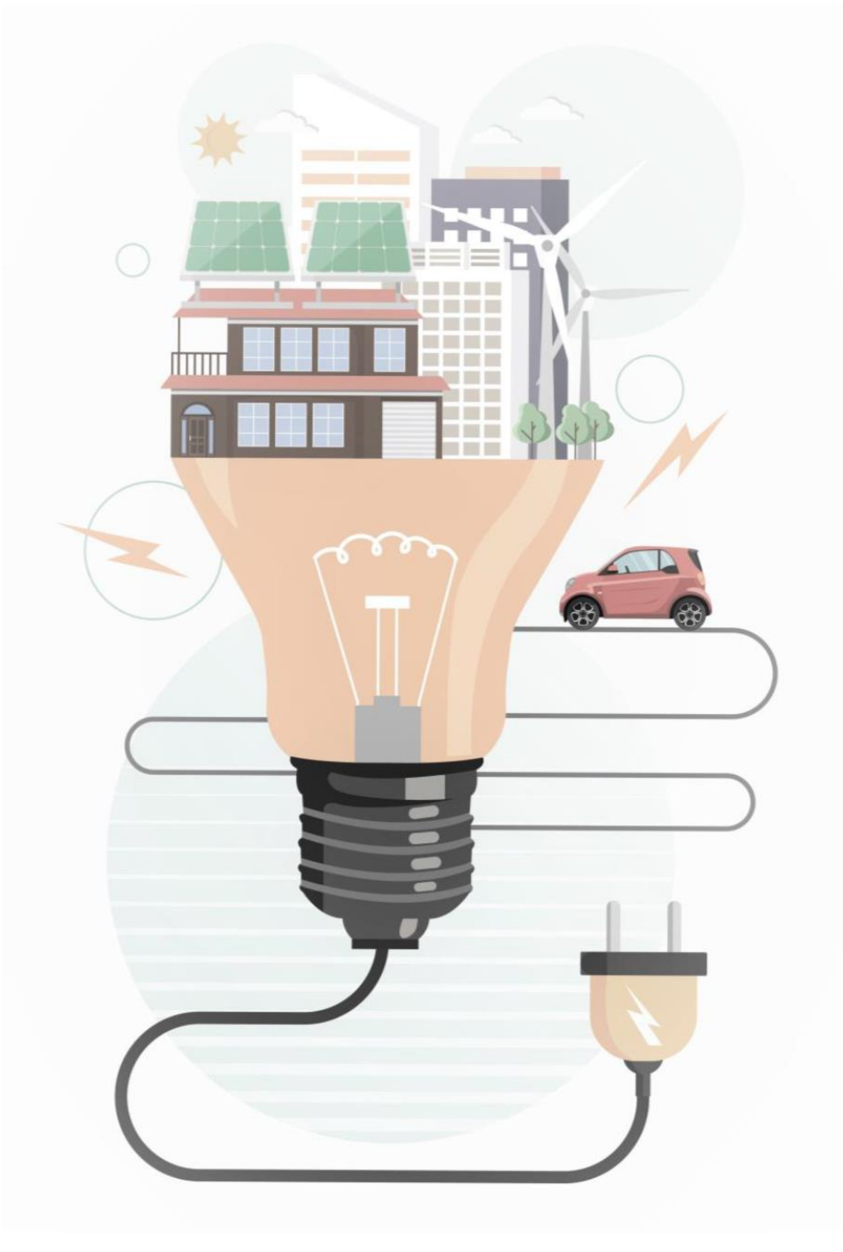
European Commission

Asset Study on

Digital Technologies and Use Cases in the Energy Sector



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1 Executive summary

The European Commission's European Green Deal provides an updated framework for achieving a net zero economy by 2050. The drive to delivering this target by 2050 is creating large changes in the EU energy system. Digital technology will be a key enabler of the future energy system that supports a net zero economy.

The objective of this report is to provide the European Commission with an overview of the value chain and supply chain for key digital technologies that enable critical use cases in the EU energy system. The report provides an overview of the markets for digital technology across the EU and identifies leading EU and non-EU organisations that deliver vital digital technology. Furthermore, the report highlights key considerations in the supply chain for leading vendors providing these technologies to the European market.

This report explores ten uses cases and associated digital technologies identified in the EU's Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal market report (PwC & Tractebel, 2019). Figure 1 provides an overview of these use cases.

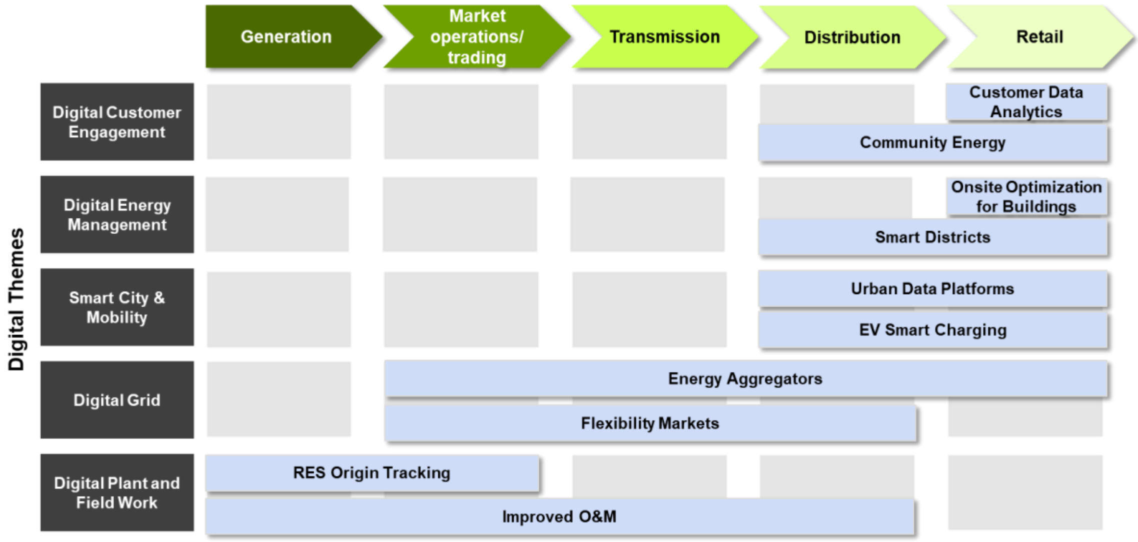


Figure 1: Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal market – use case overview (based on EU's Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal market report).

The landscape of digital technologies in the energy sector spans beyond the use cases and technologies discussed in this research. This study selected several technologies across software and hardware to research further.

Overall, across many use cases and technologies, EU companies are considered leaders in the EU market. Table 1 provides an overview of the technologies considered, the market size in 2020 & 2030 and the leading EU and non-EU vendors considered in this study.

Table 1: Use case and technology overviews including market sizing and leading market vendors

Use Case	Technology	2020 EU Market Size (€M)	2030 EU Market Size (€M)	CAGR (Comp. annual growth rate)	Leading EU companies	Leading non-EU companies
On-site optimization for buildings	Home Energy Management Systems (HEMS)	300	800	10%	Schneider Electric	Oracle, Uplight, Bidgely, Itron
	Building Energy Management Systems (BEMS)	1,160	3,450	12%	Schneider Electric, Siemens, Johnson Controls, Trane Tech	Honeywell
Smart districts	Advanced metering infrastructure (AMI)	2,630	2,160	-2%	Enel, Iskraemeco, Kamstrup, ADD Group	Landys+Gyr, Itron
Energy aggregators	Virtual Power Plant (VPP) Platforms	100	830	24%	ABB, Next Kraftwerke, Centrica Business Solutions, Schneider Electric, Enel X	-
EV smart charging	EV charging infrastructure	500	5,200	26%	ABB, EVBox, Efacec, Alfen, New Motion	Tritium
	EV charging platforms	130	1,500	28%	Virta, Fortum Charge & Drive, has.to.be, GreenFlux, Last Mile Solutions	Driivz
Urban data platforms	Urban data platforms	40	160	15%	SAP, ENGIE	Microsoft, Itron, Amazon Web Services, Cisco, Huawei
Improved O&M	IoT devices for O&M	1,150	1,730	4%	Hitachi ABB Power Grids, Siemens, Schneider Electric, Eaton	Itron (H), GE (M), Schweitzer Engineering Labs (L)
	Software platforms for O&M	90	160	6%	Hitachi ABB Power Grids, Schneider Electric	GE, IBM, Oracle, C3.ai

Flexibility markets	Distributed Energy Resource Management Systems (DERMS)	50	250	17%	Hitachi ABB Power Grids, Schneider Electric, Siemens	GE
	Advanced Distribution Management Systems (ADMS)	660	1,110	5%	Schneider Electric, Hitachi ABB Power Grids, Siemens	GE, Oracle, OSI
Customer data Analytics	Advanced Meter Infrastructure (AMI) data analytics platforms	446	1,020	9%	*These use cases are excluded from detailed analysis, therefore no vendors are listed.*	
RES origin Tracking	Blockchain platforms for certificate validation	10	1,700	67%		
Community energy	Blockchain platforms for peer to peer (P2P) trading					

The market size and growth of digital technologies in the energy sector varies across technologies and individual countries. The difference in energy policy and regulation in the US and EU influences the deployment of digital technology in these key geographies. Although the Clean Energy Package and recent European Green Deal aim to provide a common framework for energy policy, certain specific detail on regulation is open to individual Member States to determine. As an example, the market for digital technology to support EV charging will depend extensively on the number of EVs purchased. The number of EVs purchased is highly dependent on local policy that incentivises the purchase of EVs. In addition, the market for DERMS, VPPs and ADMS could be impacted by the number of distributed energy resources that are deployed, and local energy regulation that details how utilities should use flexibility services to manage the energy system more efficiently.

The analysis from this study highlights that across use cases and technologies the type of organisations offering service can be roughly classified as:

- Vendors closely aligned with utility organisations e.g., Enel X
- IT organisations e.g., Microsoft
- Mature technology providers e.g., Schneider
- Startup technology providers e.g., Last Mile Solutions

Depending on the nature and maturity of the technology, different vendor types capture smaller or larger parts of the EU market share.

Some of the larger EU and non-EU organisations such are GE, Hitachi ABB Power Grids, Schneider Electric, Siemens and Itron operate effectively across multiple digital technologies that enable several use cases. Several of these vendors have an extensive history delivering critical assets e.g., transformers, switchgear, metering to utilities that provides them with key relationships and experience that enables them to expand into newer digital technologies such as; ADMS, DERMS, APM platforms.

In certain use cases such as EV smart charging market and energy aggregators, the current market is growing rapidly. The fast-changing pace and regulation of this market has provided an opportunity for smaller, agile organisations to compete with larger established organisations. Across these use cases several startups are leaders, however analysis is increasingly showing that as the market continues to grow, larger organisations based in the EU and outside the EU are entering the market through the acquisition of smaller startups.

The market size for software based digital technologies considers both the sale of software licenses and the deployment costs associated with implementation. Typically, across Europe, the market for deploying and integrating the software is larger than the sale of individual software licenses.

When considering the supply chain for software based digital technologies (DERMS, ADMS, APM, EV charging platforms, platforms for O&M, VPP platforms and urban data platforms), the analysis clearly shows that companies very rarely rely on third parties when developing their software. However, several organisations rely on cloud platforms such as; Amazon Web Services, or Microsoft Azure. Although organisations typically use a single third party cloud platform provider, they reduce their dependency on these products by ensuring that their software can easily be deployed on a range of cloud platforms.

Several use cases such as; smart EV charging, smart districts and improved O&M, rely on the deployment of hardware such as; charging infrastructure, AMI, and IoT sensors. The analysis from this study highlights that typically organisations manufacture and assemble their products in facilities that are nearby large demand centres. Research from this study indicates that leading EU organisations that supply the European market with EV smart charging infrastructure and IoT devices for improved O&M do not rely on external third parties for critical components in their products. However, in some cases standard components such as printed circuit boards (PCBs) or products enclosures are purchased from external non-EU organisations. Where organisations do rely on non-EU based companies for these components, they typically also have EU based companies that can supply similar products, therefore they minimise any supply chain risks.

Detailed analysis of each use case and technology is available in Chapters 5 to 14 of this report and individual one-pager overviews of key use cases are available in Chapter 15.

2 Table of Contents

List of Acronyms

AC	Air Conditioning	**ICE**	Internal Combustion Engine
AC	Alternating Current	**IEC**	International Electrotechnical Commission
ADMS	Advanced Distribution Management System	**IEEE**	Institute of Electrical and Electronics Engineers
AI	Artificial Intelligence	**IHD**	In Home Display
AIS	Air-Insulated Switchgear	**IO**	Input and Output
AMI	Advanced Metering Infrastructure	**IoT**	Internet of Things
AMS	Asset Management System	**IR**	Infrared
APM	Asset Performance Management	**ISO**	Independent System Operator
AWS	Amazon Web Services	**ISO**	International Organisation for Standardization
BAS	Building Automation System	**IT**	Information Technology
BEMS	Building Energy Management System	**IVVC**	Integrated Volt-VAR Control
BMS	Building Management System	**IWMS**	Integrated Workplace Management Systems
BRP	Balance Responsible Party	**LAN**	Local Area Network
BTM	Behind-the-Meter	**LPWAN**	Low power Wide Area Network
C&I	Commercial and Industrial	**LSV**	Ladensäulenverordnung
CAGR	Compound Annual Growth Rate	**LTE**	Long-Term Evolution
CAIDI	Customer Average Interruption Duration Index	**LV**	Low Voltage
CALM	Connected Asset Life cycle Management	**MDMS**	Meter Data Management System
CAPEX	Capital Expenditure	**MHz**	Mega Hertz
CBA	Cost-Benefit Analysis	**MSM**	Modular Switchgear Monitoring
CBS	Centrica Business Solutions	**MSP**	Mobility Service Provider
CHP	Combined Heat and Power	**MV**	Medium Voltage
CIM	Common Information Model	**MW**	Mega Watts
CIS	Customer Information System	**MWMS**	Mobile Workforce Management System
CITE	Crédit d'Impôt de la Transition Énergétique	**NB-IoT**	Narrow Band Internet of Things
CNR	Compagnie Nationale du Rhône	**NIC**	Network Interface Card
CPO	Charge Point Operator	**NMS**	Network Management System
CVR	Conservation Voltage Reduction	**O&M**	Operation and Maintenance
DA	Distribution Automation	**OBD**	Onboard Diagnostic Port
DC	Direct Current	**OCPP**	Open Charge Point Protocol
DCS	Distributed Control System	**OEM**	Original Equipment Manufacturer
DER	Distributed Energy Resource	**OMS**	Outage Management System

DERMS	Distributed Energy Resources Management System	**OPEX**	Operational Expenditure
DG	Distributed Generation	**OS**	Operating System
DLT	Distributed Ledger Technology	**OT**	Operational Technology
DMS	Distribution Management System	**P2P**	Peer to Peer
DNO	Distribution Network Operator	**PCB**	Printed Circuit Board
DR	Demand Response	**PEV**	Plug-in Electric Vehicle
DRMS	Demand Response Management System	**PMU**	Phasor Measurement Unit
DSM	Demand Side Management	**POC**	Proof of Concept
DSO	Distribution System Operator	**PPA**	Power Purchase Agreement
EAFO	European Alternative Fuels Observatory	**PRL**	Primary Control Reserve
EAMS	Enterprise Asset Management System	**PV**	PV
EC	European Commission	**R&D**	Research and Development
ECJ	European Court of Justice	**RES**	Renewable Energy Sources
EDF	Électricité de France sa	**RMU**	Ring Main Unit
EDP	Energias de Portugal	**RTO**	Regional Transmission Operator
EE	Energy Efficiency	**RTU**	Remote Telemetry Unit
EM	Energy Management	**SaaS**	Software as a Service
EMS	Energy Management System	**SAIDI**	System Average Interruption Duration Index
eMSP	Electro-Mobility Service Provider	**SAIFI**	System Average Interruption Frequency Index
ENTSO-E	European Network of Transmission System Operators for Electricity	**SCADA**	Supervisory Control and Data Acquisition
ERP	Enterprise Resource Planning	**SCMS**	Substation Control and Monitoring System
EU	European Union	**SLA**	Service Level Agreement
EU-MS	European Union Member State	**SOA**	Service Oriented Architecture
EV	Electric Vehicle	**SoC**	State of Charge
EVSE	Electric Vehicle Supply Equipment	**SRL**	Secondary Control Reserve
FACTS	Flexible AC Transmission System	**T&D**	Transmission and Distribution
FCI	Fault Current Indicator	**TDSM**	Transmission and Distribution Sensing and Measurement
FIT	Feed-In Tariff	**TE**	Transactive Energy
FLISR	Fault, Location, Isolation and Service Restoration	**TfD**	Time of Departure
GDPR	General Data Protection Regulation	**TOU**	Time of Use
GH	Guidehouse	**TRL**	Tertiary Control Reserve
GHG	Greenhouse Gas	**TSO**	Transmission System Operator
GHz	Giga Hertz	**TWh**	Terra Watt-Hours

GIS	Geographic Information System	**UDP**	Urban Data Platforms
GIS	Gas Insulated Switchgear	**UK**	United Kingdom
GMS	Generation Management System	**US**	United States of America
GW	Giga Watts	**V1G**	Unidirectional Charging
GWh	Giga Watt-Hours	**V2G**	Bidirectional Charging with Vehicle-to-Grid Power Delivery
HEM	Home Energy Management	**VAR**	Volt-Ampere Reactive
HEMS	Home Energy Management System	**VAT**	Value Added Tax
HER	Home Energy Report	**VGI**	Vehicle-to-Grid Integration
HV	High Voltage	**VPP**	Virtual Power Plant
HVAC	Heat, Ventilation and Air Conditioning	**VSE**	Východoslovenská energetika as
ICCP	Inter-Control Centre Communications Protocol	**VVO**	Volt-VAR Optimization

3 Introduction

The European Commission's European Green Deal provides an updated framework for achieving a net zero economy by 2050. The drive to delivering a net zero economy by 2050 is creating large changes in the EU energy system. Digital technology will be a key enabler of the future energy system that supports a net zero economy.

As described in the EC's Study on 'Assessment & roadmap for digital transformation of the energy sector', digitalisation of the energy sector is having a profound impact on how consumers, prosumers, retailers, traders, producers, and network operators are engaging with the energy system. Digital technologies will be fundamental in enabling the decentralised and decarbonised energy system of the future.

In this study digital technologies are considered a range of hardware and software technologies that generate, collect, transfer, process, and/or store data. Digital technologies have been maturing over several years and now exist within a competitive market landscape; however, several technologies remain at a low scale of maturity and therefore require additional research/trials before being widely utilised.

Understanding the value of digital technologies across the energy system will be vital in delivering an efficient and effective energy system for the future. The goal of the study is to develop an improved understanding of the digital technologies market across the full energy value chain (generation, transmission, distribution & consumption) in Europe.

Specifically, the study aims to understand the value chain and supply chain associated of digital technologies that are applicable to the use cases described in the study.

Chapter 4 provides an overview of the study approach. Chapters 5 to 14 provide detailed analysis of the technology, market and supply chain for each of the use cases and technologies considered in this study. Chapter 15 provides one-pager quick reference overviews for several of the use cases and technologies.

4 Study approach

This study was conducted in three consecutive phases. The two early phases of the project aimed to develop overviews of the use cases, associated technologies, markets sizes and forecasts, and leading vendors. The last phase involved conducting vendor interviews, with the aim of generating insights on the supply chain for leading vendors in the EU market.

The use cases selected as part of the study demonstrate the range of applications of digital technology in the energy sector. The use cases were based on the European Commission's study called; Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal market, authored by Tractebel and PwC. Figure 2 presents the range of use cases across various components of the energy value chain categorised by digital theme.

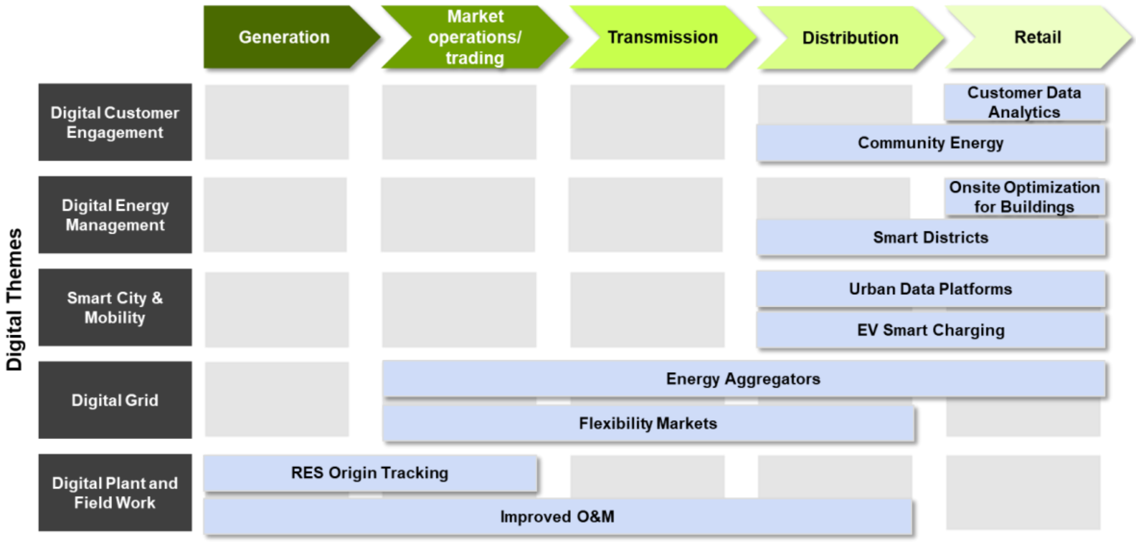


Figure 2: Assessment and roadmap for the digital transformation of the energy sector toward an innovative internal market – use case overview (based on EU's Assessment and roadmap for the digital transformation of the energy sector toward an innovative internal market report).

Utilising the ten use cases presented in Figure 2, Guidehouse shortlisted a range of enabling digital technologies for further investigation in this study. Some technologies listed in Table 2 enable several use cases. For example, advanced metering infrastructure (AMI) is a critical technology that enables several use cases including; customer data analytics, community energy, and on-site optimization for buildings. We recognise that several additional digital technologies are required to fully enable certain use case, however this study focuses on a selected number of critical technologies.

Table 2 presents an overview of the use cases and technologies assessed in this study and highlights to what level of detail the research has been completed.

Table 2: Use case and technology overview

Use case	Technology focus	Detail of research
On-site Optimization of Buildings	Home Energy Management Systems (HEMS)	Technology, market, vendor, buyer and supply chain overviews, incl. vendor interviews. (Phase 3)
	Building Energy Management Systems (BEMS)	
Smart EV Charging	EV Charging Infrastructure	
	EV Charging Platforms	
Energy Aggregators	Virtual Power Plant (VPP) Aggregation Platforms	
Flexibility Markets	Distributed Energy Resource Management Systems (DERMS)	
	Advanced Distribution Management Systems (ADMS)	
Improved O&M	Software platforms for O&M	
	Internet of Things (IoT) devices for O&M	
Smart Districts	Advanced metering infrastructure (AMI)	Technology, market, vendor, buyer overview (Phase 2)
Urban Data Platforms	Urban data platforms	
	Communication Technologies	High level technology and market overview (Phase 1)
Energy Communities	Blockchain platforms for Peer to Peer (P2P)	
RES origin tracking	Blockchain platforms for certificate validation	
Customer Data Analytics	Advanced Meter Infrastructure (AMI) data analytics platforms	

The first phase of the study developed high level use case, technology, and market overviews. Based on the initial findings from Phase 1, several use cases and technologies were shortlisted to the next phase of the study that developed more detailed insights on the market sizes and forecasts, maturity in various EU Member States in deploying the technology, and leading vendors in the market. Following this analysis, the EC shortlisted several use cases and technologies to progress to the vendor interviews. The objective of the vendor interviews was to better understand the supply chain for leading vendors in the markets.

This section describes the methodology for generating insights that are presented in this study. In Table 3 below, we provide an overview of each research item, the approach, and main sources.

Table 3: Approaches and sources for each research item

Item	Approach	Major sources
Market size	• Guidehouse Insight's market size forecast is based on the subject matter expert's estimation of each technology with respect to the stage of development of the industry in the EU-27 and the economics of technology installations. The supply-side accounting method is used to monitor past, present, and future installations on a regional or technology level. • Estimates of the outcome beyond 2025 are based on an interpretation of the geopolitical picture in relation to climate change and energy security issues, as well as commitments to renewables.	• GH Insights expertise
Market growth	• Projections are general guidelines given the many uncertainties associated with policy frameworks and other factors that are likely to change significantly over the next decade as existing markets mature and new markets emerge. • The outlook is indicative of the current regulatory environment, taking into consideration future projects and the progression in the market.	• GH Insights expertise
Leading Vendors	• Leading vendors in the market have been identified as organisations who have an estimated higher market share relative to other market participants.	• GH Insights expertise
Market share	• Market share calculations are based on revenue estimates of selected key players in the market. Each company was examined for their presence across the value chain and market share for each vendor was estimated in the EU-27 market.	• GH Insights expertise
Maturity of EU Member States	• The maturity of countries has been assessed through the scale of the deployment of the digital technology, in combination with the technical functionality and complexity associated with the deployments.	• GH Insights expertise
Supply chain	• The insights on supply chains from various technologies have been informed through several interviews with vendors providing services in the relevant market. A questionnaire was followed to focus the conversations on supply chains and associated risks.	• Vendor interviews

5 On-Site optimization for buildings

The building sector accounts for about 32% of total EU energy consumption (European Commission, n.d.),[1] making it essential to reduce energy consumption in residential as well as commercial buildings. Energy Management (EM) solutions, i.e., Home Energy Management Systems (HEMS) and Building Energy Management Systems (BEMS) that are comprised of software, hardware and service solutions, enable energy use optimization through consumption monitoring and management by the building users and owners. Additionally, EM systems create awareness of the users' energy consumption habits and can motivate them to actively participate in energy usage optimization.

Several aspects are driving the EM system deployment within the commercial, industrial and residential buildings:

- **Regulatory requirements:** EU energy efficiency and greenhouse gas (GHG) reduction targets are a strong driving force behind EM system market growth. These drive the market in two ways: (1) regulators have set targets for utilities encouraging them to utilise digital technologies to deliver energy consumption notifications to customers; and (2) building users and owners are pushed by regulation or become increasingly motivated to monitor and reduce their energy usage themselves.
- **Technology advancement and accessibility**: EM solutions employ software platforms with advanced computing processes, tools and methods that provide deeper savings and additional benefits, such as proactive maintenance or space management. HEMS and BEMS hardware and software are accessible and easy to deploy for building users and owners. The technologies provide improved energy monitoring and granular control of energy use, leading to reduced energy bills.
- **Utility and customer engagement**: Utilities and energy providers are adopting digital tools integrated with HEMS/BEMS as a strategic priority to connect with customers more frequently and through various channels. This allows companies to meet the customer expectations of personalized experience and recommendations for energy use reduction, as well as timely, relevant, and up-to-date information regarding energy usage and bill rates from their energy providers.

There are several technologies within the EM system scope that enable on-site optimization of energy usage:

- Advanced Metering Infrastructure (AMI) sensors (i.e., smart meters);
- Building automation/management systems and sensors (e.g., HVAC, lighting, fire, safety, security access control systems, etc.);

[1] European Commission. Energy Use in Buildings. Retrieved at: https://ec.europa.eu/energy/eu-buildings-factsheets-topics-tree/energy-use-buildings_en

- Communication technology between sensors and software platforms;
- EM software platforms (such as web-based platforms and mobile applications).

This study focuses on the BEMS and HEMS. They are key to enable on-site optimization for energy use for C&I and residential buildings. The following sections of the report will capture respective overviews for technology, market, vendors, buyers, and the supply chain.

5.1 Home Energy Management Systems (HEMS)

5.1.1 Technology overview

HEMS are a broad range of technologies and services that consumers use to better manage and control home energy consumption and production (Guidehouse Insights, 2019)[2]. HEMS have evolved from standalone hardware solutions such as smart metering infrastructure, thermostats and in home displays (IHDs) to integrated hardware and software systems that utilise data analytics leveraging machine learning and AI techniques to uncover deeper energy consumption patterns in homes and provide recommendations for optimized energy usage. The HEMS space is creating business opportunities for new market entrants, further evolving the HEMS technology, and increasing market competition.

The four main technology segments within HEMS, i.e., home energy reports, digital tools, standalone HEM, and networked HEM, and their comparative value proposition to consumer energy savings are provided in Figure 3.

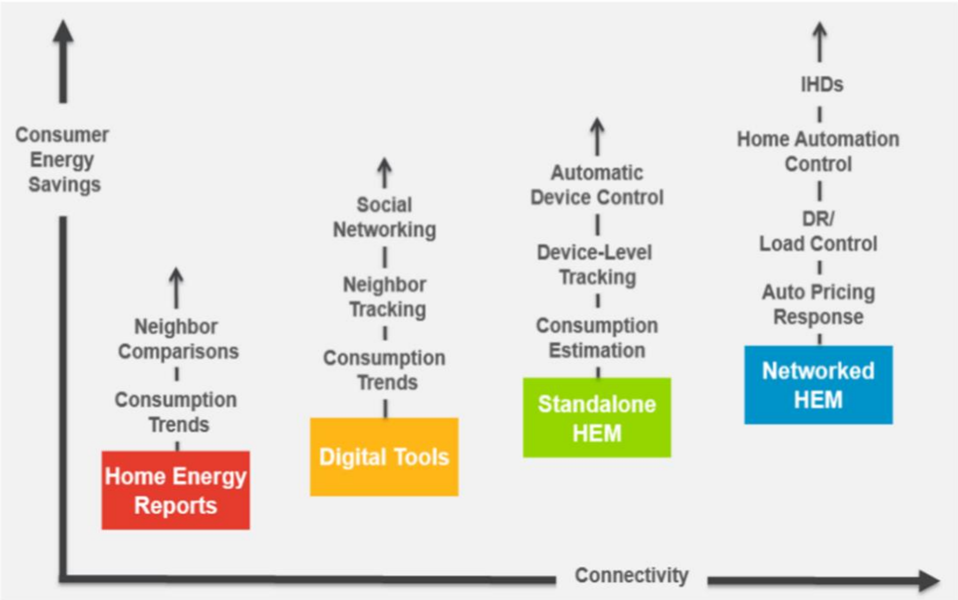


Figure 3: HEM technology segments

A growing number of smart devices can collect and communicate energy usage information from residential homes to energy providers. These devices include smart

[2] Guidehouse Insights. (2019). Navigant Research Leaderboard: Home Energy Management.

meters, smart plugs, smart thermostats, smart electric heaters, and smart lighting, as well as behind-the-meter DER such as smart inverters / PVs, energy storage and EVs. In turn, combining data from multiple devices, energy companies can provide more nuanced and personalized insights regarding their energy usage to homeowners.

Due to growing demand for HEMS, energy companies now emphasize on advanced analytics, personalization, and targeted engagement with energy users. These features have become mainstream elements of HEMS. Current HEMS range from direct-to-customer energy monitoring apps to white-label software platforms for utility customers that are then rolled out to end users[3] (Guidehouse Insights, 2019). All solutions support basic energy monitoring functionality, alerts, and report features. More advanced platforms support personalization and disaggregation and help identify faulty equipment or similar appliance-level data. For example, instead of generic suggestions to multiple customers to reduce AC consumption when outdoor temperatures rise, a specific homeowner can receive an optimal setpoint or be informed of abnormalities in an AC unit that suggest it needs to be serviced or replaced.

5.1.2 Market overview

HEM market revenue features two main categories of spending:

- HEMS software is the money spent on the digital programs, platforms and analytics tools that provide the data and processes to homeowners for managing energy consumption in their homes, including interactive web portals.
- HEMS services is the money homeowners or consumers pay to a utility or some other service provider for monitoring and managing consumption as part of a bundle or as a standalone offering.

