Guidehouse INSIGHTS

White Paper

Unlocking Real-Time Visibility & Situational Awareness

The Role of Next-Generation AMI in Facilitating Real-Time Awareness

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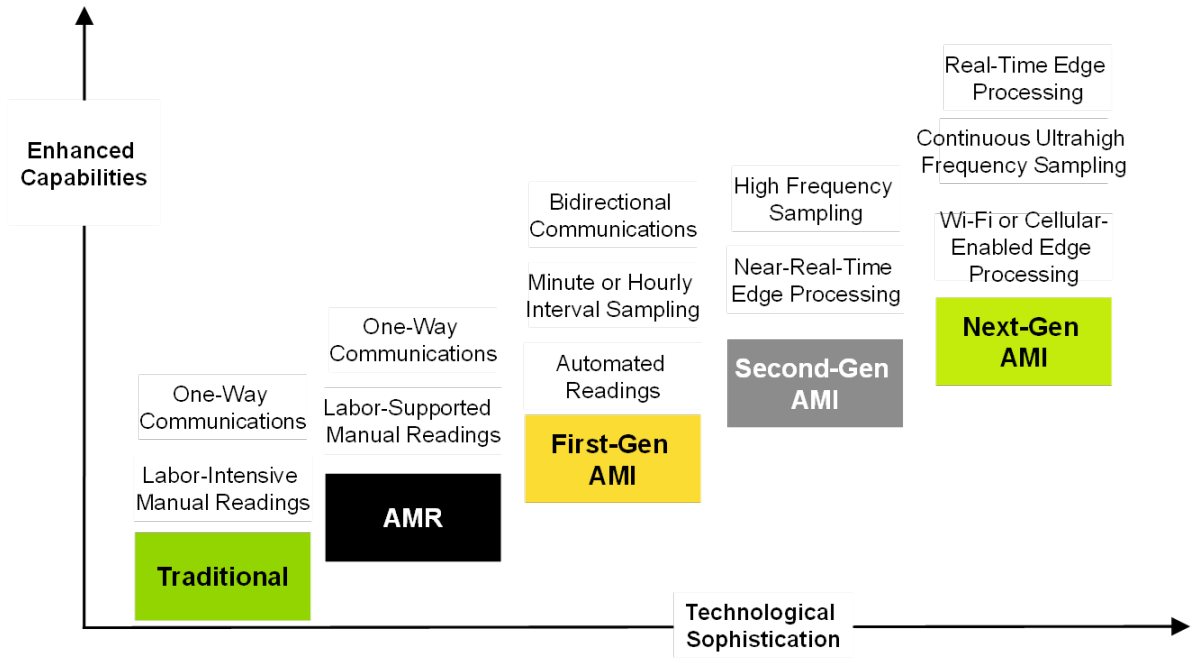
Introduction

An electric meter was originally designed to provide utilities with a simple number—the amount of electric current that flowed through the meter each month. The first significant technological evolution came with the rise of first-generation smart meters and the transition from analog devices to basic digital technologies. With the development of more sophisticated hardware and the miniaturization of computing power, "second-generation" smart meters have leapfrogged traditional definitions and now encompass connected networks of intelligent edge-computing devices, fully equipped with onboard sensors, computers, and communications capabilities. Furthermore, these devices can now measure and monitor the waveform in addition to energy, current, and voltage, and capture these measurements at sub-second intervals. These flagship functionalities should not overshadow one of the more overlooked capabilities—location awareness.

However, there is still a fair degree of technological differentiation throughout the space, as highlighted in Figure 1-1. For the purposes of this white paper, second-generation AMI constitutes these baseline enhancements, while the term next-generation AMI is reserved for the continuous sampling of ultrahigh resolution data (at a minimum of 15 kHz) across all smart meters, significant local processing, and real-time networking functionalities[1]—requirements that some devices labeled as next-generation AMI meet to varying degrees.[2] These innovations aim to align the energy industry with other verticals in enabling real-time experiences to meet modern-day expectations.

