White Paper

Unlocking Real-Time Visibility & Situational Awareness

The Role of AMI 2.0 in Facilitating Real-Time Awareness

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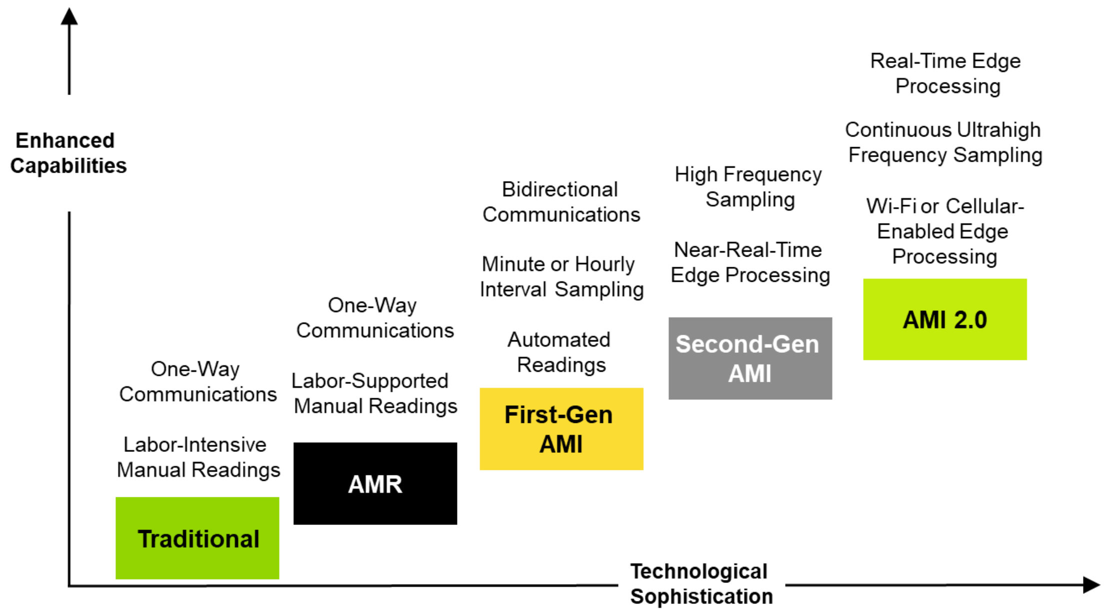
Introduction

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 the full waveforms of current and voltage, and capture these measurements at sub-second intervals.

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 AMI 2.0 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 AMI 2.0 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.

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Predominant Market Drivers

Several market drivers are coalescing to increase demand for second-generation smart meters and AMI 2.0 solutions throughout the globe, which are discussed below.

Customer Satisfaction: By creating personalized user experiences enriched by enhanced, real-time insights and intuitive touchpoint interactions, utilities can simultaneously boost their customer satisfaction (CSAT) scores and hedge against associated reputational, financial, and regulatory risks. For example, multiple stakeholders cite increasing alignment between CSAT scores and utility rate case approvals from state regulators.

Electrification: Home electrification is becoming a major policy priority for countries with aggressive decarbonization goals. This opens two opportunities for driving AMI 2.0 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 dollars 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.[3,4]

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

EV Management: AMI 2.0 allows utilities to detect EV ownership by using disaggregated load profiles—without the extraneous investment in third-party analytics or advanced distribution management systems (ADMS) applications. Furthermore, where use cases demand real-time intelligence, such as notifying a customer that they have activated an EV during a higher priced time interval, AMI 2.0 is the logical enabling technology.

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. The temporal requirements of these use cases demand real-time intelligence to ensure DER and demand response (DR) programs efficiencies, both operational and financial, are realized.

Network Model Integrity: While most utilities still rely on manual processes to resolve connectivity data issues, this costly and time-intensive method should be replaced by AMI 2.0 solutions that can continuously analyze asset network models to isolate potential problem areas and suggest corrective actions.

Peak Demand Management: Utilities are facing significant operational challenges due to growing imbalances in traditional peak demand profiles. AMI 2.0 enables peak period disaggregation and allows utilities to educate customers about peak energy usage (broken out by appliance) and how to reduce

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

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

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associated bill costs via behavioral changes.[5] This in turn creates multi-pronged benefit streams for both utilities (peak demand pressures, system costs, transmission and distribution deferrals) and customers (consumption-based bill savings).

