., 2.1), and maintain backward compatibility with them to ensure long-term stability

**Key points for improvement:**

- From "Protocol" to "Platform Cornerstone":OCPP 2.0.1, through its modular and backward compatible future development strategy (compatible with 2.0.1), has been upgraded from a pure communication protocol to a platform cornerstone that can support future complex charging scenarios (such as V2G, energy management system integration).
- Refined management for operation and maintenance: The device model is not only data reporting, but also closely binds configuration, monitoring, fault diagnosis with physical/logical components. It reflects the transformation from passive reporting to active, customizable refined remote operation and maintenance, which directly reduces operating costs and downtime.
- User-centered experience optimization: The introduction of multilingual support, dynamic cost display, and diverse authorization methods shows that protocol design is starting to take a deeper look at the end user experience, rather than just the technical communication itself.

- Strategy to deal with fragmented market: By introducing functional blocks (Functional Blocks) and certification profiles (Certification Profiles), OCPP 2.0.1 provides advanced functions while allowing low-cost charging stations to selectively implement core functions, balancing complexity and universality to adapt to diverse market needs.
- The improvement of distributed decision-making capability: The responsibility of generating transaction ID is transferred from CSMS to the charging station itself, and the introduction of serial number improves the independent operation capability of the charging station in offline state, enhances the robustness of data transmission, and reduces the dependence on network connection

For example, when the photovoltaic power generation drops sharply, the power needs to be reduced immediately. OCPP1.6 is difficult to support the dynamic adjustment of charging pile power




Since the configuration of OCPP 1.6 is device-level parameter modification, the configuration can only be effective after the charging pile restarts, and the real-time response of <300ms cannot be achieved.

### 7.2.1 Comparison table of basic functions

| characteristic | OCPP 1.6 | OCPP 2.0.1 | OCPP 2.1 |
|---|---|---|---|
| Release year | 2015 | 2020 | 2025 |
| Communication infrastructure | WebSocket JSON-RPC | WebSocket JSON Schema | WebSocket JSON Schema |
| TLS support | TLS selectable | Mandatory TLS 1.2+ | Enforce TLS 1.3 + quantum security preparations |
| Connect authentication | Base API key | X.509 certificate two-way authentication | Multi-factor authentication (certificate + biometrics) |

| Security level | Foundation | Senior | Enhanced seniority |
|---|---|---|---|
| ISO 15118 support (Plug and Charge) | Limited | Partial support | Fully support |
| Device model | Charging station + connector | Charging station +EVSE + connector | Charging station +EVSE + connector |
| Intelligent charging capability | Load balancing, static charging profiles | Dynamic intelligent charging, flexible schedules, energy optimization | Support V2G (vehicle to grid) and strengthen the interaction between the grid |
| Market adoption rate | Tall | Centre | Low (growing) |
| Expansibility | Limited | Good | Outstanding |
| Implementation complexity | Low | Centre | Tall |
| Single connection concurrency | No more than 50 piles (performance bottleneck) | No more than 200 piles | ≥ 1000 piles (binary optimization) |
| Error handling | Simple error code | Hierarchical error codes (business/transmission/security) | Predictive error correction (AI-driven) |

### 7.2.2 Comparison table of data reporting capability

**Typical scenario comparison**

| Competence | OCPP 1.6 | OCPP 2.0.1 | OCPP 2.1 |
|---|---|---|---|
| Measuring accuracy | Only current (A) and percentage (%) are supported | Support power (W), voltage (V), current (A) | New energy (kWh), power factor (PF), carbon emissions ($gCO_2$/kWh) |
| Frequency of sampling | Minimum 1 minute (fixed interval) | Second-level sampling (minimum 1 second) | Millisecond sampling (minimum 0.1 seconds, support for burst data flow) |
| Data transmission measure | Text JSON (high redundancy) | JSON Schema compression (reduces volume by 40%) | CBOR binary encoding (reduces volume by 70% and supports fragmented transmission) |
| Real-Time | Delay> 5 seconds (depending on polling mechanism) | Delay of 1-3 seconds (event driven reporting) | Subsecond delay (<500ms, supports AI predictive reporting) |
| Measurement direction | One-way (only charging) | Bidirectional (support independent charge/discharge metering) | Three-direction metering (charge/discharge/self-consumption) |
| data integrity | No checksum mechanism (packets may be lost) | CRC check + retransmission mechanism | Blockchain storage (imtamble audit) |
| Self-Defining data | Nonsupport | Limited support (passed CustomData field) | Open data model (scalable IoT sensor data) |

| | | | |
|---|---|---|---|
| Special metering for V2G | ❌ Not have | ⚠️ Basic charge and discharge data | ✅ Grid service metering (frequency modulation times/response delay compensated benefits) |

## Photovoltaic charging station data reporting

| Movement | OCPP 1.6 | OCPP 2.0.1 | OCPP 2.1 |
|---|---|---|---|
| Photo-induced mutation | Report the current change after 5 minutes | Report power fluctuations within 1 second | Predict and report the fluctuation trend within 200ms |
| Measurement error | ± 15% (assuming dependent voltage) | ± 2% (direct power measurement) | ± 0.5% (high precision sensor +AI calibration) |
| Grid current detection | Fail to identify | Power direction after analysis | Block and alarm in real time |
| Data value | Basic billing | Load optimization | Carbon footprint tracking +V2G revenue settlement |

