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# The integration of EV charging wallboxes with smart meters in the European market in 2025 - state of the art and future opportunities

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**Executive Summary**

As European DSOs advance with smart meter rollout plans, this review assesses the current state and future opportunities for the direct integration of commercial wallboxes for EVs and smart meters in a selected number of European countries. Direct integration is challenging: while wallboxes are sold on international markets and follow recognized standards, smart meters are mostly national or regional products, and grid operators have developed their own proprietary Advanced Metering Infrastructures (AMI) (or metering system?). Here, we first advocate the case for direct integration, noting that it is particularly well suited when EVs are the only flexible load in the household, a common situation in Europe, and for implementing flexibility services based on real-time grid signals. We then review smart meters data exchange protocols and communication interfaces and identify the common issues hindering smart meters exploitation. We eventually propose a set of recommendations to tackle smart metering infrastructures limitations and unlock the identified potential.
*Keywords: Smart grid integration and grid management, Smart charging, Standardization, Consumer behaviour, Electric Vehicles*

## 1 Introduction

The European Union has long committed to the introduction of smart meters as a core element in the policies that target end-user energy awareness, system competitiveness, and environmental sustainability of energy markets [1]. Through smart meters, end users shall gain access to real-time consumption data and other information required to optimize load consumption and lower the electricity bill, promoting a more efficient use of the grid, fostering the adoption of smart appliances and the uptake of demand-response flexibility services [2]. These assumptions have been confirmed by relevant demonstrators in a number of European and national projects [3], [4], [5]. Smart metering has been directly addressed in

Directive 2019/944 on 'Common rules for the internal market in electricity' [6], as enabling technology to support (i) flexible connection agreements (Art. 6), (ii) dynamic electricity price contracts (Art. 11), and (iii) aggregation markets based on Demand-Response schemes (Art. 13 and 17). By 2020 EU countries were expected to achieve a substantial share of smart meter installations in domestic households. Despite some delays after the COVID pandemics, recent monitoring reports [4], [7], [8] have confirmed the wide adoption of smart meters in most EU countries.
The situation should therefore look quite promising for vehicle grid integration solutions. However, as thoroughly discussed in this paper, despite an overall successful deployment, the installed smart meters support different communication protocols and respond to a wide range of different design criteria defined by Member States and local authorities which, in fact, limit the ability of commercial wallboxes to use smart meter data for behind-the-meter charging optimization and grid flexibility services.
This paper originates from a wide European collaboration and is devoted to highlighting the opportunities and challenges related to integration between domestic commercial wallboxes and EV Supply Equipmets, which are industrial products based on internationally recognized standards (OCPP, ISO 15118) and sold on the European Single Market and domestic smart meters, which are mostly national/regional products supporting different communication protocols both at the physical and transport layer (*f.e.* PLC/DLMS/COSEM, RJ45/M-Bus, *etc.*.) as well as at the application layer for data representations.
The paper is organized as follows. First, we point out few relevant use cases where the direct integration of the wallbox and the smart meter has a clear edge over more complex solutions where Customer Energy Managers or external platforms are involved. We then summarize the roll-out situation and the technical specifications of smart meters in selected European countries (IT, ESP, DK, NO, GER) and highlight the differences in supported interfaces, data shared with the end user, and all the information relevant to the provision of smart charging solutions and flexibility services. Finally, we identify the most pressing issues that hinder the exploitation of smart meters data for the development of advanced charging functionalities and flexibility services with commercial recharging equipment.

## 2 The case for wallbox – smart meter direct integration

The literature on EV grid integration and flexibility services is rich of case studies based on the use of custom Energy Management Systems (EMS) and V1G/V2G flexibility schemes, for instance [9], [10], [11], [12]. While it is well understood that fully electrified households with rooftop PV generation, EVs and a smart EMS can greatly optimize the load consumption, reduce energy costs and provide grid flexibility services, it is also important to note that this situation is far from the reality of most European households. As reported by Eurostat [13], most Europeans live in flats in densely populated urban areas where residential buildings often have a centralized heating and cooling system. As consequence, residential flats have relatively modest volumes of electricity consumption, between 2-4 MWh/year. Furthermore, small heat pumps and water boilers usually offer limited energy saving functionalities which are based on proprietary apps and are not designed to integrate with one another. All these conditions make the adoption of customer EMS not attractive to most Europeans for the limited economic gain versus the effort towards understanding home automation, energy bills and consumption patterns. Indeed, 73% of households in the EU are under a regulated fixed-price or market-based fixed-price electricity contracts [4]. Looking at 2030 and beyond, when EVs are expected to be widely adopted, this situation is not going to change significantly and in most cases the EV will be the only relevant flexible load on the household. In this case, We argue that a direct coordination between the wallbox and the smart meter is the simplest and most cost-effective solution to achieve local load management and the provision of novel demand-response flexibility services based on real-time local grid signals such as low voltage flexible connection agreements.