Figure 1-1. Evolution of AMI Technologies



(Source: Guidehouse Insights)

[1] Sense, **AMI 2.0: A Buyers Guide**, May 2024.

[2] Brandon Dyer, **The Smallest State Is Building Big Benefits for Energy Customers**, Sense, December 2023.

The coalescence of business and operational pressures facing European DSOs—from first-generation AMI issues (e.g., value realization, technical constraints, customer dissatisfaction) to escalating network congestion and peak demand pressures—demand new solutions and real-time intelligence at the grid edge. This white paper discusses the role of next-generation smart meters in facilitating real-time insights for DSOs and customers worldwide, whilst also contextualizing these insights and recommendations for the Netherlands energy market and its citizens specifically.

Predominant Market Drivers

Several market drivers are coalescing to increase demand for second- and next-generation AMI solutions throughout the globe, which are discussed below.

Peak Demand Management: DSOs are facing significant operational challenges due to growing imbalances in traditional peak demand profiles. Next-generation AMI enables peak period disaggregation and allows DSOs to educate customers about peak energy usage (broken out by appliance) and how to reduce associated bill costs via behavioral changes.[3] This in turn creates multipronged benefit streams for both DSOs (peak demand pressures, system costs, transmission and distribution deferrals) and customers (consumption-based bill savings). While Netherlands' DSOs have been proactive on this front, via record investments in power grid expansion and the provision of energy usage data to customers (using current smart meters), this has still proven insufficient to resolve escalating grid congestion and peak demand challenges; according to Alliander, "traffic jams" will recur on the Dutch electricity network for at least another 10 years.[4]

Electrification: Home electrification is becoming a major policy priority for countries with aggressive decarbonization goals (e.g., Netherlands effort to increase energy savings by 1.5% annually[5]). It has also become a natural response to market pressures – for example, rising gas prices led Enexis customers to switch to electricity faster than the DSO had expected.[6] This opens two opportunities for driving next-generation AMI adoption. The first is providing enhanced management to avoid expensive and time-consuming distribution equipment replacement and electrical panel upgrades. The second opportunity comes from providing a streamlined system for managing new electrical equipment.

Energy Affordability: Energy affordability can logically be improved upon in two ways: lower charges (rates) or lower consumption (bills). While AMI and demand side management (DSM) critics note that project expenditures often add a few euros to monthly distribution rates, the cumulative energy savings delivered from these programs have been shown to have a greater impact on average monthly bill costs.[7,8] Enexis reports that high energy prices has led to an

Grid modernization plans focused exclusively on hardware often come with significant financial impacts to customers. The software-oriented strategies of next-generation AMI help offset these costs and minimize customer rate hikes and bill impacts.

[3] Brian Walsh and Jeff Scheb, **Powering the Energy Transition AMI 2.0**, Energy Central, February 2024.

[4] Smart Energy International, **Dutch Demand Continues to Outstrip Supply Despite Record Grid Investments**, March 2024

[5] Government of the Netherlands, **Central Government Promotes Energy Savings**, accessed June 2024.

[6] Enexis, **Shortage of Transmission Capacity on the Electricity Grid is the New Reality**, February 2023

[7] Emily Levin, **The Value of Energy Efficiency: Past Successes and Future Strategies**, VEIC, August 2021.

[8] U.S. Environmental Protection Agency, **Energy Efficiency Program Best Practices**, accessed June 6, 2024.

enormous increase in the number of customers requesting access to their energy usage information.[9]

EV Management: Next-generation AMI allows DSOs to detect EV ownership by using disaggregated load profiles—without the extraneous investment in third-party analytics or advanced distribution management systems (ADMS) applications. Where use cases demand real-time intelligence, such as notifying a customer that they have activated an EV during a higher priced time interval, next-generation AMI is the logical enabling technology. This is especially lucrative in the Netherlands, as the country has been at the forefront of promoting EV ownership - for example, the government has set a target of ensuring all new cars on the road are emission-free by 2030. And according to the CBS Dutch statistics office, the number of domestic EVs has tripled in the last four years, from almost 43,000 in 2019 to nearly 128,000 in 2023.[10]