Market size

Figure 4 shows an aggregation of those two categories, as individual data is not available. The European HEMS market represents about 30% of global revenue and is expected to grow at a CAGR of 10.3% between 2020 and 2030. Though not as large as the US-North American HEMS market at this time, there is significant room for growth in EU Member States as both energy providers and consumers seek to benefit from hardware, software and integrated services that drive down energy consumption for cost-saving reasons and to meet energy conservation targets set by local and EU regulators.

[3] Guidehouse Insights. (2019). *Home Energy Management Overview*. Retrieved at https://guidehouseinsights.com/reports/home-energy-management-overview

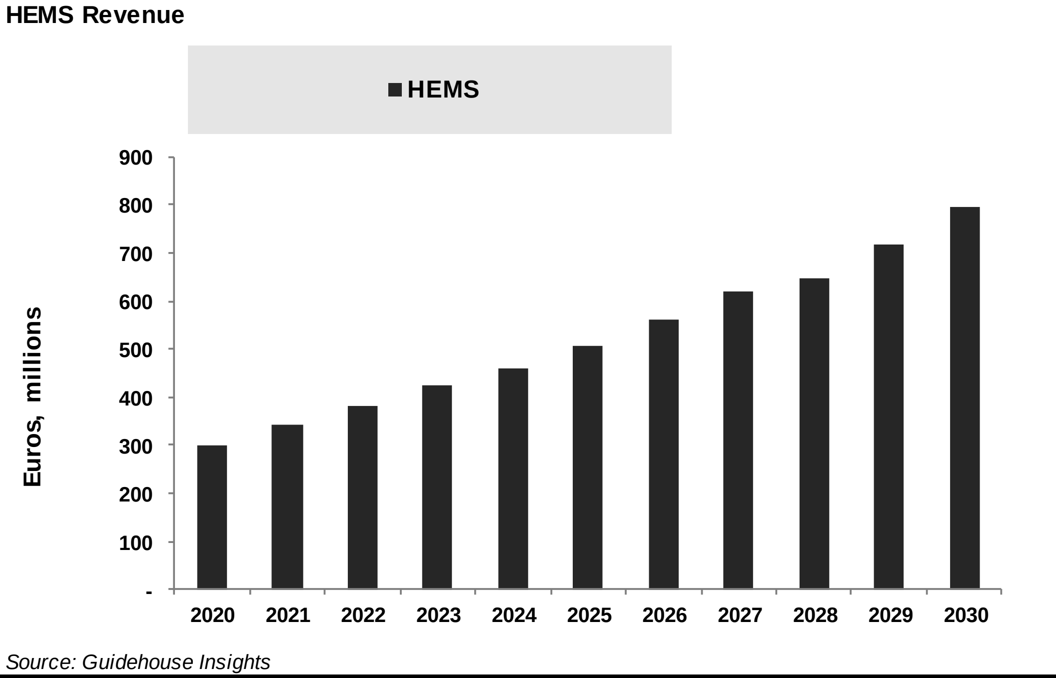


Figure 4: HEMS Revenue, EU-27 Market

Market maturity in EU Member States

HEMS solutions have been adopted at different rates throughout the EU. Overall, there is lower HEMS penetration in the EU compared to the US due to lower penetrations of enabling hardware, especially smart meters with sub-monthly data granularity. Lower interest from and more regulatory barriers for EU utilities also have limited penetration of HEMS solutions. This said, customer retention, opt-in consumer journeys and engagement analytics are of value to EU utilities and they are investing in these solutions either through partnerships with third party specialists (some non-EU based, such as Bidgely and Uplight) or through in-house development efforts. Most of these companies' revenue is money spent by utilities who buy the software solutions or platforms that fuel consumer interactions.

A noteworthy technology and market challenge of HEMS vendors in the EU is related to data privacy. HEMS vendors rely on data transmission mainly to North America for data storage and processing. Such data traffic must adhere to GDPR and was regulated in the agreement between the US and the EU called privacy shield. Since that agreement was invalidated by the European Court of Justice (ECJ) in July 2020 and a new regulation still must be agreed upon, such data transfers are currently limited. Furthermore, EU customers (utilities) tend to prefer ownership of SaaS solutions, which hinders such software vendors. Lastly, low smart meter penetration is a clear market barrier, just as high penetration was described as a market driver above.

In the following, the French, Dutch, German, and Nordic HEMS markets are highlighted as the most mature or with the best outlook for growth in the EU.

France

French utilities are strong incumbents in their market and tend to provide HEMS-related solutions in-house. France is also the largest electric heating market in Europe, which is a critical load for HEM systems to optimise. Government support for home energy savings has also been strong. Until the end of 2019, the main form of financial assistance for home energy conservation was a tax credit called the Crédit d'Impôt de la Transition Énergétique (CITE). Since 2019, this tax credit is being phased out, to be replaced by a grants system called MaPrimeRénov. This programme offers several rebates for energy efficient home technologies. As programs like these proliferate HEM hardware, increasing opportunities will emerge for HEMS providers to engage with utilities on customer churn prevention through solutions deployments.

Netherlands/Germany

Dutch regulatory policies strongly encourage energy efficient homes. Among energy providers in the Netherlands, Eneco stands out with its HEM solution based on Quby, a connected home offering. Long-standing programs like Energiesprong have also supported home retrofit efforts and continuously engaged consumers in HEM concerns, leading to a mature market despite regulatory barriers for third party operators.

While the German market lags in smart meter deployment, it is the largest centre of potential HEMS growth (in absolute terms) due to high adoption of residential solar PV and storage and increasing need for management of these assets. As German feed-in tariffs decrease, HEMS will also gain value by maximising self-consumption.

Nordics

Sweden and Finland are the leading EU markets for HEMS in terms of relative penetration. Norway, although not an EU Member State, should be included in that group. High penetration of smart meters and electric heating appliances combined with dynamic tariffs have made these countries attractive markets for HEM solutions. Norway, in particular, has seen very high EV uptake, leading to increased demand for vehicle-to-grid HEMS. Low Nordic electricity retail prices and low volatility of dynamic tariffs however limits the ultimate cost savings value that HEMS can provide.

5.1.3 Vendors overview

From a software standpoint, HEMS providers emphasize their ability to gather and interpret large data sets and then distil the information for individual customers. The leaders in terms of skills tend to be the US vendors like Oracle, Uplight, and Bidgely, given that is their specialty. In Europe, though, Schneider Electric and Itron have key supplier relationships with energy providers and their software platforms provide important tools to enable enhanced energy management.

Based on revenue, the leading vendors of HEMS in EU-27 are Schneider Electric, Oracle, Itron, Uplight and Bidgely, in that order. Table 4 provides and overview of these leading vendors.

Table 4: Leading vendors of HEMS

Vendor	Company overview and related offerings
Schneider Electric HQ: France Market Share: High	• Schneider Electric, with operations in more than 100 countries, offers integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Schneider Electric’s HEM strategy is based on its Wiser Energy management system that continuously monitors a home’s electrical consumption and can detect inefficiencies that needlessly boost energy bills. The system includes a mobile app for monitoring usage and is compatible with devices such as Phillips Hue and smart plugs. For energy providers, Schneider’s HEM solution leverages its EcoStruxure platform and tools.
Oracle HQ: USA Market Share: High	• Oracle offers software solutions for business integration, IT consolidation, and supply chain management, as well as designs, develops, and produces pre-packaged computer software for industry, business, and technology. Oracle EMEA serves clients worldwide. • Oracle acquired Opower that provides utility engagement and energy efficiency (EE) cloud services. Oracle’s (Opower) solutions include a suite of customer digital engagement tools and communications, energy insights and alerting, EE, and DR. Oracle announced new products that include behavioural load shaping, DER customer engagement, EV detection, and disaggregation.

Vendor	Company overview and related offerings
Itron HQ: USA Market Share: Medium	• Itron serves utilities and cities in 100+ countries. The portfolio encompasses smart networks, software, services, meters, and connected sensors with integrated networking and communications. • Itron’s HEM product is called IntelliSOURCE and includes capabilities for demand management, EE, and customer engagement. It enables energy providers to deepen customer engagement by adding integrated EE capabilities to DR programs while providing tools to better manage customer participation with mobile apps, smart thermostat controls, automated price response, and actionable tips.
Uplight HQ: USA Market Share: Medium	• Uplight was established in 2019 by combining the recent acquisitions of EEme, EnergySavvy and FirstFuel with Tendril’s data analytics platform and Simple Energy’s consumer engagement marketplace. • Uplight’s platform supports engagement through home energy reports (HERs), electronic HERs, a customer engagement portal, high usage alerts, rates marketing and calculators, activation through marketplace integrations, online home energy audits, HER advertising, smart speaker-voice integration, next-best actions, nonresidential engagement and analytics, and programme enrolment. The platform also offers a demand management solution via smart thermostats.
Bidgely HQ: USA Market Share: Medium	• Founded in 2011, Bidgely is a SaaS company analysing meter data to help utilities better engage and satisfy customers with more personalized energy information. • Bidgely’s UtilityAI platform enables utilities to target all customers, regardless of whether they have a smart meter installed. The platform can deliver personalized insights from actual customer data. Bidgely has expanded the platform to help improve centre operations. • The company’s overall solutions also help with customer engagement across multiple channels, including mobile apps, web portals, email, and paper reports.

5.1.4 Buyers overview

The primary buyer of HEMS technology is a distribution network operator or a utility providing energy to residential customers. The buyer is seeking tools or methods for helping its residential customers reduce their energy consumption. Often, these tools take on a digital form as in emails or text alerts, or even video, sending pertinent consumption information and recommendations to the customer who can then choose to take various actions to lower energy use. In some cases, the buyer can set up or enable an online marketplace of energy management products or services the customer can browse and make purchases.

The primary buyer is motivated to adopt HEMS technology to meet several demands. One is to satisfy policy mandates for increased EE. For example, the European Commission’s EE directive calls for Member States to provide frequent and useful energy consumption data to consumers. Member States are the enterprises responsible for carrying out the particulars. In addition, residential customers themselves have come to expect help in managing energy from DNOs or utilities. As they adopt rooftop solar systems, smart thermostats, and electric vehicles (EVs), for instance, customers expect their energy provider to deliver timely and useful information to help them efficiently use energy. Also, whether residential customers purchase new energy-related equipment or not, there is a growing demand or expectation from many customers that their energy providers will provide vital usage information to help them reduce consumption, lower their bill, reduce their carbon footprint and lead more environmentally sustainable lives.

Case study: VSE, Slovakia pilot using Bidgely's customer engagement and EE solution

VSE, one of Slovakia's largest electricity distributors, offers a case study in HEM technology adoption from the buyer's perspective. VSE wanted to accelerate its move from selling electricity and gas only to offering a variety of products and services to its customers. VSE chose Bidgely as the solutions provider for a pilot programme that used Bidgely's customer engagement and EE solution that is powered by AI. The pilot featured emails with itemized energy usage by appliance, and a web platform that provided deeper energy usage insights for customers along with a process to fill out a home profile for enhanced personalization. The solution also supported call centre staff who could schedule a field agent for an in home visit where relevant products and services could be recommended. Results from the initial pilot showed high customer satisfaction, with 97% of customers wanting VSE to continue offering the services and 95% saying the services were useful. In addition, the upsell potential more than doubled, according to the vendor.

5.1.5 Supply chain overview – vendor interviews

For the purpose of this study, interviews were conducted with the following vendors: Bidgely, Oracle (Opower), and Uplight.

Two key insights were gained during the vendor interviews:

(1) Software supply chain depends on non-EU players mainly for data storage

(2) Hardware supply chain is not the focus of key HEMS players, but external hardware strongly impacts the market such as smart meters or EV uptake

The software supply chain can be divided in two main segments. The main platforms to interact with the user and customer are mainly developed in-house. That takes place in the EU but also in the US and Canada. A clear dependency on third parties for data storage and processing is characteristic for the industry. This is mainly conducted in the US or India. Click tracking and interaction data tracking are two examples of offshored data processing. Except for the data privacy debate mentioned before, the industry players do not perceive any supply chain risks.

As HEMS core hardware is not the focus of the main players in this technology, hardware enters the stage in a different form. Uptake of external hardware such as smart meters can have a significant impact on HEMS market developments. Further examples include

EV charging and roof top solar installations. Since those strongly impact energy flows in homes, their penetration is a key driver of HEMS uptake as well.

5.2 Building Energy Management Systems (BEMS)

5.2.1 Technology overview

BEMS have evolved from simple controls to sophisticated intelligent building applications over the past 15 years. BEMS currently range in sophistication from simple tracking of energy consumption to proactive management of energy use and integration with other commercial building systems. Simple energy reporting applications may start with utility bill or utility data analysis. Heating, Ventilation, and Air Conditioning (HVAC) and lighting are the next biggest areas for energy consumption analysis as they are the largest energy-consuming equipment in commercial buildings. Deeper savings come from a more comprehensive approach to building energy management where all equipment work together towards better efficiency. Finally, more complex BEMS employ sensor-driven insights that combine energy and operational efficiencies in the areas of facilities management, occupancy, asset and space management, wayfinding, and others. The current BEMS market is primarily driven by a proliferation of behind-the-meter sensor technologies, enabling more advanced analytics and visibility into a wider range of assets and technologies.

The four main value segments within BEMS, i.e., visualization and reporting, fault detection and diagnostics, predictive maintenance and continuous improvement, and optimization (including integrated workplace management systems, IWMS) are provided in Figure 5.

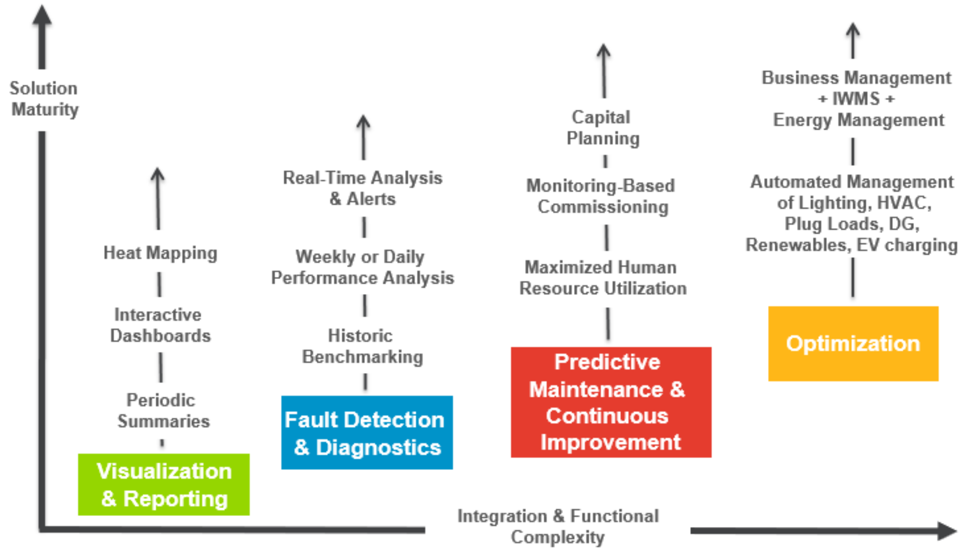


Figure 5: Four main value segments within BEMS

BEMS vary in levels of integration and functional complexity, and each offering is progressively more integrated and connected than its predecessor. Data collected and analysed from building systems can be integrated into a larger enterprise system, which can inform IoT use cases such as occupancy data for space utilisation, location data for behaviour analytics in the retail sector, security and access control via smartphone applications, and more. Additionally, BEMS predictive maintenance and continuous improvement functionality allows for detecting anomalies in energy usage and identifying appliances for maintenance purposes.

There can be significant overlap in deployment between BEMS and general building automation and management systems. The latter usually control and optimise HVAC and lighting systems but also integrate security, fire and safety, and master control systems into cross-silo data platforms. BEMS can work alongside or within these systems provided they have high degrees of interoperability, upgraded capability and responsiveness to the unique operational needs of different commercial verticals and building sizes.

5.2.2 Market overview

Market players that have advanced software capabilities have a BEMS market advantage. This entails advanced data analysis capabilities, including data stream integration, predictive analytics, trend identification, and other features. All market leaders in BEMS have both advanced hardware and software capabilities. They have built on their expertise in building systems and controls to layer on analytics, IoT, AI, and other advanced digital technologies to support energy management. The trend is towards more emphasis on advanced software as the market matures and the hardware becomes more commoditized.

As an outlook, innovation in BEMS markets is likely to focus on handling big data. Efficient transmission and processing of large volumes of data is key in the development of further BEMS services. Fault diagnostics and remote control of buildings and all aspects around energy and well-being of building users is another central area of research and innovation.

Market size

Software is the central part of the BEMS value chain and is defined as money spent on the digital programs, platforms, and analytics tools used to provide customers the data and processes for managing energy consumption, including interactive web portals. Next to software, hardware is also required to deliver the final service. That includes among others communication devices, controllers, sensors, valves and actuators, and edge devices. However, since those are not necessarily the parts exclusively relevant for the BEMS value chain, those are not included in the market size estimates. From a revenue perspective, the hardware can be up to five to ten times the market size of the software segment.

As shown in Figure 6, the EU-27 market for BEMS software is expected to grow from EUR 1.2 billion in 2020 to EUR 3.4 billion in 2030 at a CAGR of 11.5% during this period.

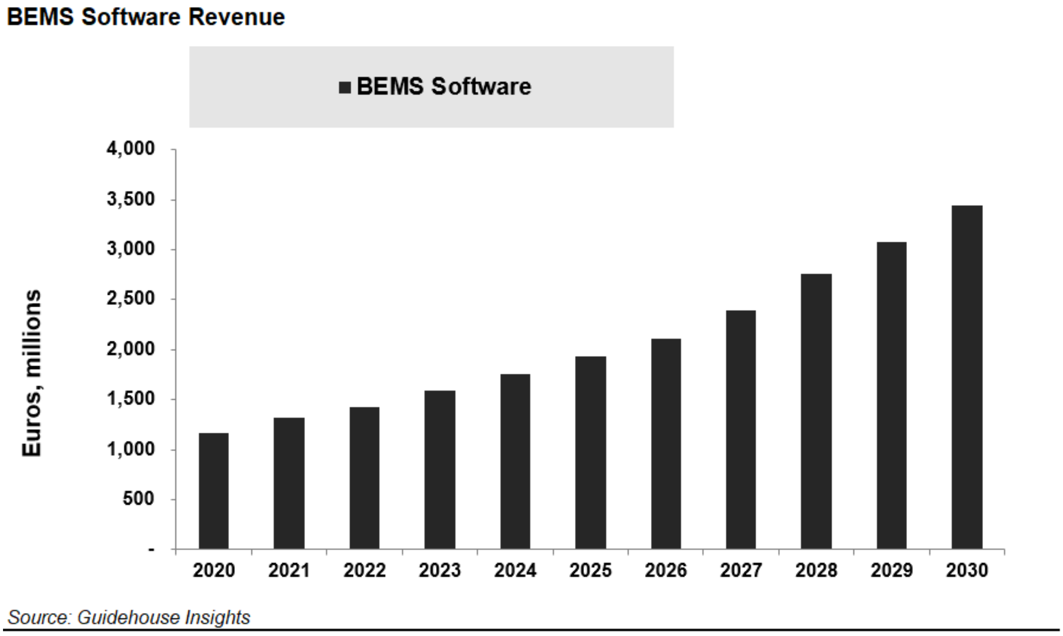


Figure 6: BEMS Software Revenue, EU-27 Market

Market maturity in EU Member States

BEMS market development correlates closely with national policy support for EE, fuel switching measures for buildings, and demand side programs to promote specific technologies, primarily building HVAC and lighting. Sustainability plans of individual enterprises are also a major driver, as is consumer comfort with remote building management, a key element in many BEMS offerings. The EU Energy Performance of Buildings Directive has also driven minimum energy performance requirements for new buildings and national inspection schemes. National subsidies vary widely with respect to investments in increased EE in buildings and therefore also to BEMS investment. However, these subsidies are generally on a growth trend throughout the bloc, with exceptions in Hungary, Portugal, and Greece.

France/Italy/Germany

For varying reasons, the largest European economies are also the most mature BEMS markets. Italy and France have high smart meter penetration rates and have launched large demand response (DR) programs aggregating behind-the-meter energy storage and capacity. France has performance-based building codes that require residential and nonresidential projects to comply with a maximum primary energy consumption, called the Cepmax coefficient. In addition to the technical requirements, France has comprehensive design and technical installation elements in their codes. The three economies also offer rebates for BEMS technology that meets stringent EE standards, and are operations bases for global building controls vendors such as Schneider Electric and Siemens. These countries have the majority of the EU's commercial building stock as well, making them the likely centres of future BEMS growth in absolute terms, especially considering growing government support for energy efficient building investments under the EU Green Deal.

Nordics

Sweden and Finland are again the leading EU markets for BEMS in terms of relative penetration. Norway, although non-EU Member State, needs mentioning as well. Buyers in these markets have a high level of comfort and familiarity with remote building management. That is a key consumer concern and barrier to adoption if it is low. Current Norwegian building codes require all new buildings to be designed to passive house standards. Many jurisdictions are also planning for holistic mini-grid integration, allowing for multiple buildings to share the power they generate through DER, integrate energy storage, and incorporate sustainable transportation options. BEMS are needed to coordinate this approach.

5.2.3 Vendors overview

The EU-27 is a global leader in BEMS. Many companies headquartered in the EU have reached global BEMS leader market status in commercial building energy management solutions. These include Schneider Electric, Siemens, Trane Technologies, Johnson Controls, and others. These companies' leadership role in BEMS is primarily driven by their legacy role as building controls and HVAC hardware providers. They have successfully leveraged their expertise in building systems to move into digital technologies and applications. Table 5 provides an overview of the leading vendors in BEMS technology.

Table 5: Leading vendors of BEMS

Vendor	Company overview and related offerings
Schneider Electric HQ: France Market Share: High	• Schneider Electric is a global player offering integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Schneider Electric offers BEMS under its EcoStruxure suite as 'EcoStruxture Building Operation' that is built upon open & secure integration framework that allows collaboration across third party systems and supports standard open protocols out of the box. • Further, EcoStruxure Energy Expert is an embedded software module that enables energy usage to be monitored, and managed in the same system as HVAC, lighting, and fire safety.
Siemens HQ: Germany Market Share: High	• Siemens is a global technology provider positioned in the electric power value chain by offering solutions for generation, T&D, smart grids, smart cities, and energy efficiency. • Siemens is an incumbent energy management, automation, and digital solutions provider spanning all building segments, industrial sites, data centres, and power management. The company is developing and promoting intelligent digital building technologies from design/construction to the end of the building's life. • Desigo and Apogee are Siemens' leading building management software platforms.
Honeywell	• Honeywell is a Fortune 100 software-industrial company that delivers industry-specific solutions including aerospace

HQ: USA Market Share: High	and automotive products and services, control technologies, and performance materials globally. • Key products include Enterprise Building Integrator, Honeywell FORGE, WEBS Building Automation System, Ascent Building Management System, CentraLine Integrated Building Management, ComfortPoint Open BAS, and Trend BMS.
Johnson Controls HQ: Ireland Market Share: Medium	• Johnson Controls provides HVAC, building automation and controls, security, fire detection and suppression, digital, and other solutions for intelligent buildings. • The company focuses on intelligent buildings, efficient energy solutions, integrated infrastructure, and next generation transportation systems. Metasys, Verasys, York, Hitachi HVAC, and SIMPLEX are brand names associated with the offerings.
Trane Technologies (Ingersoll Rand) HQ: Ireland Market Share: Medium	• Trane Technologies is a global HVAC equipment and controls manufacturer and service provider that has transformed into a leading intelligent building system product and service provider. • Trane Intelligent Services and Trane Building Advantage brands use analytics to extract useful insights from building data to improve overall building performance.

5.2.4 Buyers overview

BEMS solutions offer varying levels of integration and functional complexity across commercial verticals and building sizes. Key differentiators for buyers, as well as for market entrants, are the level of integration between IT and operational technology (OT), the ability to scale sensor, monitoring and analytics capabilities at enterprise level, low upfront costs for installation, and interoperability with legacy systems in place. Large enterprises are the primary buyers for the vendors listed above, who primarily operate on proprietary networks and offer strong cybersecurity packages. Examples include corporate real estate firms owning commercial buildings or large housing projects.

The mid- and small-size building market is largely served by smaller vendors whose offerings more often integrate IoT architectures and advanced functions such as cloud-based analytics, space utilisation analysis, predictive maintenance, and on-demand services through app-based portals. The midsize commercial retail, office, and healthcare verticals have seen the most uptake of these systems. Data collected and analysed can inform IoT use cases such as occupancy data for space utilisation in healthcare, location data for behaviour analytics in the retail sector, security, and access control via smartphone applications in commercial office, and more. In general, larger scale BEMS buyers are more conscious of energy and cost savings than HEMS buyers, and utilities can engage them more successfully with this motive in mind.

Case study: Regionservice Skåne deployed Schneider Electric's EcoStruxure solutions at 11 buildings

One example of this combined savings motive in action for larger buyers is Regionservice Skåne, an organisation that manages 31 healthcare facilities across approximately 16 million square feet in the Skåne region of Sweden. Regionservice Skåne partnered with Schneider Electric for its EcoStruxure for Healthcare solution, upgrading 11 buildings with an open, interoperable, IoT enabled system architecture and platform connecting products, edge control, apps, analytics and services to streamline control and visibility. Schneider Electric guaranteed 85% of estimated heat savings using the EcoStruxure for Healthcare solution. Three buildings became Green Building-certified, with improved indoor climate, reduced maintenance costs, and annual operational and energy savings of approximately €2.37 million.

5.2.5 Supply chain overview - vendor interviews

For this study, interviews were conducted with the following vendors: Siemens, Honeywell with their subsidiary Trend Controls, and Schneider Electric.

For BEMS, the supply chain can be divided in two segments: Hardware and software. BEMS hardware for the European market is mainly manufactured and assembled within EU Member States. However, some manufacturing is also done in the US, Mexico, and China. This holds for the assembly and other late-stage manufacturing steps. Basic parts such as circuit boards, microprocessors, and raw materials are mainly sourced from Asia. This is a pattern that can be seen across some of the other technologies in later sections as well.

On the software side, vendors consistently stress that all core development is done in-house, which is either the EU or North America. A predominant trend for outsourcing is visible for those solutions depending on cloud hosting. Here, as is the case for other digital technologies covered in this study, firms like Microsoft Azure or Amazon Web Services (AWS) are commissioned with providing the cloud infrastructure.

An important distinction is made between core and adjacent business of BEMS vendors. Diagnostics and sensors are seen as core and are developed in-house. Innovation focuses on these core components. A tendency to outsource also development of non-core supply chain steps was mentioned. Although considered core, the vendors stressed that for their software solutions, they do not rely on in-house hardware. Components such as sensors can be from any manufacturer and are nevertheless compatible to their systems.

6 Energy Aggregators

An energy aggregator combines multiple consumer loads or generated electricity for sale, purchase, or auction in any electricity market (Art. 2 of the new Electricity Directive). Aggregators act as a facilitator, by bundling in particular demand response or distributed flexibilities (i.e., available dispatchable capacities) from different customers and generators and offering it to the different actors that need it (i.e., BRP[4], DSO, TSO).[5] Aggregation provides an opportunity to bundle flexibilities from smaller consumers and prosumers to reduce the peak demand and improve load balancing in the grid. In turn, consumers and prosumers receive direct payments or bill reductions for altering their consumption and generation patterns. In this regard, flexibility refers to controlling consumption, decentralized generation, and storage.

DR aggregators have been enrolling C&I customers in DR programs for two decades. The business model is mature, and customers are comfortable with their benefits and responsibilities. More recently, other types of distributed energy resources (DER) such as EE, solar PV, energy storage, generator sets, and EVs have started to proliferate and become eligible for energy market participation. However, it is not necessarily a simple endeavour to integrate different resource types or to find the right mix of vendors to provide them.

While the concepts and technologies behind utilising DER have been developing, each asset type has been developing at its own independent pace due to different drivers for growth, without full consideration of how they could be integrated and optimized. It is just in the past few years that technological, economic, and regulatory changes have made the idea of integrated DER feasible for C&I customers. The control systems to optimise them and the aggregation platforms to connect them create the link between DER assets and the grid. This has led to vendors develop software platforms to aggregate these DER and provision them to the market as Virtual Power Plant (VPP) that respond to market based dispatches. Several technological evolutions are contributing to making VPPs a viable solution for DER management with a special focus on smoothing out of variable renewable energy generation. These include a shift to a neural grid of intelligent and granular telemetry, market structures that allow trading between retail and wholesale markets, and continued growth in IoT, particularly at residences as VPPs expand to include ever widening pools of previously ignored DER assets.

The energy aggregators use cases focus on VPP aggregation software platforms as the types of ancillary services that VPPs could provide to wholesale markets are enabled by innovative aggregation. Among these ancillary services are demand response (DR) and to some extent, frequency regulation. As DER pools increase over time, surpassing our reliance upon centralized generation sources, VPPs will ensure grid reliability, provide asset owners with revenue streams, and reduce the economic and environmental (carbon) cost of the grid.

[4] BRP – Balance Responsible Party is a key market participant responsible for settling imbalances between injections and withdrawals detected subsequently in its balance perimeter. Definition source: RTE, France.

[5] See also Article 2 of the Electricity Directive (EU) 2019/944 for a definition of an aggregator

6.1 Virtual Power Plant (VPP) aggregation platforms

6.1.1 Technology overview

VPP aggregation platforms are software platforms that enable aggregators to manage a portfolio of DER such as batteries, photovoltaics and EVs in a manner that allows customers to access a greater number of electricity markets. These DER could span from the behind-the-meter assets to grid scale assets. Based on the DER asset capabilities and customer decisions, aggregation platforms optimise the dispatch of DER assets to align with market needs. The increasing DER creates a large opportunity for aggregators to leverage VPP aggregation platforms. For this study, a VPP aggregation system is defined as:

> *A system that relies on software and a smart grid to remotely and automatically dispatch DER flexibility services to a distribution or wholesale market via an aggregation and optimization platform.*

The core technology for VPPs is the software platform that enables the remote, automatic control of DER to deliver grid services. VPP technology stands distinct from traditional DR management systems in that it must possess a few key elements. These elements include the ability to receive market signals, determine optimal power draw/output for component DER according to current information (price / incentive signals, DER status) and algorithms, and remotely control and monitor other components of DER. Figure 7 provides a schematic overview of the components that interact with a VPP.