### 2.1 Local load managment

We draw the case of a fixed price and fixed available power electricity contract. In this case, if a wallbox can read directly from the smart meter the contracted power and the real-time power consumption of all other non-flexible appliances, the maximum recharging power can be easily calculated to deliver the fastest recharging possible without any risk of circuit breakings or penalties for excessive power withdrawals. If information on local real-time PV generation is also available, the same logic can be extended to optimize behind-the-meter renewable auto-consumption. These functionalities were demonstrated in [14].
The same could be achieved with a custom domotic system that typically consists of an additional submeter and a local controller. However, if smart meter data are directly available and only one flexible load is connected, such as the wallbox, all these extra electronic components are clearly unnecessary, as they only increase equipment costs, stand-by load consumption and, ultimately, electronic waste.

## 2.2 Low voltage flexible connection agreements

We draw the case of a flat tariff electricity contract with flexible available power. In order to promote load shifting towards hours when the grid is not congested, grid operators and electricity providers can design electricity contracts where the available power is not constant over time, but may change throughout the day according to either pre-established time intervals or local grid conditions. Contracts of this kind can be particularly effective at the distribution level to prevent grid congestion because they provide an simple instrument for local load management not linked to the intricate and still immature mechanisms of distribution systems flexibility markets [15]. A pilot of this idea at residential level is currently ongoing in Italy, where the National Regulatory Agency grants EV owners the right to withdraw up to twice their contracted power during night hours at no extra cost.

In its most general formulation, the implementation of this use case requires wallboxes to be updated in real-time with information on the extra available power. From a system perspective, this means that all citizens, regardless of their local DSOs and commercial electricity suppliers, shall be equally able to sign up for this contract upgrade.

Thus, it is clear that the smart meter is the optimal gateway to signal the availability of extra power to the wallbox, since it is the only element common to all possible service configuration.

These functionalities were demonstrated and discussed in [14] and will be further duscussed in paragraph 4.1.3.

# 3 Review of European smart meters

We review the different smart meters currently being installed in Europe and their data communication protocols. The aim is to quantify to what extent they provide open and interoperable real-time access to end-users and flexible loads such as domestic wallboxes for smart charging functionalities. In general, there are two ways to access smart meter data.

One way is through internet platforms provided by DSOs or national agencies. In this case, it is typically important to discuss the update frequency of quarterly data and if the authentication protocols allow remote access also to smart energy loads.

The other way is through a direct connection to the smart meter on the local household network. In this case, the important things to discuss are typically the nature of the physical interface to connect to the smart meter (PLC, Rj46, ethernet, ..), and the data acquisition protocols.

## 3.1 ITALY

Italy started early with the installation of smart meters. The first generation was distributed between 2001 and 2007, and in 2017 the second generation was introduced. The rollout in 2025 has already reached over 90% households. The Italian smart meter implements Power Line Communication (PLC) technologies, with a backup radio channel only for emergency situations. All DSOs on the national territory have adopted the same product Open Meter developed by E-Distribuzione. The communication with DSOs is bidirectional and makes use of the A-band PLC (3-95kHz), which in Europe is reserved for energy operators. The communication with end-users on the other hand is mono-directional and uses the open C-band (125 -140 kHz) on the household network [1].

Periodic quarterly load consumption data are always recorded and communicated to DSOs and end-users. On top of that, if a sudden change in the instant voltage and or current is observed (greater than 10% wrt the last recorded value) a real-time non-periodic timestamped measurement is communicated to the end-user on the C-band PLC.

### 3.1.1 Data flow towards the DSO and national online platforms

DSO communication is bidirectional and uses the reserved PLC A-band. It supports the collection of periodic quarterly data and execution of control functions such as remote switching, changing the contractual and available power and the ruling time-of-use periods. Due to the limited bandwidth and range of PLC systems, households smart meters data are collected by local concentrators placed in the LV or MV substations, where they are aggregated and sent the DSOs central systems with standard communication protocols. DSOs validate the acquired measurements and eventually push the data to the national web platform[2] where citizens can authenticate and view/download their data. With regards to data availability for the end user, we observe limitations: authentication is only done through the national citizen digital identification protocol, which requires strong, two-factors authentication and does not allow remote programmatic access nor sharing data with other third party platforms. Quarterly validated data

[1] https://www.e-distribuzione.it/open-meter/chain-2.html

[2] https://www.consumienergia.it/portaleConsumi


Figure 1: Flexible connection agreement for EV owners: charging operation at nighttime that exploits the extra available power from 3 up to 6 kW. (Image courtesy from [14]).

should be available within 48 hours from the actual measurement, however publication delays and inconsistencies are commonly experienced and there is no official figures for the accuracy of the numbers reported.