## Detailed comparison of smart charging

| Competence | OCPP 1.6 | OCPP 2.0.1 | OCPP 2.1 | Upgrading |
|---|---|---|---|---|
| Control granularity | Only basic static charging plans are supported （ChargingSchedule） | Support dynamic charging strategy and real-time adjustment | Support predictive charging strategies (PV/load forecasting) | Realize minute level, second level and predictive control |
| Control Model | One-way charging (Charging Only) | Add external set points （ExternalSetpoint） | Added V2G charge/discharge control (bidirectional energy flow) | Support third-party system intervention → vehicle network collaborative optimization |
| strategic flexibility | Fixed power distribution | Support bidirectional charge and discharge limitation (Positive and negative values are set) | Support multi-objective optimization strategy (electricity price + carbon emissions + grid demand) | Paving the way for V2G to achieve comprehensive energy optimization |
| Transaction interruption recovery | Nonsupport | Supports restarting and restoring charging strategies in the event | Support cross-session policy recovery (user reinserts gun to continue policy) | Improve user experience = ensure charging continuity |
| Direct power control | Not supported (only allowed Type "Yes A" or "Percentage") | Support (unit: W) | Support (unit: W/kW/kWh) | Current control → precise power control → energy management |
| Real-time response speed | Minute-level (requires restart) | Instant (effective immediately) | Hao Xiao Ke (less than 500ms) | Meet the basic demand → meet the power grid regulation → meet the real-time V2G transaction |

| | | | | |
|---|---|---|---|---|
| V2G support | Not ❌have | ⚠️Basic support (vehicle required) | ✅Complete V2G service (grid Ancillary service interface) | From scratch to achieve two-way interaction between cars and networks |
| Multi-strategy collaboration | Single ❌strategy coverage | ✅Support stack level priority | ✅AI dynamic optimization (automatic coordination of conflict strategies) | Avoid strategy conflict → intelligent strategy optimization |
| Predictive charging | Not ❌have | ⚠️Limited support (based on simple rules) | ✅AI-driven prediction (weather + historical data + grid signals) | Responsive control to predictive optimization |
| Grid service interface | Not ❌have | Not ❌have | ✅Support FCR/FRR (grid frequency modulation service) | From energy consumption unit to grid regulation resource |
| Energy unit support | Just ❌current | Power ✅（W） | Energy ✅(kWh) + power （kW） | Charge process control → charge and discharge energy management |
| Charging strategies persist | Restart ❌is invalid | Valid ⚠️in the context | ✅Cloud synchronization (automatic recovery after power failure) | Improve system robustness |

## 7.3 EEBUS&SG-ready

The EEbus protocol was developed in response to the urgent need for standardized communication in rapidly evolving energy systems, officially launched in 2017. Its primary objective was to establish a universal, non-proprietary communication language for energy applications. This initiative aimed to address the growing challenge of "increasingly specialized bus protocols, which hindered the integration of physical devices into larger systems."

EEBUS is built on a robust hierarchical architecture that has been meticulously designed for flexibility, scalability, and security, enabling seamless communication across various energy devices. To achieve universal interoperability, EEBUS establishes a clear technical framework addressing the complexities of machine-to-machine communication in energy management, ranging from basic data exchange to sophisticated control signals.

The EEBUS system architecture consists of five distinct layers corresponding to the widely recognized Smart Grid Architecture Model (SGAM): component, communication, information, function, and organization.

SHIP (Smart Home IP) serves as the primary transport protocol in the EEBUS protocol stack, operating at the communication layer of SGAM. Acting as an underlying transmission mechanism, it enables message transmission via either User Datagram Protocol (UDP) or Transmission Control Protocol (TCP). This strategic choice leverages widely adopted internet communication technologies to achieve broad compatibility. Designed for secure machine-to-machine (M2M) communications in home automation and related fields,SHIP is an IP-based protocol. A key feature of SHIP is its stringent communication security, aligning with the HAN (Home Area Network) interface specifications for smart meter gateways outlined in TR-03109 version 1.0 by Germany's Federal Office for Information Security (BSI). This collaboration underscores critical cyber security concerns vital for critical infrastructure. Built on industry-standard IP technology, SHIP integrates advanced security features including TLS 1.2, common cryptographic suites, various elliptic curve encryption algorithms, and robust certificate renewal mechanisms to ensure state-of-the-art security for both current and future applications.

SPINE (Smart Place Interoperability Neutral Message Exchange) operates independently on top of SHIP, covering the information layer of SGAM. As a carefully designed universal data model, it enables cross-domain interoperability between all energy-related devices and systems. This is crucial for enabling various equipment from different manufacturers to "use the same language" and exchange meaningful information. SPINE supports a wide range of evolving use cases, with all scenarios meticulously coordinated and integrated regardless of specific device types or stakeholder roles. Advanced use cases that allow companies to implement specific business logic extensively utilize the EEBUS SPINE specification. A key feature of SPINE is its modular and flexible design, enabling gradual development over time without sacrificing backward compatibility. Additionally, it adapts to any underlying transmission technology, ensuring seamless data transfer and maintaining its forward-looking nature. The functional layer directly above SPINE is responsible for defining a series of use cases designed to deliver optimal benefits for customers

Integration with Emerging Technologies: The flexible and modular design of the EEBUS Data Model (SPINE) ensures its adaptability to evolving transmission technologies and diverse future applications, thereby guaranteeing long-term compatibility and investment security for integrated systems. This includes potential integration with vehicle-to-everything (V2X) technology to enhance grid stability, as

well as emerging standards like Matter.

The cornerstone of EEBUS functionality lies in its automated self-discovery and plug-and-play mechanisms. This eliminates the need for expensive, specialized configuration tools, thereby simplifying device integration. Devices equipped with EEBUS can communicate their self-descriptions through machine-to-machine (M2M) messages, which can even be dynamically updated during operation. This unique capability enables systems to automatically connect devices and discover their functionalities via EEBUS use cases, ultimately creating self-renewing systems with reliable connectivity.