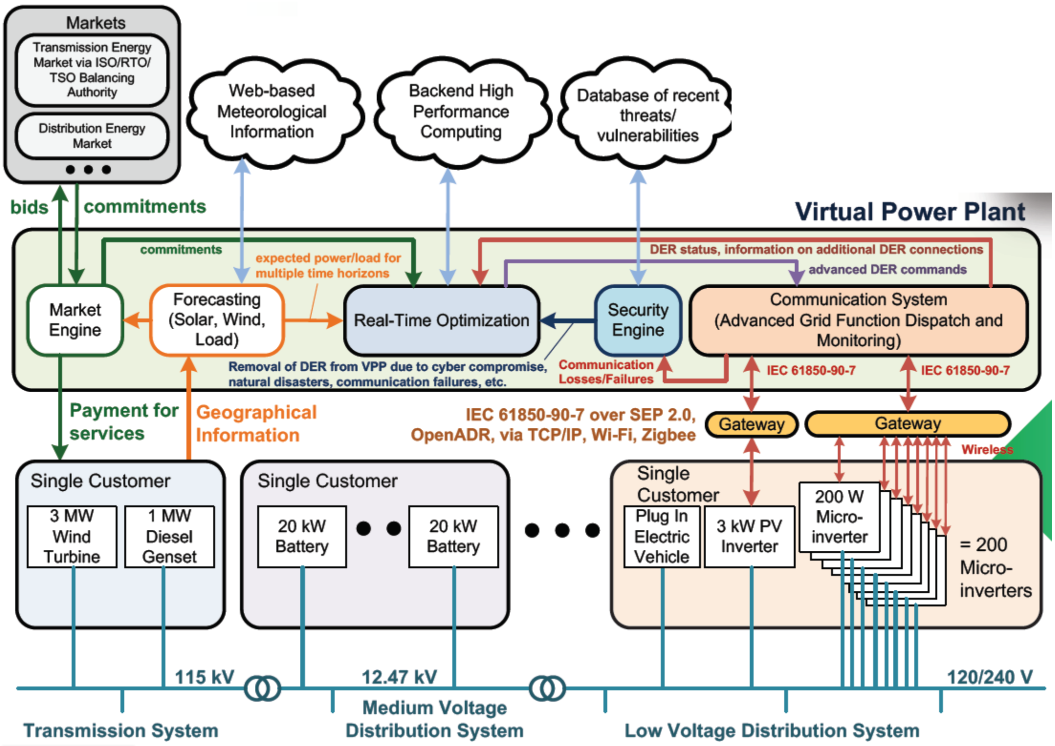


Figure 7: VPP Platform Schematic (*Source: Sandia National Labs*)

The basic design of the schematic could be augmented with hybrid control, where centralized and distributed control are combined to allow for rapid response use cases. Responding to sudden spikes or dips in local frequency are often impossible when using a central controller alone due to communication latencies. Distributed control allows for preprogramed controls to address these frequency disturbances through sub-second curtailments or injections of active power (Sandia National Laboratories, 2017).[6]

The evolution of energy markets is accelerating in the direction of a greater reliance on DER, either those that generate, store, or consume electricity. VPPs can help to transform passive energy consumers into active prosumers through the integration and optimization of technologies such as DR, solar PV systems, advanced batteries, and EV supply equipment (EVSE). At scale, VPPs represent the concept that intelligent aggregation and optimization of DER can provide the same essential services as a traditional 24/7 centralized power plant.

The high number of value streams VPP technologies can capture indicates that, relative to other DSM initiatives, VPPs offer a more holistic, nimble, and pointed flexibility service. The payments for those flexible capabilities are explored in the following market value streams shown in Table 6.

Table 6: VPP technology use cases and value streams

Capacity	Certain VPPs can participate in capacity markets to provide resource adequacy. However, the rigidity of capacity requirements can make it difficult for all VPPs to participate—assets must guarantee that they are able to provide contracted power when called on by grid operators. The variable generation of renewables and the variable load of demand side assets can make them less well equipped to act a guaranteed grid backstop.
Energy	VPPs can control assets to respond to real-time electricity prices and day-ahead markets. Traditional generators participate in the same markets. While optimizing consumption around demand charges and TOU pricing is not special to VPPs, they are key components of how VPPs deliver value. However, participating in grid operator markets, such as day-ahead markets, require the aggregated capacity and control of VPPs.
Ancillary Services	VPPs can help address grid volatility through ancillary services. VPPs can provide frequency regulation services necessary to maintain system stability. The rise of weather-dependent generation increases grid variability and the need for ancillary services' smoothing. Next Kraftwerke, a European VPP operator, explains the process in the European TSO context. Next Krafwerke receives a notification of a frequency imbalance and request for a certain amount of control reserve. This signal is relayed to the VPP

[6] Sandia National Laboratories, "Design and Implementation of a Secure Virtual Power Plant", September 2017, prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2017/1710177.pdf

	that decides, according to its algorithm, which resources to ramp up or ramp down (Next Kraftwerke, n.d.).[7]

6.1.2 Market overview

Europe has been and continues to be (for the foreseeable future) the global VPP leader in terms of capacity (GW). This leadership is due to the large supply-side VPP capacity. Companies like Next Kraftwerke control large fleets of grid scale renewable assets on their VPP platforms. This VPP capacity is anticipated to grow into the future as Europe continues to push VPPs forward, both directly (through government backed VPP pilots) and indirectly (through EU and national climate goals).

The VPP platform is agile; its attributes are being tested and expanded upon in Europe. Although the names of products, services, and markets are different across each regional market, they tend to have strikingly similar requirements for market participation. Germany is the largest and most mature VPP market, it leads the region in current deployments and is expected to continue holding that position over the next decade. Germany is anticipated to capture about one-third of the total VPP market's annual capacity by 2028. Increased VPP-related trading activity is also opening in the Netherlands, Belgium, the Nordic countries, and across certain Italian energy retailers. With its Eurocentric focus on energy trading, technologies used for financial transactions, tracking, and settlements are setting the stage for future VPPs throughout Europe.

Further, there have been varying regulations across EU Member States. Most EU Member States do not allow VPP aggregation software to be hosted in the cloud, because it is regarded as a critical system. Although, data privacy is not an issue as the vendors do not directly own the assets data but access only upon requirements such as forecasting.

Market size

Europe has also been the driving force behind VPP spending, accounting for nearly 45% of global spending in 2020. This is a function of several factors, including DER growth, market opening, valuation of non-traditional assets, and carbon reduction and efficiency goals. The market sizing is distributed into two cost components – software and deployment. While software cost is majorly attributed by the licensing, development and customizations, the deployment consists of implementation and integration services to enable VPP aggregation platform and provide ongoing maintenance activities. Offered by system providers or third party systems integrators, deployment makes up most of the value chain as services often cost more than initial software licenses. Once the solution is deployed, platform providers provide ongoing operations and maintenance; this may consist of back-end operations support, integration of new devices, and updates to security or communications protocols.

[7] Next-Kraftwerke, "Ancillary Services," www.next-kraftwerke.com/products/vpp-solution/ancillary-services

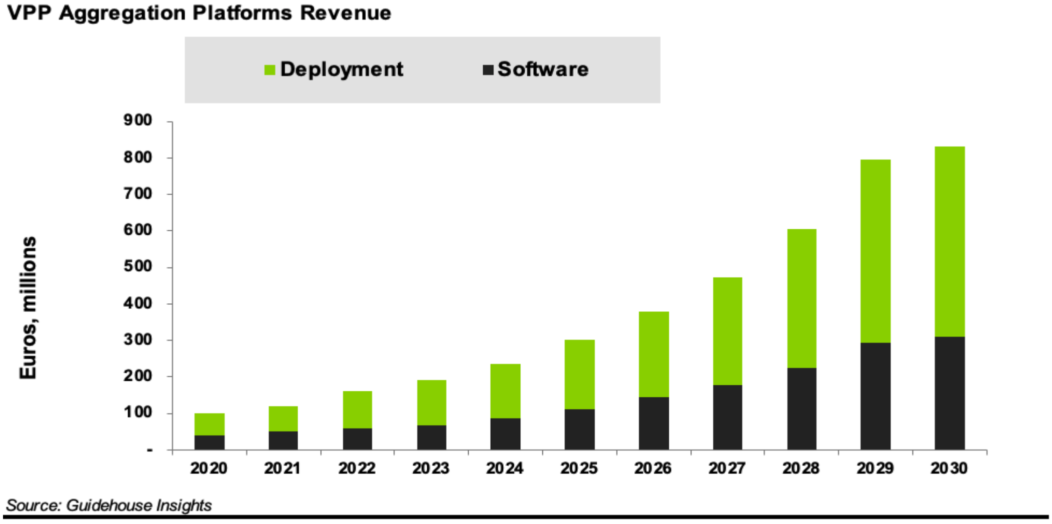


Figure 8: VPP Revenue, EU-27 Market

As seen from Figure 8, Europe is forecast to spend between 100 million euros in 2020 and about 800 million euros in 2030. Current forecast growth rates of DER indicate that the demand for VPP-enabled solutions will continue to grow beyond 2030. As advanced grid management technologies continue to evolve and DER penetration on the grid increases, grid operators may require both the economic optimization provided by VPP platforms and the physics-based management provided by a DER management system (DERMS). Thus, a hybrid VPP-DERMS solution may become more prominent moving towards 2050. This would follow the natural evolution toward modular software systems witnessed across the utility industry over the past decade.

Europe is pushing the VPP in new directions too. The European VPP market historically centred around renewable energy integration. While individual countries such as Germany, France, and the UK have enacted market reforms to enable VPPs, the tightly connected countries in the EU (and the UK) have an advanced market integration. This integration is taking VPP platforms into a more sophisticated direction, stacking complex use cases that are vital contributors to the continent reaching its climate and economic efficiency goals and targets. The key distinguishing feature of Europe's VPP market is the use of advanced software platforms to enable smart energy trading. As a result, this region is proving exciting new possibilities to examine how VPPs can balance the grid, provide economic value exchanges between prosumers and the larger grid, and usher in commercially viable forms of transactive energy[8]. The continent is adapting platforms to provide new, more sophisticated capabilities to maximise the value of flexibility. At the same time, Europe is opening doors to new value streams linked to creative ancillary service markets and real-time energy trading.

[8] GridWise Architecture Council Transactive Energy Framework v1.1 defines transactive energy as "*A system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter*".

Market maturity in EU Member States

Germany is a world leader and the leading VPP hotspot in Europe and is home to the world's first VPP, launched in October 2008, aggregating nine hydroelectric plants (8.6 MW), each ranging from 150 kW to as large as 1.1 MW. More recently, Germany has seen a rise in grid-edge VPP solutions.

The residential storage market is expected to continue to grow as German homeowners seek to take advantage of falling system costs and insulate themselves from rising electricity prices and declining FITs. Germany's transmission system operators have recently changed IT systems to accommodate smaller capacity resources. This change may enable energy storage providers and VPP operators to capitalize on the recent growth of residential storage to provide value to both the grid and grid-edge prosumers.

France's VPP market has been lagging those in Germany and the UK. Much like in other Western European countries, supply-side resources initially constituted the bulk of VPP capacity, with projects mainly from renewable energy developers. CNR, for example, already aggregates roughly 550 MW from 120 producers. Several other supply-side aggregators, like BKW or Agregio (supply and demand side aggregator), are also active on the market. Valuation of non-traditional assets has been rapidly expanding in the last few years. Storage-based VPPs have been a reality on France's island territories (several MW-scale systems for firming the renewable generation) and capacities are increasing as part of the government's focus of reaching 100% renewable energy penetration on these off-grid systems.

6.1.3 Vendors overview

VPP players focus on providing the software to dispatch DER flexibility services to distribution or wholesale markets via an aggregation and optimization platform. These players differ from DSM players that focus on reducing electricity use BTM rather than at the point of generation. A major shift in the market is the emergence of more companies from Europe, arguably the most mature and crowded VPP market in the world. Vendors develop and offer solution flexibility in terms of combining DERMS and VPP, as the vendors see considerable overlaps specifically in terms of software capabilities; particularly monitoring and controlling of energy assets. The VPP asset portfolio includes both the C&I and residential customers. C&I sector strategizing and investing into sustainability and decarbonisation efforts is among the key drivers for VPP growth in EU market.

The following companies shown in Table 7 have clearly differentiated themselves from the competition through exceptional software platform development, robust portfolios in diverse markets, and a sustainable business model. Leaders are currently in the strongest position for long-term success in the VPP market.

Table 7: Leading vendors of VPP aggregation platforms

Vendor	Company overview and related offerings
ABB HQ: Switzerland & Sweden Market Share: High	• Established since past 130 years, ABB is a leading global engineering company based in Zurich, Switzerland, that connects software to its electrification, robotics, automation, and motion portfolio.[9] • ABB offers VPP aggregation platform OPTIMAX through its ABB Ability Energy Management and allows its clients to participate in wholesale energy market or provide energy as a subscription service. OPTIMAX can support DER aggregation and optimization. ABB uses its Dynamic Optimizer solution to model VPP functionalities and to calculate the optimal setpoints for each of a VPP's technical units in real-time. • Next Kraftwerke manages the Europe's largest VPP using ABB OPTIMAX VPP solution.
Next Kraftwerke HQ: Germany Market Share: High	• Next Kraftwerke was founded in 2009 and is headquartered in Cologne, Germany. The Dutch distribution system operator, Eneco, acquired a minority interest of 34% in Next Kraftwerke in 2017. • It operates the largest VPP in Europe (covering Germany, Austria, Belgium, France, The Netherlands, Poland, Switzerland, and Italy) managing about 9,516 units out of 8.2 GW of networked capacity. • In 2018, Next Kraftwerke developed (in-house) NEMOCS is a VPP platform offered as SaaS that connects DER assets through the customer hardware equipment or through Next Kraftwerke developed Next Box. NEMOCS offers monitoring, asset optimization based on market and weather data, and fully automated control based on individual asset rules.
Centrica Business Solutions HQ: UK Market Share: Medium	• Centrica Business Solutions is part of Centrica – a global energy and services company and it operates across the UK and Ireland, Europe and North America and is at the forefront of the distributed energy market. • Centrica Business Solutions (CBS) offers a VPP platform as part of the former REstore company headquartered in Belgium. CBS's European portfolio of peak flexible power now stands at 2.8 GW, includes clients such as EDF and 50Hertz. • CBS offers a mixed-asset VPP aggregation platform through its FlexPond solution technology platform containing insights, optimization, and energy solutions like batteries and CHPs. The FlexPond solution is a combined VPP and DERMS platform that is protected by 38 patents.

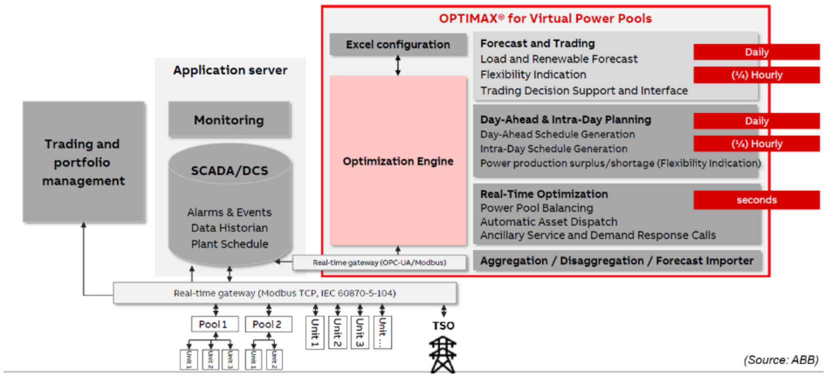
[9] In July 2020, ABB completed divestment of 80.1% of its power grids business to Hitachi and allows ABB to focus on electrification of transport and industry, automated manufacturing, digital solutions and increased sustainable productivity. The ABB OPTIMAX for VPP remains within ABB.

Vendor	Company overview and related offerings
Schneider Electric HQ: France Market Share: Medium	• Schneider Electric, with operations in more than 100 countries, offers integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Schneider Electric has partnered with and invested in AutoGrid to serve as a global reseller of the AutoGrid Flex platform; this joint solution integrates Schneider's EcoStruxure ADMS. The company thus has vast VPP share in Europe despite not serving as a standalone VPP provider.
Enel X HQ: Italy Market Share: Low	• Headquartered in Rome, Italy, Enel X was founded in 2003 by Enel group and is now a global company in the energy industry – an open strategy at the crossroads of sustainability, digitalization, and innovation. Enel X portfolio includes Enel X North America, Demand Energy Networks and eMotorWerks. • Enel X's VPPs are offered to C&I customers and utilities and include energy information systems, DR, energy procurement, and professional services for both C&I and utility customers. • Enel X has activities in all open wholesale markets in North America and in many countries in Europe and Asia Pacific. As a result, Enel X has a customer base of more than 18,000 related to its e-Industries product line, and more than 6 GW of DR capacity across the globe.

6.1.4 Buyers overview

VPP aggregation platforms are typically deployed by companies that specialize as VPP aggregator and integrates assets including DR, supply-side and mixed assets. VPP aggregation platforms allow the market participants to offer their energy services – consuming and producing. The largest clients to the VPP aggregation platforms are TSOs and utilities. However, the aggregation platforms are also integrating large C&I customers and residential homes into the VPP aggregation. ABB offers its VPP platform both to TSOs and the VPP aggregators such as Next Kraftwerke. Next Kraftwerke's in-house developed VPP platform NEMOCS is offered to utilities, C&I customers, and local aggregators. Centrica Business Solutions offers its solution to utilities and the large C&I customers.

Case Study: Next Pool – Europe's largest VPP operated by Next Kraftwerke using ABB's OPTIMAX for VPP



In 8 years, Next Kraftwerke grew from a modest startup to one of the biggest Virtual Power Plant operators in Europe. In 2020, Next Kraftwerke's virtual power pool (Next Pool) has linked more than 9,516 producing and consuming units across eight countries. The pool manages around 8,179 MW of capacity. The smallest unit generates a few kilowatts of solar power, while the largest plant (a biomass plant) produces 20 MW.

With this Next Pool, Next Kraftwerke begs the position of the being the largest VPP aggregator in Europe.

Given the flexibility of the ABB-supplied control and optimization system OPTIMAX, Next Kraftwerke grew from a pool of 20 units to 2,800 in its first 3 years. New customers and generating units are added continually without interrupting operations because all hardware and software additions are made without system shutdown. The solution is a win-win for the Next Kraftwerke, the TSOs responsible for the grids, and the 1000s of small and medium-size producers connected to the virtual power pool and energy market.

6.1.5 Supply chain overview - vendor interviews

EU market has seen some of the world's largest VPP aggregation pools. While the market varies from member state to member state, following are three key insights gained around the supply chains within VPP aggregation software industry. These insights were generated based on interviews with Next Kraftwerke, Centrica Business Solutions and ABB.

Highly integrated in-house software supply chain:

- Supply chain within VPP aggregation software industry is highly integrated because the software vendors favour the software development in-house. Furthermore, unlike the trend of increased dependence of cloud-based software solution provisioning in other technologies, VPP aggregation being regarded as a critical system, vendors do not host their software on cloud.
- Some vendors are also looking at installing their own chips into 3rd party manufactures of home appliances and equipment to efficiently provision an end-to-end software solution.
- However, the system integration is often dependent upon local companies depending on the buyers' requirements.

7 Smart EV Charging

The EV market has seen significant growth over the past 10 years. Guidehouse Insights estimates that the global EV fleet passed 10 million in 2019 and forecasts that it will likely surpass 120 million by 2030 (Guidehouse Insights, 2020)[10]. The market for charging hardware and software solutions is driven by expectations that EVs will increasingly replace internal combustion engine (ICE) powered vehicles. These expectations are borne from widespread government policies to decarbonise economies. The transportation sector is a leading target, as it is responsible for 14% of global greenhouse gas emissions, over 70% of which stem from road vehicles. Coupled with encouraging declines in technology costs and improvements in technical capabilities, many are seeing electric power as the most economically and technically feasible alternative to petroleum power. Originated as a feasible option for passenger vehicles only, the EV offerings are also increasing in commercial vehicle classes for public transit and delivery uses. Digital technologies are aiding the EV market growth by enabling data driven and service driven business models for the mobility solution providers.

The use case explores digital technology application to smart EV charging and charging management for emerging mobility business models. Smart charging systems allow for EVs, charging stations and operators to share data and optimise energy consumption by scheduling the charging process to avoid peak consumption. Smart charging technology assumes some form of control over the EV charging process and enables EVs to function as means of power system flexibility (i.e., battery on wheels).[11]

The major drivers of smart EV charging are the need for reduced vehicle downtime through increased charging speed; improved charging convenience through wireless and on-demand mobile charging; and more efficient charging through grid and renewables integration. EV charging infrastructure and charging management platforms are the key components to meet these market demands.

The value chain that is explored as part of this use case is related to unidirectional (V1G) and bidirectional (V2G) charging applications. Unidirectional (or V1G) charging infrastructure provides only one-sided flow of energy (i.e., grid to vehicle). Bidirectional charging infrastructure allows for two-way flow of energy (i.e., grid to vehicle and vehicle-to-grid). Bidirectional (V2G) charging can significantly improve the financial benefits of smart charging by sending power back to the grid. The EV battery can become a much more asset providing power quality and frequency regulation services. This capability can also turn the EV into an emissions-free electricity generator to buffer power loss during temporary grid outages.

Smart charging technology deployment will be mainly driven by Charging Point Operators (CPOs) and Mobility Service Providers (MSPs). CPOs own and operate a pool of charging points, collect data on diagnostics and service maintenance. MSPs help clients find available charging points, activate charging, handle payments, billing, and e-roaming. Smart digital platforms enable the communication between the CPOs, MSPs and EVs, as well as energy providers.

[10] Guidehouse Insights (2020). EV Charging Equipment Overview. Retrieved from https://guidehouseinsights.com/reports/ev-charging-equipment-overview

[11] PwC, Tractebel, Engie (2019). Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal energy market.

7.1 EV charging infrastructure

7.1.1 Technology overview

For the purposes of this report, EV charging infrastructure is broadly defined as charging hardware technology that supplies electric energy from the grid for recharging plug-in EVs. There are five major categories of charging hardware technologies, distinguished by technical variations in how electricity is delivered to the EV. These categories are AC chargers, DC chargers, wireless chargers, pantographs, and battery swap systems. Deployment of these technologies is often supported by software tools for business services and load management in addition to hardware such as onboard diagnostic port (OBD-II) dongles, load controllers, power modules, and energy storage devices.[12]

AC chargers deliver grid-sourced AC power (120 V or 240 V) into an EV, where an onboard vehicle charging unit converts it to DC power and delivers it to the EV battery. AC chargers are mainly deployed for unidirectional charging application for home and private networks and destination charging stations. Beyond increases in charger speed, many home and private network chargers are being made smart, meaning the energy can be managed for various objectives such as grid services or renewables integration. Bidirectional charging can also be delivered through AC charging ports, but it requires automakers to add equipment to the EV that has not yet proven to be cost-effective for mass-market models. Suppliers of private network deployments (e.g., corporate campuses and office buildings) that use AC chargers are increasingly looking to use behind-the-meter (BTM) load balancing systems, which use network and property data to optimise distribution of load to EVs within the network capacity limitations. Such systems can prevent increases to peak loads and reduce costs for expanding the charger network by avoiding or deferring feed-in capacity upgrades. For destination AC charging stations (e.g., shopping malls, public parking lots), there is a strong competition from 24 kW DC chargers, which provide faster charge rates and use the same feed-in infrastructure as AC 240 V units.

DC chargers convert grid-sourced AC power into DC power via a rectifier and delivers it to the EV battery. DC chargers are more technically complex than AC chargers and have higher equipment and maintenance costs. Most DC chargers are high power solutions used for fast charge services that are analogous to the petroleum retail business model. The capacity range here typically begins at 50 kW and ends at 500 kW, though most fast charge service deployments are being built up to 350 kW. Low power DC chargers are a niche opportunity that is more costly than AC wall boxes, but they can increase efficiency if used in tandem with rooftop solar and batteries. These chargers may also present an interesting opportunity in the future if EV makers produce offerings without an AC charging port and the required onboard AC charging hardware, which would reduce EV cost. Bidirectional DC chargers are an emerging technology largely in a testing phase. They enable users to offload energy back to the grid, a building, or other electricity-consuming devices and infrastructure. There are significant financial opportunities here, but significant challenges to tapping these opportunities also exist, such as regulations for grid service markets and uncertainties about impacts on battery life.

[12] Guidehouse Insights (2020). EV Charging Equipment Overview. Retrieved from https://guidehouseinsights.com/reports/ev-charging-equipment-overview

Wireless chargers are another emerging technology with promise among premium vehicle segments and plug-in hybrid EVs. Wireless chargers use magnetic resonance coupling to transfer power from a transmitter placed in or on road surfaces to a receiver placed in the EV's undercarriage. Wireless charging is technically complex, and equipment costs are high relative to conventional corded solutions. In the past, wireless power transfer has produced an efficiency loss of around 10% in addition to the 10% loss typical of AC/DC power conversion. Standards for wireless charging are being tested, which distinguish wireless charging by four capacity levels up to 22 kW. Wireless charging standards over 22 kW have yet to be released. Currently, the technology is deployed mainly as an aftermarket retrofit. Its impact is likely to grow once standards are released and adopted among automakers, which can integrate the technology into new vehicle manufacturing, thus reducing cost and expanding the addressable market for wireless charger vendors.

Pantographs can be deployed in two configurations: up and down. The up configuration extends the pantograph towards suspended conductive wires or a contact plate attached to a pole or ceiling. The down configuration is mounted on a pole or ceiling and extends towards rails on the vehicle roof. EVs may charge while driving using the up configuration with conductive wires, but EVs must be stationary if using pole or ceiling mountings. It is likely that most pantograph deployments for upcoming EVs will use pole or ceiling mountings. They are also likely to use DC power with capacities between 50 kW and 500 kW.

Battery swapping solutions are primarily developed by EV manufacturers. The deployed systems use robotics to remove and replace battery packs from EV undercarriages. Swapping has many advantages beyond avoiding charging wait times. One of the most important advantages is the ability of operators to monitor battery health and regulate charging to lengthen battery life and ensure a reliable supply to drivers.

Load balancing and battery buffering application should become increasingly important in fleet depot charging deployment as fleets move from tests to full adoption. The type of charging hardware deployments will vary significantly depending on the vehicle types in a fleet, their operating schedules, and the existing infrastructure available at parking depots and along routes. The process for transitioning the entire fleet of EVs requires increasing electrical capacity, which may be a complicated and lengthy process if it requires upgrades to distribution grids. A potential alternative is to deploy batteries, on-site generation sources such as solar, and load balancing algorithms to optimise charging within the existing facility capacity.

Beyond the hardware, charge point owners often use a management platform that can handle business-related aspects of ownership such as broadcasting location, availability, and costs to EV drivers in addition to handling transactions and charger upkeep. A critical component of the management platform is access authorisation, which is a rapidly maturing area.

7.1.2 Market overview

Market size

Guidehouse Insights estimates the current market for EV charging equipment in Europe at nearly EUR 500 million in 2020 and predicts it will surpass EUR 5.2 billion by 2030 as shown in Figure 9. Most of the market is captured via development of public infrastructure: destination chargers and fast charge services. These segments collectively account for 65% of the market. However, significant growth in home and fleet charging is expected on behalf of technological innovations in passenger EV onboard charging capacity and vehicle grid integration and growing availability of commercial EV options. By 2030, home and fleet charging will represent 27% and 16% of market revenues respectively. Still after 2030 similar growth rates are likely as EV penetration is expected to further rise in EU markets.

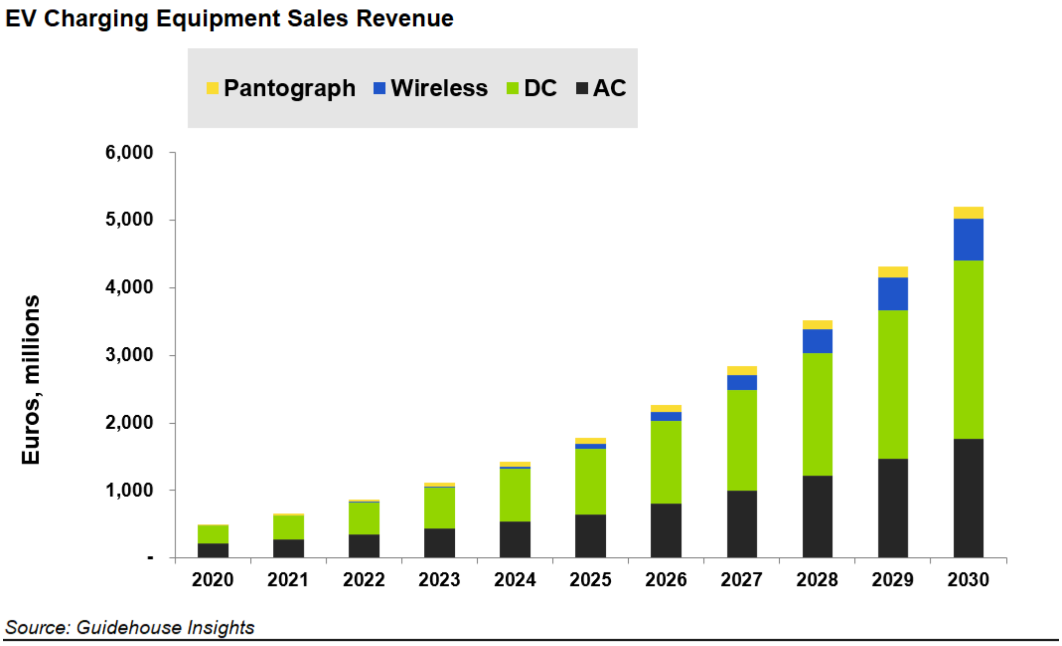


Figure 9: EV Charging Equipment Sales Revenue, EU-27 Market

Market maturity in EU Member States

The development of EV charging in European national markets has been varied. This is best demonstrated in non-EU-MS Norway and EU-MS the Netherlands where EV sales penetrations have been well ahead of the other European countries, driven primarily by strong government incentives. In both countries the charging market has responded differently. Norway has relied more on home charging and DC fast charging services, whereas the Netherlands has relied more on publicly available AC charging. The two markets are exemplary of their respective regions; Scandinavia has tended to have less dense public infrastructure with more fast charging, while Western Europe has had denser public infrastructure and less fast charging as demonstrated in Table 8.

Table 8: EV charging infrastructure development in key European markets, 2020 (Source: EAFO)

Countries	Ratio of EVs to public chargers	Fast charger share of public chargers	EV share of vehicles in use
Netherlands	4	2%	2.6%
Sweden	15	17%	2.5%
France	7	8%	0.8%
Germany	7	15%	0.6%

Non-EU countries			
United Kingdom	11	25%	1%
Norway	24	26%	14%

7.1.3 Vendors overview

Leading charging hardware suppliers are producing solutions across the major use cases and technology segmentations. Europe is highly competitive with a dense market of suppliers. The market has seen significant investment from established power & automation suppliers, oil and gas companies, and electricity suppliers. An overview of the leading vendors in shown in Table 9 (Guidehouse Insights, 2020).[13]

Table 9: Leading vendors of EV charging infrastructure

Vendor	Company overview and related offerings
ABB HQ: Switzerland & Sweden Market Share: High in DC	• Established 130 years ago, ABB is a leading global engineering company based in Zurich, Switzerland, that connects software to its electrification, robotics, automation, and motion portfolio. • The Swiss-Swedish automation company ABB produces chargers for all use cases but is best positioned in the DC fast charger market and in other high power charging solutions like pantographs for electric bus charging. • ABB offers an end-to-end solution with its Connected Asset Life cycle Management (CALM) product; modular AMS, APM, MWMS architecture.
EVBox HQ: Netherlands Market Share: High in AC	• EVBox, based in the Netherlands, was acquired by the energy utility company and global service provider ENGIE in 2017. EVBox provides smart and scalable charging infrastructure and charging management software to EVs around the world. • EVBox is a leading producer of AC chargers. It also has a substantial business in DC fast charging on behalf of its acquisition of EVTronic in 2018.
Enel X HQ: Italy Market Share: High	• Part of Enel Group, an Italian energy company, Enel X offers solutions around the energy transformation in the spaces of e-mobility, smart home, demand response and distributed generation, and smart cities. • In e-mobility, it provides DC and AC charging stations, home charging solutions and other charging hardware between 11 kW and 50 kW fast chargers. The company also acts as a public charge point operator in developing EV markets in Southern Europe and South America and provides software solutions for charge point management. Enel X has also established itself as a leader in residential smart charging and works with many utilities in North America to connect residential chargers to utility demand management programs.

[13] Guidehouse Insights (2020). Guidehouse Insights Leaderboard: EV Charging Hardware Suppliers

Vendor	Company overview and related offerings
NewMotion HQ: Netherlands Market Share: Medium	• Founded in 2009, acquired by Shell in 2017, NewMotion installed 150,000+ charge points in 35 European countries. • The firm uses contract manufacturing in Europe to build chargers it designs, and supports smart charging solutions for business charging, home charging, and charging on-the-go. • Target industries are leasing companies, car manufacturers, business locations, and homeowners.
Efacec HQ: Portugal Market Share: Medium	• Headquartered in Portugal, Efacec's business activities includes Transformers, Switchgear, Service, Energy, Environment and Industry, Transportation and Electric Mobility. • Efacec produces chargers for all use cases and has a broad innovative product portfolio including wireless charging technologies and DC fast chargers with embedded battery storage. Efacec follows ABB in terms of DC fast charger market share.
Alfen HQ: Netherlands Market Share: Medium	• Based in the Netherlands, Alfen designs, develops, and produces smart grids, energy storage systems and electric vehicle chargers and combines these in integrated solutions. • Alfen is a leading producer of AC chargers.
Tritium HQ: Australia Market Share: Medium	• Tritium is an Australian-based EV charger manufacturer that focuses on DC charging solutions and has established itself by providing white-label solutions to charger manufactures like ChargePoint and Siemens.