#### 3.1.2 Data flow towards the end user

As discussed, every 15 minutes or at significant changes in power consumption, the smart meter sends a signal with all relevant information on the local electric network with the Chain 2 protocol, which is an application layer specification to be used on top of the C-band PLC DLMS/COSEM protocol.
This real-time information contains both electrical measurement data, namely voltage, current, frequency, active power, and contractual data such as contracted power, holding time-of-use tariff and available power.
Smart meter data are always encrypted to guarantee privacy. DSOs are responsible for the encryption and only qualified vendors are allowed to ask for decryption keys. Few commercial products are available on the Italian market that can read smart meter Chain2 data and make it available to end users via more common protocols such as modbus or MQTT.

#### 3.1.3 Pilot activity: Flexible connections for EV owners

An experimental campaign to test the interoperability of Italian smart meters for the provision of smart charging functionalities was conducted in 2023 and 2024 [14] with the participation of several different commercial manufacturers. The tests covered different aspects: (i) local load balancing against non-flexible loads, (ii) the provision of load balancing services to a remote aggregator, and (iii) the implementation of a flexible connection agreement devoted to EV owners[3].
In the latter case, the exact start/stop time and amount of extra available power were directly communicated via the PLC Chain2 protocol by the smart meter to the wallboxes upgraded with a dedicated PLC interface. The resulting charging behaviour is shown in fig. 1 for one particular charging event. The same result was achieved in different households with different electricity contracts and charging equipments. In order to achieve this level of interoperability, information on the time-changing available power had to be signalled directly from the smart meters to the wallboxes, which in turn didn't need to know any specific logic related to the connection agreement itself nor had to set up dedicated communication interfaces with the DSO for the task.
We argue that to achieve the same result without the Chain2 smart meter protocol would have required a much bigger coordination effort among all actors involved. From a system perspective, it is vital to optimize the normative and standardization effort towards scalable solutions with potential to support the highest number of use cases possible.

### 3.2 SPAIN

The massive installation of smart meters in Spain was driven by the Orden ITC/3860/2007, which mandated the complete substitution of traditional electricity meters with smart meters by 2018. This process

[3] https://www.arera.it/en/atti-e-provvedimenti/dettaglio/20/541-20

is currently regulated by the Orden ICT/155/2020, which defines the features of smart meters. The main technology used for data communication is PLC, which employs two main protocols: the PLC PRIME (PoweRline Intelligent Metering Evolution) protocol [16], led by Iberdrola and compatible with most commercial smart meters (ZIV, Elster, Circutor, GE, Itron, Janz, Landis+Gyr, ORBIS) and the Meters&More protocol, which is proprietary to Endesa and is also used in Italy. Both protocols are open. In Catalonia, 94% of smart meters are operated with the Meters&More protocol, whereas the remaining 6% with the PLC Prime [17].
Similarly to the Italian system, data concentrators are deployed in substations to collect data, which are then transmitted to control centers via fiber optic or 4G/5G routers.
According to the national directive Resolución 129 de 2 de junio de 2015 [18], system operators are required to make energy consumption data accessible to consumers. This data should be provided by each operator through a dedicated website or application, ensuring transparency. The directive specifies the following key features for consumer access:

- Communication channels: operators must offer a website where users can access and review their hourly load curves.
- Structure and format: the hourly load curve should be available for download in CSV format.
- Data update: data should be provided no later than five days after billing.
- Confidentiality: data are confidential and operators are not allowed to use them for purposes unrelated to energy distribution.

Currently, two-factors authentication is not required to access smart meter data, end users only need to create a username and password. However, the absence of a more cybersecure approach has already resulted in significant smart meter data leakage, exposing both smart meter information and personal billing details. In addition to the specific platforms offered by each operator, a unified platform, called Datadis, has been developed [19]. Datadis enables users to access, visualize, and manage their energy consumption data, regardless of the specific provider. Through its API, it facilitates automation in energy management. This platform could simplify home smart charging, when integrated with a charging wallbox. The platform has the potential to simplify interoperability across Spain. However, to date, no Spanish home smart charging projects have been found that integrate Datadis data for smart meters, energy pricing, or energy management systems.
An alternative approach to remote data retrieval is the installation of additional sensors at the local level to monitor energy demand. However, this alternative is often expensive and the solution is not scalable, as the interface with the wallbox would differ depending on the provider of the monitoring equipment.