Grid-Interactive DER: Many of the behind-the-meter (BTM) distributed energy resources (DER) being deployed are grid interactive, enabling automated peak load management functionality should customers opt into specific programs. For example, one in three Dutch households now have solar panels (growing by 30% between 2022 and 2023), along with ~384,000 private charging stations and ~170,000 connected heat pumps nationwide[11] – this presents both tremendous opportunities and challenges for regional DSOs. The temporal requirements of associated use cases demand real-time intelligence to ensure DER and demand response (DR) program efficiencies, both operational and financial, are realized.

Network Model Integrity: While most DSOs still rely on manual processes to resolve connectivity data issues, this costly and time-intensive method should be replaced by next-generation AMI solutions that can continuously analyze asset network models to isolate potential problem areas and suggest corrective actions.

Time-of-Use and Complex Rate Structures: The market is increasingly interested in experimenting with complex rates and automated feedback mechanisms. For example, real-time rate structures can inform more precise management of residential generation, storage, and controllable loads, which can be optimized based on real need as reflected in wholesale prices. This approach has potential to replace event-based DR, with high prices at times of peak load signaling residential devices to curtail or signaling storage to dispatch.

Inevitability of Next-Generation AMI

The essentiality and ubiquity of metering equipment offers a competitive advantage against potential alternatives. The logic is fairly simple: regardless of the DSO or meter type—electromechanical, automated meter reading (AMR), or AMI 1.0—every meter is necessary and eventually needs to be replaced.

In the Netherlands, the initial first-generation smart meter rollout was met with some hesitancy from the public due to broad privacy concerns and fears over meter inaccuracy. Despite these ancillary concerns, smart meter adoption has increased year-over-year with nationwide coverage completed in 2020. In

[9] Enexis, **Annual Report 2022**, 2022

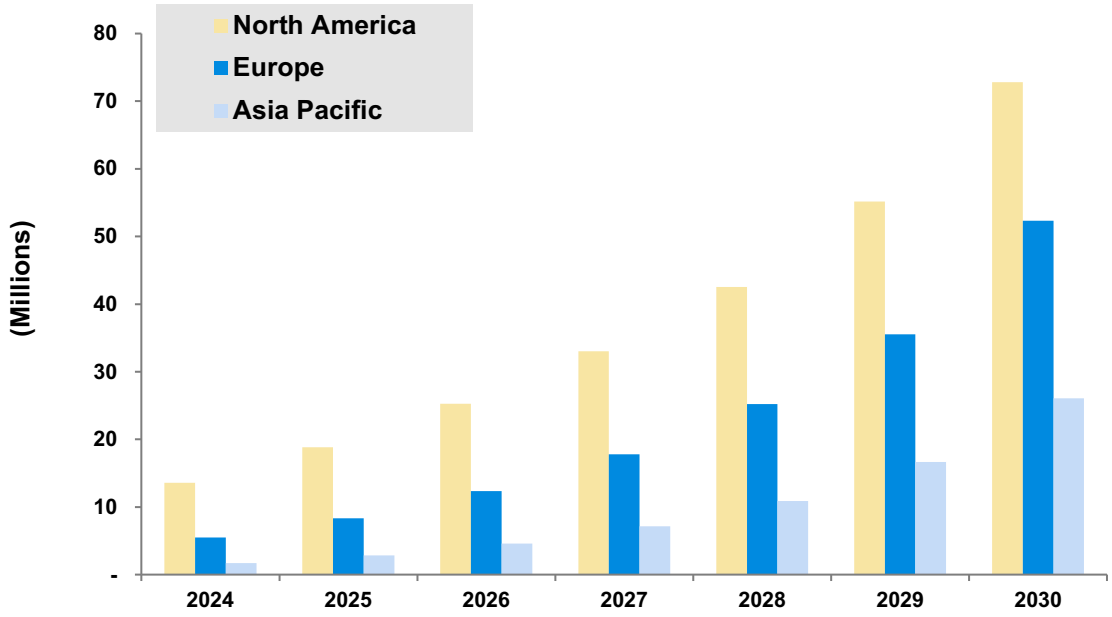
[10] Dutch News, **What You Need to Know About Buying an Electric Car in NL**, February 2024