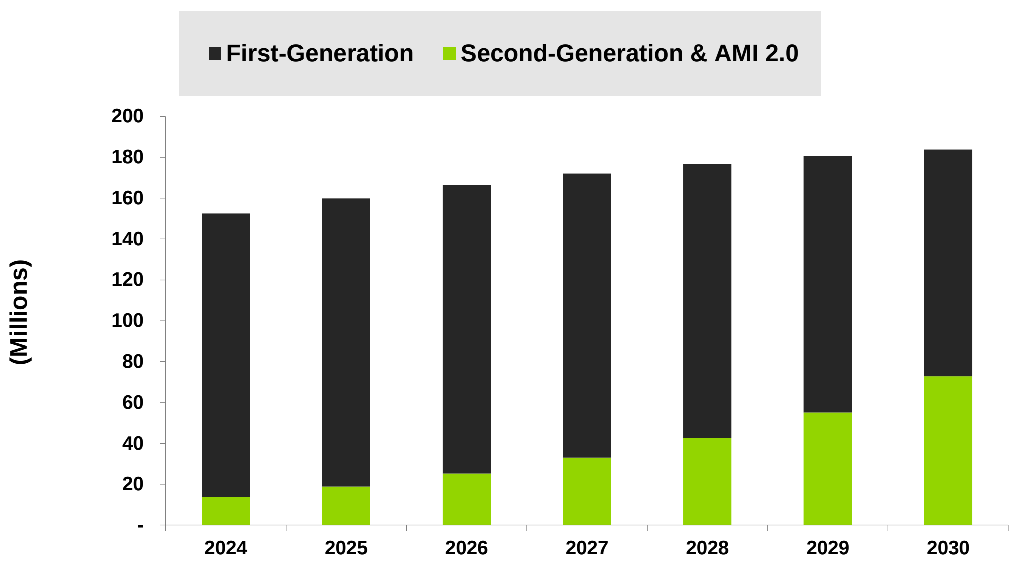
Time-of-Use and Complex Rate Structures: The market is increasingly interested in experimenting with complex rates and automated feedback mechanisms. For example, real-time rate structures can inform more precise management of residential generation, storage, and controllable loads, which can be optimized 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 utility or meter type—electromechanical, automated meter reading (AMR), or first-generation smart meters—every meter is necessary and eventually needs to be replaced.

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 first-generation smart meter deployments is 10-15 years, with meter failures, capacitor degradation, technology obsolescence, security issues, and underwhelming value acting as prominent upgrade and replacement drivers.

Chart 1-1. Electric Meter Installed Base by Type, US: 2024-2030



(Source: Guidehouse Insights)

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

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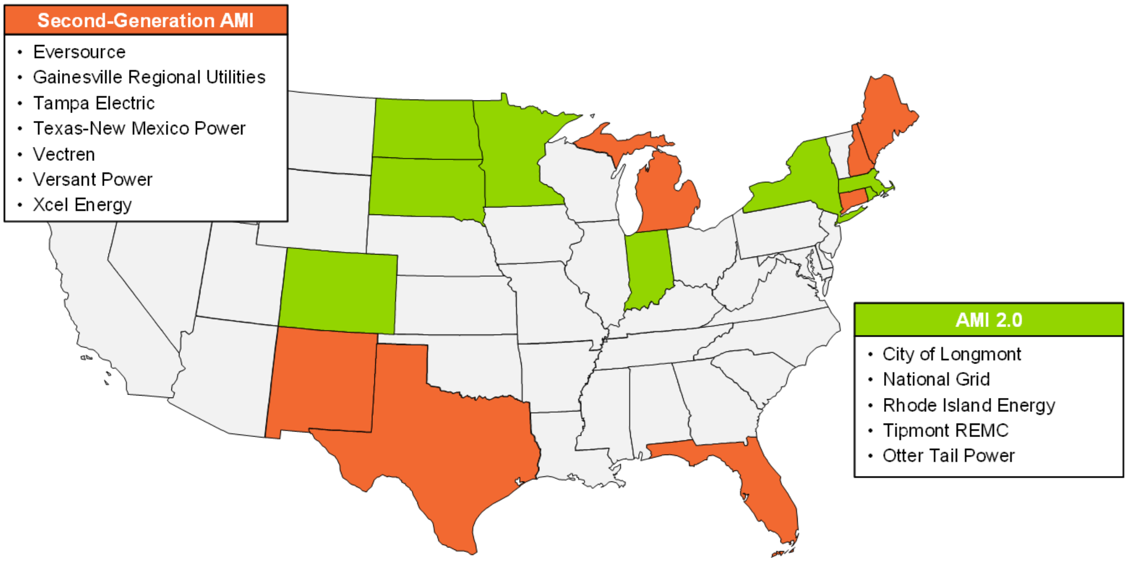
It is also uncommon, if not unheard of, for energy companies to deploy non-AMI meters as part of large-scale replacements, at least over the past decade. This implies that smart meters installed between 2009 and 2012 are logical candidates for AMI 2.0 now and in the near term. These meters correlate with a large surge of smart meter installations across the US during the late 2000s and early 2010s under the American Recovery and Reinvestment Act of 2009—illustrated by the 53 million smart meters that will be 12 years old or older by 2025, with nearly 87 million reaching this age by 2030.