## 3.3 GERMANY

In Germany, the first generation of smart meter infrastructure components was developed in the early 2010s. However, installations were limited due to high security and interoperability standards. In 2020, the second generation deployment phase of the system started with the commissioning of devices certified according to version 2.0 of the technical standard TR-03109 of the Federal Office for Information Security (BSI) [20]. As of 2024, the smart meter rollout has not yet achieved 10% of residential households [4] and it lags behind the coverage rates achieved in many European countries. However, Germany aims to have approximately 28 million smart meters in operation by 2032 and the relatively slow progress of the process can be explained by the fact that all components in the system have to be certified, multi-actor structures require coordination, and data security is of high importance [20, 21].
The smart meter rollout in Germany is centered around a security-certified communication device called the Smart Meter Gateway (SMGW). This device collects meter data and enables a secure and controlled exchange of data between different actors (e.g., distribution system operators, suppliers, end users, and third-party service providers). The SMGW is equipped with X.509 digital certificates to protect data confidentiality and system integrity, and is managed by the BSI's Smart Metering Public Key Infrastructure (SM-PKI) [21]. It also supports advanced functionalities such as time-based tariff applications, flexible consumption management and near-real-time consumption information to the users. The smart meter architecture is built on three separate communication networks based on the principles of data security, functional separation and role-based access. As illustrated in Figure 2, the SMGW acts as a bridge between these three main communication networks: LMN (Local Metrological Network) for connection to the meters, WAN (Wide Area Network) for data exchange with market participants, and HAN (Home Area Network) for data presentation to the end user.

### 3.3.1 Local Metrological Network (LMN)

The LMN is the network layer where direct data exchange takes place between th SMGW and the local meters (e.g., electricity, gas). The meters send network information such as consumption and injection to the SMGW [22]. The communication is usually based on the HDLC/RS-485 protocol. Meters only generate data, they are closed to outside access. In this respect, the LMN forms the inner perimeter of the system and is isolated from external threats [20].

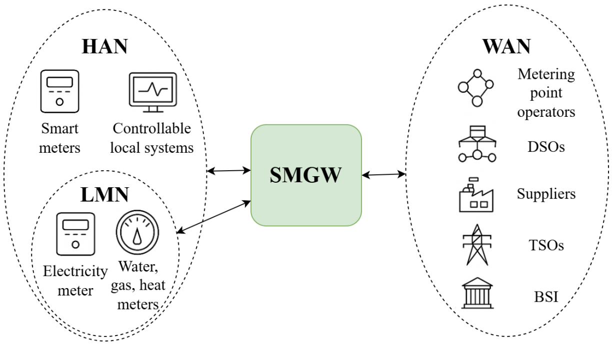

Figure 2: German Smart Meter Gateway (SMGW) Architecture and Network Integration

### 3.3.2 Wide Area Network (WAN)

The WAN is the layer where the SMGW communicates with the outside world (e.g. Gateway Administrator, DSO, energy supplier). The communication here is only initiated by the SMGW, i.e. external systems cannot establish a direct connection to the SMGW [22]. Thanks to this integrated security principle, the system is protected against external attacks. Access is only available to actors certified by the SM-PKI, and all communication is performed via bi-directional authentication using the Transport Layer Security (TLS) protocol [20].
While this structure is highly effective in securing data, it also prevents direct access by end users over the WAN. Therefore, EMS systems and devices such as wallboxes can only access data over the HAN. Data provision over the WAN is only possible through market actors' own systems, but these platforms are usually not standardized. This makes the HAN-CLS interface the only interoperable channel for wallbox manufacturers [23].
Theoretically, real-time dynamic pricing signals can be transmitted over the WAN, and the system infrastructure is designed accordingly [20]. However, the widespread use of such signals has not yet materialised in practice. At present, these functionalities are regarded as future potential and, in practice, are largely limited to fixed or time-of-use tariffs [24].

### 3.3.3 Home Area Network (HAN)

HAN is the link between SMGW and end-user and local systems (e.g. energy management systems, heat pumps, EVSEs). It is classified into two:

- HAN-CON (Home Area Network – Consumer Interface): Access point for the end user and the service technician to the SMGW.
- HAN-CLS (Home Area Network – Controllable Local Systems): It provides automatic communication and load control between devices within the home. Especially designed for energy management systems (EMS) and flexible consumers.