**Table 1: EEBUS protocol stack components and their functions.**

| Ingredient | SGAM layer / OSI, model layer | Major function | Ground floor technology | Main features |
|---|---|---|---|---|
| SHIP （smart home IP） | Communication layer (SGAM), transport layer (OSI) | Secure machine-to-machine communication; message transfer | UDP、TCP、IP | TLS 1.2 security, common password suites, elliptic curves, certificate update mechanism, BSI TR-03109 alignment, user-friendly device connection establishment |
| SPINE (Natural message exchange for intelligent place-to-place interoperability) | Information layer (SGAM), functional layer (OSI) | Common data model for cross-domain interoperability; use case specifications | Independent of transmission technology | Modular and flexible design, backward compatible evolution, self-discovery mechanism, M2M readable self-description, supporting a wide range of use cases |

Article 14a of the German Energy Industry Act (EnWG) and Technical Guide BSI TR-03109-5. Effective January 1, 2024, all equipment falling under Section 14a must be controllable. Both the Federal Network Agency (BNetzA) and the Federal Office for Information Security (BSI) have explicitly confirmed that EEBUS technology meets these requirements, establishing it as a "secure compliance pathway" for manufacturers and operators. This regulatory endorsement provides strong market incentives for Germany's adoption of EEBUS.

The EEBUS application scenario is as follows:

- Smart Home Energy Management System (HEMS): EEBUS serves as a pivotal driver for HEMS, enabling seamless smart communication between diverse devices including thermostats, heat pumps, washing machines, and EV chargers. This interoperability allows HEMS to dynamically optimize energy usage based

on real-time factors such as electricity prices, solar availability from residential photovoltaic systems, or current grid demand. Through this intelligent coordination, homeowners can significantly reduce energy costs while maximizing local renewable energy self-sufficiency.

- Electric Vehicle (EV) Charging and Grid Integration: Given the substantial energy consumption of EVs, EEBUS is essential for integrating them into integrated energy management systems. This integration coordinates charging processes among household or building energy consumers (e.g., heat pumps) and energy producers (e.g., photovoltaic systems), thereby optimizing costs, reducing carbon emissions, and enhancing grid stability. EEBUS defines specific use cases for EV charging coordination, including overload protection through current limiting in EV charging systems and optimized utilization of self-generated energy during charging. Looking ahead, the protocol envisions scenarios where EV batteries can be utilized for active grid stabilization through Vehicle-to-Grid (V2G) functionality. Additionally, EV energy management aligns with ISO 15118 standards.
- Integration with Heat Pumps, Photovoltaics, and White Goods: EEBUS facilitates intelligent networking across these diverse sectors. Manufacturers in white goods, HVAC (Heating, Ventilation, and Air Conditioning), photovoltaic/battery inverters, and EV charging systems (EVSE) have collaborated to develop this protocol. EEBUS enables seamless communication between devices, delivering comprehensive energy management that influences grid-connected equipment behavior regardless of power flow direction. For instance, EEBUS compatibility allows inverters to automatically coordinate with heat pumps, maximizing energy efficiency through optimized self-consumption.
- Dynamic pricing and grid-friendly practices: EEBUS's strategic positioning serves as a key enabler for implementing dynamic pricing, enabling smart user control, and promoting grid-friendly applications. This aligns with emerging regulatory requirements such as Article 14a of Germany's Energy Working Group Act, which mandates the use of controllable devices.
- The Role of Distribution System Operators (DSOs) and Energy Service Providers (ESPs): EEBUS provides customized solutions for DSOs and ESPs. DSOs can monitor power consumption, frequency, and voltage at building or equipment levels. Enhanced transparency and control at grid connection points

enable DSOs to implement dynamic power rationing, thereby optimizing local grid utilization and preventing congestion. For ESPs, EEBUS facilitates flexible market organization and enables energy sales based on current electricity market prices, allowing them to optimize energy equipment operations according to market signals.

- Currently, EEBUS faces challenges in transparency and functional support: Not all EEBUS devices support all features, and the exact compatibility levels between devices are not always transparent. This may result in some devices claiming universal EEBUS compatibility but failing to achieve full interoperability as expected. There is also a lack of open-source solutions, with primary references being the EEBus open-source implementation projects.

**SG-ready**

SG-ready, the acronym for "Smart Grid Ready", is a certification label that verifies heat pumps or supplementary management technologies' capability to respond to defined external control signals. Developed through collaboration between the German Heat Pump Association (Bundesverband Warmepumpe, BWP) and 17 manufacturers, this certification aims to enhance external control capabilities of heat pumps, enabling them to support grid operations, reduce carbon footprints, and improve cost efficiency through optimized performance. As such, SG-ready represents a specialized "Smart Grid Ready" certification specifically designed for heat pump applications.