This anticipated influx of smart meter upgrade projects is already playing out in some areas. Figure 1-2 illustrates the growing number of utilities that have selected second-generation AMI, and highlights the subset that meet the definition of AMI 2.0 specifically.

Figure 1-2. AMI 2.0 and Second-Generation AMI Adoption by State, US



(Source: Guidehouse Insights)

Limitations of Existing Technologies

In order to create the reliable, flexible, efficient, and renewable grid that tomorrow's demands require, utilities and grid operators need a full picture of what is happening. At the feeder level, most utilities 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.

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 utilities 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

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.

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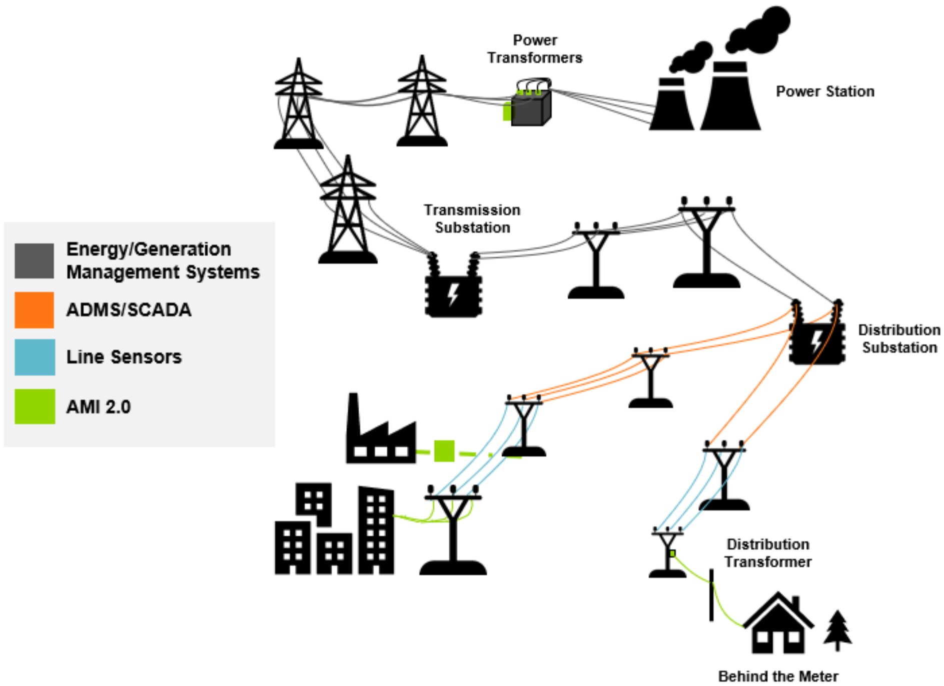
often too much for utility decision makers to stomach. Thus, highly scalable software at the edge has an important role to play in managing these costs.

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 utility 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 utilities today, especially given the existing and rising rate pressures.

First-Generation Smart Meters 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. In regard to FTM applications, while first-generation smart meters can serve as outage sensors and current/voltage monitors to enhance grid visibility, AMI 2.0 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.

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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 AMI 2.0, 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 AMI, and AMI 2.0 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” feeder networks and distribution transformers—and ubiquitously fall short for BTM.