[11] Netbeheer Nederland, **Facts and Numbers**, accessed June 11, 2024.

assuming a 15-year meter lifespan, Dutch households will already approach end of life estimates beginning in 2025.[12]

Several factors will ultimately determine meter lifespans, such as weather conditions, availability of new technologies, analytics roadmaps, and communications requirements. While major meter manufacturers typically cite the lifespan of smart meters at around 20 years, this is largely overestimated. Based on a jurisdiction scan of the Guidehouse Insights *Global AMI Tracker*, the average lifespan of AMI 1.0 deployments is 10-15 years. Netbeheer Netherlands reinforces similar estimates of ~15 years as a function of increased risks of component failure, the phase-out of telecom technologies, limitations for development of new functions, and expiring contracts with current suppliers.[13]

Chart 1-1. Second- and Next-Generation Smart Meters by Region, Global Markets: 2024-2030



(Source: Guidehouse Insights)

Limitations of Existing Technologies

In order to create the reliable, flexible, efficient, and renewable grid that tomorrow's demands require, DSOs need a full picture of what is happening. At the feeder level, most DSOs lack true situational awareness. The confluence of escalating operational pressures, from reliability and resilience to electrification and decentralization, demand more comprehensive, high resolution, and real-time data powered by scalable and cost-effective technologies.

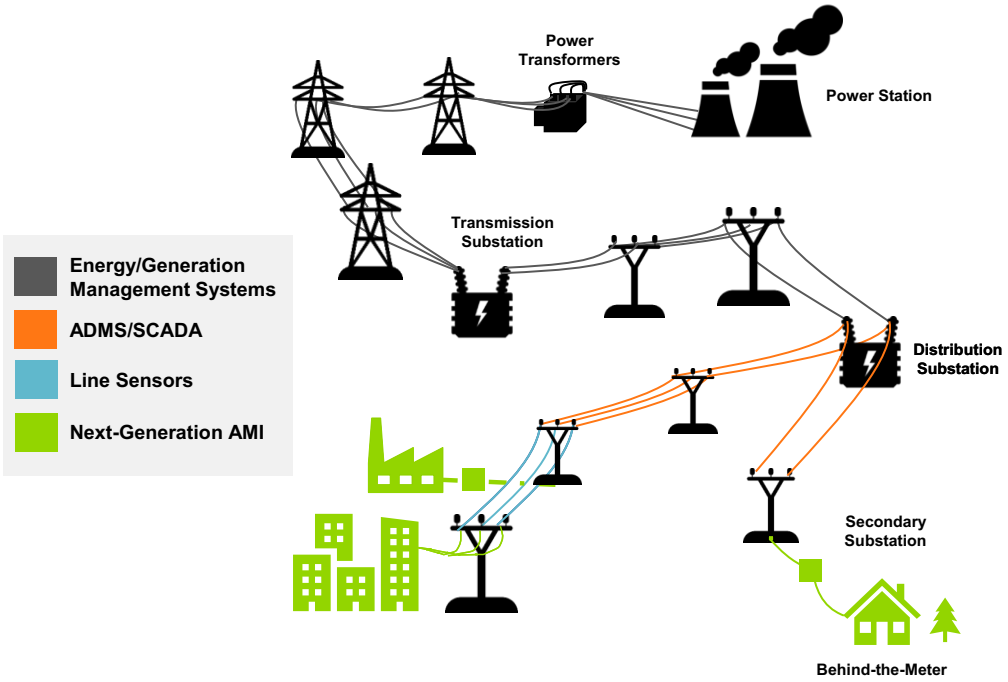
[12] Netbeheer Netherland, **NextGen Dutch Energy Metering System**, January 2024

[13] Ibid.