In the context of EV charging another company needs to be mentioned: Tesla, based in the US. Tesla is an integrated electric mobility provider whose business model focuses on selling EVs. However, with its EVs, Tesla also sells home charging equipment and installs and operates fast charging infrastructure for Tesla drivers alongside key motorways in Europe. Charging hardware is designed and manufactured in-house and only applicable to Tesla vehicles. Nevertheless, given the different business model focus and an expectation of the market of Tesla to continue focusing on developing and selling EVs, the company is not seen as a key vendor of charging infrastructure.

7.1.4 Buyer overview

Vendors produce chargers for a broad customer base. Key customer groups include consumers, logistics providers, public transit companies, commercial real estate owners and property managers, fuel retailers, cities, corporations, and utilities among others. Vendors often approach these consumer groups through partnerships with EV charging network platforms that integrate the deployed charger into a public charging network and manage operational aspects of charging services. In approaching consumers outside of traditional home appliance retail avenues, vendors will approach the market through partnerships with automakers and utilities. The latter typically requires the vendor to have a proven smart charging capability.

Case Study: In 2018, the Municipality of Rotterdam deployed 4,000 new chargers in partnership with ENGIE Services as eMSP and EVBox as charging stations hardware provider (EV Box, n.d.)[14]

The city of Rotterdam has taken further its objective of improving the air quality in the region by increasing the available EV charging infrastructure to encourage the use of electric transport. In 2016, the Municipality of Rotterdam partnered with ENGIE Services to deploy, manage, and operate 4,000 new charging points in its concession area including City of Rotterdam with 1,800 charging points. Smart big data analysis is crucial to this project, as ENGIE Services and the region of Rotterdam will closely monitor where, how, and how often EV drivers will be using these charging stations. Based on these analyses, the region of Rotterdam will install charging points where demand is indicated high. This project led by ENGIE Services relies on the smart charging technology and quality of EV-Box charging points. EVBox provided 4,000 charging stations in 2018.

7.1.5 Supply chain overview - vendor interviews

For this study, interviews were conducted with the following firms: Alfen, New Motion, Tritium, and ABB. The key insights from these interviews are presented in this section.

Three key insights were gained with regards to the supply chain of EV charging infrastructure.

(1) Supply chain of manufacturers is mainly local and/or regional, in particular for EU based vendors
(2) Basic electronic parts e.g., PCBs are purchased in Asia
(3) The value chain is not fully mature yet as vendors develop, design, and manufacture mainly in-house, with some contract manufacturing

Across the interviews, vendors stressed that their suppliers are mainly located in the same region. Basic parts such as printed circuit boards are produced in Asia and purchased as standard products. Nevertheless, local adjustments need to be made for the different EU Member States, as each market has its local preference. Examples include single phase vs. three phase and typical breaker sizes. That entails specific designs for each market.

For both segments of the supply chain, COVID-19 has shown the importance of resiliency. None of the vendors reported significant risks in their supply chain. Contingency plans seem to be in place and the global pandemic has led to broader scenario analyses of potential supply chain risks.

A key component of the sector’s business is research and development. Given the nascence of the businesses, innovation drives the market developments. Vendors stressed they need to be at the forefront to be successful, as the market is not mature yet. As it becomes more mature, there may be potential for outsourcing certain parts of the value chain.

[14] Source: https://evbox.com/en/press/evbox-4000-charging-points-rotterdam

7.2 EV charging platforms

The Plug-in EV (PEV) charging services industry has been developing for nearly a decade, and it is still maturing. Initial charging services were not sophisticated: monitoring the charging station's status and collecting payments. Now services have evolved into EV charging platforms that include more sophisticated features for managed charging to control energy costs, BTM load balancing, grid services, and the calculation of carbon emissions offsets at times of renewables integration shifting demands to times of highest renewables generation.

Plug-in EVs (PEVs) have progressed across road vehicle segments since Lithium-Ion battery technology made grid-supplied electricity a feasible alternative to petroleum-powered ICEs. The displacement of the ICE has been greatest among light duty passenger vehicles; but displacement is likely to advance even more quickly in markets for light and medium duty goods delivery vehicles and medium and heavy duty public transit bus fleets.

7.2.1 Technology overview

The EV charging market comprises of a broad range of technologies designed for a variety of vehicle types and use cases. Therefore, for the purpose of this report, the EV charging platform is broadly defined as *a software tool for managing charge point business activities and energy demands*. The EV charging platform essentially enables either or both of the integration formats shown in Table 10.

Table 10: Enabling Vehicle-to-Grid Integration (VGI) components (Source: Guidehouse Research)

VGI Format	Management Platform	Communications Capability	Inverter
V1G	Cloud-based clearinghouse to link operator signals to PEVs	Installed in the vehicle or charger	Not required
V2G			• AC—Installed in the vehicle • DC—Installed in the charger

Based in the cloud, this technology manages the interaction between grid operator and PEV or EV supply equipment (EVSE). A collection of charging service companies, also known as electric mobility solutions providers (eMSPs), have developed these platforms primarily for activities that are not VGI related. Thus, the leading eMSPs have adopted varying V2G Integration (VGI) capabilities to court utility funded VGI projects. Depending on the VGI capability, the requirements of the platform can be considerable. For instance, with V2G, the platform must assess multiple data points such as PEV availability, battery state of charge (SOC), and expected PEV time of departure (TfD); then bid the resulting capacity into the service market; directly control and measure discharge and charge; and finally compensate the PEV assets accordingly. It is unsurprising that although there are numerous eMSPs with VGI capabilities, few have participated in V2G trials.

EV charging management platforms largely originated from charging manufacturers, however, numerous companies specializing here are not manufacturers. When considering VGI, most platforms have connected to the vehicle through the charger.

However, as vehicle connectivity becomes standard, it is likely that VGI platform capabilities will move to the vehicle.

7.2.2 Market overview

The market for charging services is driven by the PEV population. The PEV market is primarily driven by declining battery prices, and government transportation energy policies, such as fuel efficiency standards and carbon pricing. In this regard, the continued decline in the battery prices and increasing scrutiny of transportation energy in Europe is going to continue to push PEV sales penetrations and populations higher. The PEV population is the long-term driver because it broadly affects the market.

Market size

The market size for EV charging platforms is analysed in terms of total annual operation and maintenance (O&M) revenues. The O&M revenues are inclusive of all services the platform provides. The services include business and energy management, this is through the subscription of the provider, and often includes maintenance bundled within the subscription. This takes a form of remote diagnostic, repair and signalling of technician networks where a physical repair is required. The physical repair itself is not part of the market though. Guidehouse Insights estimates that the total market is likely to grow at a CAGR of 27.9% between 2020 and 2030. Figure 10 shows the EU market growth from 2020 to 2030.

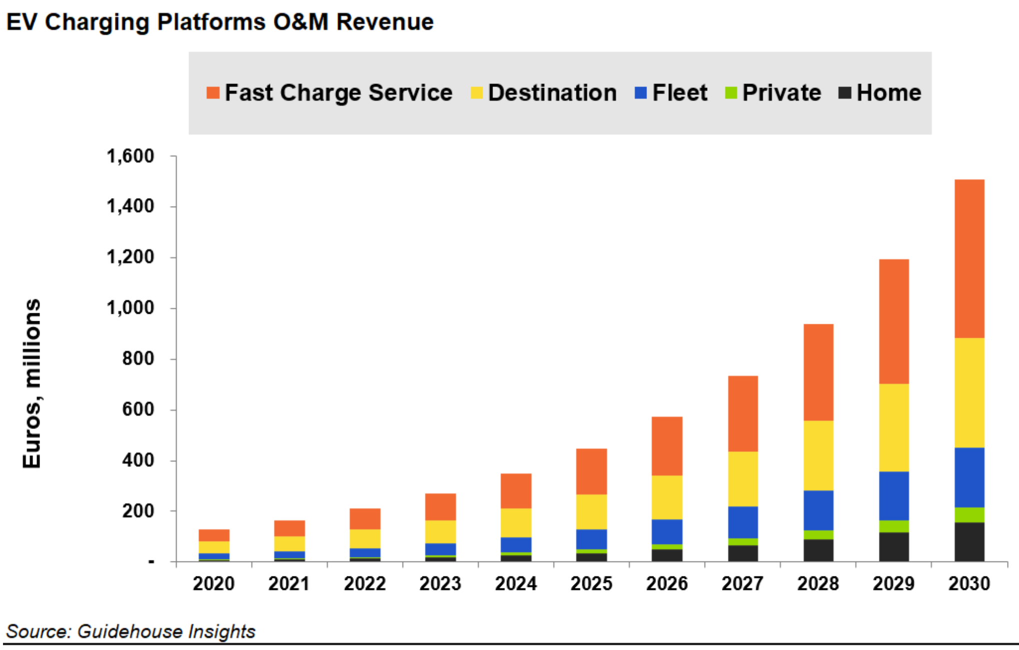


Figure 10: EV Charging Platforms O&M Revenue, EU-27 Market

Market maturity in EU Member States

The number of VGI tests, pilots, and demonstrations have grown alongside development of the larger PEV market. V2G projects have largely been highly sophisticated, meant to test implementation challenges, battery impacts, and economic potential under a variety of grid service applications. The projects, relative to V1G, are small, consisting of 5-15 bidirectional chargers. Recent projects in Europe are scaling to between 50-100 chargers. These larger scale projects are viewed as early commercialization activities.

While much of the early focus for V2G was on fleet applications, the latest tranche of European projects in Denmark and the UK largely focuses on residential applications.

The charging services market has matured since the initial infrastructure rollouts in the early 2010s. Many startups and business lines of major power infrastructure companies were unable to survive long. Now that the herd has thinned, energy companies have entered through acquisition. Power providers see operating EV charging networks as a natural extension of their business, and fuel providers such as BP and Shell, acquired companies as electricity will increasingly take market share in transportation from liquid fuels. European based companies have made all these acquisitions.

In the R&D and innovation process of the sector, an expansion of smart charging from the charging device to the vehicle itself is visible. More vehicles are connected offering new smart charging opportunities. As such, beyond-the-meter activities become more relevant and platforms move into new types of charging arrangements. Key customers of charging platform vendors already start to be automotive OEMs. In the following, a few of the European key markets are highlighted, including the non-EU Member State Norway.

The Netherlands

The Netherlands has also pushed forward their policy and incentives with fiscal measures that offer reduced vehicle purchase and circulation tax including reduction in tax for private use of company cars. Additionally, there are rebates on environmental investment and various local and regional incentives. This has driven the EV charging market in the Netherlands. Most of the public chargers have now smart charging capabilities, which encompasses additional services next to simply charging the vehicle (not necessarily a V2G functionality though). The Dutch roaming system is the only national roaming system in the world between independent operators and providers – MSPs and CPOs both from the Netherlands and Belgium can interoperate. The EV charging market will grow further as in January 2020, the Metropolitan Region Amsterdam (MRA) Electric has tendered a contract to Total, the French oil company, to install 20,000 EV charging stations.

Germany

As of early 2020, approximately 18,000 charging stations were open to the public in Germany, and an additional 50,000 public charging points are to be built over the next two years, with the long-term goal of a total of 1 million by 2030. Under the LSV, all charging station operators are obliged to provide every EV user with the option of ad hoc charging outside of an ongoing customer relationship. This applies to all charging stations installed since December 2017. Either payment by cash, online payment or debit/credit cards must be available options if charging is not free. In addition to these government initiatives, Germany also offers subsidies to both EV owners as well as the companies that develop and operate the charging networks. For example, pursuant to the Funding Directive for Charging Infrastructure for EVs, the CPOs undertake to run charging stations for a minimum period of six years (WFW, n.d.)[15.] Such policies have provided boost in investor confidence and would result in further market maturity when the planned 50,000 charging points come alive.

15 Source: https://www.wfw.com/articles/the-future-of-e-charging-infrastructure-germany/

Norway – not part of EU-27

Although not an EU Member State, Norway is a key European market with strong influence. Norway's policies and incentives have pushed the market share and net amount of PEVs, as Norway plans to meet their targets on climate goals, emission reduction investment in new environmentally friendly technologies especially e-mobility. This sets the plan for both national and local levels. The Norwegian parliament has set a national goal of all new cars sold should be zero emission (electric or hydrogen) by 2025. As noted earlier that EV charging adoption is driven by PEV population. Norway offers several incentives for zero emission vehicles. These incentives include no purchase/import tax, exemption from 25% VAT, no annual road tax, no charges on toll roads or ferries, free municipal parking, access to bus lanes and fiscal compensation for scrapping of fossil vans when converting to a zero emission vans.

These initiatives from the Norwegian market has attracted many EV charging platform providers and network companies to test products and solutions at scale with a relatively large and growing consumer base.

7.2.3 Vendors overview

The EV charging market across EU countries is poised to grow as the EU marches toward its decarbonisation goals. With that, clean technologies adoption and sales increase and with the deployment of rising numbers of charging stations growing demand of PEVs is met. The market, however, is still nascent and many startups enter and energy companies including conventional utilities (e.g., e.on) and oil (e.g., Total) companies extend their business into the EV smart charging. This has led to a broad range of products and services and business models being tested and deployed around the countries. Figure 11 shows the interaction between various components in the value chain.

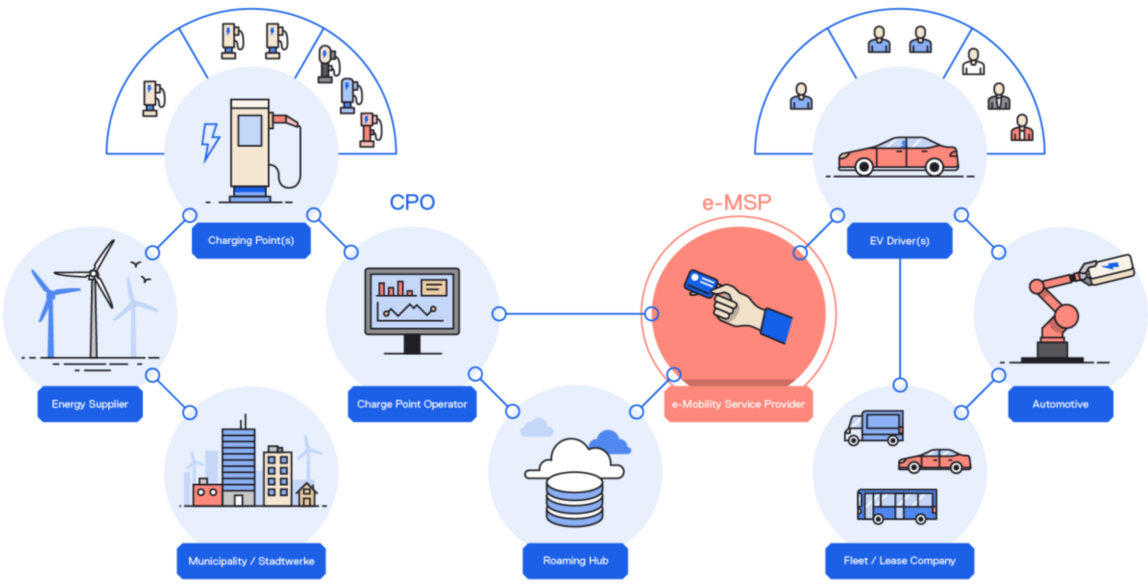


Figure 11: EV Charging Platforms enabling eMSPs and CPOs (Example by Last Mile Solutions)

This has given rise to multiple companies taking multiple roles – from pure play EV charging equipment manufactures taking up MSP roles to EV charging network companies taking up CPO roles and aggregators where V2G is growing. This report focuses on those vendors that provide the software platform for enabling and integrating services around V1G and V2G. Some companies are only offering back-office software solutions or those that offer both hardware and back-office solutions but do not have a public-facing branded network, such as Driivz and ABB. Table 11 provides and overview of the leading vendors.

Table 11: Leading vendors of EV charging platform

Vendor	Company overview and related offerings
Driivz HQ: USA Market Share: High	• Driivz was founded in 2013 as a global EV charging management solutions company and is present in 16 countries with a majority in Europe and US. • The Driivz cloud-based charging management platform has capabilities including self-healing algorithms that can resolve up to 70% of charger issues remotely, driver self-service applications, portals for both drivers and operators, a comprehensive billing module, and full ISO/IEC 15118 compatibility. • The company's VGI features includes load balancing on fixed capacity networks, renewables integration accounting, demand charge avoidance.
Virta HQ: Finland Market Share: High	• In 2013, 18 Finnish energy utilities founded Virta to build-up a national charging network. • Virta serves EV drivers, private homeowners, residential buildings, commercial parking, retail & hospitality, real estate developers, car dealers, energy utilities, CPOs, eMSPs and petrol retailers. • Its cloud-based platform allows for managing charging networks, setting up prices and managing usage. • Virta's energy services are available for energy companies and businesses that work closely with local energy utilities.
Fortum Charge & Drive HQ: Finland Market Share: High	• Founded in 1998, Fortum is an energy company with a significant presence in the Scandinavian EV charging services market. • Fortum operates a public charging network and provides a cloud-based software management tool to private networks. Its network has spans across the EU. • The Fortum Charge & Drive is a SaaS cloud platform that offers white-label customer apps, network management, end user account management and mobile apps.

Vendor	Company overview and related offerings
GreenFlux HQ: Netherlands Market Share: Medium	• GreenFlux is a provider of cloud-based SaaS for managing charge points. • Their software includes the following components: asset management & diagnostics, tariff setting & billing, operability & roaming, smart charging & smart energy management. • In 2020, 23,000 connected charge points to the GreenFlux charging platform.
has.to.be HQ: Austria Market Share: Medium	• Founded in 2013, has.to.be operates as an e-Mobility company from Radstadt (Salzburg), Vienna and Munich. • The company's beENERGISED is a software to manage charging stations. It provides white-label software, EV drivers app, portal for eMSPs, user management, CO_2 certificate management, OCPP support and station marketing; among other features. However, the company is still to venture into V2G space. • The company also works with automakers (Audi, Porsche, Man) with a cross-manufacturer transparency software.
Last Mile Solutions HQ: Netherlands Market Share: Low	• The firm focuses of e-mobility and smart energy management and in 2010 introduced their third generation e-Mobility management platform. • It provides packages for eMSPs and CPOs including billing and payment options, large roaming capabilities, self-service driver tooling, and bespoke reporting services. • The company connected over 25,000 charge point and implemented load balancing, battery storage, solar integration and generation and vehicle-to-grid with over 75 customers including Entega, ENGIE, Tauron. • Additionally, the company has developed 15+ white-label apps catering to municipalities, automobile, and fleet companies.

7.2.4 Buyer overview

The market has seen plethora of companies offering EV charging related services – some based of their own end-to-end portfolio and some limiting to few use cases as operators and some pure play cloud software platform providers. This report focuses on the EV charging planform providers, the buyers are service providers (eMSPs, energy utilities, municipalities, fleet owners, automakers) and CPOs. The buyers tend to start off with V1G and e-services enablement and venture into testing and piloting V2G use cases before full deployment as a service offering. As these platforms are cloud-based and offer white labelling software services, there has been rise in companies that prefer such platforms rather than developing their own solutions. For instance, EVGo, a US-based EV charging network company, uses Driivz's IT platform, whereas Bulgarian based ELBUL leverages Virta's solution.

Case Study: ELBUL – Virta white-label services in practice (Virta, n.d.)[16]
White labelling allows the platform service to be reproduced to look and feel like the customers' brands. The end customer will only see the customer's brand; the visual and textual world that they are already familiar with. In Bulgaria, the local EV charging network is being built and developed by ELBUL. The ELBUL was founded in 2017 and is using Virta's back-end service to manage its charging network. The back-end services include for instance station management with flexible pricing system and invoicing in the local currency, POI data management and business insight tools. The management system parameters are features defined by the charging point owner, in this case, ELBUL.

As can be seen in Figure 12, web apps, including the registration page, customer portal and charging station map, are rebranded, and the same can be done for different payment methods: in the ELBUL-case for the mobile application and one-time payment solution. End users are also able to reserve charging points in advance from the mobile application.

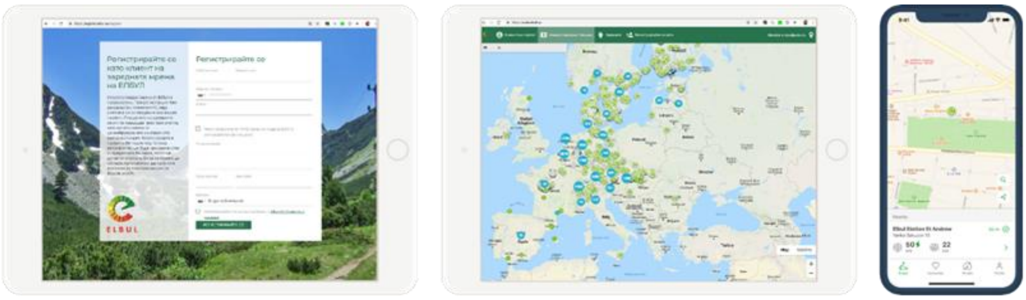


Figure 12: ELBUL uses Virta while label services, Source: Virta

7.2.5 Supply chain overview - vendor interviews

For this study, interviews were conducted with the following firms: Driivz, GreenFlux, Kaluza, The Mobility House, and Jedlix to understand the supply chain of their products. The key insights from these interviews are presented in this section.

The supply chain of EV charging platform vendors is highly integrated. Across the interviews, the firms stressed that design, development, and testing is done in-house. Due to the level of integration, there are only limited risks to be noted in the supply chain. One risk mentioned was capacity challenges. For capacity reasons, certain steps are outsourced, although the capabilities exist in-house as well. Such a close collaboration with partners is visible in other parts of the supply chain as well.

A noteworthy detail is that a general dependence on US-based cloud hosting offers is visible in the sector. Amazon Web Services (AWS), Microsoft with its Azure platform, and the Oracle Cloud Infrastructure were all mentioned as being part of the offered EV charging platforms. However, such a dependence is not seen as a key risk, as switching from one supplier to another does not seem to relate to large transaction costs.

[16] Source: https://www.virta.global/customers/case-elbul-virta-white-label-services-in-practice

8 Improved O&M

O&M are fundamental processes in the asset management life cycle. Across the energy sector, utilities continuously explore innovative solutions to operate and maintain their assets efficiently and effectively. These assets could range from power plants, renewable generators to transmission and distribution network infrastructure.

Historically, O&M strategies followed a reactive or preventative approach to asset management. The reactive approach would allow assets to run to failure before they are replaced or maintained. The preventative approach would rely on maintaining or replacing assets on pre-defined tie periods. In some cases, regulated utilities could have pre-agreed maintenance schedules in place with regulators, therefore have less incentives to drive efficiencies in the asset management lifecycles. However, as regulators and organisations are more often expected to deliver better value for customers and shareholders, they are increasingly aiming to decrease their operational expenditure, by optimizing the way assets are being maintained, whilst still delivering high quality services. This has resulted in utilities now shifting towards predictive maintenance strategies that are enabled by an increasing number of digital technologies. Predictive maintenance strategies utilise extensive data, modelling, and forecasting algorithms to determine the optimal maintenance and replacement schedules for assets thus reducing operational costs. Figure 13 shows the asset management transition phases of improving maintenance.

Figure 13: Asset management transition phases, (Guidehouse Insights, 2018)[17]

In successfully delivering predictive maintenance, utilities rely heavily on understanding the behaviour of assets over extended periods of time. To understand the status of assets, utilities rely on additional sensors and measurement devices that collect data in real-time. These sensors could be measuring several characteristics of the assets, including; current, voltage, temperature, vibrations, and humidity. Typically, this data from these sensors is communicated to a central analytics platform that can be used to analyse the data to generate insights about how the asset is likely to behave in future. The central analytics platforms are known as Asset Performance Management (APM) platforms. APM platforms help utilities understand their assets in greater detail and support in forecasting future asset conditions. They help reduce (O&M) costs, improve efficiency, reduce unplanned downtimes, and extend the lifetime of the asset. With increasing maturity of cloud technology and reducing costs of data storage, utilities can collate large amounts of data regarding individual assets that can be analysed using latest machine learning techniques to determine the likelihood and impact of future asset failures.

[17] Guidehouse Insights/Navigant Research (2018). T&D Sensing and Measurement Market Overview

Key growth drivers for the deployment of advanced sensors and IoT grid monitoring devices include: Firstly, regulators and ratepayers demand grid reliability, resilience, flexibility, and visibility. For the low voltage part of the grid, monitoring is mainly in its infancy. Secondly, integration of DER into the grids poses new challenges on O&M such as the monitoring of voltage sags and swells, capacity issues and pole reversal. Thirdly, an aging asset fleet of current transmission and distribution networks in Europe requires replacements and retrofits, giving on the one hand the opportunity of upgrade monitoring, and on the other hand requiring increased monitoring given the occurring network changes.

This study explores two key digital technologies that enable improved O&M:

1) IoT monitoring devices (hardware) for O&M
2) APM platforms

Another core enabler for the value chain is the communication between the sensors and measurement devices and the APM platforms. Oftentimes, this is achieved using 4G technology. This chapter of our study does not capture this element of the value chain.

In recent years, there is an emergence of distributed intelligence that does not rely on central analytics platforms, however due to the nascency of this technology and application across this sector, this has not been considered.

8.1 IoT Monitoring devices (hardware) for O&M

8.1.1 Technology overview

IoT monitoring devices that are used for the purpose of O&M in the energy sector can cover a range of sensors. These sensors could be monitoring and measuring several parameters that may be critical in understanding the condition of a specific asset type. Among the sensors are current, voltage, temperature, humidity, pressure, vibration, and partial discharge measuring devices and monitors (such as dissolved gas analyser). These include measuring devices that are not necessarily uniquely used in the energy sector. Many if not all are deployed in other sectors as well such as the chemical industry or other production facilities.

In transmission and distribution (T&D), early generations of sensors were designed to measure voltage and current, telling the utility simply the strength and quality of the power flowing through the system. As the grid becomes diverse, the complexity of sensing and measurement devices will also evolve. Modern sensors are devices that respond to a variety of physical stimuli (heat, light, sound, pressure, magnetism, motion, current, voltage, etc.) and translate the signals into data points interpreted by utility software (see section ☐ on APM platforms). Sensors are typically placed at strategic points throughout the T&D network, designed to provide maximum network visibility and transparency to operators and utilities.
As an example, problems with transformer bushings represent one of the most significant causes of catastrophic failure in transmission substations. Bushing failure, along with insulator failure, is often caused by contamination or a build-up of foreign objects or substances on the equipment. When a build-up forms, dry-band arcing can occur, leading to a flashover and tripping a breaker, causing a power outage. Advanced leakage current sensors monitor the leakage current flowing down the surface of a

bushing or insulator and gives the utility notice when the probability of a flashover is getting higher.

T&D sensing and measurement (TDSM) devices are paving the way towards a more advanced, self-monitoring, and self-healing electric grid. As the cost of sensors and connectivity falls, utilities are expected to deploy these systems farther and faster than ever before. An advanced sensor, paired with real-time communications and analysis, provides a utility with vital system health information and tools for monitoring asset functionality, assessing safety risks, and preventing extended network interruptions. Many utilities worldwide will undertake significant investments in automation and monitoring solutions in substations, T&D lines, transformers to improve reliability, upgrade and replace aging infrastructure, and effectively integrate new distributed energy resources (DER) into the grid.

In addition to communicative condition monitors and sensors, AMI meters can and do act as connected IoT devices and can have significant reduction impacts on overall O&M costs. Many new AMI meters are edge IoT devices equipped with hardware and software that enables the meter to function as an outage sensor. The meters can communicate with each other, help the Outage Management Systems (OMS) eliminate false outage alarms, and locate the outage as accurately as between two connected meters. The OMS can initiate dispatching the necessary crews to repair the outage at the pinpointed location, rather than scour the network to locate it. This process can reduce distribution outages by 50% compared to traditional smart metering.

New, increasingly complex grid sensors such as line monitors and transformer sensors can collect and transmit data in real-time. Advanced grid sensors (particularly PMUs) can collect as many data points as one million basic (non-edge computing) meters over a given period. Devices with built-in computing power eliminate the need to send data in such high volumes back to a centralized system where it must be analysed and returned with an action. Edge computing devices can increase grid visibility by sending only the results of their distributed computations back to a centralized IT system, providing insights while not hogging communications bandwidth.

Included in this study is an assessment of the technology and market for connected sensors and monitors on the T&D network, deployed for network reliability improvement and reduction O&M costs. Products included are:

- **Transmission Line Sensors**
    - E.g., Current, voltage, conductor temperature, GPS
- **Transmission Substation Sensors**
    - Temperature Sensor
    - Current Transformer
    - Voltage Transformer
- **Distribution Transformer Sensors**
    - Integrated and add-on
- **Distribution Line Sensors**
    - E.g., Current, voltage, conductor temperature, GPS
- **Distribution Substation Automation with Monitoring, Communication and Analytics**

An additional major benefit of IoT devices, especially those with onboard computing power is the relief they provide to the communications network in the form of reduced data transmission volumes. The ability of the edge computing IoT device to collect data and then act on that data without the need to send it back to a centralized IT system over grid communications networks eliminates the need for communications network upgrades, deferring utility investment and improving communications and distribution network performance.

TDSM IoT devices are the basis not only for O&M but for many of the use cases covered in this study. Although not in the breadth of different types of sensors as in this use case, in a way measuring and analysis is part of all uses cases mentioned. Along with the need for enhanced sensing and connected IoT hardware comes demand for the expansion and semi-universal adoption of diverse communication networks to handle the bandwidth of information captured by these devices. The goal of real-time grid monitoring and predictive asset analytics and maintenance is only attainable with the right combination of sensing hardware, communications, and utility asset management software framework.

Broadly, the entire T&D infrastructure is transitioning away from modular or integrated analog sensors, and moving towards multifunctional digital sensors, and even further onto connected, interactive IoT devices. This represents significant technological advancements. The adoption of T&D sensors and measurement IoT devices and communication are among the key drivers for software platforms and APM in particular as discussed in greater details in Section □.

8.1.2 Market overview

Across the T&D networks, various asset types can be equipped with IoT, communicating sensing and measurement devices, ranging from full-blown integrated automation to add-on standalone sensors. As the price of sensor devices themselves continues to fall, and communications and compatible IT systems become more ubiquitous, market penetration will continue to grow in the European market.

This section includes hardware devices only, and does not account for the software platforms, communications networks, data platforms, or other centralized software platform. Included in the forecasts below, however, are the integrated communications components as the LAN switch, RTU and NIC, which enable the device to be connected to an existing utility network. The cost of the network is not included. Similarly, each substation is required to have a licence to be integrated into a utility's existing SCADA or ADMS platform. The cost of this licence is typically between €10,000 and €25,000 for each distribution substation and is included in the forecasts below.

- LAN Switch
- RTU
- Network Interface Converter
- Auto-Recloser
- Electronic Smart Relays
- DMS/ADMS Human Machine Interface
- Upgraded Server
- Ambient Temperature Sensor
- Power Quality Sensor and Meter
- Visual Camera
- IR Camera
- Load Tap Changer
- Gassing Sensor
- Bushing Insulation Leakage Current Sensor
- DMS/ADMS Licence for Individual substation integration (for IOs)

- Transformer Temperature Monitor
- Cybersecurity Kit
- PMU
- Asset Condition and Performance Monitor

Market size

Figure 14 depicts the market size and forecast for the EU-27 Member States. It includes the components as laid out above. Across the forecast period, Guidehouse Insights estimates that the EU-27 market for the sensors and monitors outlined above shall grow from €1.15bn in 2020 to €1.73bn by 2030, at a compound annual growth rate (CAGR) of 4.2%. Across all technologies described above, there are common market drivers and barriers for the deployment of advanced sensors and distributed IoT grid device. Growth rates are expected to decrease toward the end of the 2020. The outlook beyond 2030 is expected to follow this trend and growth is likely to be lower.