SG-ready defines four distinct operating modes for heat pumps that communicate through a simple system of two binary switches.7 This simple control mechanism allows flexible interaction with the smart grid:

- Mode 1 – Blocking Operation (1:0): In this mode, the heat pump's operation is limited to a maximum of two hours per day. This configuration also maintains backward compatibility with traditional practical blocking periods, which are typically implemented at fixed intervals. The blocking signal remains active for at least 10 minutes and can only be reactivated after 10 minutes following the previous activation, with daily switching not exceeding three times.
- Mode 2-Normal operation (0:0): The heat pump operates in standard, energy-efficient normal mode, consuming electricity as needed to maintain heating and hot water supply. 9

- Mode 3-Encouraged Operation (0:1): Encourages the operation of heat pumps to increase electricity consumption for heating and hot water. It should be noted that this is an "activation recommendation" rather than a mandatory start command. This mode is typically used to absorb surplus electricity, such as that from photovoltaic systems.
- Mode 4-Sequential Operation (1:1): The heat pump is explicitly commanded to operate. This state supports two scenarios: either directly starting the heat pump or starting it while increasing the hot water temperature to fully utilize the thermal storage capacity. When electricity is abundant or inexpensive, electrical energy can be stored as thermal energy.
- Requirements for heat pumps: To obtain the SG-ready certification, heat pumps (including those with or without domestic hot water heating, water source, air source, or ground source heat pumps) must explicitly support all four defined operating modes. They must also be equipped with a controller capable of raising the set temperature to enhance thermal storage (corresponding to Mode 4). Additionally, certification requires providing detailed documentation specifying the load management settings of the heat pump. Using a simple thermostat is insufficient to prevent heat pump operation.
- Requirements for interface-compatible system components: Equipment transmitting digital control signals to heat pumps via SG-ready operation mode (e.g., inverters, energy management systems, or other automation technologies) must support at least two of the four operational modes and provide adequate documentation. These components must also ensure self-sustaining optimization (when integrated with local power generation like photovoltaic systems), price-sensitive operation (in conjunction with dynamic electricity pricing), and grid-supporting functionality (e.g., stabilizing grid loads through load adjustment). Currently, the primary digital protocol implemented in Germany is EEBUS.

**Table 2: SG ready operation mode and corresponding control signals.**

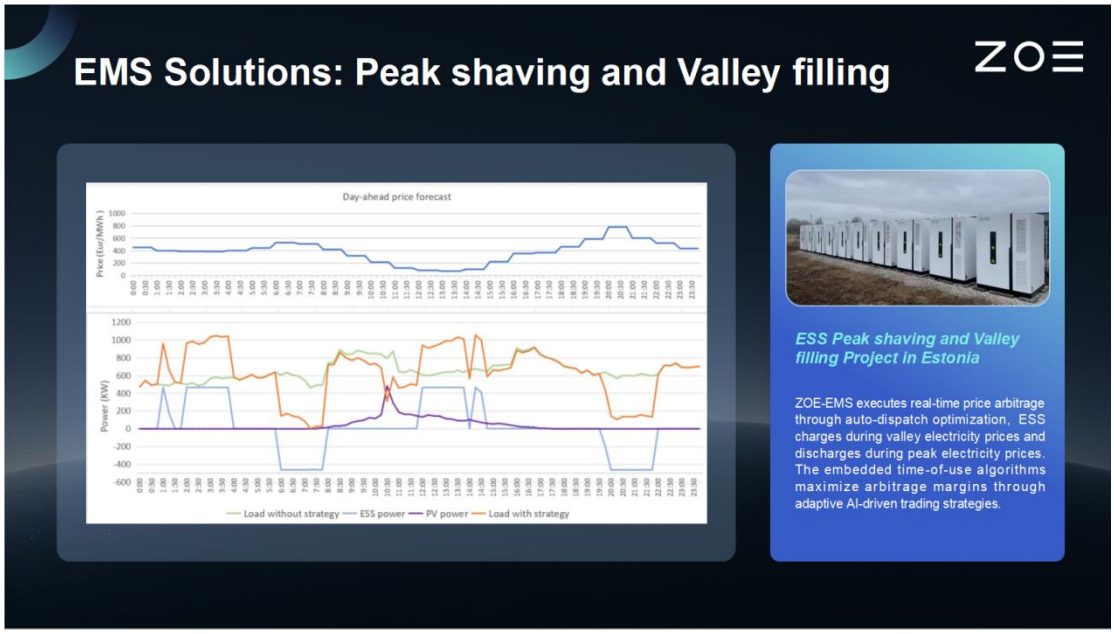
| Work pattern | Binary signal (SG1:SG2) | Heat pump behavior description | Grid/user benefits | Restrain |
|---|---|---|---|---|
| Mode 1 (blocking operation) | 1:0 | Heat pump operation is blocked. | Stable power grid (avoid peak load) and avoid power grid overload. | Up to 2 hours per day; up to 3 times per day; the signal is valid for at least 10 minutes, and reactivated 10 minutes after the last |

validity.