While grid operators have dramatically improved the level of visibility within their networks over the past two decades, there remains a notable blind spot from the substation to the home.

The pure size of the distribution network makes it difficult to monitor the entire system effectively via existing solutions, such as operational technology systems (e.g., SCADA, ADMS), cloud-based sensing and measurement platforms, and first-generation smart meters. These solutions often lack the precision, forecasting accuracy, and real-time data requirements needed to holistically manage future grid networks (front of the meter [FTM] and BTM). While DSOs can opt to instrument their distribution networks with dedicated sensing and measurement devices, the cost-prohibitive price tag associated with these types of deployments is often too much for DSO decision makers to stomach. Thus, highly scalable software at the edge has an important role to play in managing these costs.

Figure 1-3. Real-Time Visibility Enablement of Existing Solutions



(Source: Guidehouse Insights)

ADMS Provide Limited Downstream Visibility. ADMS provide distribution-level visibility for grid operators and are typically used to assist with DSO planning and operations. However, ADMS have their limits, as these systems typically rely on SCADA measurements as the primary source of data ingestion. The number of phenomena monitored is often low, and real-time data availability is confined to the substation. Furthermore, there is typically minimal monitoring at the actual feeder level, particularly across longer power lines. This gap highlights the need for visibility between the substation and end customer, particularly in areas where feeder lengths exceed 10 or more kilometers.

Distribution Network Instrumentation Is Often Cost-Prohibitive. This approach requires special hardware and firmware capable of waveform data capture, such as modern relays, fault recorders, condition monitors, and power quality monitors. The costs associated with full instrumentation of distribution systems, in particular for better situational awareness, will prove economically infeasible for most DSOs today.

AMI 1.0 Provides Limited Upstream Visibility. The low frequency data capture and limited processing power of first-generation smart meters cannot support real-time measurements or true edge-based analytics. Furthermore, multiple Netherlands DSOs report struggling with AMI 1.0 issues ranging from inaccurate energy readings and data accessibility issues to inherent technical limitations and overburdened call centers. In regard to FTM applications, while current smart meters can serve as outage sensors and current/voltage monitors to enhance grid visibility, next-generation AMI facilitates more advanced use cases—including fault detection and isolation, real-time transformer loading, and power quality monitoring.

These applications are impossible with first-generation smart meters and may prove untenable with second-generation smart meters if sampling rates are below the requisite minimum of 15 kHz.

In-Home Devices Struggle with Business and Market Scalability Issues. These solutions collect real- or near-real-time energy usage information from in-home monitors and sensors the resident purchases and an electrician installs—often in circuit breaker boxes. They communicate relevant insights to homeowners through mobile applications (apps), web portals, and sometimes in-home hubs. While these devices enable many of the same customer-facing use cases as next-generation AMI, there are inherent limitations to business and market scalability. The use of business-to-consumer models creates inherent inequities by placing the financial obligation on end customers—inequities that regulators are increasingly working toward eliminating.

Second-generation smart meters, and next-generation AMI more specifically, represent the next key enabler of real-time visibility throughout grid networks. While existing solutions can support portions of this technical claim on their own, each are either insufficient or cost-prohibitive when applied to “last-mile” secondary substations and feeder networks—and ubiquitously fall short for BTM.

Unlocking Real-Time Visibility

The development of sophisticated, next-generation smart meters was born from the need to provide energy stakeholders with more detailed, real-time information to manage the burgeoning complexities of a more dynamic ecosystem. This is a logical progression—real-time visibility has always been a core tenet of generation and transmission operations. However, only recently has this extended to distribution networks via mass investments in ADMS and distribution SCADA. While these innovations ensure real-time visibility from generation to the substation, most DSOs are left blind with regard to last-mile feeder networks, secondary substations, and BTM. This is where the next evolution in situational awareness comes into play—and where next-generation AMI aims to make its mark.