A few factors limit the market for standalone sensor equipment. One is the trend to fully integrate sensors and IoT equipment into major primary assets like transformers and protective equipment. Thus, the market size and growth for standalone metering devices is capped. Furthermore, devices can cost as little as € 50-100, with some exceptions. So even large volumes do not necessarily lead to a very large market. Lastly, the transmission side of the market is already well equipped with monitoring devices, lowering the necessity for new equipment in that part of the market.

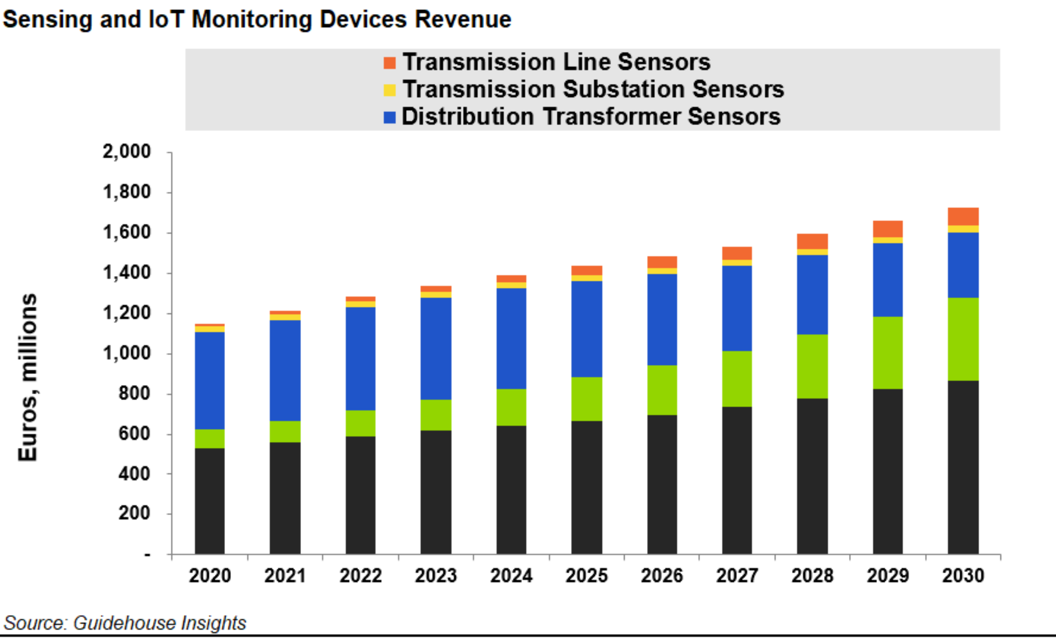


Figure 14: Sensing and IoT Monitoring Devices Revenue, EU27 Market

Market maturity in EU-27 Member States

Maturity is different across the EU Member States, with the Northern European countries showing relatively higher levels of maturity as compared to rest of the Europe.

Denmark
Coupled with Denmark's vision of establishing one of the leading testing and demonstration facilities for smart grid and clean technologies, the public funding for research, test, development and demonstration has fostered this market in Denmark as leading in the world in smart grid technology; positioning Denmark with one of the highly mature markets in the Northern Europe in particular. For example, Kinectrics setup Europe's first T&D equipment testing facility in Denmark. By 2020, there are now over 10 startups companies in the IoT devices technology space and over 60 smart grid companies. The T&D sensing and measurement hardware innovations in Denmark include T&D enhancement through advanced transformers sensors, wire and cable sensors, power conditioning equipment, PMUs, and other sensors.

Norway (non-EU-27)
An assessment of all-electric-Norway scenario at Statnett estimated that Norway will add new 30-50 TWh of power consumption per year due to replacing fossil fuel consuming industries to electric. This ambitious scenario called for reinforcement of existing T&D networks especially. To achieve this vision, Norway's market for T&D has opened the avenues not only for the T&D equipment manufacturers, but also for the smart grid technology; T&D sensing and measurement. For example, Oslo's transmission lines are on average around 50 years old and Oslo has initiated projects to reinforce the transmission lines and substations to cater to the increased electric power demand and renewables penetration. Oslo has many projects undergoing construction and deployment of smart substations equipped with FACTS equipment.

8.1.3 Vendors overview

The IoT sensor and monitoring device hardware market consists of several major players with broad portfolios, and dozens of medium and small companies which sell only very specific products in only very limited markets. The vendors included below are major vendors in the international market for sensors, monitors, and grid IoT devices broadly, with high activity levels in the EU and advanced IoT monitoring capabilities.

Guidehouse Insights estimates that the top players cover approximately 70-75% of the European market. The remainder of the market is made up of smaller, local players, and low-cost sensor and device providers from China. Major AMI providers are not included in this technology and use case, as the products are fundamentally different. Table 12 provides and overview of the leading vendors in this sector.

Table 12: Leading vendors of IoT monitoring devices (hardware) for predictive maintenance

Vendor	Company overview and related offerings
Hitachi ABB Power Grids HQ: Switzerland & Sweden Market Share: High	• Hitachi ABB Power Grids is a Switzerland (co-head quartered in Sweden) based major global technology company in power and automation for utility, industry, transport, and infrastructure customers. The current company is the result of a 2020 merger with Hitachi. It employs about 36,000 people over business units: Grid Automation, Grid Integration, High Voltage Products, and Transformers.

Vendor	Company overview and related offerings
	• ABB Ability product lines for IoT based sensing and monitoring devices currently include a vast portfolio that includes digital switchgear for medium voltage under their UniSec Digital portfolio, for low voltage under their Ability Low Voltage Switchgear Digital portfolio that comprises NeoGear, MNS, MNS iS, and Ability TXpert Digital Dry-Type Transformers.
Siemens HQ: Germany Market Share: High	• Siemens AG, based in Munich, Germany, is a global technology provider positioned in the electric power value chain by offering solutions for generation, T&D, smart grids, smart cities, and energy efficiency. Siemens reported revenue of €86.8 billion ($92.7 billion) in 2019. • Siemens provides equipment and software solutions for all segments of power grids. Siemens AG offers a full range of T&D products as well as a diverse and extensive suite of solutions. • Its sensor and IoT device product line includes HV, MV, and LV, breakers, reclosers, controllers, remote terminal units, custom-designed transformers, monitoring equipment and sensors, and other intelligent electronic devices and communications equipment.
Itron HQ: USA Market Share: High	• Based in Liberty Lake, Washington, USA, Itron serves utilities and cities 100+ countries. The portfolio encompasses smart networks, software, services, meters, and connected sensors with integrated networking and communications. • Across most product platforms, Itron has increased its focus on distributed intelligence. Its gas and electric meters, and other edge devices like sensors and lighting controls, are equipped with onboard computer processors.
Schneider Electric HQ: France Market Share: High	• Schneider Electric, with operations in more than 100 countries, offers integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Most of Schneider's sensing and measurement offerings are for LV and MV distribution operations. It offers a wide array of controls, relays, sensors, switches, transformers, and other devices for distribution system monitoring. • Schneider's flagship grid management platform, EcoStruxture, is designed to fuse a system of connected products, edge control, and apps, analytics, and services.
GE HQ: USA Market Share: Medium	• Boston, Massachusetts-based General Electric (GE) is a global conglomerate that operates in the energy, technology infrastructure, capital finance, and C&I sectors. GE reported 2018 revenue of €102.98 billion. • In 2015, GE acquired Alstom's power and grid business which led GE's continual focus on merging its integrated

Vendor	Company overview and related offerings
	software platforms and expertise with industry-leading hardware solutions. • GE's Multilin line monitoring system provides time-synched grid information along distribution feeders. The sensors can detect faults, sense current, amplitude, phase, and conductor temperature, and produce dynamic line rating data.
Eaton HQ: Ireland Market Share: Medium	• Eaton Corp., based in Dublin, Ireland, provides industrial products and services to the aerospace, energy, water, transportation, and military industries. • Eaton's sensor series is a conductor-mounted device that can be installed throughout the distribution network to provide real-time line monitoring of electrical current and can locate fault directions and provide indications for capacitor bank failure. • Eaton's global footprint, significant partnerships and additional integration with internal and non-Eaton companies give it a strong presence across Europe.
Schweitzer Engineering Laboratories HQ: USA Market Share: Low	• Pullman, Washington-based Schweitzer Engineering Laboratories (SEL) researches, designs, manufactures, and provides support for an array of grid control and protection products. The employee-owned business operates manufacturing facilities in the US and Mexico. • SEL's distribution sensor offering consists of a wireless connected FCI for Overhead Lines, and an underground distribution sensor. SEL's overall market presence benefits greatly from its global customer footprint of over 160 countries, with facilities in 30-plus countries.

8.1.4 Buyer overview

Sensing and IoT monitoring devices are typically purchased and installed by the utilities or network operators. DSOs and TSOs are leading buyers for critical parts of their infrastructure assets. Across the entire European markets for grid monitoring, sensors, and connected IoT devices, Guidehouse Insights estimates that more than 90% of overall new investment is occurring on the distribution networks. The majority of Europe's transmission networks are already highly instrumented, and intelligent connected transmission sensors are not necessarily needed due to high existing network visibility. On the distribution grids, however, networks are very rarely fully equipped with sensors, so we do expect to see most of the overall investment in Europe on the distribution side.

Case study: Siemens deployment of monitors at Stedin
For the Dutch city of Stedin, Siemens was asked to find a smart way to avoid the frequently occurring power failures in the distribution grid. Substations were upgraded with sensing equipment, older ring main units (RMUs) received upgrade kits and a "regional controller" was introduced that automatically localizes faults, isolates it and

restores power (Stedin, n.d.).[18] With those upgrades Stedin is able to restore power within a minute in most cases of power outages.

8.1.5 Supply chain overview – vendor interviews

To understand the supply chain for IoT monitoring devices, we conducted interviews with vendors of IoT devices in the EU and global market. Vendors that were interviewed included Siemens, Aclara Hubbel and Hitachi ABB Power Grids. From the interviews, vendors highlighted several considerations in the supply chain:

- Certain clients only purchase products that are manufactured in specific geographic locations. The EU market demand is mainly sourced with products manufactured in EU.
- Most EU organisations have the capability to manufacture components in-house but can source some components (such as raw materials, electronics PCBs, etc.) from around the world. Larger global organisations manufacture and assemble products across geographic locations to be closer to large demand centres.
- The supply chain risks are mitigated by relying on multiple vendors around the world, if the components are sourced.
- To ensure quality assurance, vendors perform extensive in-house testing on any individual components used in the technology stack where they are purchased from EU or non-EU suppliers.
- The lifetime of IoT monitoring devices is very long (15 – 20 years), which provide vendors enough time to plan and adapt their supply chain based on latest requirements.

8.2 Software platforms for O&M

8.2.1 Technology overview

IT systems are a crucial component for the digital transformation taking place in the electric utility industry. The proliferation of low-cost sensors throughout generation, T&D networks has led to unprecedented levels of data generation that require IT software to process the data for improved efficiency, operation, and maintenance of assets. APM technologies are rapidly taking shape as vendors aggressively address the market for predictive asset analytics. At a high level, APM is a platform that integrates multiple systems and sources of asset data, with dedicated asset analytics that sit on top.

APM builds a bridge between software such as enterprise asset management systems (EAMS), geographic information systems (GIS), meter data management systems (MDMS), mobile workforce management systems (MWMS), and other relevant sources of data that pertain to assets. Upon consolidating this information, analytics can translate data into meaningful insights that cut costs and improve safety and reliability of the power grid.

APM provides much of the insight for utilities seeking to develop condition-based and predictive asset management strategies. Predictive maintenance analytics is a rapidly growing field that promises to optimise both CAPEX and OPEX for utilities. These

[18] Siemens (2020). Link.

emerging systems will help operations personnel see a failure before it happens, preventing outages and saving millions of euros for the utility industry. These benefits are in addition to decreasing the number of truck rolls by limiting the need for scheduled asset maintenance.

Looking at the software implementation itself, there is a growing acceptance of software as a service (SaaS) purchase models for utilities. For applications that are not highly time-sensitive, asset management as a service may be an economical alternative to the installation and management of an internal system. Analytics solutions also lend themselves to the SaaS purchase model. Under the SaaS model, the utility avoids most of the large upfront capital costs of systems and integration, instead paying a smaller monthly fee based on the number of endpoints (devices) from which data is collected. Additionally, SaaS models help utilities avoid the cost of maintaining a large, sophisticated team of IT professionals.

A growing number of hosted and managed solutions for asset management and grid monitoring have been made available recently. This has been one of the more monumental industry shifts in recent years; while CAPEX/OPEX considerations and security concerns have traditionally hindered the cloud-based market, perceptions are rapidly changing. Major vendors have responded to a surge in utility interest with cloud-first software strategies (such as GE and Oracle).

Although many utilities are interested in evolving their approach and tools for APM, market penetration is relatively low. This leaves vendors with good technology and a strong market vision hungry for opportunities to prove the success and ROI for their solutions in the field.

8.2.2 Market overview

APM technologies are rapidly taking shape as vendors aggressively address the market. Yet, defining APM remains difficult, and leading solutions vary greatly in terms of technology and scope. Broadly, APM is a new sub-market of utility IT & analytics that takes AMS to the next level by enhancing the availability of information on assets and offer tools for optimized decision-making. APM tools are made up of platforms that integrate multiple systems and sources of asset data, and dedicated asset analytics that sit on top.

Per John McDonald, smart grid Business Development Leader at GE Grid Solutions, APM refers to “the strategic and business imperatives for obtaining optimal performance of grid assets across their full life cycle, from planning, design and construction to operations and maintenance and disposal.”

Adoption of condition-based and risk-based maintenance, T&D sensors and decarbonisation strategies are the key drivers for the market adoption and growth for APM solutions.

Market size

As shown in Figure 15, Guidehouse Insights estimates that the APM revenue in EU-27 market will grow at a CAGR of 6.4% between 2020 and 2030. While the UK has been removed for the purpose of this analysis, it remains a strong regional market, accounting for approximately 10-15% of the EU-27 APM market.

The scope of analysis includes APM software and deployment spending. APM software consists of software licence fees and SaaS spending, while deployment includes implementation and integration services as well as annual maintenance fees. While still nascent, the market for APM solutions can be viewed as relatively strong from a global perspective. The market covers spending of T&D network operators. APM software related to generation is only included if owned by a T&D network operator. APM for generation only would be a considerably larger market. The size and growth of the market are limited by similar factors as for the previous technology: Some APM capabilities may be integrated and leveraged as a function of EAMS. Additionally, APM across T&D networks is still largely nascent, with growth potential depending on the developments in advanced analytics, low-cost sensing devices, and enhanced communications. Therefore, beyond 2030 growth rates are expected to continue their slight decline.

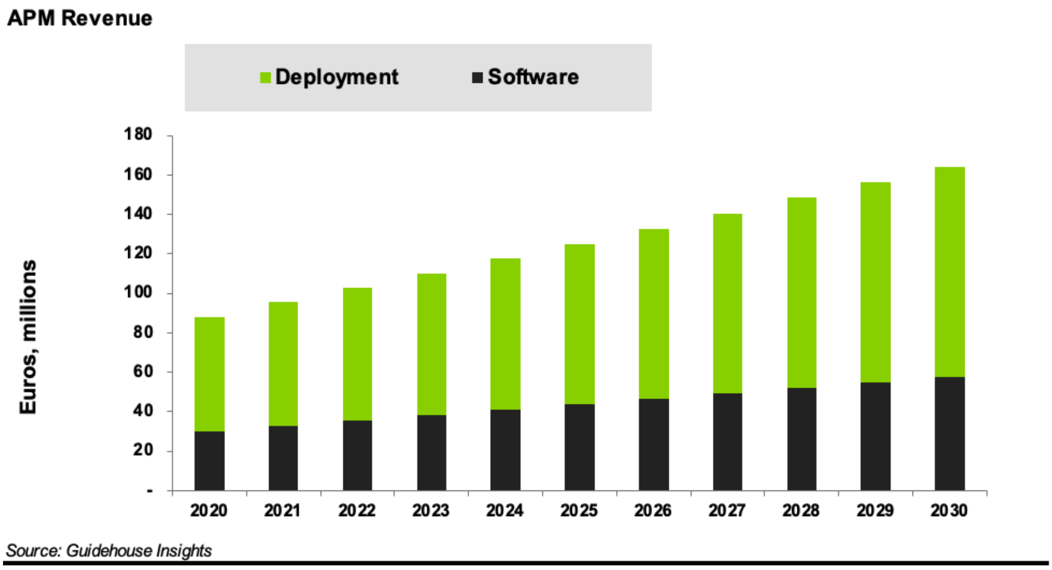


Figure 15: APM Revenue, EU-27 Market

Market maturity in EU-27 Member States

Asset management is one of the most complex elements of the utility business. Many utilities' practices are plagued by rudimentary technologies and outdated strategies. The first step forward came with adoption of dedicated asset management systems (AMSs) and enterprise resource planning (ERP) systems, which act as the system of record. Although these software platforms offer an upgrade over archaic spreadsheet practices, they still rely on largely static data and outdated time-based maintenance programs. These systems have reached near maturity in developed markets, while developing areas (Asia Pacific, Latin America, Middle East & Africa) are seeing accelerating adoption.

With the emergence of APM technologies, utilities are using static AMS data in new ways (e.g., systems integration, data analytics) to create actionable intelligence around asset life cycle management. While traditionally, an exercise performed at the transmission level, energy companies are increasingly moving their efforts downstream into the distribution network for both technological (extension of networking and communications) and strategic (need to reduce operating costs) reasons.

The nascent nature of APM technologies leads to a lack of maturity across nearly every market. While APM analytics have been leveraged by utilities at the generation-level, advanced analytics at the transmission-, sub-transmission-, and distribution-levels still show low penetrations regionally and globally. Guidehouse Insights has observed higher activity at the multi-utility level, including utilities that maintain assets across generation, transmission, and distribution. This includes utilities like Enel (Italy), EDP (Portugal), and others. Below are a few examples of utilities advancing APM technologies further toward the grid-edge.

Italy – Moderate maturity
In Italy, mega-utility Enel has advanced several grid innovation projects. Enel has been working with C3.ai since 2013 to improve its fraud detection and predictive maintenance capabilities. Enel deployed the C3.ai predictive maintenance application for five control centres. The application uses AI to analyse real-time network sensor data, smart meter data, asset maintenance records, and weather data to predict feeder failure (C3 AI, n.d.).[19] In addition to predictive maintenance for distribution assets, Enel deployed C3.ai analytics for their conventional generation assets to identify, diagnose, and predict failures of key rotating equipment components. The application helped to accurately identify impending cooling system failures with greater than 15-28-day advance warning, allowing for more flexible scheduled maintenance and avoidance of emergency plant shutdowns and lost power production.

GE also has several Italian-based APM projects including with A2A, Sorgenia Power S.p.A., and Novel S.p.A. GE's Predix platform has been utilized by Enel for examining, predicting, and enhancing Enel's power plant reliability (Power Engineering International, 2019).[20]

Finland – Low maturity
In June 2018, FinGrid selected ABB (now known as Hitachi ABB Power Grids) to upgrade its 400-kilovolt (kV) Länsisalmi substation. As part of the project, ABB replaced an outdoor air-insulated switchgear (AIS) installation with its compact gas insulated switchgear (GIS) technology. In addition to this turnkey supply, ABB installed modular switchgear monitoring (MSM) devices to enable online condition monitoring of the circuit breakers. This data is uploaded to ABB's Ability APM platform. FinGrid is piloting the use of APM to perform predictive analytics across the transmission asset fleet, including transformers, circuit breakers and transmission network equipment (News Cision, 2018).[21]

Portugal – Low maturity
In January 2018, Energias de Portugal signed a 5-year agreement with GE to deploy its APM system at 23 EDP hydroelectric plants, including its "intelligent Condition Monitoring System" (iCMS) at 12 facilities (Hydro Review, 2018).[22]

[19] https://c3.ai/customers/enel/
[20] https://www.powerengineeringint.com/coal-fired/equipment-coal-fired/top-predictive-maintenance-and-power-industry-companies-identified/
[21] https://news.cision.com/abb-power-grids/r/abb-to-upgrade-landmark-substation-in-helsinki,c2541319
[22] https://www.hydroreview.com/2018/01/19/ge-to-begin-digitalization-of-edp-hydroelectric-fleet/#gref

8.2.3 Vendors overview

APM is a relatively new sub-market of utility IT & analytics, and no vendors' position is carved in stone. The competitive landscape for APM technologies is a relatively diverse mix of IT and OT system providers, data management solution providers, and analytics vendors. This includes companies such as Hitachi ABB Power Grids, IBM, Schneider Electric SE, Oracle, GE, Siemens, and C3.ai. Schneider Electric SE and Siemens are the key EU based providers of APM technologies. Table 13 lists the main vendors in Europe, a qualitative estimate of their respective market share and a brief description of their APM related offerings. A moderate market share indicates an estimated market penetration of 5-15%

Table 13: Leading vendors of APM software platforms

Vendor	Company overview and related offerings
Hitachi ABB Power Grids HQ: Switzerland & Sweden Market Share: Medium	• Hitachi ABB Power Grids is a Switzerland (co-head quartered in Sweden) based major global technology company in power and automation for utility, industry, transport, and infrastructure customers. The current company is the result of a 2020 merger with Hitachi. It employs about 36,000 people over business units: Grid Automation, Grid Integration, High Voltage Products, and Transformers. • The company offers an end-to-end solution with its Connected Asset Life cycle Management (CALM) product; modular AMS, APM, MWMS architecture. • As of February 2020, it monitored 1.3 million assets in production around the globe on a continual basis.
GE HQ: USA Market Share: Medium	• Boston, Massachusetts-based General Electric (GE) is a global conglomerate that operates in the energy, technology infrastructure, capital finance, and C&I sectors. GE reported 2018 revenue of €102.98 billion. • In 2015, GE acquired Alstom's power and grid business which led GE's continual focus on merging its integrated software platforms and expertise with industry-leading hardware solutions. • GE offers a holistic software portfolio (advanced distribution management systems, i.e., ADMS, GIS, MDMS, MWMS) alongside its AMS and APM capabilities. APM includes modules for generation, renewables, and T&D applications.
IBM HQ: USA Market Share: Low	• IBM, headquartered in the state of New York in the US, is a multinational technology company focused on computer hardware, middleware, and software • IBM's Maximo enterprise AMS holds a substantial portion of market share in North America and Europe. IBM's Watson IoT solution provides the backbone for APM applications. Related offerings include MWMS and outage management system (OMS).

Vendor	Company overview and related offerings
Schneider Electric HQ: France Market Share: Low	• Schneider Electric, with operations in more than 100 countries, offers integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Schneider offers enterprise AMS and APM solutions under its AVEVA acquisition. APM applications include information management, augmented reality for operation and maintenance, condition management, control of work, and predictive analytics. Supplemental solutions include ArcFM (GIS add-on) and Wonderware eDNA (data historian).
Oracle HQ: USA Market Share: Low	• Oracle is a California, US, based database, cloud and enterprise software focused, multinational company. • It offers software for utilities including customer service and engagement, metering, operation and asset management, grid and network management, and data analytics. • Oracle Utilities offers Work and Asset Management tool covering AMS, APM, and work order planning/scheduling.
C3.ai HQ: USA Market Share: Low	• Founded in 2009, Redwood City, California-based C3 is a software analytics firm that targets its SaaS solutions at several industries. The company has gone through several reinventions, from an initial focus on oil & gas, to downstream energy, and a series of name changes, from C3 Energy to C3 IoT to C3.ai. • Underlying all of C3's applications is an analytics platform that integrates enterprise data with third party datasets. The platform is designed to scale to large volumes of data and enable real-time data loading and deployment in a private or public cloud. C3 offers a series of applications, including predictive maintenance.

8.2.4 Buyer overview

APM buyers are typically in the utility sector. DSOs and TSOs are leading buyers for critical parts of their infrastructure assets. On the generation side buyers are a mix of power utilities and large corporates that operate and maintain larger renewable generation assets such as solar or wind farms. Roof top solar generation of households or offices and business do not play a role yet. Some utilities have also opted to develop APM capabilities in-house.

Case Study: Enel deployment of C3.ai modules

As mentioned in Section 8.2.2, Enel has deployed multiple C3.ai modules across its asset fleet, including fraud detection and predictive maintenance. The system provides Enel with high levels of situational awareness, aggregating data from eight disparate systems (SCADA, Grid Topology, Weather, Power Quality, Maintenance, Workforce, Work Management, and Inventory) to generate actionable insights. Key innovations include a temporal view of Enel's as-operated network state and the use of advanced machine learning algorithms to improve prediction performance. This has resulted in:

- 4 production applications deployed at scale
- 50M+ sensors monitored

- €2.5B cumulative economic benefit target from digitalization by 2021

8.2.5 Supply chain overview – vendor interviews

For this report, the interviews were conducted with Hitachi ABB Power Grids, GE and Oracle that helped gain further insights into their supply chains. These insights are summarized as follows –

- The software supply chain is highly integrated in-house except for the dependence on the open source software and tools that enable the vendors to develop their software solution in-house.
- The supply chain risks stem mostly from the cloud providers' software support in case when external cloud providers' (such as Microsoft Azure, Amazon AWS, and others) platforms are leveraged; however, such risks are normalized through SLAs.

9 Flexibility Markets

In a system with a growing share of variable renewable energy sources (RES) and distributed energy resources (DER) congestion starts appearing, creating demand for inter-TSO and TSO-DSO coordination across voltage levels. DER must provide flexibility at local and system levels. Flexibility market platforms (e.g., DERMS) are means to achieving this. The use case focuses on actors that require flexibility (e.g., system operators). Flexibility services are key for the development of a residential energy as a service market, as they provide a route to capture the value of distributed energy resources (DER) assets deployed at customer premises.

The DER that are intermittent in nature often present system reliability issues onto the distribution grid, and sometimes propagate to the transmission grids. Fortunately, the inherent technical and operational flexibility available with both utilities and private parties (including end consumers and prosumers) once integrated to the grid through the market mechanisms make the flexibility market more valuable. More importantly, the trend in decarbonisation and associated increase in the renewables penetration will make these intermittency issues more challenging if the current markets do not capture the value of the flexibility. A previous digital transformation study[23] identified the following three services under the flexibility market shown in Table 14:

Table 14: Flexibility market services

Services	Delivered To
Ancillary services for system balancing	TSOs
Services for congestion management	TSOs and DSOs
Commercial flexibility services	Market parties like BRPs

The technologies like DERMS and Advanced Distribution Management System (ADMS) have been deployed to address the issues of system imbalances, congestion, and value creation. A detailed overview of both technologies is discussed in subsequent sections. At a higher level, ADMS (DMS, OMS and SCADA) has always been the core distribution operational technology that helps the utility achieve highest performance standards for the grid (e.g., SAIDI, SAIFI, CAIDI). On the other hand, DERMS becomes more valuable in the jurisdictions where the grid has more DER connected and the share of the renewables amongst these distribution connected DER is relatively higher. There are some vendors that offer DERMS as a submodule within their overall ADMS product offerings.

In addition to DERMS and ADMS that enable the flexibility market use case, there are other technologies that also play roles of varying degrees of significance in enabling the flexibility. For instance, Advanced Metering Infrastructure (AMI) enables the flexibility market through provisioning of the end-consumer/prosumer data and communications to both behind-the-meter and front-of-the-meter DER. Similarly, Virtual Power Plants (VPPs) and aggregators are increasingly becoming popular where the markets have matured enough to allow the participation of aggregated energy services into the

[23] Assessment and roadmap for digital transformation of the energy sector towards an innovative internal energy market, Final Report, October 2019

mainstream markets. As shown in Figure 16, this participation is augmented through advanced market clearing and incentivization mechanisms that the flexibility markets are anticipated to offer to its market participants.

(Source: +CityxChange Project report on the Flexibility Market v0.6)

Figure 16: +CityXChange Example of DSO-led flexibility market

The flexibility market use case focuses on DERMS and ADMS as these technologies are instrumental for enabling the essential technical capabilities for both TSOs/DSOs and other market participants to reliably dispatch to the DER. Both DERMS and ADMS has direct visibility into the underlying electricity network and all its assets – most importantly all the busses that have DER connected. The grid parameters – voltage, phase angle and frequency – are directly accessible to DERMS and ADMS in real-time. Furthermore, the system integration with other systems (such as SCMS[24], network planning and modelling, billing and reconciliation, asset management and GIS, market interfaces, analytics, customer portals) has matured in the past two decades through the adoption of the standardized communication protocols (such as IEC 61850, IEC 60870 family, IEEE 2030, OCPP) and associated electrical topological information models (such as IEC 60968/60970 CIM – Common Information Model).

9.1 Distributed Energy Resources Management System (DERMS)

9.1.1 Technology overview

DER have traditionally been isolated, however, DER are now integrated and operated with the distribution grid as adoption drivers grow and adoption of DER becomes more evenly allocated. This allocation has resulted in new opportunities and challenges for utilities, and vendors are keenly focused on how they can participate in this changing market.

DERMS as a DER and grid management system is broadly defined as –

[24] SCMS stands for Substation Control and Monitoring System, a system with a vital role of real-time monitoring and control of the substation assets. SCMS and IEC 61850 have revolutionized the substation automation technologies as they provide standardized model-based system definition, monitoring and control of entire substation.

> *A control system that enables optimized regulation of the grid and DER to the extent that a utility can dispatch and control DER. To minimise disruptions and the presence of phantom loads, utilities need to manage the grid more proactively. Common use cases include Volt/Volt-ampere reactive (Volt/VAR) optimization (VVO), power quality management, and the coordination of DER dispatch (when possible) to support operational needs.*

As the roles of stakeholders evolve and change for all players including the end customer, many questions remain around how DER will be optimally managed for utilities, policymakers, and everyone in between. Several important trends affect the market for DERMSs. These stretch from baseline technical challenges to a wider discussion around policy and the emergence of new markets and business models for energy and utilities.

As a core software technology, DERMS enables the flexibility market use case and particularly its services as listed in Table 14. DERMS enables the implementation, provisioning and integration of the above services that are core the flexibility market platforms at TSOs and DSOs.

The active grid management functionality including Volt/VAR optimization and control, power quality management and power flow management are the main product features of DERMS that either wholly or in conjunction with the TSOs/DSOs systems enable the flexibility services in the market.

TSOs and DSOs equipped with DERMS perform surgical network operations by deploying localized Volt/VAR control for voltage regulation services. Similarly, the power flow management allows for deploying ancillary services through active power control and frequency response including the spinning reserve control for the available DER. The BRPs are positioned to offer commercial flexibility services into the market through DERMSs that can essentially deploy similar grid services at their contracted participants. In addition, when microgrids are involved, DERMS’s islanding management technical capability turns into the market-oriented capability and starts providing dispatchable ancillary services.

9.1.2 Market overview

EU growth will be driven by several market and technology factors, including the proliferation of DER, network constraints, high levels of grid automation, carbon and EE requirements, and larger digital transformation initiatives.

There have been varying regulations across EU Member States. ENTSOe rules around harmonization as well as data driven policy/decision-making, and enabling market mechanisms or lack thereof, are some of the key challenges for DERMS deployment. However, regulation around DER transparency as part of grid forecasting data transparency between DSOs and TSOs is one key market driver for DERMS deployment.