Thanks to this structure, both user and device automation systems can access the system in isolation according to their roles. Access is usually protected by HTTP Digest Authentication and IP access rules are strictly defined (using a private IP pool in accordance with RFC1918) [20, 22].
The HAN-CLS interface is the only universal and standardized access channel for interoperability for wallbox manufacturers and EMS providers. The primary reason for this is that the SMGW has restricted all communication with the outside world to specific roles and secure channels only. The WAN connection is available exclusively to market actors who are certified under SM-PKI, including but not limited to Gateway Administrator, DSO and supplier. End-user devices, e.g., EVSEs or heat pumps, cannot therefore communicate directly with the SMGW over the WAN. Rather than being able to connect to other segments, these devices are only able to connect to the HAN. In this case, they must use the HAN-CLS channel. According to the [23], such devices must be integrated with a CLS communication adapter that supports the TLS-Proxy mechanism to access the SMGW. This approach enables the realisation of functions such as load control, time-of-use responses and adaptation to potential dynamic prices through the SMGW, while ensuring communication is physically and logically constrained to the HAN.

## 3.4 DENMARK

In 2013, the Danish parliament decided that, by 2020, all the Danish households should have been equipped with a smart meter[4]. As of 2025, the rollout has been successful and more than 90 % of the Danish households are equipped with smart meters [4]. The most widespread models are the Kamstup Omnipower[5], and the MTR 3000/3500 Series IEC Poly Phase (PLC/M2M) smart meters by Networked Energy Services[6].

### 3.4.1 Smart meter features

Both smart meters are usually set to measure the RMS phase current, line-to-ground RMS voltage, and the phase differences between the currents and the voltages. Additional capabilities to record the total/single harmonic distortion, operating frequency, single phase voltage and currents are also available, but usually disabled. The estimated parameters are instead the cumulated energy (absorbed/injected), instantaneous active and reactive power (absorbed/injected). The time resolution spans from 5 to 60 min, but the vast majority of the smart meters are set to only record hourly values, as increasing the measurement frequency would rapidly increase the size of the recorded dataset. The effect of net hourly net metering on Danish prosumers was studied in [25], and it was found that self-consumption increases by 15% when moving from instantaneous per phase netting to hourly summation, with a corresponding saving of at least 50/year € can be achieved by considering the sum of the three phase positive and negative currents.
Both models support communication via Ethernet, PLC (Power Line Communication), or LTE (3G/4G). The communication protocol used is OSGP (Open Smart Grid Protocol) for the MTR 3000/3500, and DLMS/COSEM (Device Language Message Specification/Companion Specification for Energy Metering) for the Kamstrup Omnipower. While the first is globally adopted for smart metering activities, with support to many devices and media due to being certified by IEC standards, the second one is more niche, and is mostly used in Europe/US for smart grid and utility automation, and provides a more specialised environment. Finally, DLMS/COSEM is certified by the ETSI (European Telecommunications Standards Institute). For these reasons, the most widely spread smart meter model is the Kamstrup Omnipower, but a relevant number of MTR 3000/3500 still exist.

### 3.4.2 DSO and Users' Perspectives

The DSO generally reads hourly active, reactive, and apparent power values, together with registry values of cumulated energy (total and for different tariff periods) and peak power absorption. More information are usually available, such as the phase unbalance indices, frequency, and power factor, but they are generally not recorded. It is possible to remotely disconnect users, in case any problems arise during normal operation, thanks to a switch available on the meters. However, no power modulation is available at present (no possibility to lower the max consumption without disconnecting the users). In the MTR 3000/3500, communication is encrypted via Enhanced security (AES-128), Role-Based Access, and E2E Encryption, while the Kamstrup Omnipower uses either Enhanced security (AES-128) or TLS if the DLMS/COSEM protocols are supported (in the last models).
The information which is available to the user on the smart meter screen is a subset of the one available to the users, and includes the accumulated active/reactive/apparent positive and negative energy, the number of phases used, the cumulated energy in the different tariff periods, the quadrant (Q1-Q4), the currently applied tariff (T1-T3), and a number of other error/warning indicators. The Danish system allows each smart meter owner to access electricity information via the eloverblik.dk website[7], which gives them access to a database for smart metering data called Datahub[8], created and managed by the Danish TSO, Energinet. The access is managed via the digital citizen ID (MitID) and requires strong two-factor authentication by the user the smart meter is registered to. Within the authenticated area, the user can enable remote API access for Third Parties with a token that has one year validity. The data is usually available with a 8 h delay from the measurement time, which doesn't allow for any smart meter real time control. The Datahub manages, at present, 3.3 million metering points [9].
The DataHub also works as a data exchange platform for DSOs, energy retailers, and third party service providers. DSOs read the consumption from the smart meters, then the information is sent to the