The enhanced resolution and visibility of next-generation AMI lays the foundation for enhanced situational awareness for DSOs—combining real-time data sources in a way that provides a better understanding of what is happening on the grid. It also enables unprecedented levels of energy awareness for end customers via personalized, real-time insights. Yet these technological innovations necessitate additional market forces and best practices in order to effectively scale over the mid and long term.

Creating and Scaling Next-Generation AMI Markets

In creating and scaling still-nascent markets, multiple enabling forces must be realized: 1) enriched vendor ecosystems that ensure cost differentiation and technological sophistication; and 2) proper roadmap planning, internal training, and outbound education.

Second-generation AMI has already attracted a flurry of innovation from a diverse set of competitive stakeholders. At the forefront of this transformation are major smart meter manufacturers Landis+Gyr and Itron. These companies have intuitively embraced modern software design principles, most notably through "app stores" that are supported by open ecosystems of approved and verified software partners. Landis+Gyr embraces this approach via its Revelo (next-generation AMI) meters and Gridstream Connect Apps ecosystem—edge software developer kits (SDKs) enable third-parties to either convert existing software to an edge app hosted on the meter, or to create an app to address specific needs.[14] Energy companies then deploy and manage apps using the same "app store" concept[15] that led to the rise of the smartphone era.

There was simultaneous recognition from these manufacturers that localized analytics development should logically be outsourced. The facilitation of a vibrant and diverse ecosystem of analytics partners is critical to enabling continuous innovation in an open-standards market. This is evidenced by the ongoing surge in partnership announcements and nascent product developments aimed at second-generation smart metering. Yet the majority of these engagements are still early stage given the relative immaturity of field-deployed use cases today.

Table 1-1. Status of Analytics Providers' Second-Generation AMI & AMI 2.0 Engagements

Provider	Key Partners	Description
Sense	Itron Landis+Gyr Sensus	**Sense** has partnered with multiple solution providers under business-to-business models. While other third-party analytics partners can access metering ecosystems and their high resolution data streams, Sense is embedding its software directly in the meter, essentially assuring that every meter has its core software stack. This ensures higher resolution data can be processed with real-time device detection and grid fault detection at a lower cost and latency. In July 2024, the company partnered with Sensus to develop what is expected to be the first electric meter capable of capturing and processing 1 MHz data in North America.[16]
NET2GRID	Itron	**NET2GRID** was the first company to introduce real-time EV detection and interactivity alerts into Itron's DI meter app store.
Bidgely	Itron	**Bidgely** white labels its EV and solar detection agents to Itron in support of DI-enabled applications.

(Source: Guidehouse Insights)

In order to maintain market success, DSOs must realize the value from next-generation AMI. Industry stakeholders often cite a lack of sufficient preplanning and internal training as common pain points in large-scale technical deployments such as smart metering. When supported by proper planning, training, and education, utilities can hedge against common first-generation smart metering pitfalls while ensuring customers are not overlooked in the process.

[14] Jeff Scheb, **Powering the Energy Transition AMI 2.0**, Energy Central, February 22, 2024

[15] *Itron similarly embraces the "app store" concept via an open partnership ecosystem focused on edge-based software, allowing utilities to download applications directly onto the meter.*

[16] Sense, **Sense and Xylem's Sensus Team to Drive a New Standard for High-Resolution Data with Next-Generation 1MHz Meter**, July 9, 2024

Enabling Real-Time Customer Insights

Next-generation AMI enables customers to engage with real-time energy insights in support of energy savings and demand management. Integrating enhanced data streams and localized analytics into the customer experience presents an opportunity to inspire greater action and levels of engagement by adding a new layer to DSM programming.

In enabling customers to view energy usage data—in real time—electricity companies can realize a multitude of untapped use cases and efficiencies. Whether it is branded as energy efficiency, DR, DER, or home energy management programming, the technical innovations and open software ecosystems of next-generation AMI can be viewed as essential stepping stones in elevating customer engagement, experience, and satisfaction.