Market size

As shown in Figure 17, Guidehouse Insights estimates that the DERMS revenue in EU-27 market will grow at a CAGR of 18.0% between 2020-2030. This growth is slightly lower than the overall global CAGR of 24%. The disproportionately high global CAGR is a function of the nascency and low revenue profiles of international markets (excluding North America) today. Beyond 2030, growth rates in the same range can be expected.

The market sizing is analysed in terms of DERMS revenue from software and deployment of the solution. From buyers' perspective, it represents the annual spending. The software cost accounts for the licensing, development, and customizations, whereas the deployment cost consists of implementation and integration services to enable DER solution and provide ongoing maintenance activities and SaaS subscriptions fees.

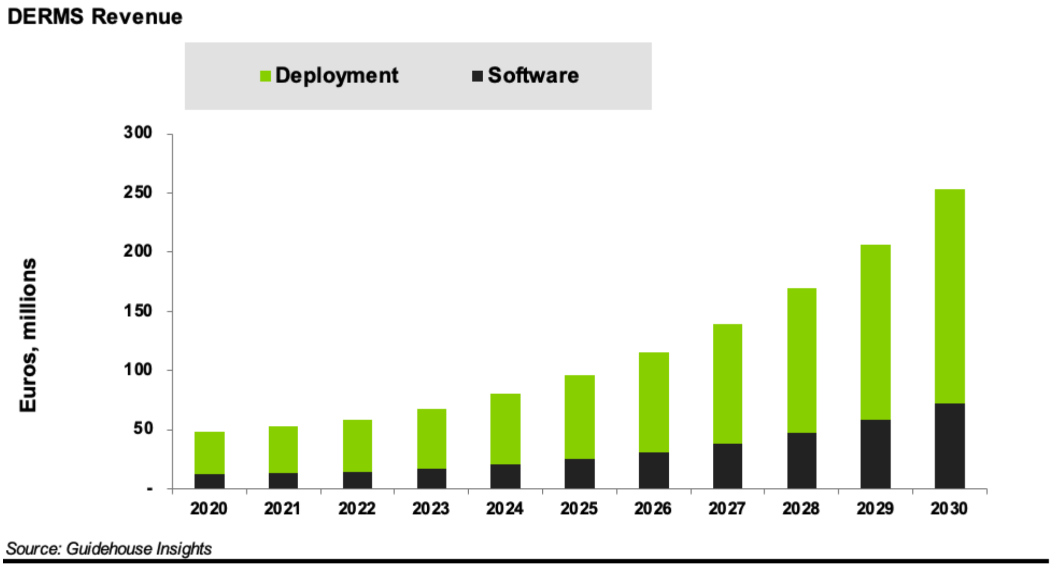


Figure 17: DERMS Revenue, EU-27 Market (Source: Guidehouse Insights)

Western Europe has shown a greater propensity to invest in DERMS technologies than its Eastern counterpart. Naturally, countries with higher penetration of renewables and DER have an increased incentive to explore DERMS technologies given grid constraints and economic optimization goals.

Market maturity in EU Member States

The nascent nature of DERMS technologies leads to a lack of maturity across nearly every market. A lot of industry participant focus has been on areas such as California and New York in North America, and the United Kingdom, The Netherlands, and Germany in Western Europe. These areas are proactively investigating market and policy restructuring to better support DER adoption alongside DER-enabling infrastructure development. However, they are the exception to the wider industry's reactive position—and represent the early stages of what will inevitably be a longer process guided by trial and error.

There is limited harmonization particularly between the TSOs and DSOs to coordinate with one another within the flexibility market construct. EU's Horizon 2020 research and innovation programme has funded INTERRFACE – a project for large-scale demonstrations of innovative grid services through DR, storage and small-scale (RES) generation among TSOs, DSOs and consumers. One of the key objectives of this project is to create a common architecture that connects market platforms to establish a seamless pan-European electricity exchange linking wholesale and retail markets and allowing all electricity market players to trade and procure energy services in a transparent, non-discriminatory way.[25] The DERMS market nascency is mostly driven by vendors waiting to see the INTERRFACE project outcomes before they increase market investments.

Germany
Siemens helped Germany's Innogy SE to successfully manage a decentralized energy system with a trading platform. Siemens connected ~30,000 assets in DER, such as generators, consumers (loads) and storage units; this enables earnings creation from all kind of ancillary services (PRL, SRL, TRL) or Spot/Intraday market. Among the benefits was support of the Grid SCADA System via ICCP Connection in case of grid congestions.

The Netherlands
GE delivered a software solution that forecasts power flow across T&D networks and helps manage increasing levels of renewable energy generation. The solution enhances electric power flow forecasts at interconnection points between the TSO and Stedin. It uses market participants' declarations as well as machine learning techniques to generate power flow forecasts at Stedin's 39 primary distribution substations. A joint view of forecasting with high accuracy allows the TSO to balance the transmission grid while allowing Stedin to avoid congestion at the distribution level, thereby increasing efficiency and reliability for end customers (General Electric, n.d.).[26]

UK
The UK is one of the leading markets in Europe for the deployment of DERMS. This is partly driven by the high deployment of DER connected and the regulatory framework (Ofgem, n.d.) [27], that incentivizes DSOs to leverage smart solutions as an alternative to traditional reinforcement. To date, several DSOs have implemented DERMS systems that enable active network management.

9.1.3 Vendors overview

The DERMS market is largely characterized by a small pool of overall vendors.
While DERMS capabilities are more sought after in North America in terms of demand (Guidehouse Insights, 2020)[28], Siemens & Schneider Electric are both leading EU based DERMS providers and hold moderate technology market shares. Vendors have seen value in making their DERMS system more modular such that it can be deployed along with ADMS as an embedded module within the ADMS or a standalone deployment comprising only DERMS functionality.

There is fierce competition among major OT vendors, including ABB, GE, and OSI. While outside of the scope of the EU-27, UK-based Smarter Grid Solutions and Swiss based ABB (now known as Hitachi ABB Power Grids) have several DERMS deployments across the US and Europe. Other global vendors include Oracle, ACS Power (Indra), OATI, and ETAP. There are also several innovative startups in this space currently coming out of the North American market.

[25]Source: (INTERRFACE, n.d.)
[26] https://www.ge.com/digital/blog/leading-way-forward-der-grid-management
[27] https://www.ofgem.gov.uk/ofgem-publications/64031/re-wiringbritainfspdf
[28] Guidehouse Insights. *Virtual Power Plant Overview.* 2Q 2020.

As noted above, Schneider Electric and Siemens are the primary EU based vendors of DERMS technologies. Other global vendors include GE, OSI, ABB, Smarter Grid Solutions, and ACS Power. Table 15 provides and overview of the leading vendors in this sector.

Table 15: Leading vendors of DERMS

Vendor	Company overview and related offerings
Schneider Electric HQ: France Market Share: Medium	• Schneider Electric, with operations in more than 100 countries, offers integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Schneider Electric EcoStruxure Grid as a DERMS can serve as standalone or embedded with existing ADMS which allows complete visualization of DER in the distribution grid. • EcoStruxure can connect residential thermostats through industrial installations. It allows dispatching select technologies over set periods of time and contains Microgrid Advisor allowing utilities to remain flexible as grid modernization projects develop over time.
Siemens HQ: Germany Market Share: Medium	• Siemens, based in Munich, Germany, is a global technology provider positioned in the electric power value chain by offering solutions for generation, T&D, smart grids, smart cities, and energy efficiency. Siemens reported revenue of €86.8 billion ($92.7 billion) in 2019. • Siemens offers Decentralized Energy Management System as a DERMS and combines distributed power plants into a VPP and dispatches to distributed generating units, storage systems, and loads. It includes forecasting, scheduling, real-time optimization, process connection, modelling environment, and comprehensive recording of operating resources. • Siemens positions DERMSs as a grid management (ADMS), aggregation (VPPs), and customer (demand response management system [DRMS]).
GE HQ: USA Market Share: Medium	• Boston, Massachusetts-based General Electric (GE) is a global conglomerate that operates in the energy, technology infrastructure, capital finance, and C&I sectors. GE reported 2018 revenue of €102.98 billion. • GE DERMS encompasses advanced energy management, ADMS, real-time insights, DER orchestration, and geospatial services. • GE DERMS enables integration of small-scale renewables, grid-connected smart buildings, and energy storage systems to adjust offers with demand, optimise EV charging and manage Demand Response (DR). • In 2019, GE added IEEE 2030.5 support and enhanced analytics with automation and forecasting modules.
Hitachi ABB Power Grids	• Hitachi ABB Power Grids is a Switzerland (co-head quartered in Sweden) based major global technology

Vendor	Company overview and related offerings
HQ: Switzerland & Sweden Market Share: Medium	company in power and automation for utility, industry, transport, and infrastructure customers. The current company is the result of a 2020 merger with Hitachi. It employs about 36,000 people over business units: Grid Automation, Grid Integration, High Voltage Products, and Transformers. • Hitachi ABB Power Grids Ability DERMS promotes four core functionalities – resource management, resource optimization, market participation, and commercial settlement. Its Network Manager includes VVO, cloud-based registration for end users, and behind-the-meter forecasting. • Hitachi ABB Power Grids Ability DERMS automates and manages microgrids via its Microgrid Plus System and stabilizes a 100% renewable microgrid with its PowerStore ESS.

9.1.4 Buyer overview

Leading DERMS providers offer comprehensive solutions that can be tailored to operate in a wide variety of regulatory environments and by different actors in the power market such as market operators, system operators, energy suppliers, or aggregators. The primary buyers of DERMS technologies are network operators, as these entities are tasked with maintaining grid reliability and mitigating disruptions caused by renewables and DER. DERMS offering enables energy companies to orchestrate technical, contractual, and geographical DER modelling, connection acceptance. The offering also coordinates utility and non-utility DER alongside traditional T&D grid levers to enhance resiliency in both real-time and look-ahead modes.

There are a handful of major OT software vendors leading the DERMS market. Deployment is also largely led by this pool of vendors. While some deployments may leverage a third party systems integrator, these larger OT providers typically have the requisite expertise for implementation and integration services. Once the solution is deployed, platform providers provide ongoing operations and maintenance; this may consist of back-end operations support, integration of new devices, and updates to security or communications protocols.

Case Study: Hitachi ABB Power Grids DERMS Pilot

A European utility experiencing an increase in the adoption of electric vehicles wanted to establish a pilot programme that would facilitate a balance between the demand for EV charging and the availability of surplus wind energy. A real-time monitoring and management system was deployed to balance the charging of EVs with the availability of wind energy reserves. In addition, the solution enabled the utility to draw power back from the EVs onto the grid to stabilize energy availability. This solution also provides advanced modelling of supply, demand, and grid flows by collecting data and providing real-time analytics.

The ability to monitor grid performance and energy availability in real-time allows for the diversion to alternate energy resources automatically, which optimizes grid flow and performance. With this solution, the utility increased the number of EV charging stations without disrupting the energy use patterns of its customers.

9.1.5 Supply chain overview - vendor interviews

The following are the insights have been identified following interviews with key vendors provide DERMS products. The following vendors were interviews as part of the study; Siemens, Hitachi ABB Power Grids and Oracle.

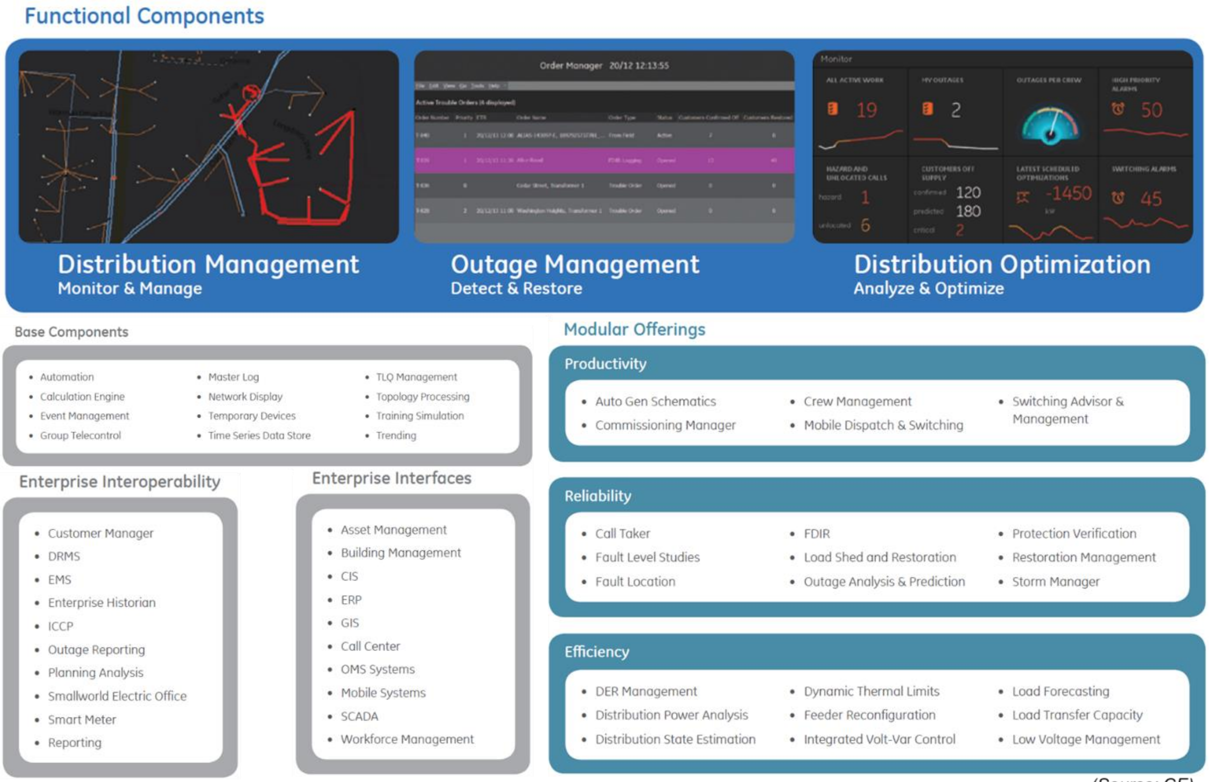
Highly integrated in-house software supply chain:

- Supply chain within DERMS software industry is highly integrated because the software vendors favour the software development in-house.
- Some vendors' software supply chain in terms of third parties only include the system integrators for 3rd party systems and integration with aggregators especially where customers DER are required to be access via DER providers' technology or cloud.
- While some vendors see risks particularly when small third parties enter supply chain with limited capacity and capability within the context of distribution network complexity, some see low risks from third parties that are the industry leaders in Database and OS.

9.2 Advanced Distribution Management System (ADMS)

Initially deployed to analyse power flows, optimise grid management, and support automation, distribution management systems (DMSs) have been around for more than a decade. However, utilities that deployed DMSs noted several redundancies associated with supporting different systems (e.g., OMS and SCADA) that relied on a model of the distribution network but maintained separate and therefore incomplete models. Because of this, tiresome updates and cross-verification of data were required, effectively slowing the processes of both. This led to the evolution of the modular, advanced DMS (ADMS).

An ADMS unifies operational and engineering data for state analysis, switching, outage management, and planning. It maintains a single as-operated model of the distribution network based on the as-built model (typically from a GIS). This consolidated suite of applications includes real-time monitoring, simulation, static engineering applications, and outage management. Figure 18 provides and overview of the key components of an ADMS.



(Source: GE)

Figure 18: Advanced Distribution Management System (ADMS) Overview - Example: GE

Applications include distribution power flow analysis; contingency analysis; switch order management; short-circuit analysis; integrated volt/volt-ampere reactive control (IVVC); fault, location, isolation, and service restoration (FLISR); loss analysis; simulation training; field device control; historical data gathering and event reporting; outage prediction and management; and reconfiguration.

9.2.1 Technology overview

Many vendors and utilities consider ADMS to be a combination of SCADA, DMS, and OMS. This integrated architecture has grown in recent years to include energy management system (EMS) and DERMS modules, though this is not universal across vendors. Such growth is a natural technological extension of ADMSs. The boundary between networks is thinning and future network operators require access to transmission, distribution, and BTM applications. Guidehouse Insights believes that most systems available in the marketplace qualify as ADMSs.

However, this description can be misleading due to the nature of energy IT and asset replacement cycles as well as the segmented approaches to business and network management. Because an ADMS conceptually includes many of the functions of the distribution SCADA, it is natural to consider it fundamental to the system. Many utilities' SCADA systems are not yet at the end of their useful life. Therefore, desired ADMS upgrades may require integration with these systems (as opposed to replacement). Vendors typically offer an ADMS as a suite that includes a modular set of systems with multiple licenses that can be purchased over time to facilitate gradual installation.

As the industry matures and homegrown systems reach the end of useful life, utilities are expected to be in a much better position to manage their networks. From a human standpoint, it is difficult to manage interfaces between homegrown and new ADMS modules. For ADMS upgrades (typically every 3 years), a whole new round of testing is required and can dramatically increase the upgrade timeline. It introduces control room inefficiencies (i.e., five user interface screens) that are mitigated with modular, integrated solutions.

To operate a modern ADMS, the data requirements (level of fidelity) are far superior to that of a traditional DMS. Advanced GISs can maintain that level of data fidelity and feed the ADMS as a quasi-digital twin. This fidelity allows utilities to maintain the operating state of the network with a single source of truth and aims to dramatically improve the plague of poor connectivity models across the utility industry.

ADMSs and DERMSs control critical functions that most utilities are expected to keep in-house for the foreseeable future. However, many utility IT solutions are offered as a hosted or managed service, i.e., software as a service (SaaS). There is a small but growing list of utilities that have already deployed core DMS or SCADA functionality in the cloud, and now most vendors have begun to consider how they can offer microservices, or core functionality, in the cloud.

To maximise the value of increased data proliferation, a robust platform that can integrate data from multiple functional areas – an ADMS – is required. Pertinent grid solutions which may feed data into an ADMS include AMI, demand side management (DSM), distribution and substation automation and integrated Volt/VAR control (IVVC) and conservation voltage reduction (CVR).

9.2.2 Market overview

As DER drives the need for ADMS and DERMS, the businesses are focused on cybersecurity, technologies that address modularity, and operational factors such as data proliferation and DER integration. As the need for multitude of IT systems grows, implementation and integration can become exponentially more challenging and expensive. Vendors are responding by making their suites of systems highly interoperable and adopting modular system architectures.

There have been varying regulations across EU Member States. ENTSOe rules around harmonization as well as data driven policy/decision-making, and enabling market mechanisms or lack thereof, are some of the key challenges for ADMS deployments. However, regulation around data provision including grid forecasting data transparency between DSOs and TSOs is one key market driver for ADMS deployments.

Market size

As shown in Figure 19, Guidehouse Insights estimates that the ADMS revenue in EU-27 market will grow at a CAGR of 5.4% between 2020 and 2030. EU market growth will be driven by several market and technology factors, including the proliferation of DER, network constraints, high levels of grid automation, carbon and energy efficiency requirements, and larger digital transformation initiatives. The ADMS software revenue stems from the licensing costs and software customizations, whereas the deployment revenue is the annualized spending on the implementation and integration services and support and maintenance. Beyond 2030, a similarly sized growth rate can be expected.

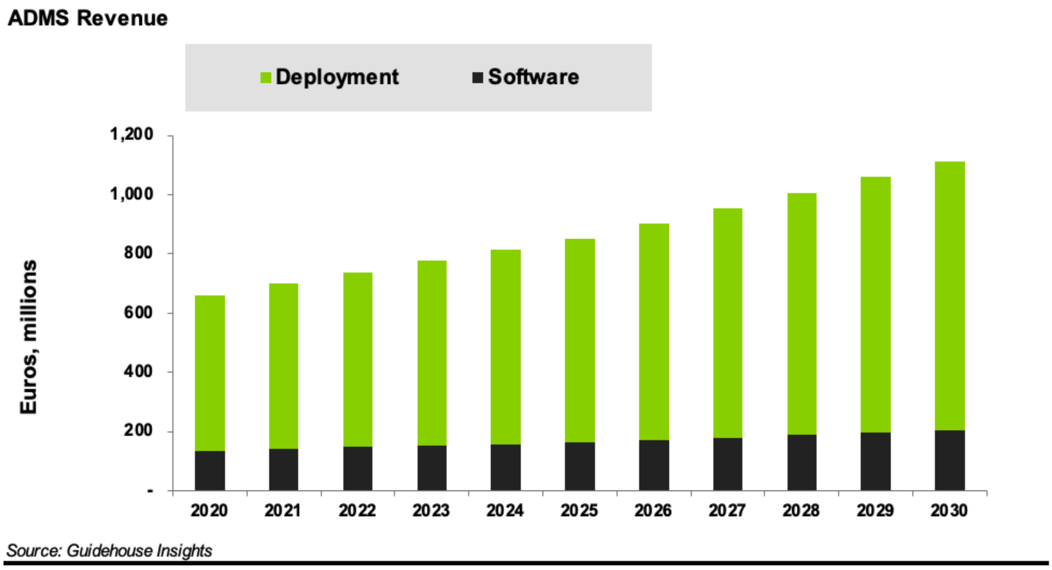


Figure 19: ADMS Revenue, EU-27 Market (Source: Guidehouse Insights)

Europe has the highest penetration of ADMS technologies globally. Most Western European utilities are expected to have one or more ADMS modules deployed. This is due to several factors, including high rates of substation and feeder automation, carbon and EE targets, adoption of renewables, smart metering initiatives, and more. Eastern Europe shows lower rates of ADMS penetration regionally.

Market Maturity in EU Member States

Italy

Enel uses Schneider Electric EcoStruxure ADMS to provide a visual, mathematical model of its distribution network, including detailed models for voltage management, micro-generation, frequency variation, DR, and other smart grid management data. The utility now has more accurate data and a system that can predict the impact of power outages, generation, and voltage variation (Schneider Electric, 2019).[29]

Spain

Iberdrola Distribución Eléctrica installed monitoring sensors on substations, transformers and power serving some 350,000 consumers. The technology offers new insights into what is happening on the network. UPGRID, a mobile app version of GE's ADMS, allows utility control rooms use to monitor and control activity on their distribution grids (GE, 2017).[30]

9.2.3 Vendors overview

The ADMS market is largely characterized by a small pool of overall vendors. The competitive landscape for ADMS is unique given the extensive requirements and growing list of modules captured under the ADMS umbrella. This has led to a smaller,

[29] Source : https://download.schneider-electric.com/files?p_enDocType=Customer+success+story&p_File_Name=998_20427480_GMA_US.pdf&p_Doc_Ref=Customer_success_story_Enel
[30] https://www.ge.com/news/reports/smart-electrons-software-apps-make-europes-electricity-digital

more refined pool of vendors. The pool is made up of traditional, large OEMs (General Electric, Schneider Electric, Oracle, Siemens, Hitachi ABB Power Grids, and Advanced Control Systems—Indra). It also includes a couple smaller, more nimble vendors (ETAP, OSI, and Survalent Technology Corporation) making inroads around managed services and cooperative and public utility targeting. Ultimately, the selection of ADMS vendor depends on a utility's business objectives and constraints.
As with DERMS, Schneider Electric and Siemens are the primary EU based vendors of ADMS technologies, and both hold high technology market shares. Other global vendors include GE, OSI, ABB, and ACS Power. Table 16 provides an overview of the leading vendors in this sector.

Table 16: Leading vendors of ADMS

Vendor	Company overview and related offerings
GE HQ: USA Market Share: High	• Boston, Massachusetts-based General Electric (GE) is a global conglomerate that operates in the energy, technology infrastructure, capital finance, and C&I sectors. GE reported 2018 revenue of €102.98 billion. • PowerOn Advantage is GE's ADMS encompassing SCADA, DMS, OMS, and mobility within a single platform and includes additive solutions around DERMS, GIS, mobility, analytics, and EMS. • In 2019, GE announced a new grid analytics that combine domain expertise with AI and ML to tackle challenges in storm readiness, network connectivity, and effective inertia. • GE has garnered 170 distribution customers globally and has ability to scale from smaller utilities (~25,000 customers) to larger ones (8-10 million customers).
Schneider Electric HQ: France Market Share: High	• Schneider Electric, with operations in more than 100 countries, offers integrated energy solutions across multiple market segments, including nonresidential and residential buildings, industrial and machines manufacturers, utilities and infrastructure, and data centres and networks. • Schneider Electric developed its ADMS solution in 2006-2008 and now includes DMS, OMS, SCADA, EMS, GMS, automated FLISR and VVO, MWMS, and most recently DERMS for DG and microgrids. • With its modular ADMS, Schneider Electric caters to both upstream (EMS) and downstream (DERMS) in recent years. Its DERMS module can serve as a standalone system or embedded within ADMS for complete visualization of DER. • The company deployed highest number of ADMS functional components in production and is more successful with customers with more advanced requirements.
Hitachi ABB Power Grids HQ: Switzerland & Sweden Market Share: Medium	• Hitachi ABB Power Grids is a Switzerland (co-head quartered in Sweden) based major global technology company in power and automation for utility, industry, transport, and infrastructure customers. The current company is the result of a 2020 merger with Hitachi. It employs about 36,000 people over business units: Grid

Vendor	Company overview and related offerings
	Automation, Grid Integration, High Voltage Products, and Transformers. • Hitachi ABB Power Grids Ability Network Manager is its ADMS that consists of DMS, SCADA, OMS, and DERMS modules with a Common Graphical User Interface and Common Data Model. The company is adopting a microservices architecture to open new markets and facilitate centralized, non-disruptive upgrades. • More than 80 utilities use Hitachi ABB Power Grids Network Manager (DMS, SCADA, or OMS) globally; including EON Nordic (Sweden) and tpg (Switzerland).
Siemens HQ: Germany Market Share: Medium	• Siemens AG, based in Munich, Germany, is a global technology provider positioned in the electric power value chain by offering solutions for generation, T&D, smart grids, smart cities, and energy efficiency. Siemens reported revenue of €86.8 billion ($92.7 billion) in 2019. • Siemens Spectrum Power is its ADMS solution. Its Adapter Framework for SOA integration including CIM (IEC 61968) enables the integration of OT and IT. • Spectrum Power ADMS integrates distribution SCADA, outage and crew management and advanced fault and network analysis via a Common User Environment. • Spectrum Power (EMS/ADMS) global install base exceeds 1,300.
Oracle HQ: USA Market Share: Low	• Founded in 1990, the company offers software solutions for business integration, IT consolidation, and supply chain management, as well as designs, develops, and produces pre-packaged computer software for industry, business, and technology. Oracle EMEA serves clients worldwide. • Oracle's offers Network Management System (NMS) as ADMS with the core DMS, OMS, and SCADA modules. Oracle's DERMS module targets DERMS from a grid management (ADMS) and customer (DERMS and Customer Solutions division) perspectives. • Oracle NMS include VVO, FLISR, feeder load management, load shedding, DERMS, and active network management.
OSI HQ: USA Market Share: Low	• Founded in 1990, Open System International, Inc. (OSI) supplies open automation solutions for real-time management and optimization of various industries. OSI was purchased by Emerson Electric in August 2020. • OSI Spectra is its DMS product built upon its Monarch SCADA with modules such as OMS, MWMS, substation automation, and switch order management for FLISR and VVO. Spectra eMap provides network model, state estimation, load flow, and a topology/one-line graphical user interface. • OSI has already deployed several full-blown SaaS control systems and attracted more than 80 DMS customers globally.

9.2.4 Buyer overview

The primary buyers of ADMS technologies are network operators, as these entities are tasked with maintaining grid reliability and facilitating grid automation. There are a handful of major OT software vendors leading the ADMS market. Deployment is also largely led by this pool of vendors. While some deployments may leverage a third party systems integrator, these larger OT providers typically have the requisite expertise for implementation and integration services. Once the solution is deployed, platform providers provide ongoing operations and maintenance; this may consist of back-end operations support, integration of new devices, and updates to security or communications protocols.

Case Study: Enel Efficiency and Sustainability with Schneider Electric EcoStruxure ADMS

Enel is Italy's largest power company and Europe's second listed utility for installed generation capacity. Enel operates in 40 countries worldwide, has around 95,000 MW of net installed capacity, and sells power and gas to more than 61 million customers. Enel recognized the need for an advanced distribution management system but lacked the internal resources necessary to create mathematical algorithms to enhance distribution management.

Enel used Schneider Electric EcoStruxure ADMS to provide a visual, mathematical model of its distribution network, including detailed models for voltage management, micro-generation, frequency variation, DR, and other smart grid management data. The utility now has more accurate data and a system that can predict the impact of power outages, generation, and voltage variation. By implementing Schneider Electric EcoStruxure ADMS, Enel has experienced significant energy and cost savings through the optimization of its existing network resources and operations. This has led to streamlined energy production and decreased CO_2 emissions. The EcoStruxure ADMS resulted in energy savings of 144 GWh per year, significant cost savings through optimization of existing network resources and operations and open architecture enabling smooth integration with the utility's SCADA, GIS, and OMS.

9.2.5 Supply chain overview - vendor interviews

Following are the insights[31] gained for the ADMS vendors' supply chains with Siemens, Hitachi ABB Power Grids and Oracle.

Highly integrated in-house software supply chain:

- Supply chain within ADMS software industry is highly integrated because the software vendors favour the software development in-house.
- Some vendors' software supply chain in terms of third parties only include the system integrators for 3rd party systems that pose minimal risks in vendor's supply chain.
- While some vendors see risks particularly when small third parties enter supply chain with limited capacity and capability within the context of distribution

[31] These supply chain insights are very similar to that of ADMS, as many vendors have both ADMS and DERMS offerings often as DERMS deployed as a module embedded within ADMS or as a standalone system.

network complexity, some see low risks from third parties that are the industry leaders in Database and OS.
- In certain instances, specific aspects of ADMS solutions utilise third party engines to support modules of the ADMS. Some vendors utilise power flow or state estimation engines from 3rd party software providers to deliver key functionality of their ADMS.

10 Smart Districts

Smart districts are city spaces that facilitate interconnections between smart buildings, mobility, and public spaces (e.g., streets, public lighting) with the ultimate goal to self-sustain themselves through their energy production. Smart districts actively manage energy consumption and energy flow between buildings and other consumers in the public space, exchanging net flows from distributed energy production with the grid. Through the application of smart meters and IoT technology in an integrated system, buildings become active components of smart districts, capable of monitoring, controlling, balancing, and forecasting energy requirements and uses. Such a system enables optimal use of local RES, energy storage, smart grids, DR, innovative energy management (electricity, heating, and cooling) and user interaction.

Smart meter infrastructure is at the heart of delivering smart districts that enable consumer empowerment. For this reason, this chapter will explore the value of smart metering technology as a key enabler of smart districts from a perspective of energy management. The following sections of the report capture a technology overview, market overview, vendor overview and buyer overview.

10.1 IoT monitoring devices for energy management

10.1.1 Technology overview

The original smart meter was perhaps the most transformative addition to the global energy network since its inception. The ability to remotely read usage information and communicate with electric meters allows utilities, municipalities, and customers to understand energy usage across their networks, cities, or properties.

Smart meters provide real-time data to manage either the microgrid or the relationship with the DSO for balancing purposes in smart districts. Many smart meters allow two-way communication through interacting with other devices, and remote real-time monitoring of power consumption by service providers. Smart meters collect data from different metering devices for electricity and other essential utilities, such as water and gas. This data helps energy providers provide accurate billing and provide customised solutions offerings. Consumers can use smart meters to monitor their electricity usage via mobile or web applications, respond to price changes and limit wasting energy

Smart meters monitor the energy usage at residential and C&I properties. In the EU, Member States are at different levels of AMI market penetration. Unionwide rollout follows the EU Electricity Directive recommending the rollout of smart meters across Member States. However, different Member States have varying approaches to deploying smart meters. Access rights to the smart meter data across relevant players also varies across Europe.

The following sections will look at the AMI market in the EU-27, as this is a key enabler for smart districts. Submetering behind-the-meter for e.g., heating systems' cost distribution is not part of the market analysis.

10.1.2 Market overview

Market size

Market sizes indicated in below graph include the entire AMI EU-27 sales as this provides a broader context rather than limiting the application to smart cities. Forecast spending is exclusive to hardware, including metering devices and communications modules; this does not include installation services.