[4] https://www.ea-energianalyse.dk/wp-content/uploads/2020/10/Liberalisation_of_the_Danish_power_sector_2020_09.pdf
[5] https://www.kamstrup.com/en-en/product-centre/omnipower-three-phase-meter#tab=Resources
[6] https://www.networkedenergy.com/en/resources/datasheets-networked-energy-services
[7] https://eloverblik.dk/
[8] https://energinet.dk/data-om-energi/datahub/
[9] https://en.energinet.dk/media/irmcgncr/danish-electricity-retail-market.pdf

DataHub, where it can be accessed by both energy and service providers. This way, users can seamlessly change their provider, since the database for billing is unique and owned by the TSO, and service providers can access the data they require to provide services and create new data-based business models. Balance responsible parties (BRPs) receive data from the DataHub every day, and they can use it to balance the production and consumption during the different market auctions, for the customers they represent.

### 3.4.3 Future perspectives

In this context, the DSOs could set up flexibility contracts with an aggregator, so they can provide grid flexibility. An example of this can be found in [26], where a smart charging mechanism for electric vehicle (EV) owners in a community is set up by an aggregator to avoid transformer overloading. This provides a 5-24% increase in self-sufficiency for the community (with related economic savings), and avoids an expensive transformer replacement. In order to do this, in the paper, an aggregator is responsible to set up a communication infrastructure that reads from the smart meters, both at the point of distribution (POC) and at the EV charging station, to run the algorithm that determines the EV charging setpoint. This is quite complex, both in terms of devices, signal transmission, data security and storage. If the smart meter at the EV charging station was able to communicate with the POC one, the EV could modulate its charging power based on the house appliance net consumption, considering also the possibility of a behind-the-meter PV system. In the case of grid services, an additional signal would be required from the DSO, so the communication with the smart meter would have to be bidirectional.
This is particularly interesting if we consider the perspective of vehicle-to-home (V2H), which, at the moment in Denmark, is the only profitable use case for behind-the-meter (no grid services) usage of bidirectional power transfer [27]. In that case, the EV connected to the charging station could power up the home appliances based on the signal provided by the POD smart meter. A price signal would be required, in this case, but a simple indication of the currently applied tariff is already available to the users in the two described smart meter models. If the EV charging station could communicate with the smart meter directly, concepts like edge computing could be used to avoid the establishment of complex communication infrastructures, and, in this case, without requiring an aggregator at all. The storage capability could still be provided by the DataHub, in this case, and all the benefits of edge computing, such as low latency, improved security, and better reliability, could be targeted.

## 3.5 NORWAY

Norway's smart meter rollout is among the most comprehensive in Europe, with nearly 99% of metering points in the low-voltage distribution grid equipped with Advanced Metering Systems (AMS) by 2023[28]. There are three main suppliers of AMS meters in Norway: Kaifa, Kamstrup, and Aidon. All implement the HAN interface and data transmission according to the national standardization coordinated by NVE and NEK (respectively, Norwegian Water Resources and Energy Directorate and Norwegian Electrotechnical Committee), and are capable of automated 15-minute to 1-hour resolution data transmission to grid companies and the national data hub, Elhub. While there are minor differences in update intervals and list structures, the core functionalities and data content are harmonized across all suppliers to meet regulatory requirements [29, 30].

### 3.5.1 Architecture and Dataflow: From Meter to DSO and User

Smart meters in Norway are designed for automated, two-way communication with the Distribution System Operator (DSO). Consumption data is typically sampled at hourly intervals, but configurable down to 15 minutes, and is transmitted securely to the DSO's Advanced Metering Infrastructure (AMI). Norwegian smart metering infrastructure employs a hierarchical architecture where smart meters communicate over RF mesh networks to local concentrators, which then use GSM/LTE cellular networks to transmit aggregated data to the DSO's AMI Head-End System [31]. The data is then forwarded to Elhub. Elhub, operated by the Norwegian TSO Statnett, is the digital backbone of Norway's electricity market, receiving all validated metering data from DSOs and providing secure, standardized access to suppliers, aggregators, and authorized third parties[10]. The data in Elhub includes basic information at measurement points, such as energy consumption, installed capacity, and capacity limits. For low-voltage residential customers, data resolution is per hour, whereas for large/opt-in customers, the resolution is per 15 minutes. However, this data is made available to the users only the day after. In addition, Elhub contains the hourly spot price for electricity in each Norwegian price area, expressed in NOK per kWh. This price is set the day before delivery and is available for each hour of the following day, allowing consumers and market actors to plan and adapt consumption in response to expected price changes [32].
End-users can access their data in Elhub through secure authentication using the national digital identification protocol, BankID, which requires two-factor authentication. They also have full control over their data and can manage access rights by granting or revoking permissions to third parties. In addition,