For example, customers can better identify energy-intensive appliances and visualize the usage impacts associated with behavioral change in real-time—without any upfront cost or installation annoyances. This is especially notable in the Netherlands where smart device ownership (i.e., meters, thermostats, lighting) greatly exceeds that of the European Union, on average.[17] Yet, while the country is supported by aggressive government initiatives, incentive schemes, and dynamic pricing models, it has yet to empower homeowners to fully harness its potential.[18]

For energy usage insights, whereas AMI 1.0 use cases tend to revolve around monthly insights, high bill alerts, and neighborhood comparisons, next-generation AMI enables real-time usage insights on a device-by-device basis. For example, next-generation AMI can send proactive notifications indicating that household appliance malfunctions may occur and recommend a set of corrective actions. This level of energy awareness for customers was previously only possible with expensive in-home energy monitors.

While these enhancements assume that customers will indeed participate, several studies and industry stakeholders highlight the positive correlation between real-time data availability and customer buy-in. For example, Sense partnered with OhmConnect to determine whether access to real-time, device-level information could boost customer response to DR incentives. In a California-based pilot project, the provision of real-time insights more than doubled the usage reductions that otherwise would have been achieved during DR events.[19]

Unlocking Grid-Based Synergies

The provision of real-time energy intelligence to enhance consumer experiences is a notable and prominent marketing message in support of next-generation AMI. Yet there is growing recognition of the multipronged and overlapping benefit streams for DSOs and customers alike—from improved reliability and safety to system performance and energy affordability.

European and Netherlands-based DSOs are already utilizing first-generation smart meters in support of outage detection, voltage quality monitoring, and other grid management use cases. For example, Stedin recently expanded its use of smart meter data to enable widespread voltage monitoring – encompassing over 90% of its grid. Yet, the number of reports from customers experiencing voltage quality problems increased by 119% over the same period (2022-2023) due to overvoltage conditions and solar inverter

[17] Statistics Netherlands, **Nearly Three Quarters of the Dutch Population Use Smart Devices**, January 2022

[18] Eliq, **The Netherlands is 'Saving Energy Now!',** April 2024

[19] Ryan Hledik et al., **Xcel Energy Colorado Demand Response Study: Opportunities in 2030**, Brattle Group, June 2022.

disconnections.[20] And in 2023, Alliander highlighted the direness of the country's network congestion and peak demand pressures, citing significant growth in clean tech assets, such as heat pumps, solar panels and e-boilers, as well as transportation electrification-each of which offer their own aforementioned, customer-oriented synergies.

The first wave of field-deployed, second-generation applications has largely focused on safety-based use cases and theft detection, such as detecting high temperature events, high impedance, and meter bypass events. As shown below, there are a plethora of smart meter analytics applications that are similarly enhanced or enabled through both second- and next-generation AMI solutions.

- **Load Forecasting:** The inherent driver for load forecasting is simple: more accurate data. As simplistic load forecasting gives way to more dynamic applications powered by sophisticated algorithms and diverse inputs (e.g., cloud cover, wind forecasts, EV penetration), real-time data streams enhance the accuracy and value of load forecasting. For example, understanding the proportion of energy used for heating and cooling allows for more accurate correlation of demand with weather forecasts in support of operational and financial efficiencies. Multiple DSOs cite the importance of accurate consumption forecasts in the functioning of its energy market, with smart meter data serving as the foundational input. Yet, DSOs are simultaneously struggling with out-of-date (i.e., self-generation) and unavailable (i.e., EV charging) energy usage profiles that distort load forecast calculations from actual situations. This reality is only expected to increase as more customers purchase solar panels, heat pumps, EVs, and other grid-interactive DERs.[21]

- **EV Detection:** Understanding the size of chargers and identifying charging patterns allows DSOs to analyze the effect that EVs will have on the grid, both now and in the future. With additional information, it is possible to identify feeder lines or even individual secondary substations that could come under strain due to multiple EVs and tag them for upgrades, or to ensure customers in that region are on EV rates or controlled chargers to encourage load shifting. With the added capabilities from second-generation smart meters, EV detection in real-time could enable more dynamic charging to maximize surplus generation and reward customers who curtail charging during peak demand periods.