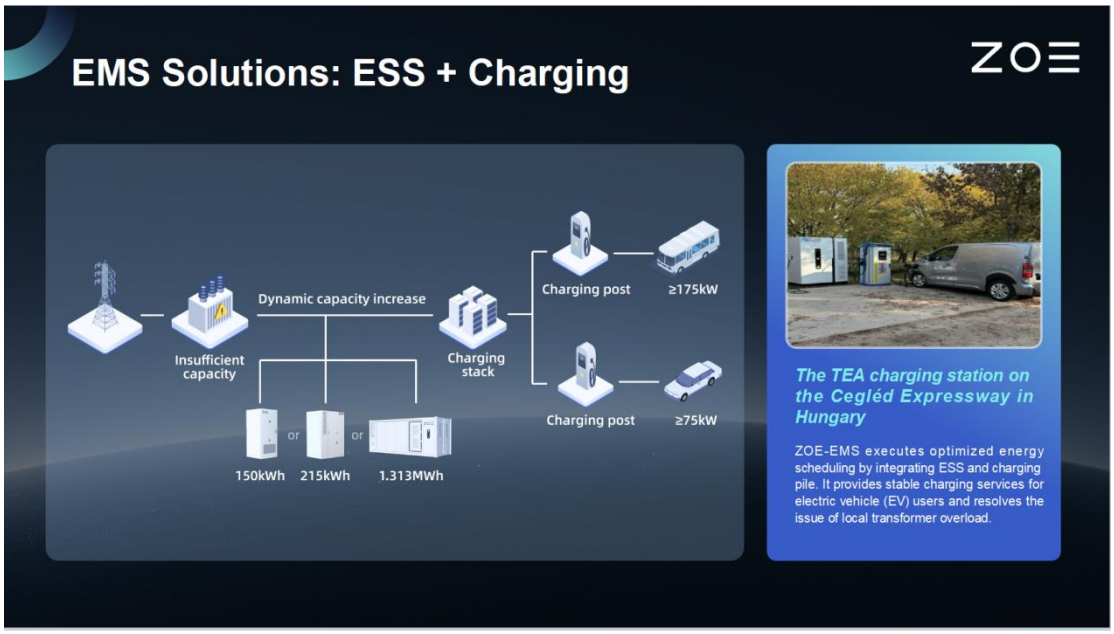
| | | | | |
|---|---|---|---|---|
| Mode 2 (normal operation) | 0:0 | The heat pump operates in normal mode with energy saving. | Standard heating and hot water supply. | None (default operation). |
| Mode 3 (encouraging operation) | 0:1 | Encourage operations that increase heating 热水 consumption. | Increase local photovoltaic self-use and save costs during low prices. | Opening suggestions are not explicit commands. |
| Mode 4 (ordered operation) | 1:1 | The heat pump is ordered to run, which may increase the temperature of the warm water. | Stable grid (absorbing surplus energy); heat storage; increase self-consumption. | Supports two variants: Open, or open and raise the water temperature. |

# 8 Global application cases of BTM energy storage of ZOE

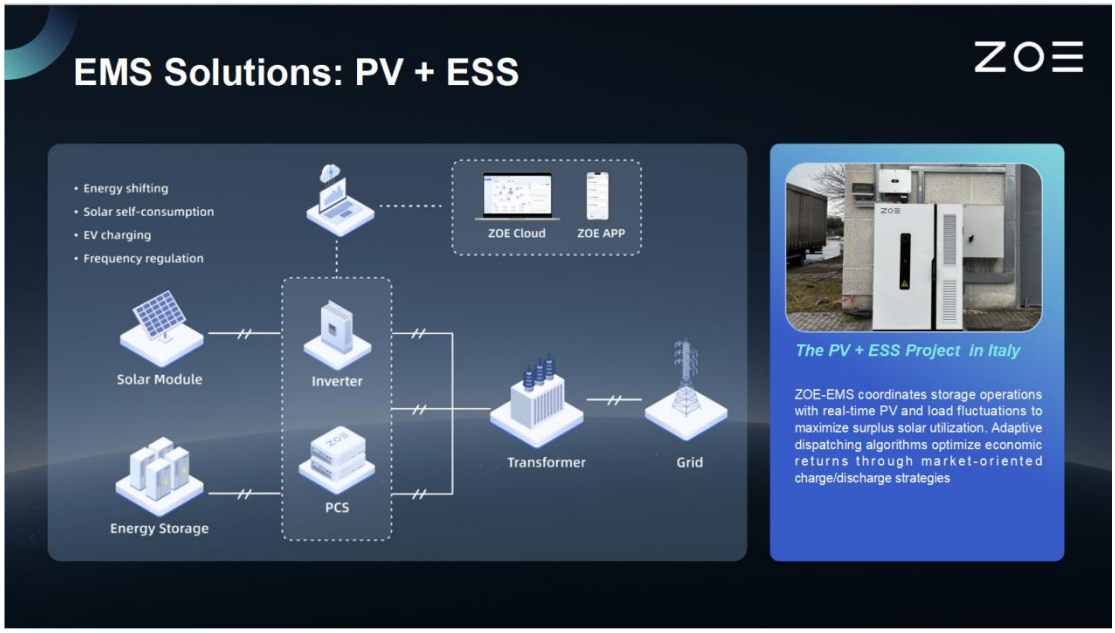
**（1）Estonia Peak-Shaving and Valley-Filling Project:** ZOE-EMS achieves real-time price arbitrage through automatic scheduling optimization. The energy storage system charges during valley electricity prices and discharges during peak electricity prices. The embedded time-sharing algorithm maximizes arbitrage profits through adaptive AI-driven trading strategies.