[10] `https://elhub.no`

Elhub provides detailed data via dedicated APIs to grid companies, power suppliers, and authorized authorities for purposes such as statistics, analysis, or control. Elhub publishes several open aggregated datasets, for example per pricing area, per grid settlement area, and per municipality.
A distinctive feature of Norwegian smart meters is the HAN port (Home Area Network), which uses an RJ45 connector and implements the M-Bus protocol (EN 13757-2) to deliver real-time metering data directly to end users. Once activated by the grid company, the HAN port delivers detailed, near real-time information, including[11]:

- Real-time active power consumption (typically updated every 2–10 seconds, depending on meter and configuration)
- Energy consumption (kWh), with hourly resolution
- Voltage and current per phase (e.g., L1, L2, L3), with 10 seconds resolution
- Reactive power (import/export) and, for prosumers, active power exported to the grid (e.g., from solar panels)
- Local date and time from the meter
- Meter identification data (serial number, OBIS list version, etc.)

Access to the HAN port is consumer-controlled and must be requested from the local grid company. Once opened, a variety of devices, such as home energy management systems, smart EV chargers, or in-home displays, can be connected to the HAN port to read and use this data for home automation, visualization, or cloud-based analytics.

### 3.5.2 Real world experiences

After the rollout of smart meters in Norway, a range of pilot projects have tested both the Elhub platform and the HAN port, each serving different roles. Elhub has been used on market-focused initiatives, providing standardized hourly or 15-minute consumption data, that can support billing and market analytics, which can be used for demand response as demonstrated in pilots from iFlex and CINELDI projects [33, 34]. Its main advantage is the ease of integration for third-party services, as access typically requires only customer consent and no additional hardware. However, since Elhub data is made available to market actors and end users on a daily basis, and not in real time, in its current version cannot be used for device-level, real-time flexibility control. On the other hand, the HAN port offers direct, high-frequency, real-time data access right at the customer's premises—an essential feature for advanced flexibility services and local energy management, as tested in projects like ENERGYTICS [35]. This local high-resolution data stream enables immediate response from local measurements, independently on cloud connectivity. However, it is important to note that while the HAN port can provide real-time data locally, many smart services still depend on cloud connectivity for receiving price signals or remote control, so true "offline" operation is not always guaranteed. Conversely, solutions relying solely on Elhub data are limited by the daily update cycle and may face challenges in locations with poor connectivity, such as building basements where EV chargers are often installed. Overall, the collective experience from Norwegian pilots shows that Elhub is best suited for standardized, market-wide applications and analytics, while the HAN port is indispensable for real-time, device-level monitoring and control. This makes them complementary tools in the smart operation of flexible loads such as EV chargers.

## 4 Results and discussions

As widely acknowledged, most European countries achieved a high level of smart meters installation, and the few that are still lagging behind, such as Germany, have a clear rollout plan and have regulated all communication protocols and IT architectures for their smart metering data infrastructures.
In stark contrast to this situation, we observe a general lack of commercial market products and innovative energy services able to leverage smart meters data to implement innovative demand-response consumption schemes and reduce end-user electricity costs. Unfortunately, this is also true at the research level, where relatively few pilot activities were found prototyping smart products and testing new energy services based on smart meter data [14], [35], [34]. We identify several reasons for explaining this situation.

[11] `https://www.nek.no/info-ams-han-brukere/`

### 4.1 Cloud platforms limitations

Cloud platforms can provide the easiest and most interoperable access to smart meter data and have demonstrated potential to actively engage end-users in the adoption of demand-response behaviours based on day-ahead dynamic pricing information [34]. Notably, the most impactful behavioural change observed was shifting EV charging at night hours. However, most smart metering cloud platforms reviewed in this work have severe limitations: (i) They are not able to deliver real-time data. Validated load consumption data is usually only available after more than 24 hours from the actual time measurement; (ii) Non-validated real-time data is not available even as historical data; (iii) Strict authentication policies like 2FA do not allow third party access for energy consumption analytics, tariffs comparison and savings opportunities, remote monitoring and basic automation; (iv) Only few platforms already integrate electricity price data and other grid information, which is necessary to interpret load consumption data and understand how to optimize electricity consumption.

### 4.2 Hurdles on the local Home Area Networks (HAN)

Acquiring smart meter data directly on the HAN is an excellent technical option for sharp real-time, device-level monitoring and control, as demonstrated in [14] and [35]. Unfortunately, any real-world implementation aiming at a wide European market is bound to collide with the complexity of technologies and protocols adopted by different smart metering systems.
The following list is written from the perspective of a wallbox manufacturer that is considering upgrading its product with an HAN interface to implement advanced smart charging functionalities.