Figure 20 depicts the market size and forecast for the EU-27 Member States. Across the forecast period, Guidehouse Insights expects the EU-27 market for smart meters to grow from €2.6bn in 2020 to €2.2bn by 2030, at a compound annual growth rate (CAGR) of -1.9%. Declining revenue profiles early in the forecast period are primarily a function of multiple first-generation deployments coming to completion. The second-generation upgrade market (along with first-generation late adopters) will support market growth later in the forecast period. Additionally, the life cycle of smart meters has decreased over the past decade, with lifetimes averaging in the 8 to 12-year timeframe, rather than the traditional 15 to 20 years. This will support higher upgrade revenue profiles moving forward as a function of more frequent replacements. Low-level to moderate growth is expected to continue into the 2030s as late adopters come to the table and the frequency of second-generation upgrade projects grows. Eastern Europe is expected to disproportionately support new installations while Western Europe will dominate the upgrade and replacement market.

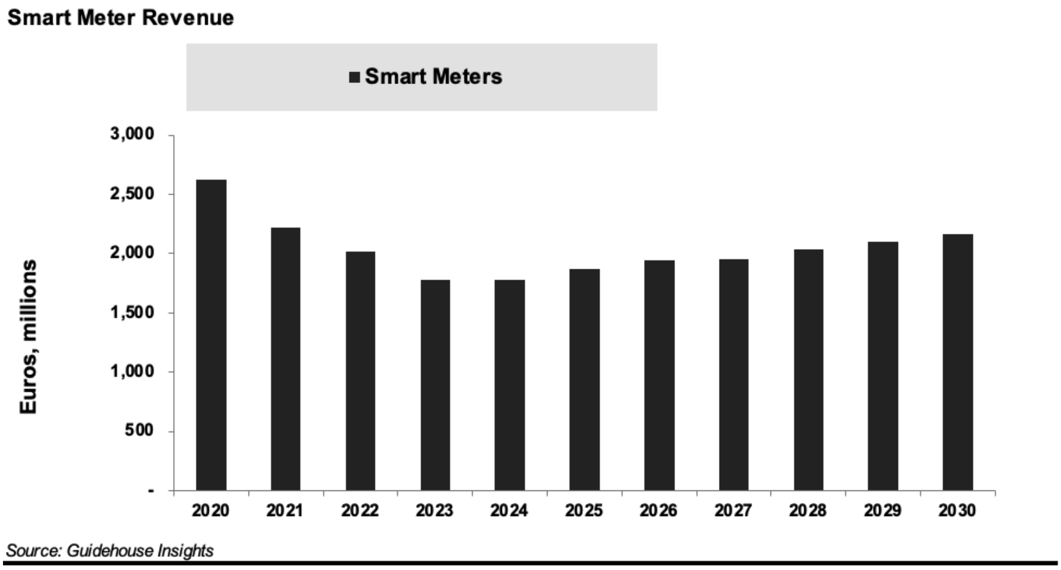


Figure 20: Smart Meters Revenue, EU-27 Market

Market maturity

The European market remains fragmented along the lines of east (emerging) versus west (mature), though this divide is lessening as multiple Western deployments near their completion and Eastern Europe picks up the pace of new installations.

The Western European market can be broken down across three levels of maturity. This landscape was spawned in 2009 following an EU Electricity Directive recommending the rollout of smart meters across Member States. Contingent upon a positive cost-benefit analysis (CBA), Member States are expected to supply 80% of their customers with smart meters by 2020.

At one level, countries like Italy and Spain skipped the CBA all together and began deploying smart meters. While Spain concluded its smart meter rollout in 2018, Italy (Enel) is already working on its second-generation upgrade. Italy is a microcosm of a larger, burgeoning market for second-generation deployments across Europe, including Denmark, Finland, and Sweden.

Most EU Member States fall into the second level: nations that calculated positive CBA scores and are undertaking large-scale rollouts in advance of the 2020 target. This includes the UK, France, Netherlands, Austria, Denmark, and more, although there have been some major delays in the UK. Although Denmark is already exploring second-generation smart metering, Austria, France, and the Netherlands continue to plough ahead towards nationwide coverage. The UK is a story, with various delays and technical challenges plaguing the rollout. As of June 2020, the initial 2020 deadline had been extended to 2025.

Finally, there are those Member States that have stayed on the side lines due to negative or inconclusive CBA results, including Belgium, Germany, and Portugal. This is no longer the case for several of these markets:

- In Portugal, Energias de Portugal is now aiming to deploy 6 million smart meters by 2020; this timeline is likely ambitious given EDP’s smart meter penetration rate (~49% in 1Q20; 41% in 1Q19).
- In Belgium, Eandis and Infrax are set to rollout 1.3 million narrowband Internet of Things (NB-IoT) enabled smart gas and electric meters by 2022.
- In Germany, large consumers with average annual consumption more than 10,000 kWh are required to install smart meters under the Digitisation of the Energy Turnaround Act. This threshold drops to 6,000 kWh in 2020, which applies to approximately 15% of electricity consumers.

In Eastern Europe, project activity has largely been led by Poland, with several small initiatives across several other countries. Russia is expected to dramatically increase its smart metering initiatives; for example, Rossetti is planning to rollout smart meters to its 22 million customers by 2030.

In the following the five most mature markets (Member States) in the EU-27 are briefly presented.

Italy

Enel began its foray into smart meters back in 2001 with the commencement of its Telegestore project. Completed in 2006 at a cost of €2.1 billion, this project saw the installation of approximately 30 million smart meters for Italian households and businesses. Additional deployments brought this total to approximately 32 million today. The success of the project contributed to the advancement of the smart meter movement, as it provided a valuable template for other utilities looking to get their feet wet. During implementation, Enel reported that 80 utilities had visited the company to gain insights into the Telegestore project. Ultimately, this project helped demonstrate the feasibility and financial and operational benefits that smart meters can provide to the utility industry.

Enel, through its Italian distribution grid operator business e-Distribuzione, is now advancing its second-generation smart meter project, with a planned 41 million smart meters (32 million replaced; 9 million new connections). This decision is being driven by increased smart meter performance and functionality, as well as dramatically lower costs since Enel's initial go-around. The project will also leverage Enel's new smart meter.

Sweden

In 2002, the Swedish government mandated monthly electricity metering for all household consumers. Albeit indirectly, this mandate has resulted in a first wave of smart meters being installed by power distribution companies, with nationwide coverage completed by 2009/2010. And while developing at a slightly slower pace than Italy, Sweden is also in the process of replacing all 5.4 million smart meters as a part of its second-generation upgrade project.

Vattenfall, one of Sweden's largest DSOs, commenced its four-phase project in February 2020 to replace 900,000 smart meters as a function of new requirements from both the EU and the Swedish government by 1 January 2025 (Eltel Group, 2020).[32]
In July 2019, E.ON announced an agreement with Landis + Gyr for the supply of 1 million NB-IoT enabled smart meters as a function of its upgrade and replacement project (PR News Wire, 2019). [33]

Finland

In Finland, there are approximately 80 DSOs and 70 electricity suppliers that serve 3.5 million electricity metering points, equipped with smart meters (Dittmar, 2018).[34]mart meter legislation was enacted in Spring 2009, and led to the successful deployment of smart meters by 2014, far in advance of the EU 2020 smart metering target. Finland is currently preparing its second-generation smart meter deployment in transition to 15-minute interval readings (from 60-minute intervals).[35]

Spain

Spain concluded its nationwide rollout of 27 million smart meters in 2018, largely led by Endesa and Iberdrola. Landis+Gyr was the primary supplier to both mega-utilities, contributing to its high estimated regional market share.
While some of the nation's utilities may reach ubiquitous coverage, they will be allowed to maintain up to 2% non-smart meters, provided this is due to causes not attributable to the utilities themselves.

Denmark

Denmark is set to complete its nationwide rollout of 3.3 million smart meters by 2020, with some utilities already exploring second-generation upgrades. Additionally, it is mandated that electricity suppliers enable their IT systems and DataHub to handle

[32] https://www.eltelgroup.com/en/eltel-installs-236000-smart-meters-in-sweden-for-eur-22-million/
[33] https://www.prnewswire.com/news-releases/landisgyr-secures-major-contract-with-eon-in-sweden-300879486.html
[34] https://www.dittmar.fi/insight/finland-moves-forward-in-the-development-of-a-smart-electricity-system/
[35] Ibid.

hourly settlement. These evolutions follow the 2003 decision to liberalise the Danish electricity market (Energinet, n.d.).[36]

10.1.3 Vendors overview

In below table, the five main players in the smart metering market in the EU are listed. Compared to most technologies covered in this study, many European based firms are included. It is estimated that Swiss based Landis+Gyr captures the highest market share, followed by US-based Itron as the only non-European company included. Iskraemeco operates out of Slovenia and is present in several EU and non-EU markets in Europe. Enel started its own smart metering business and its strong presence in the Italian market leads to a relevant presence in the EU-27 overall. Danish Kampstrup and Moldova-based ADD group have smaller market shares more regionally focused on the Nordics and Eastern EU countries, respectively. All vendors in Table 17 are estimated to have an aggregated EU market share of 65-70%.

Table 17: Leading smart meter vendor overviews

Vendor	Company overview and related offerings
Landis+ Gyr HQ: Switzerland Market Share: High	• Landis+Gyr manufactures metering equipment including software and has a global presence. • It has contributed to several of the largest EU based smart metering deployments, e.g., in France, Spain, and Portugal.
Enel HQ: Italy Market Share: Medium	• Enel is Italy's largest utility generating and distributing electricity and is privately owned. • Enel has developed its own smart meter, the Open Meter. These devices are being installed as a part of Enel's second-generation upgrade project (41 million smart meters). Enel holds moderate market share as a function of this mega-project upgrade.
Itron HQ: USA Market Share: Medium	• Itron is a globally active technology company serving mainly utilities and cities. • The portfolio encompasses smart networks, software, services, meters, and connected sensors with integrated networking and communications. • Main market in the EU is France.
Iskrae-Meco HQ: Slovenia Market Share: Low	• Iskraemeco is a Slovenia-based provider of smart meter and smart city solutions. • The firm is active all over Europe, with a relevant footprint in Eastern European Member States such as Croatia, Slovenia and Slovakia.
Kamstrup HQ: Denmark Market Share: Low	• Kampstrup is a Danish metering company offering water, electricity, heat & cooling metering solutions incl. submetering. • Key EU markets for Kampstrup are the Nordic EU Member States.

[36] https://en.energinet.dk/-/media/Energinet/El-RGD/El-CSI/Dokumenter/ENGELSKE-DOKUMENTER/Danish-electricity-retail-market.pdf

Vendor	Company overview and related offerings
ADD Group HQ: Moldova Market Share: Low	• Republic of Moldova-based (non-EU MS) ADD Group designs and manufactures smart metering solutions. • Sales focus is on Eastern Europe, the Middle East, and Asia.

10.1.4 Buyers overview

The primary purchasers of smart meters and associated software platforms are distribution network operators. Associated software platforms typically include Head End Systems and Meter Data Management Systems, along with any value-add analytics modules. While it is common for meter manufacturers and software suppliers to be the same entity (e.g., Landis + Gyr, Itron), there are also standalone hardware and software providers serving the space.

In the use case of smart districts, the buyer of the necessary AMI infrastructure depends on the organizational model. It is mainly also the DSO operating the smart grid in the district. But it can also be a real estate firm which develops the district, or third parties commissioned with the technical operation of the district.

Case study: 200,000 smart meters deployment at Helen Electricity Network, Finland by Landis+Gyr (Landis & Gyr, n.d.)[37]

As one of the early adopters of smart meters and AMI, the Finnish utility Helen Electricity Networks recognizes the central role that smart metering plays in overall energy efficiency improvements and the deployment of smart grid of the future. The utility awarded a contract Landis+Gyr to deploy a smart metering solution including 200,000 smart meters over two years period and the meter reading services for at least the following 10 years.

The contract includes deployment of Gridstream, Landis+Gyr's smart metering solution. With this project, the utility's remaining 200,000 customers will switch to smart metering and have access to hourly-based information on their individual consumption. In addition to hourly consumption information, the solution provides faster and more precise information of the network status and power quality. The Gridstream smart metering solution from Landis+Gyr for Helen Electricity Network includes meter reading services, smart electricity meters, communications, smart metering software and the integration to Helen Electricity Network's IT systems. The communication solution for the utility was optimised by combining 2G/3G communications, Zigbee and Mesh Radio Frequency technology. Landis+Gyr will also be responsible for project management, installation of the equipment together with their partners and training for the utility's personnel.

11 Urban Data Platforms

As the number of cities developing smart city strategies grows and existing programs evolve, focus is intensifying on more integrated approaches that rest on the notion of a city platform. There has been long-standing interest in the concept of an integrated technology platform that can support the many aspects of smart city development.

[37] Source: https://www.landisgyr.eu/news/landisgyr-agreement-in-helsinki-is-at-the-forefront-of-smart-meter-deployment-in-eu/

However, this concept has largely been a theoretical idea promoted by diverse suppliers that has gained limited traction in city strategies. But today, cities are looking to develop platforms that will enable continuous service and technology innovation and enable them to adapt to a world where platform offerings dominate many business areas.

Urban data platforms are emerging from the myriad pilot projects around the world. Growing interest in open data and big data analytics and the broader impact of the IoT in cities are providing momentum. The idea of the smart city platform has both a technical and business heritage and, like the term smart city itself, it can mean many things to many people. What the different approaches share is an interest in new forms of integration and flexibility in the delivery of city services.

The shape such a platform takes for each city will be determined by the specific needs and circumstances of each city—but it will also be determined and limited by the products and architectures being developed by industry. Cities will define their own platforms and service models, but they will do so within the constraints and influences of broader technology industry developments. As demand spreads from innovative cities that are leaders in technology adoption to more cautious adopters, there will be a growing standardization of requirements and greater need for off-the-shelf solutions and "as a service" models.

Cities need to define their own priorities for how a city platform can support an evolving vision for urban development and innovation. A platform strategy needs to be shaped by this vision and should articulate core principles in terms of openness, use of standards, and alignment with other technology and business programs.

Urban Data Platforms (UDPs) operate at the digital crossroads of infrastructure and societal needs. They enable data to be combined from a wide range of sources to support communities and offer improved services. UDPs also enable municipalities to cooperate with other stakeholders, including private sector technology and service providers, to generate new revenue streams or improve well-being of their citizens.
There is a close link to use case No.2. Smart district systems (see section 10) which can be integrated in urban data platforms. Their underlying IoT monitoring devices are key enablers for some of the demand-side-related urban processes.

Two technologies are pivotal for the use case of UDPs: (1) the platforms/ applications themselves that process and analyse data from IoT devices (linking to UC #10) and (2) IoT communication technology. In this step of the study we focus on the platform itself.

11.1 Platforms that process, and analyse data from IoT devices

11.1.1 Technology overview

Urban data platforms, as part of smart city platforms, can be defined as "*an integrated capability for coordinating data, applications, and services at one or more levels across operational domains for multiple stakeholders* (Guidehouse Insights, 2020)*.*"[38] Guidehouse Insights includes urban data platforms as part of the Smart Government segment of the overall smart city market (Guidehouse Insights, 2019).[39]

[38] Guidehouse Insights (2020). Guidehouse Insights Leaderboard: Smart City Platform Suppliers.
[39] Guidehouse Insights (2019). Smart Cities Overview

The technology behind an urban data platform consists of two key functionalities: (1) gathering, storing, and processing information and (2) communicating with users. Gathering data e.g., with a sensor network across the city but also from existing data sources such as local transport service, existing GIS databases and other form the basis. Regarding energy, use case No.2 covers IoT monitoring devices.

Urban data platforms can be used for a broad range of potential interaction between the city and its data and citizens and businesses using that data. From an energy point of view, applications can include e.g., transparent energy usage of the city and/or its administration, GHG emission reporting, or managing smart streetlights. Energy management applications, however, are likely to be deployed by local utilities, such as the distribution system operator (DSO), and less likely to be included in urban data platforms.

The value stream of an UDP consists of several steps, that can integrate seamlessly and are not always separable: (1) data input interface, (2) data processing and management, and (3) data output/visualization interface. Leading market players offer integrated solutions covering these steps, and even more, such as sensors and communication and transmission hardware and software.

The underlying technologies for UDPs are mature, but wide scale deployment is still in relatively early stage in local government. Market barriers hindering deployment include financial constraints on cities (even before the effects of the coronavirus outbreak), immaturity of public sector IT architectures and IoT deployments, and organizational silos (Guidehouse Insights, 2020).[40].

11.1.2 Market overview

At present, full commitment to an urban data platform is the preserve of larger or more ambitious cities with considerable experience in smart city development or with a strong appetite for innovation. Most cities will move more cautiously as their data needs and IoT deployments expand. Investment in platforms for urban mobility or new energy systems will provide a basis for further development for many cities.

At present, the market is characterized by a limited number of large-scale projects and wide diversity of smaller initial projects and early pilots. The projected growth reflects the steady dispersion of urban data platforms across cities as their broader smart city programs and initiatives mature. During this period, platforms of data and IoT integration will become standard capabilities within the digital architecture of most cities and even smaller municipalities. By 2030, most cities will have at least some basic platform capabilities, and many will have developed sophisticated systems for the management of city services and data.

Market size

As shown in Figure 21, Guidehouse Insights estimates that the EU-27 market for urban data platforms will grow from €40.4 million to €161 million by 2020. Beyond 2030, a similar development with slightly lower growth can be expected.
The market estimate spans the adoption of three tiers of city platforms:

[40] Guidehouse Insights (2020). Guidehouse Insights Leaderboard: Smart City Platform Suppliers.

(1)Advanced: Horizontally and vertically integrated platforms that are developed to underpin ambitious citywide strategies for IoT and service integration.
(2)Core: Investment in extending vertical platforms into broader enabling environments (e.g., streetlighting platforms and mobility platforms), citywide sensor platforms, and advanced data platforms.
(3)Basic: Entry-level investments in open data platforms, IoT demonstration platforms, and smaller vertically focused projects.

The forecast excludes hardware investments (e.g., meters, sensors, communications networks, control rooms) and sector-specific applications and solutions (e.g., for smart streetlighting, smart parking, smart grids, traffic management, or public safety).
As enabling environments for the integration of city data and services and for extended collaboration between multiple players, urban data platforms are key to the broader development of the smart city market. Such platforms will underpin a market for smart city solutions and services. The platforms will represent a small proportion of that investment, but they will be important enablers and amplifiers of value within that market.

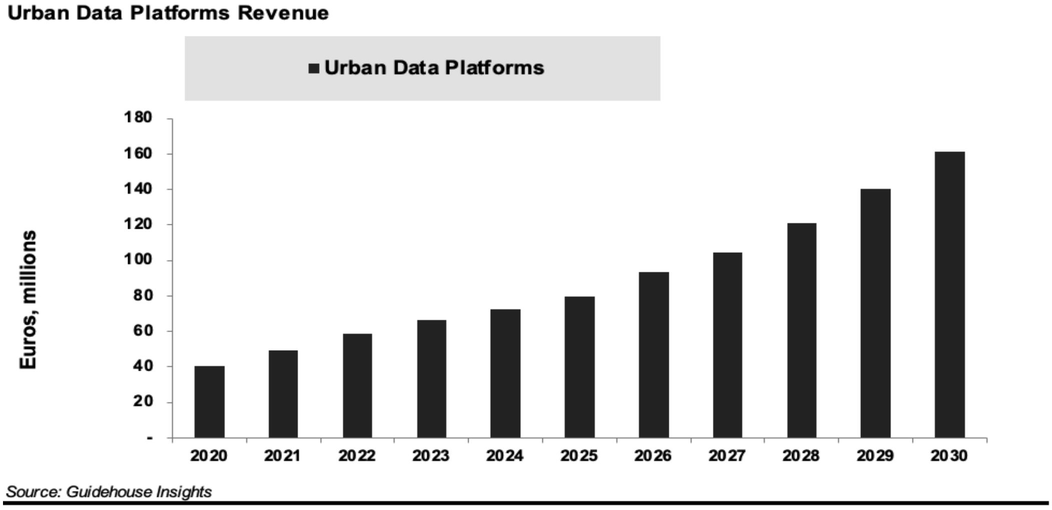


Figure 21: EU-27 Urban Data Platform Revenue, EU-27 Market

Market maturity in EU-27 Member States

European cities have been leaders in promoting open data platforms and exploring the possibilities for cross-sector collaboration in cities. Several EU-supported demonstration programs have emphasised the value of cooperation, sharing, reuse, and scalability. It is likely that the latest round of projects will have a greater impact on future investment models. However, European cities are also financially constrained and have limited capacity for major investment in unproven infrastructure. For this reason, Europe is likely to see fewer large-scale, big bang projects. Instead there will be a pragmatic extension of platform deployments over time and an incremental move towards advanced platforms.

There is broad activity across EU countries on platform development. Countries which have cities with notable developments include:

France:
French cities are pushing ahead with digital transformation programs, smart grid initiatives, and sustainability programs. The mayor of Paris has been a prominent voice on a range of environmental challenges facing the city and the need for innovative approaches to city services. Lyon continues to be a hub for a wide range of smart city projects, with a strong focus on urban mobility. ENGIE's work with the Île-de-France region in north-central France is a good example of local government digital innovation.

Spain:
Spanish cities have been among the leaders in many smart city and urban data innovations. Barcelona is a global leader in terms of its own innovation and as a catalyst for collaboration across cities worldwide. It also plays a key role in understanding the impact of smart city technologies on democracy and data privacy. It has been evolving its strategy and developed several solutions to address different challenges, including a unified platform for city operations and a sensor platform for IoT deployments. Regional government is also playing a role in Spain. Catalonia is providing a government as a service platform to enable smaller local authorities to become involved in smart and digital government programs.

Denmark:

Copenhagen's City Data Exchange was a pathfinder in exploring the possibilities for the commercialization of data on city platforms. Many other cities are looking at the potential of such approaches. However, it is not yet clear this will be a viable route for most cities, and some have backed away after initial explorations. The City Data Exchange itself was eventually abandoned but it remains an important experiment and reference point. More broadly, Copenhagen remains a centre for urban innovation and the integration of multiple data source to improve city services, sustainability and mobility.

UK Market (not EU-27)
The UK is one of the more developed markets in Europe. Many of its cities have developed basic open data platforms and it is also home to several leading projects. Notable developments include:

London: As well as the London Data Store—recognized as one of the leading large-scale city data platforms—London has also been involved in several other urban data projects. For example, it developed a sustainable energy management system (SEMS) that consolidates and analyses energy data from smart meters and other intelligent devices to optimise energy production and consumption at a community level. The SEMS also links to the broader urban data platform developed as part of the EU-funded Sharing Cities programme, led by London, Milan, and Lisbon.
Manchester: As part of the CityVerve demonstration project, Manchester developed a multi-communication, multi-application platform for city operations. While the project has now ended, the team is looking at future commercialization opportunities.
Other UK cities with notable urban data platform initiatives include Leeds, Bristol, and Cambridge.

11.1.3 Vendors overview

The Guidehouse Insights leader board for smart city platform suppliers identifies Microsoft, Cisco, and Huawei as global leaders, with Itron, Amazon Web Services as the main contenders followed by a group that includes SAP, Siemens, Oracle, NEC, Nokia, and ENGIE (Guidehouse Insights, 2020).[41]

For this study, we focus on the five most relevant companies for the EU in the UDP segment. So, SAP and ENGIE have been included, not necessarily because they are both based in Europe but because they are more relevant players in the EU market. In total we estimate that the following 5 players cover about 60-70% of the EU-27 market.

Summaries for Cisco and Huawei are included for information. Cisco is focused more on the IoT device and communications layers of the smart city platform and working with partners on specific vertical applications. Huawei's city presence is in China, other parts of Asia, and the Middle East. Table 18 provides and overview of the leading vendors for urban data platforms.

Table 18: Leading vendors for urban data platforms

Vendor	Company overview and related offerings
Microsoft HQ: USA Market Share: High	• Microsoft's work with cities reflects the broader evolution of the company's offerings. Cloud-based services, IoT, and AI are key areas for expansion. City innovations in this area are supported by a growing number of Azure-based service such as IoT Hub, Azure AI (including machine learning and cognitive search services), and Azure Digital Twin. • Microsoft's smart city offering is built on the Azure platform, its data management and advanced analytics capabilities, and its mobile application support. Focus areas for the company's smart city initiatives include transportation, public safety and justice, public health and social services, public works and infrastructure, tax and finance, and social and digital inclusivity.
Itron HQ: USA Market Share: Medium	• Based in Liberty Lake, Washington, USA, Itron serves utilities and cities 100+ countries. The portfolio encompasses smart networks, software, services, meters, and connected sensors with integrated networking and communications. • Itron's multipurpose, multiprotocol IoT platform supports a variety of smart city and smart utility applications. Its SLV City Management Software serves as the centralized city dashboard to manage and control city lights and sensors. It provides comprehensive asset management, analytics, and data visualization for connected smart city assets.
Amazon Web Services (AWS) HQ: USA Market Share: Medium	• Amazon Web Services (AWS) is a subsidiary of the global online retail giant Amazon and offers a comprehensive IoT platform for city solutions and an extensive list of partners able to develop and deploy applications across many use cases. • It provides cloud-based IT infrastructure services to governments and businesses. Its products and solutions

[41] Guidehouse Insights (2020). Guidehouse Insights Leaderboard: Smart City Platform Suppliers.

Vendor	Company overview and related offerings
	include compute, networking, storage and content delivery, databases, analytics, application services, deployment and management, mobile services, and applications. • Using a comprehensive IoT platform and together with partners, AWS offers services for many city operations such as traffic management, WiFi, data management, among others.
SAP HQ: Germany Market Share: Medium	• Based in Germany, SAP was founded in 1972 and has now become the market leader in enterprise application software with 101,150 employees in 140+ countries and 24.75bn euro (FY2018). • SAP's Future Cities programme provides an end-to-end platform focused on five main service areas: governance, mobility, citizens and living, environment and infrastructure, and economy. SAP's proposition for smart cities is increasingly focused on support for advanced data analytics, IoT, and real-time city services management.
ENGIE HQ: France Market Share: Medium	• Based in Paris, ENGIE group offers turnkey solutions in renewable energy, gas and services industries. As part of its Decentralized Solutions for Cities and Territories, ENGIE acquired French 3D solutions provider Siradel and Romanian IoT company, Flashnet. • ENGIE's Livin' platform brings together its digital capabilities for cities and communities including those provided by Siradel and Flashnet. Livin' is a software platform that allows diverse users to visualize, manage, and plan urban infrastructure. Examples include streetlights, traffic controls, security cameras, parking meters, air quality sensors, EV charging posts, and message panels.
Cisco HQ: USA Market Share: Low	• Based in San Jose California, Cisco is the worldwide technology leader that has been making the internet work since 1984. • The Cisco Kinetic for Cities platform is result of the company's close collaboration over many years with cities such as USA, India, Czech Republic, Spain and others. Solutions deployed in cities include city Wi-Fi, smart parking, traffic management, smart streetlighting, city operations centres, and city safety and security.
Huawei HQ: China Market Share: Low	• China-based Huawei is well positioned in the smart city telecommunications equipment market based upon its Horizon Digital Platform. • Huawei's Intelligent Operations Centre enables it to support different approaches to city management and Horizon Digital Platform that includes cloud services, data management, cross-agency applications, and real-time large screen visualization.

11.1.4 Buyer overview

The diversity of urban data platforms—and the cities that implement them—means there is no standard buying pattern. Urban data platform adoption can be driven from a high level strategies programme instigated by city leaders, part of a broader data strategy led by a chief digital or data officer, or pragmatic development from within a single department (for example a platform focused on mobility or energy data).

Many platforms will evolve from these initial steps to meet emerging needs and to embrace a wider range of data sources. In this emerging urban platform landscape, cities need to do three things:

Define their own priorities for how a city platform can support an evolving vision for urban development and innovation. A platform strategy needs to be shaped by this vision and should articulate core principles in terms of openness, use of standards, and alignment with other technology and business programs.

Consider overarching policies that will enable the creation of adaptable city platforms. A platform should enable a broad ecosystem that will include citizens, local businesses, and global service providers.

Understand that platform development should be part of a rethinking of traditional approaches to service design, resource management, and urban planning. The potential of digital technologies needs to be considered as part of any significant investment in services or infrastructure.

Cities need to recognise that the city platform is an emerging concept—not a solution, but something to be shaped for and by a city with its partners.

Case Study: Île-de-France

The Île-de-France region in north-central France is a good example of city digital innovation and how cities can work with suppliers. Working with Siradel and ENGIE Ineo, ENGIE took on the role of designing, implementing, and supporting a cutting-edge tool for optimizing the region's data. Île-de-France Smart Services has several core functionalities including data aggregation and analytics using public and private sources. The service also has a digital twin of the region allowing for visualization of current projects and efficient planning for future ones, and a smart service platform co-built with various local stakeholders and residents. More than 50 services are expected to be developed in the coming years. The Île-de-France project is a good example of how cities work with industry partners to develop a responsive platform that addresses near term priorities and supports medium- and long-term evolutionary development

11.2 IoT communication technology

11.2.1 Technology overview

IoT data gathering devices that feed into urban data platforms use a vast range of communication technologies. A pivotal role is seen for 5G, albeit not as soon as current hype would indicate. 5G, with its estimated 10 times higher transmission speed compared to 4G LTE, will support IoT in cities (Guidehouse Insights, 2019).[42] However, existing LTE protocols are perfectly capable of supporting smart city applications (e.g., smart lighting, smart traffic management or other city applications). Additionally, 5G networks will form as a series of overlays to LTE networks in an evolutionary manner.

[42] Guidehouse Insights (2019). Smart Cities Overview

Unlike past cellular networks, where new protocols such as 3G required costly infrastructure and node replacements, 5G in many cases will develop thanks to over the air software upgrades (Guidehouse Insights, 2020).[43]

Three broad services are included in the 5G technologies: (1) enhanced mobile broadband (eMBB), (2) ultra-reliable and low latency communications (uRLLC), (3) and massive machine-type communications (mMTC) (Guidehouse Insights, 2020). [44] Key for IoT sensor deployment is mMTC with a larger bandwidth of up to 1,000 times compared to 4G in any given area. Electric utilities use connectivity—and the data it provides—for a multitude of applications. While advanced metering infrastructure (AMI), distribution automation (DA), and substation automation remain the big three, areas such as asset management and monitoring, analytics, distributed energy resource (DER) integration, and predictive maintenance solutions are growing in importance rapidly. For applications that don't require a low latency but rather longer battery life, as in energy management applications reliant on a multitude of sensors, mMTC is likely to be deployed. Providers have started already rolling out low power wide area networks (LPWAN) over existing 4G networks, establishing this 5G dimension.

5G networks are deployed in two main frequency ranges. Ranges above 25 GHz offer high speeds but short ranges. Low range frequencies between 600 MHz and 3.5 GHz provide a longer range and improved penetration. Short ranges of high-speed coverage require many more base stations, also called small cell base stations. Their low power nodes can be attached to e.g., streetlights or utility poles, where available.

4G/LTE is technologically mature, albeit network coverage still must improve for some applications. Private LTE networks are technologically mature as well and can be deployed where necessary. 5G technologies and its layers as describes above is an evolution of 4G.While the change process from 2G to 3G and 3G to 4G can be described a switch of technologies, the change process to 5G is an update and evolution, in which step by step technology layers and parts are updated. Overall, 5G networks technology is developed and tested, but large-scale application still needs to be rolled out.

11.2.2 Market overview:

Guidehouse Insights estimates the market size at €110 Million in 2020 in the EU-27, growing to €410 Million in 2030. This market encompasses smart city communication network equipment for the government sector, it might therefore be slightly larger than only 4G/5G technologies.