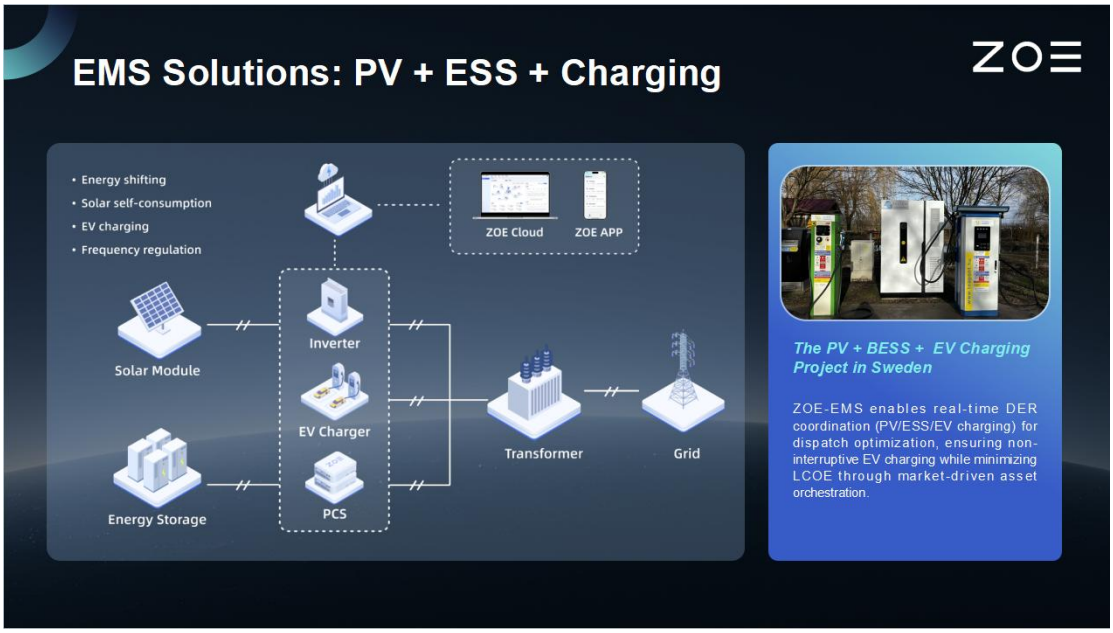

**（2）TEA Charging Station Project on Cegléd Highway in Hungary:** ZOE-EMS achieves energy optimization scheduling by integrating energy storage systems and charging piles, providing stable charging services for electric vehicle (EV) users and solving local transformer overload problems.



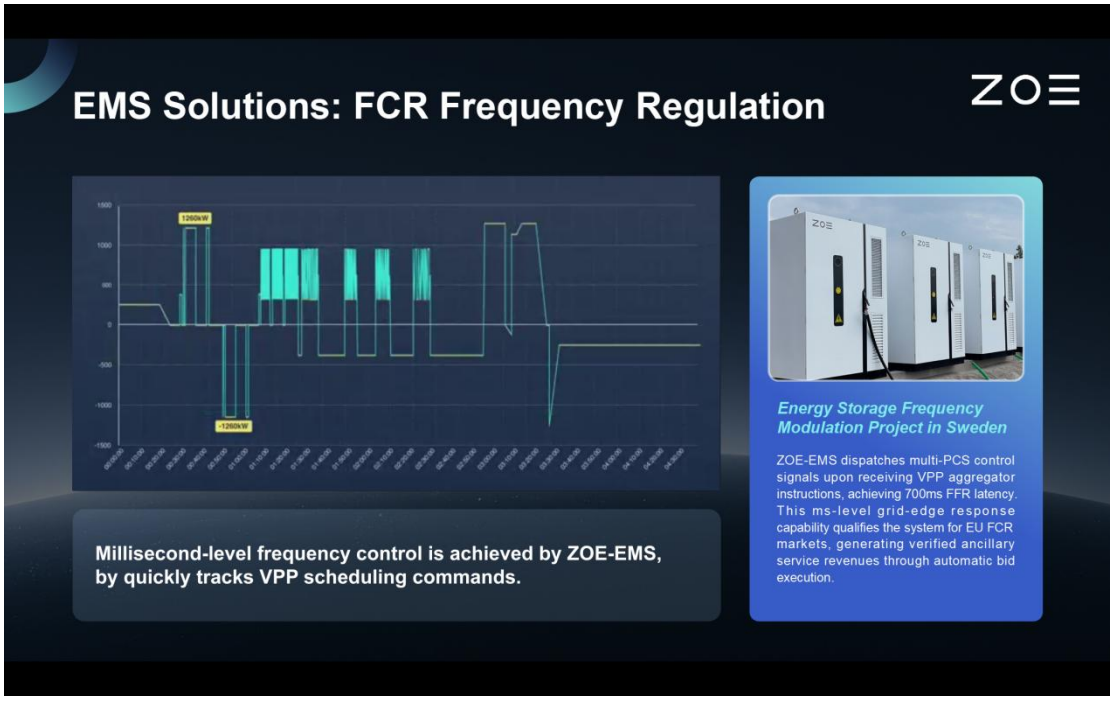

（3） **Italy Photovoltaic + Energy Storage Project:** ZOE-EMS system coordinates energy storage operation according to real-time photovoltaic and load fluctuations to maximize the use of surplus solar energy. The adaptive scheduling algorithm optimizes economic returns through market-oriented charging and discharging strategies.




（4） **Swedish PV + Battery Energy Storage + Electric Vehicle Charging Project:** ZOE-EMS enables real-time distributed energy resource (DER) coordination (PV/battery energy storage/electric vehicle charging), thereby optimizing scheduling and ensuring uninterrupted charging of electric vehicles, while minimizing the levelized cost of electricity (LCOE) through market-driven asset coordination.