- It is rather hard to gather the complete list of relevant technical documents and non-technical information required to estimate the implementation effort. (i) Access to smart meters encryption keys may be reserved only to qualified operators. From a wallbox manufacturer's perspective, this adds uncertainties to development time and costs. (ii) Technical documentation can be overwhelming with respect to the scope required and not aligned with actual meter implementations. Full-stack open source working examples would be of great help;
- Even when two countries have adopted the same communication technology, such as Italy and Spain, different application layer protocols (PRIME and Chain2) are specified. From a wallbox manufacturer's perspective, this means that, beyond software modifications, the ability of a single product to deliver the same functionalities in both countries has to be completely re-assessed, which again adds extra costs to product development;
- The lack of products and services based on smart meter data, even at research level, means that the actual protocols might change in the future. From a wallbox manufacturer's perspective, this puts at risk today's research and development efforts. This is especially true when both hardware and software modifications to the original product are deemed necessary.

### 4.3 Recommendations

Given the limited availability of market-ready products and experimental initiatives, the top priority is to identify the fastest path for enabling the broadest range of interested stakeholders to initiate their first research and development efforts. To this end, cloud integration stands out as the most accessible and easily testable solution. Cloud-based data is already sufficient to support the implementation of novel, interoperable smart charging functionalities. These can be linked to day-ahead market prices [33] or other slowly varying grid signals, such as flexible connection agreements where power availability remains constant over several consecutive hours.
Thus, in the near-short term, the priority should be given to upgrading smart metering cloud platforms to the level that allows as many real-world tests and pilot activities as possible. To this end, here are our key recommendations.

- There should be a single cloud platform for each country that offers a well-documented API suitable for programmatic access. Systems based on distinct MPOs' platforms (such as DE) shall guarantee that each platform implements the exact same API for programmatic access. In this respect, the token based authentication mechanisms offered by the Danish and Spanish platforms are very good examples to follow; It would be ideal if the APIs were most similar in all European countries, since electrical data are clearly the same everywhere and market data have some degree of similarities. Before designing a new API, the advice is to look at what was already done elsewhere and possibly stick to it.
- While real-time automation is not in the scope of cloud platforms, non validated real time data should be available within few hours at most from the actual time of measurement, like most commercial IoT devices are currently able to perform. Data quality KPIs should be defined and monitored, covering Completeness, Consistency and Timeliness;

- Electricity pricing data and other relevant grid information, such as available capacity in flexible connection agreements, shall be collected and shared at the proper frequency that allow the end-user to be timely informed of and react in response.
- Aggregate and average data shall be available to the public, market operators and consumer associations in order to promote market competition and transparency.

# 5 Conclusions

In this article, we reviewed the opportunities to use smart meter data for EV charging optimization, highlighting the potential improvements with respect to the present situation where most EV drivers achieve behind-the-meter optimization with just simple, even manual, charging scheduling. As we progress with the installation of new renewable capacity and get closer to the technical limits of distribution grids, more advanced and automated smart charging schemes based on smart meter data will offer a key technological advantage, enabling optimal real-time household load balancing and the provision of grid flexibility services.
Despite this clear potential, the development of advanced smart charging solutions that rely on smart meter data has yet to take off. This is largely due to the fragmented and varied landscape of smart metering systems across Europe, which makes it difficult to fully harness these resources. The top priority thus, is to remove the barriers stemming from system complexity against smart meter integration. Smart meter integration can be achieved at two levels, via cloud platforms and via the Home Area Network (HAN).
Integration with smart meters at the HAN level is currently only feasible on a country-by-country basis, and it typically requires both hardware and software modifications. We argued that estimating this implementation effort can be challenging and put off industry plans. Thus, we call for research projects to provide open source, hands on and step-by-step documentation on how to read and interpret smart meter data according to national specifications.
Cloud integration on the other hand is much easier to achieve, and integration tests should not be a worrisome problem even in the case where different country markets are targeted. Furthermore, several smart charging functionalities can already be achieved with just cloud integration, as demonstrated by the Norwegian example, where a well established cloud platform proved to be a true enabler for large-scale demand-response pilots, fostering end-user engagement and participation also with the help of third party apps and services that blends in with the smart grid ecosystem.
Unfortunatley, most cloud platforms are still far from this level. In the Results and Discussions, we have identified the common shortfalls affecting the smart metering cloud platforms examined in this study and have come down to a set of recommendations to fix the situation. In one sentence, cloud platforms shall be open to third party access via standard API and shall expose electrical load data, with a maximum delay of few hours, as well as electricity price and grid signals with real-time update.

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