- **Distributed Automation and Control:** The ability for second-generation smart metering to support DR and flexibility services is perhaps the most intriguing for DSOs given the immediate value proposition. Next-generation analytics architectures can inflate the value of DR resources through real-time analysis and localized decision-making. These meters have the data and computing power to facilitate grid-edge applications that will help DSOs tap the power of BTM resources like vehicle-to-grid assets while helping boost EV adoption.[22] This is particularly lucrative as DSOs develop and market more complex rate structures oriented at EV owners and real-time managed charging programs. Further, second-generation smart meters enable tapping into demand flexibility for addressing capacity not just at the bulk system level but also at the local circuit level for reliability. For example, networked decision-making across EVs on one secondary substation will be a critical grid-enhancing technology in the near future.

[20] Stedin, **Annual Report 2023**, 2023.

[21] Enexis, **Annual Report 2022**, 2022

[22] Kristen Hawkins, **Behind the Meter Intelligence Unlocks Better Grid Management**, Sense, July 2023.

While the umbrella of second-generation AMI solutions enable or enhance the use cases above, perhaps more enticing are those related to the prediction, identification, and resolution of grid faults—applications that require the continuous ultrahigh frequency sampling capabilities of next-generation AMI specifically.

- **Fault Detection:** In the world of outage management, the ability to know where power is failing is ever more critical. The granularity of waveform data can help pinpoint outage locations, high impedance connections, or hotspots issues, as well as provide root cause analyses. At the household level, it can help DSOs identify and isolate fault locations in support of both outage management and predictive maintenance.

- **Vegetation Management:** The majority (80%-90%) of outages affecting the distribution grid are caused by object-on-wire faults, which are difficult to both detect and avoid. Next-generation AMI and waveform data enable DSOs to detect, locate, and identify the cause behind different vegetation issues (e.g., vegetation brush). For example, Southern Company and Sense recently launched a project using 600 real-time sensors in support of various vegetation management applications. The project is using these devices as proxies in advance of eventual next-generation AMI deployment.

- **Power Quality Optimization:** High resolution data streams and waveform data capture can be used to identify voltage sags and swells, voltage harmonics, and power factor issues—thus facilitating higher levels of situational awareness.

Potential Value Creation

The full value proposition behind AMI 1.0 has failed to materialize for many DSOs. Compounding these challenges are a combination aggressive government targets[23] and escalating concerns related to grid congestion, peak demand, energy affordability, customer engagement, and more— next-generation AMI presents a logical solution across the board.

Yet, prior to the technical advances led by Landis+Gyr and Itron, little to no value was derived from performing AMI analytics at the edge, as the same insights could be generated by performing this analysis in the back office. It is imperative that stakeholders also understand that the selection of analytics architectures is not an either-or proposition, as these are meant to be complementary pieces within the larger next-generation AMI ecosystem. As data streams continue to grow, it makes sense to leverage edge computing that can process and execute on enhanced data streams; this creates dual benefits of alleviating bandwidth congestion and enabling low latency use cases. Cloud analytics, meanwhile, is the logical choice when processing larger pieces of information to capture trends over time, or in enabling less time-sensitive use cases.

DSOs should evaluate the ability of their existing smart meter deployments to address the problems of tomorrow. While legacy technologies may support the myriad use cases seen today, the emerging pressures of data management, customer experience, DER integration, and more are increasingly motivating DSOs and vendors to explore next-generation AMI innovations.

All the pieces are falling into place, from enriched data capture and visualization techniques to growing participation and established business cases. While the track to next-generation AMI is still being laid, the train has clearly left the station, and the headlights are becoming brighter by the day.

[23] Government of the Netherlands, **Central Government Promotes Energy Savings**, accessed June 2024.

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