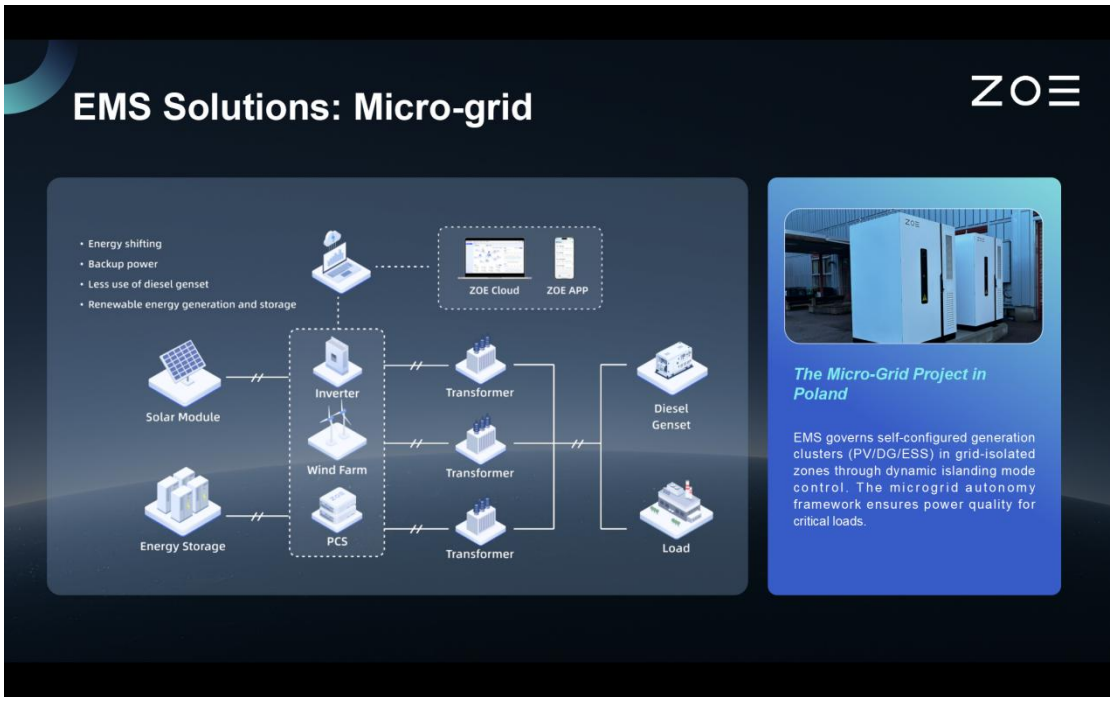



**（5）Swedish Energy Storage Frequency Regulation Project:** After receiving instructions from the VPP aggregator, the ZOE-EMS system can dispatch multiple PCS control signals to achieve 700 milliseconds FFR latency. This millisecond-level grid edge response capability enables the system to meet the requirements of the EU FCR market and generate verifiable ancillary service revenue through automatic bidding execution.

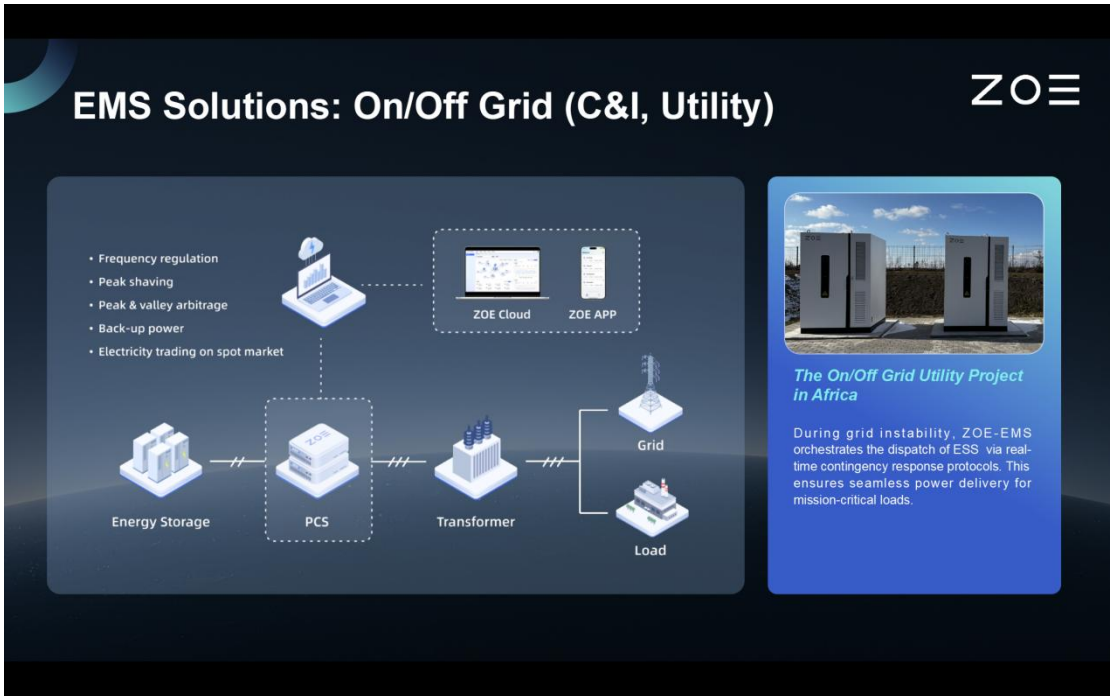



**（6）Polish Micro-grid Project:** EMS manages self-configured power generation clusters (PV/distributed power generation/energy storage systems) in

isolated areas of the grid through dynamic island mode control. The micro-grid autonomous framework ensures the power quality of critical loads.




（7）**African on-grid/off-grid utility projects**: When the grid is unstable, ZOE-EMS coordinates the dispatch of energy storage systems through real-time emergency response protocols to ensure seamless power transmission to critical loads.



# 9 Summary

Virtual Trading Parties (VTPs) will play a crucial and transformative role in the future of the UK electricity market. Becoming a VTP service provider to seize this new wave of business opportunities is imperative. Chinese companies should move beyond hardware and participate more in the competition for digital energy systems overseas, leveraging smarter brains to serve both hardware and Global electricity markets. The system should support the transition of demand response (DR) from traditional event-based DR to continuous demand flexibility (DFs).