Unlocking Real-Time Visibility

The development of sophisticated, second-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 utilities are left blind with regard to last-mile feeder networks, distribution transformers, and BTM. This is where the next evolution in situational awareness comes into play—and where AMI 2.0 aims to make its mark.

The enhanced resolution and visibility of AMI 2.0 lays the foundation for enhanced situational awareness for utilities—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 Second-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 AMI 2.0 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.[6] Energy companies

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

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then deploy and manage apps using the same "app store" concept[7] 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.[8]
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, utilities must realize the value from AMI 2.0. 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. A major part of this process is ensuring proper data management procedures are in place. The following examples demonstrate best practices among early second-generation AMI and AMI 2.0 adopters.

- **Portland General Electric** recently created a separate AMI operations department for real-time data collection, storage, and analysis. It is hoping to maximize the value of second-generation AMI by investing in data management and internal communications at the beginning of the process.
- **National Grid** released an AMI Benefits Implementation Plan in 2021 that requires AMI education and training for all employees. It was also directed by the New York State Public Service Commission

[7] *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.*

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

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to refine its approach to customer engagement, ensuring that AMI 2.0 also provides adequate customer benefits.

- **Pacific Gas & Electric** is currently drafting an incremental second-generation AMI roadmap, which includes the development of discrete capability scaling and application development strategies.

Enabling Real-Time Customer Insights

AMI 2.0 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 AMI 2.0 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. For energy usage insights, whereas first-generation smart meter use cases tend to revolve around monthly insights, high bill alerts, and neighborhood comparisons, AMI 2.0 enables real-time usage insights on a device-by-device basis. For household appliance malfunctions, first-generation smart meters may only let a customer know when something has already failed, while AMI 2.0 can send proactive notifications indicating that something may fail 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.

- In Wisconsin, a pilot study found that nearly one-third of customers who were provided with real-time usage data took actions to reduce their consumption—turning off lights, lowering the thermostat, or unplugging appliances when not in use.[9]

- **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.[10]

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 AMI 2.0. Yet there is growing recognition of the multipronged

[9] Amalia Hicks and Ari Kornelis, **Smart Home Energy Monitoring: Data-Driven Opportunities and Customer Engagement**, Cadmus Group, September 2022.

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

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and overlapping benefit streams for utilities and customers alike—from improved reliability and safety to system performance and energy affordability.

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. For example, Tampa Electric recently piloted three use cases: energy theft, residential neutral fault detection, and high impedance detection. In all cases, it found that its upgraded meters had outperformed similar back-office applications.[11]

As shown below, there are a plethora of smart meter analytics applications that are similarly enhanced or enabled through both second-generation AMI and AMI 2.0 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 while laying the foundation for more advanced use cases, such as transactive energy. For example, understanding the proportion of energy used for heating and cooling allows for more accurate correlation of demand with weather forecasts in support or operational and financial efficiencies.

- **EV Detection:** Understanding the size of chargers and identifying charging patterns allows utilities 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 transformers 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 utilities given the immediate value proposition. Edge-based 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 utilities tap the power of BTM resources like vehicle-to-grid assets while helping boost EV adoption.[12] This is particularly lucrative as utilities 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 transformer will be a critical grid-enhancing technology in the near future.

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 AMI 2.0 specifically.

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[11] Steven Rogers et al., **Enabling the Clean Energy Transition: Planning for Next-Generation Advanced Metering Infrastructure and Grid Technologies**, Deloitte, 2022.

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

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- **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 utilities 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. AMI 2.0 and waveform data enable utilities 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 to deploy real-time sensors on its distribution network in support of various vegetation management applications. The project is using these devices as proxies to understand the potential of this technology in advance of eventual AMI 2.0 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 first-generation smart meters has failed to materialize for many electricity providers. For instance, a 2022 analysis from the Mission:data coalition found that 97% of smart meters fail to provide promised customer benefits, with a 2020 report from the American Council for an Energy-Efficient Economy affirming that utilities "are largely missing the opportunity to utilize AMI data to improve their energy efficiency and demand response offerings."[13]

However, 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 AMI 2.0 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.

Utilities 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 utilities and vendors to explore AMI 2.0 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 AMI 2.0 is still being laid, the train has clearly left the station, and the headlights are becoming brighter by the day.

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[13] Rachel Gold, Corri Waters, and Dan York**, Leveraging Advanced Metering Infrastructure to Save Energy**, American Council for an Energy-Efficient Economy, January 27, 2020.

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