12 Customer Data Analytics

Energy companies are increasingly adapting service-based business models around customer engagement. Data analytics solutions allow energy companies to process customer data, provide insight into energy consumption and understand their behaviours. Large amounts of data from smart meters and behind-the-meter devices (smart sensors, appliances and other devices) allow energy companies to generate

[43] Guidehouse Insights (2020). Wireless Networking and Energy: LTE Standards Set the Stage for the 5G Era
[44] Guidehouse Insights (2020). 5G will create the hyperconnected smart city

insights about constantly changing customer behaviours that provide better customer engagement and new commercial opportunities (i.e., customer acquisition, retention and prediction of customer churn). With increasing competition across energy companies, these analytics platforms become vitally important to secure and grow market share. Typically, energy companies develop or purchase such platforms and embed them within their enterprise. In some cases, energy companies share specific insights from their analysis with their customers in the form of home energy reports. The reports provide customer insights on how their energy usage compares with similar properties in the neighbourhood.

When analysing and leveraging smart meter data, energy companies must be conscious about GDPR which describes the obligations on organisations that process customer data.

In the analytics platforms, Artificial Intelligence (AI) and machine learning algorithms can be used to detect energy demand of individual devices in cases where only smart meters are installed (i.e., load disaggregation). Different types of analysis techniques are used for customer data analytics:

- Descriptive analytics - present and compare periodic electricity consumption patterns (in kWh or currencies).
- Diagnostic analytics - identify sources of disproportionately high electricity consumption.
- Prescriptive analytics - inform consumers of potential mitigation activities in response to diagnostic analytics.
- Predictive analytics - inform consumers about the likely changes in energy consumption due to various factors (e.g., weather changes).

Due to the disparate approach in the EU by energy companies for rolling out smart meters, it is important to note that the access to AMI data may vary depending on the energy company (retailer & DSO). The access to level of access to data will significantly impact how the data is used in analytics platforms.

This chapter will study the AMI data analytics platform that are used by energy companies to facilitate improved customer engagement. AMI is a key enabler to detailed customer analytics, and therefore this technology is captured in the study in Section 10.1.

12.1 Advanced Metering Infrastructure (AMI) data analytics platforms

12.1.1 Technology overview:

- With the IoT, disparate systems can interoperate over Internet Protocol and integrate AMI data for enhanced business value.
- Application for improved customer experience through improved engagement, load analysis and disaggregation.
  - Real-time data synthesis and trend visualization. Gain insights from using big data collected from AMI. Software tools depend on continuous data flowing from IoT devices within the grid (smart meters, advanced distribution line sensors, and sophisticated communications modules)

and behind-the-meter devices (smart thermostats, submeters and DER). Platforms are required to be able to deal with increasing volumes IoT device data (Guidehouse Insights, 2018)[45].

- Load monitoring or device disaggregation solutions. Using data from smart meters to identify energy consumption patterns of different appliances in home by applying machine learning algorithm (e.g., Non-Intrusive Load Monitoring). An algorithm can work out whether appliances are used in the building at any point in time (Guidehouse Insights, 2019)[46].

Data is transferred from a smart meter to a central platform hosted by an energy company. Then the data might get stored or sent to a cloud server for applications that could be more immediate, such as outage monitoring, or for later historical purposes, like tracking asset health or billing purposes. Data reporting is important but reporting alone is rudimentary. Deeper and more insightful analysis can unlock new value (i.e., descriptive, diagnostic, predictive and prescriptive analysis). There has also been a trend of extending analytics capabilities to core Information Technology (IT) and Operation Technology (OT) systems. For example, certain home energy management applications can be leveraged as a function of Customer Integration Systems (CISs) and Demand Response Management Systems (DRMSs), whereas load forecasting applications are being increasingly rolled up into Advanced Distribution Management Systems (ADMS) and Distributed Energy Resource Management Systems (DERMS), where these are maintained in the same organisation.

The technology market is not yet fully mature across all value stream components (i.e., descriptive, diagnostic, predictive and prescriptive analytics platforms) as the technology solutions are in proof of concept stage with only a few utility customers moving to full operational status.

12.1.2 Market overview:

Guidehouse Insights forecasts a healthy growth cycle for the technology with annual revenue from providing analytics platform solutions is expected to increase from nearly €1.27 billion in 2020 to €3.64 billion in 2028. Revenue attributed to analytics solution purchases by European utilities is expected to increase from €446.29 million in 2020 to €1.02 billion in 2028. (Guidehouse Insights, 2019) (Guidehouse Insights, 2019) [47,48]

13 Energy communities

Energy communities cover a wide range of very different activities, as outlined in the ASSET report on Energy Communities (Tounquet, De Vos, Abada, Kielichowska, & Klessmann, 2019). The EC's Asset Study on 'Assessment & roadmap for digital transformation of the energy sector' highlights that energy communities is an emerging concept for which there is no widely accepted definition yet. It can cover activities in various parts of the value chain, including generation, distribution, storage, supply,

[45] Guidehouse Insights (2018). IoT and Analytics for Utilities Market Overview.
[46] Guidehouse Insights (2019). AI and Advanced Analytics Overview.
[47] Guidehouse Insights (2019). Energy IT and Cybersecurity Overview.
[48] Guidehouse Insights (2019). DER Management Technologies

consumption etc. Traditionally, community energy activities focused on joint investments in local renewable projects.

In this use case we focus on the peer to peer (P2P) energy trading business model that is enables individuals within an energy community to trade energy within a local geography. This business model relies on a community having a trading platform that typically uses blockchain technology to track and verify the purchase and sale of energy.

13.1 Blockchain technology for P2P energy trading

13.1.1 Technology overview

The blockchain technology stack consists of hardware, protocols, platforms and applications. All blockchain networks require nodes—computer hardware running a defined set of protocols that enable it to communicate and transact with other devices in the network. Protocols govern everything from the data structure used by the network to the consensus algorithm by which nodes reach agreement on the history and chronology of transactions. This report does not further discuss blockchain hardware and protocols in detail; instead, it focuses on the blockchain platform application to the use case.

Guidehouse Insights defines a blockchain or distributed ledger-based platform as an operating environment for multiple distributed applications. Platforms are analogous to operating systems on mobile computing hardware. The platform used in a blockchain architecture determines the set of tools available to developers of applications and services. Blockchain applications can be smart contracts, or collections of smart contracts, that deliver a process or service to the end user. Business logic is stored in the application layer. (Guidehouse Insights, 2020)[49]

Blockchain-supported P2P energy trading projects focus on grid-edge DER, particularly behind-the-meter PV and storage. These projects, almost exclusively led by startups, are enjoying tremendous publicity—much more than earlier transactive energy (TE) related projects ever received. Most are designed to pair DER with end-use customers, sometimes on a bilateral basis (e.g., directly connecting prosumers and customers).

The concept of P2P energy trading is losing momentum. Few vendors now mention P2P, focusing more on customer experience. This is a critical shift in the development of customer focused TE as P2P energy trading is a subset of TE, and TE is independent of blockchain. TE platforms (that include market and system) can be designed and implemented with or without P2P energy trading and/or blockchain. The blockchain is only a cog in a larger TE system; just the same way as in digital currency systems such as Bitcoin. Therefore, rather than a dynamic platform managing real-time P2P energy trading, customer focused platforms are more an innovative use of production and consumption data.

Some recent blockchain solutions address issues related to grid operation, such as power/demand balance, but typically as a secondary factor. The participation of these solutions involves responding to local conditions (e.g., on a feeder or a portion of a

[49] Guidehouse Insights (2020). A Handful of Vendors are Shaping the Energy Blockchain Landscape.

feeder), participating as an aggregator to provide ancillary services (e.g., frequency regulation), or both (Guidehouse Insights, 2020).[50]

While many P2P energy trading focused blockchain POCs have not been successful, blockchain itself has not disappeared. Rather—except for a successful handful—blockchain companies are chasing more prosaic use cases in the energy industry. Companies entering the utility industry with blockchain solutions are moving away from P2P energy trading and are instead focusing on other use cases, particularly certificates of origin.

13.1.2 Market overview

Guidehouse Research expects energy blockchain applications to generate 16.1 billion euros in cumulative revenue over the next decade (including additional technologies aside from P2P energy trading and RES origin certificates), reaching an annual market size of 6.5 billion euros in 2028, at a compound annual growth rate (CAGR) of 66.9%, with Europe's market expected to grow up to 1.7 billion euros by 2028.

14 RES Origin tracking

A prior Asset Study at EC on 'Assessment & roadmap for digital transformation of the energy sector' illustrates how digital solutions can help increasing investments in renewables by final customers of all segments (commercial, industrial, residential, public sector) by easing up the contracting of long-term renewable power purchase agreements (PPAs) schemes and other forms of direct RES financing. Due to the complexity and cost of the process, these to be a privilege to large customers only. Furthermore, digital technologies can help reduce the cost of current policies that – either directly or indirectly – require the certification of the renewable feature of RES, that is a costly process requiring a central verification agency. For instance, art. 19 of the Renewable Energy Directive (2018/2001) stipulates that guarantees of origin shall be issued for all units of renewable energy generated, with a view to show to customers the commitment of generators to produce and suppliers to procure renewable energy. While there is no specific regulatory framework on distributed ledger technologies (DLT), blockchain has a potential to enable a simplification of such processes as well as transparency. In essence, DLT are based on a decentralized verification process which records data on a transparent, accessible, time-proofed and immutable platform. Instead of trusting a third party to secure these data/transactions, it ensures accessibility and verification to all those allowed.

14.1 Blockchain for RES Origin tracking

14.1.1 Technology overview

The blockchain technology stack consists of hardware, protocols, platforms and applications. All blockchain networks require nodes—computer hardware running a defined set of protocols that enable it to communicate and transact with other devices in the network. Protocols govern everything from the data structure used by the network to the consensus algorithm by which nodes reach agreement on the history and

[50] Guidehouse Insights (2020). Market Data - Transactive Energy Global Forecast.

chronology of transactions. This report does not further discuss blockchain hardware and protocols in detail; instead, it focuses on the blockchain platform application to the use case.

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Certificates of origin (also called guarantees of origin in Europe and renewable energy certificates in the US) can take a variety of forms in different markets around the world. Their primary goal is as a market mechanism to communicate information about how, when, and where a defined unit of power was produced to buyers in wholesale markets at the state or national level.

Power plants equipped with blockchain-registered micro-sensors can function as nodes in a regional or national blockchain network, reporting and authenticating data at the point of generation and storing it in the blockchain database. A blockchain is a data structure that links network transactions together in a defined sequence using cryptography. While a consensus algorithm determines which node can append data to a distributed ledger, a blockchain protocol lays out specific rules for how the data is ordered and stored. Other data structures are possible, but a blockchain is a simple way to ensure the integrity of stored data is continuously audited and verified. Because of this, the processes for issuing, trading, and retiring certificates can be shifted to smart contracts, eliminating the potential for double counting and other types of fraud and further reducing transaction costs through disintermediation. In addition, the authenticated data stored in the blockchain database can be combined with analytics to improve overall energy management and forecasting accuracy (Guidehouse Insights, 2018).[52]

Blockchain is one of several DLTs on the market (directed acyclic graphs are one alternative). Several vendors are experimenting with non-blockchain data structures, but they remain a small minority. If these alternatives turn out to provide the same benefits as blockchain at a lower cost, it is possible they could win out as the standard (Guidehouse Insights, 2019).[53]

Energy blockchain activity is currently concentrated among a handful of vendors, but the market has not yet reached its competitive peak. Current market participants have a first mover advantage, but they control a small slice of the potential market for blockchain-based energy services

[51] Guidehouse Insights (2020). A Handful of Vendors are Shaping the Energy Blockchain Landscape.
[52] Guidehouse Insights (2018). Utility Blockchain Applications Market Overview.
[53] Guidehouse Insights (2019). Energy Blockchain Vendor and Deployment Tracker.

14.1.2 Market overview

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15 Single page overviews of key use cases

For the use cases and technologies researched in more detail, this report provides a snapshot of key insights per use case and technology on a single page.

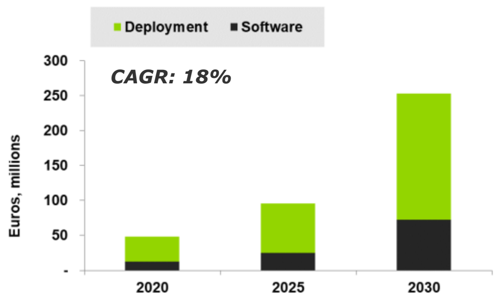
Flexibility Markets - Distributed Energy Resources Management System (DERMS)

As a core software technology, DERMS enables the flexibility market use case. DERMS enables the implementation, provisioning and integration of the above services that are core of flexibility market platforms at TSOs and DSOs. The active grid management functionality including Volt/VAR optimization and control, power quality management and power flow management are the main product features of DERMS that either wholly or in conjunction with the TSOs/DSOs systems enable the flexibility services in the market.

MARKET MATURITY

- DERMS nascency leads to a lack of market maturity. Key markets are in the US and the UK, The Netherlands, and Germany in Western Europe.
- Countries with higher penetration of renewables and DER have an increased incentive to explore DERMS.
- Regulatory frameworks can also provide strong incentives for DERMS technologies to be deployed.
- There is limited harmonization between TSOs and DSOs within flexibility markets.

EU-27 MARKET SIZE



- The market will continue to increase as more DER are connected to electricity distribution networks and existing networks become increasingly constrained. Network companies will need tools to optimally control flexibility from DER.
- Beyond 2030, growth rates in the same range can be expected.
- EU Directive 2019/944 Article 32, that mandates the use of flexibility services by DSOs, will stimulate further growth in the DERMS market.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

Hitachi ABB Power Grids
Schneider Electric
Siemens
GE

- EU companies supply a large portion of the DERMS market in the EU. GE are one of the leading non-EU leaders in the market.
- Vendors' supply chain is highly integrated because their software is developed in-house.
- Vendors' third parties include system integrators for 3rd party systems and integration with aggregators do not pose critical supply chain risks.
- Many vendors offering DERMS system with ADMS as an embedded module within the ADMS or a standalone.

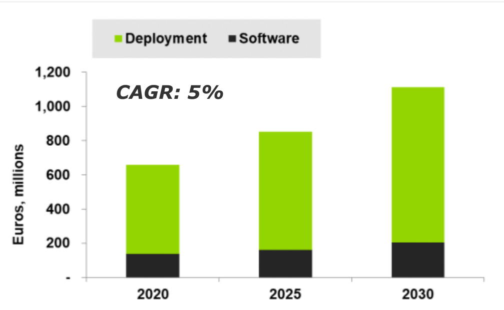
Flexibility Markets – Advanced Distribution Management Systems (ADMS)

An ADMS unifies operational and engineering data for state analysis, switching, outage management, and planning. It maintains a single as-operated model of the distribution network based on the as-built model (typically from a GIS). ADMS plays a vital role in efficiently managing flexibility in the distribution grid as well as improving system performance indices. ADMS includes active network management such as power flow analysis and state estimation, switching order management, IVVC, FLISR, operator training simulator, and outage management.

MARKET MATURITY

- Europe has the highest penetration of ADMS technologies globally.
- Most Western European utilities are expected to have one or more ADMS modules deployed, whereas Eastern Europe shows less penetration.
- ENTSOe rules around harmonization and data driven policy/decision-making, and enabling market mechanisms or lack thereof, are some of the key challenges for ADMS deployments.
- The regulation mandated grid forecasting data transparency between DSOs and TSOs is one key market driver for ADMS deployments.

EU-27 MARKET SIZE



- The growth ADMS deployment is largely attributed to the proliferation of DER, network constraints, high levels of grid automation, carbon and energy efficiency requirements, and larger digital transformation initiatives.
- Beyond 2030, a similarly sized growth rate can be expected.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Hitachi ABB Power Grids
- Schneider Electric
- Siemens
- GE
- Oracle
- OSI

- Many leading vendors provide ADMS and DERMS as a modular solution offering, that enables the DERMS to be embedded in ADMS as a module.
- Like DERMS, supply chain within ADMS software industry is highly integrated because in-house software development is preferred.
- 3rd party system integrators pose minimal risks in vendor's supply chain.

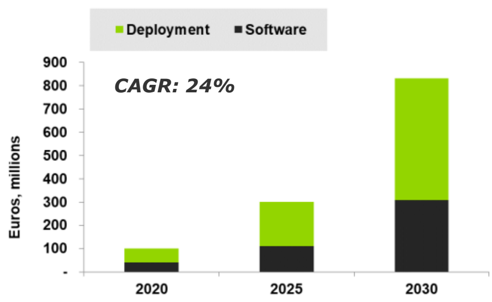
Energy Aggregators – Virtual Power Plant (VPP) Platforms

The energy aggregators use case focuses on VPP aggregation software platforms as the ancillary services that VPPs provide to energy markets are enabled by innovative aggregation. VPP is system that relies on software and a smart grid to remotely and automatically dispatch DER flexibility services to a distribution or wholesale market via an aggregation and optimization platform.

MARKET MATURITY

- Europe has been and continues to be the global VPP leader in terms of capacity (GW); largely reflecting the supply-side VPP capacity.
- VPP capacity is anticipated to grow as Europe continues to push VPPs forward, both directly (through government backed VPP pilots) and indirectly (through EU and national climate goals).
- Germany is the largest and most mature VPP market, and is anticipated to capture about one-third of VPP market's annual capacity by 2028.
- Most EU Member States do not allow VPP aggregation software to be hosted in the cloud, because it is regarded as a critical system.

EU-27 MARKET SIZE



- Europe has also been the driving force behind VPP spending, accounting for nearly 45% of global spending in 2020.
- Current forecast growth rates of DER indicate that the demand for VPP-enabled solutions will continue to grow beyond 2030.
- While countries such as Germany, France, and the UK have enacted market reforms to enable VPPs, the tightly connected countries in the EU (and the UK) have an advanced market integration.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Schneider Electric
- Next Kraftwerke
- Enel X
- ABB
- Centrica Business Solutions

- Like ADMS and DERMS, the VPP aggregation software supply chain is highly integrated as the in-house software development is preferred.
- VPP aggregation being regarded as a critical system, vendors do not host their software on cloud, hence the cloud providers pose no risk in vendor supply chain.
- Some vendors are also looking at installing their own chips into 3rd party manufactures of home appliances and equipment to efficiently provision an end-to-end software solution.

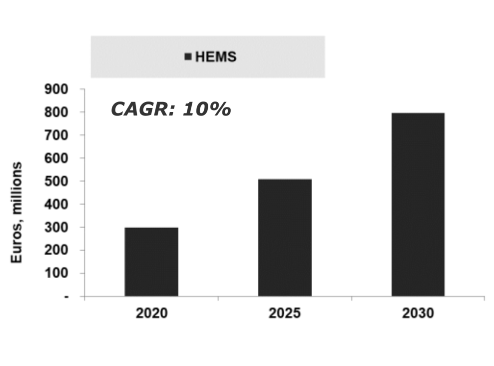
On-site optimisation for buildings – Home Energy Management Systems (HEMS)

HEMS are a broad range of technologies and services that consumers use to better manage and control home energy consumption and production. There are four main technology segments within HEMS:(1) home energy reports, (2) digital tools, (3) standalone HEM, and (4) networked HEM. All are targeted at consumer energy savings at different levels of connectivity

MARKET MATURITY

- HEMS solutions have been adopted at different rates throughout the EU.
- Nordics: Leading in terms of rel. penetration.
- France: Key drivers are high electric heating penetration and government support.
- Netherlands: Regulatory push.
- Germany: Largest growth potential (absolute).
- Overall, there is lower HEMS penetration in the EU compared to the US due to lower penetrations of enabling hardware, especially smart meters with sub-monthly data granularity.
- Noteworthy market challenge is EU data privacy rules as firms rely on data processing in the US.

EU-27 MARKET SIZE



- A growing number of smart devices on the market: meters, plugs, thermostats, electric heaters and lighting, as well as behind-the-meter DER such as smart inverters / PVs, energy storage and EVs.
- HEMS market revenue includes spending on digital programs, platforms, and analytics as well as monitoring and consumption management services.
- The European HEMS market represents about 30% of global revenue.
- Regulation is seen as main driver overall.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Schneider Electric
- Oracle
- Itron
- Uplight
- Bidgely

- Software supply chain depends on non-EU players mainly for data storage: India and US.
- Main platforms for user interaction are developed in-house.
- Hardware supply chain is not the focus of key HEMS players, but external hardware strongly impacts the market such as smart meters or EV uptake.

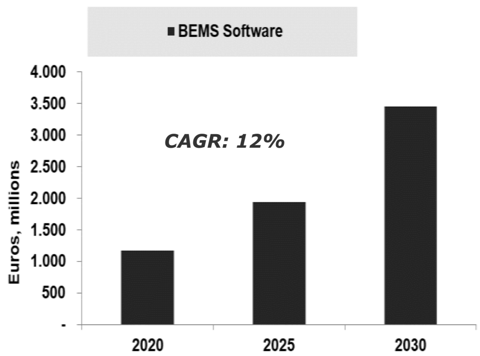
On-site optimisation for buildings – Building Energy Management Systems (BEMS)

BEMS currently range in sophistication from simple tracking of energy consumption to proactive management of energy use and integration with other commercial building systems. The four main value segments within BEMS are (1) visualization and reporting, (2) fault detection and diagnostics, (3) predictive maintenance and continuous improvement, and (4) optimization (including integrated workplace management systems, IWMS).

MARKET MATURITY

- BEMS market development correlates closely with national policy support for EE, fuel switching measures for buildings, and similar initiatives.
- Sustainability plans of individual enterprises are also a major driver.
- Nordics: Leading in relative penetration due to high level of comfort with remote building management.
- France & Italy: High smart meter penetration rates leads to most mature BEMS markets in EU.
- Germany: With majority of EU commercial building stock future growth market.

EU-27 MARKET SIZE



- Software is central part of the BEMS value chain and is defined as money spent on the digital programs, platforms, and analytics tools.
- Hardware is also required to deliver the final service. Since BEMS hardware is not necessarily exclusively relevant for the BEMS value chain, it is not included in the market size estimates.
- From a revenue perspective, the hardware can be up to five to ten times the market size of the software segment.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Schneider Electric
- Siemens
- Johnson Controls
- Trane Technologies
- Honeywell

- BEMS hardware for the EU market is mainly manufactured and assembled within EU MS.
- Basic parts such as circuit boards, processors, and raw materials are mainly sourced from Asia.
- On the software side, vendors consistently stress that all core development such as diagnostics and sensors is done in-house, which is either the EU or North America. Innovation focuses on those.
- A predominant trend for outsourcing is visible for those solutions depending on cloud hosting.

Smart EV Charging– EV Charging Infrastructure

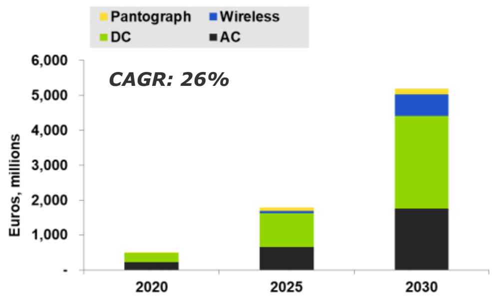
EV charging infrastructure is broadly defined as charging hardware technology that supplies electric energy from the grid for recharging plug-in EVs. There are five major categories of charging hardware technologies: AC chargers, DC chargers, wireless chargers, pantographs, and battery swap systems. Deployment is often supported by software tools for business services and load management in addition to onboard diagnostic port (OBD-II) dongles, load controllers, power modules, and energy storage devices.

MARKET MATURITY

- EV charging infrastructure develops with EV uptake
- Main driver are government incentives

Countries	Ratio of EVs to public chargers	Fast charger share of public chargers	EV Share of Vehicles in Use
Netherlands	4	2%	2.6%
Sweden	15	17%	2.5%
France	7	8%	0.8%
Germany	7	15%	0.6%
Non-EU countries			
United Kingdom	11	25%	1%
Norway	24	26%	14%

EU-27 MARKET SIZE



- A majority of the market is captured via development of public infrastructure: destination chargers and fast charge services.
- However, significant growth in home and fleet charging is expected on behalf of technological innovations in passenger EV onboard charging capacity and vehicle grid integration and growing availability of commercial EV options.
- Still after 2030 similar growth rates are likely as EV penetration is expected to further rise in EU markets.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- ABB
- EVBox
- Enel X
- NewMotion
- Efacec
- Alfen
- Tritium

- Supply chain of manufacturers is mainly local and/or regional, in particular for EU based vendors.
- Local adjustments need to be made for the different EU Member States, as each market has its local preference.
- Basic electronic parts e.g., PCBs are purchased in Asia.
- The value chain is not fully mature yet as vendors develop, design and manufacture mainly in-house, with some contract manufacturing.

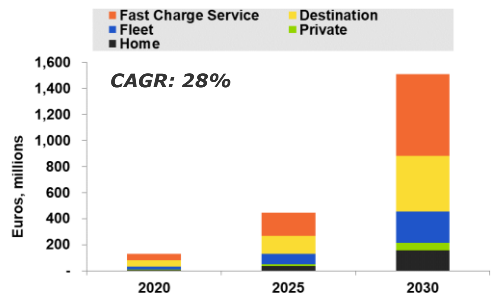
Smart EV Charging – EV Charging Platforms

The EV charging platform is broadly defined as a software tool for managing charge point business activities and energy demands. platforms include features for managed charging to control energy costs, BTM load balancing, grid services, and the calculation of carbon emissions offsets. EV charging management platforms largely originated from charging manufacturers, however, numerous companies specializing here are not manufacturers.

MARKET MATURITY

- The market for charging services is driven by the PEV population.
- Startups and major power companies were unable to survive long in the market. Now, energy companies have entered through acquisition.
- Netherlands: Most public chargers have smart charging capabilities. The Dutch roaming system is the only national roaming system globally between independent operators and providers.
- Germany: Policy driven market update is expected to increase uptake in the coming years.
- Norway (non-EU): key European market with strong influence. Platform providers test solutions at scale with a relatively large consumer base.

EU-27 MARKET SIZE



- The market size for EV charging platforms is analysed in terms of total annual O&M revenues.
- The O&M revenues are inclusive of all services the platform provides: business and energy management through the subscription of the provider, and also often maintenance bundled within the subscription.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Virta
- Fortum Charge & Drive
- GreenFlux
- Has.to.be
- Last Mile Solutions
- Driivz

- The supply chain of EV charging platform vendors is highly integrated: design, development, and testing is done in-house.
- For capacity reasons, certain steps are outsourced, although the capabilities exist in-house as well.
- General dependence on US-based cloud hosting offers is visible in the sector.
- Such a dependence is not seen as a key risk, as switching from one supplier to another does not seem to be connected with large transaction costs.

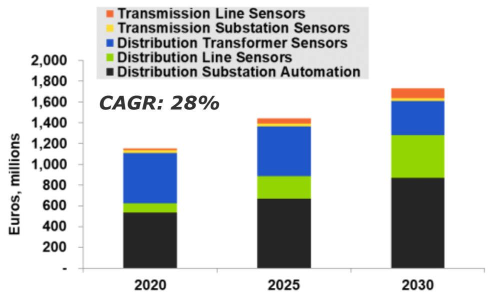
Improved O&M – Internet of Things (IoT) monitoring devices

In T&D, sensors were focused on voltage and current for grid operations. As the grid becomes diverse, the complexity of sensing and measurement devices will also evolve. Modern sensors are devices that respond to a variety of physical stimuli (heat, light, sound, pressure, magnetism, motion, current, voltage, etc.). entire T&D infrastructure is transitioning away from modular or integrated analog sensors, and moving towards multifunctional digital sensors, and even further onto connected, interactive IoT devices.

MARKET MATURITY

- As the price of sensor devices themselves continues to fall, and communications and compatible IT systems become more ubiquitous, market penetration will continue to grow in the European market.
- Denmark and Norway (although non-EU-27) show relatively higher market maturity than the rest of Europe.
- The market maturity is largely attributed a). Denmark spearheading the testing of T&D sensors and equipment, and b). Norway's ambitious all-electric scenario that calls for reinforcement of existing aging T&D infrastructure.

EU-27 MARKET SIZE



- Market trend to fully integrate sensors and IoT equipment into major primary assets like transformers and protective equipment is a factor limiting the standalone sensors equipment.
- Devices can cost as little as € 50-100, with some exceptions. So even large volumes do not necessarily lead to a very large market.
- The transmission side of the market is already well equipped with monitoring devices, lowering the necessity for new equipment in that part of the market.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Hitachi ABB Power Grids
- Schneider Electric
- Siemens
- Eaton
- Itron
- GE
- Schweitzer Engineering Laboratories

- Most EU companies can manufacture components in-house but can source some components from around the world.
- Supply chain risks are mitigated by relying on multiple vendors around the world, if the components are sourced.
- Lifetime of IoT monitoring devices is very long (15 – 20 years), which provide vendors sufficient time to plan and adapt their supply chain based on latest requirements.

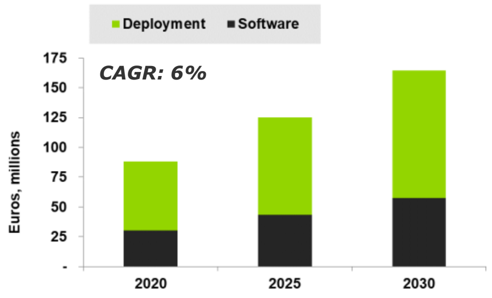
Improved O&M – Software platforms for O&M (APM platforms)

The proliferation of low-cost sensors throughout generation, T&D networks has led to unprecedented levels of data generation that require IT software to process the data for improved efficiency, operation and maintenance of assets. APM technologies are rapidly taking shape. APM can be seen as a platform that integrates multiple systems (e.g., EAM, GIS, Mobile WFMS) and sources of asset data, with dedicated asset analytics that sit on top.

MARKET MATURITY

- The nascent nature of APM technologies leads to a lack of maturity across nearly every market.
- While traditionally, an exercise performed at the transmission level, energy companies are increasingly moving their efforts downstream into the distribution network for both technological (extension of networking and communications) and strategic (need to reduce operating costs) reasons.

EU-27 MARKET SIZE



- While still nascent, the market for APM solutions can be viewed as relatively strong from a global perspective.
- APM for generation only would be a considerably larger market as APM across T&D networks is still largely nascent, with growth potential depending on the developments in advanced analytics, low-cost sensing devices, and enhanced communications. Therefore, beyond 2030 growth rates are expected to continue their slight decline.

LEADING VENDORS AND SUPPLY CHAIN

Leading Vendors

- Hitachi ABB Power Grids
- Schneider Electric
- GE
- IBM
- Oracle
- C3.ai

- Software supply chain is highly integrated in-house except for the dependence on the open source software and tools that enable the vendors to develop their software solution in-house.
- Supply chain risks stem mostly from the cloud providers' software support in case when external cloud providers' (such as Microsoft Azure, Amazon AWS and others) platforms are leveraged; however, such risks are normalized through SLAs.

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17 Index of Figures

18 Index of Tables

19 About ASSET

This study has been developed as part of the ASSET project by consortium of Guidehouse and Tractebel Impact.

The ASSET Project (Advanced System Studies for Energy Transition) aims at providing studies in support to EU policy making, research and innovation in the field of energy. Studies are in general focussed on the large-scale integration of renewable energy sources in the EU electricity system and consider aspects related to consumer choices, demand response, energy efficiency, smart meters and grids, storage, RES technologies, etc. Furthermore, connections between the electricity grid and other networks (gas, heating and cooling) as well as synergies between these networks are assessed.

The ASSET studies not only summarize the state-of-the-art in these domains, but also comprise detailed qualitative and quantitative analyses on the basis of recognized techniques in view of offering insights from a technology, policy (regulation, market design) and business point of view.

Disclaimer

The study is carried out for the European Commission and expresses the opinion of the organisation having undertaken them. To this end, it does not reflect the views of the European Commission, TSOs, project promoters and other stakeholders involved. The European Commission does not guarantee the accuracy of the information given in the study, nor does it accept responsibility for any use made thereof.

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