**European VPP and Energy Storage Market Development Opportunities (2022-2025)**

**├── Policy-Driven**

**│ ├── EU Policies (Influencing Load Management)**

**│ │ ├── Electricity Market Design Reform (2023-2024)**

**│ │ │ ├── Introduction of Peak Shaving Products**

**│ │ │ ├── Reducing Wholesale Market Bid Sizes (≤100kW)**

**│ │ │ └── Incentivizing DSOs to Procurement Flexibility Services**

**│ │ ├── Demand-Side Flexibility Network Specifications (2022-2025)**

**│ │ │ └── Defining Aggregation/Storage/Demand Reduction Service Standards and Removing Regulatory Barriers**

**│ │ ├── Renewable Energy and Energy Efficiency Directive (2023)**

**│ │ │ ├── Mandatory Intelligent Control/Bidirectional Charging for EV Charging Infrastructure**

**│ │ │ └── "Efficiency First" Principle, Encouraging Dynamic Electricity Pricing**

**│ │ └── State Aid Guidelines (2022)**

**│ │ └── Allowing support for non-fossil fuel flexibility technologies (DR, battery storage)**

**│ └── UK-specific regulations**

**│ ├── P415 (effective November 2024)**

**│ │ ├── Establishing the Virtual Trading Party (VTP) role**

**│ │ ├── Direct access for independent aggregators to the wholesale market (beyond BM)**

**│ │ └── Promoting the monetization of customer-side flexibility ("deviation" mechanism)**

**│ └── P375 (implemented June 2022)**

**│ └── Allowing for post-boundary independent asset measurement and settlement**

**├── Market impact and opportunities**

**│ ├── Market shift towards a "flexibility and consumer-centric" approach**

**│ ├── Rapid development of BTM flexibility**

**│ │ ├── Sources: Smart thermostats, heat pumps, EMS buildings, Battery Energy Storage**

**│ │ └── VPPs Play a Key Role (Aggregating DERs)**

**│ ├── Value Added (Core to the Economic Viability of BTM Energy Storage)**

**│ │ ├── Customer-Side Benefits: Demand Charge Management, Dynamic Price Arbitrage, Solar Self-Consumption, Backup Power**

**│ │ └── Grid-Side Benefits (Aggregated via VPPs/VTPs): Wholesale Market Arbitrage, Ancillary Services (Frequency Regulation, Operating Reserves, Voltage Support), Capacity Services, Deferred Investment**

**│ ├── Market Size and Revenue Potential**

**│ │ ├── UK BTM Flexibility Market: €580 Million in 2025, €2.5 Billion in 2035**

**│ │ └── Energy Storage Revenues Can Double/Triple (Driven by P415)**

**├── Security and Compliance Requirements (VPPs/Energy Storage Vendors)**

**│ ├── SaaS Software Platforms**

**│ │ ├── GDPR (GDPR)**

**│ │ │ ├── Privacy by Design and Default**

**│ │ │ ├── Data Breach Response Notification within 72 Hours**

**│ │ │ └── High Fines (4% of Global Annual Revenue or €20M)**

**│ │ └── ISO/IEC 27001:2022 (Information Security Management System)**

**│ │ └── Basic Requirements, SOC 2 Attestation Recommended**

**│ └── Equipment and EMS Software**

**│ ├── IEC 62443 (Industrial Automation and Control Systems Security Standard)**

**│ │ └── Meeting European Cyber Resilience Act (CRA) Requirements (Fully Effective February 2027)**

**│ └── NIS2 Directive**

**│ └── Grid System Access Vendor Certification Requirements**

**├── Key Technology Protocols**

**│ ├── OpenADR 3.0 (Open Automatic Demand Response)**

**│ │ ├── API Style: RESTful (JSON)**

**│ │ ├── Goal: Simplify implementation, lower technical barriers**

**│ │ ├── Incompatible with OpenADR 2.0b**

**│ │ └── Applications: Dynamic pricing, capacity management (DOE), EV charging management, GHG signaling**

**│ ├── OCPP 2.0.1 (Open Charging Pile Protocol)**

**│ │ ├── API Style: JSON-RPC (WebSocket)**

**│ │ ├── Goal: Complex charging station configuration/monitoring, high security, excellent user experience**

**│ │ ├── Not backwards compatible with 1.6**

**│ │ └── Enhancements: Device model, unified transaction processing, ISO 15118, enhanced security**

**│ └── EEBUS & SG-ready**

**│ ├── EEBUS (Energy Ecosystem Bus)**

**│ │ ├── Universal, non-proprietary energy communication language**

**(SHIP/SPINE layered architecture)**

**│ │ ├── Focus on security (BSI TR-03109 alignment) and interoperability**

**│ │ ├── Automated self-discovery, plug-and-play**

**│ │ └── Compliant with German EnWG §14a regulations**

**│ └── SG-ready (Smart Grid Ready Label)**

**│ ├── External control signal certification for heat pumps**

**│ ├── Defines four operating modes (blocking, normal, incentive, and ordered)**

**│ └── Facilitates heat pumps to support the grid and reduce carbon footprint**

**└── The relationship between energy storage and the BTM behind-the-meter power flexibility market**

**├── Core: BTM energy storage is the cornerstone of flexibility**

**├── Role: VPP/DERMS software is the "brain," coordinating BTM devices to create value**

**├── Function: Connectivity control, forecast aggregation, optimized scheduling, measurement verification, interconnection interfaces**

**└── Case studies: Estonian peak shaving, Hungarian charging stations, Italian PV + energy storage, Swedish frequency regulation/EV charging, Polish microgrids, African on-grid and off-grid solutions**

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*This report is provided with research support from ZOE Energy Storage Research Institute. As a leading innovator in the digital energy sector, ZOE Energy Storage is dedicated to the development of high-security lithium battery energy storage systems and AI-powered energy management platforms. With over 2GWh of energy storage projects deployed globally, we provide the technological foundation for smart grid transformation.*