Guidehouse INSIGHTS

White Paper

Inside-the-Meter Intelligence to Become the Norm

How Localized Analytics Is Ushering in a New Era of Sophisticated Home Energy Management and Grid Analytics

Published 3Q 2022

Commissioned by Sense

Michael Kelly
Senior Research Analyst

Laurie Wells
Senior Research Analyst

Introduction

Electric power markets are undergoing a series of massive transformations. From the digitization and decarbonization of global power networks to a revaluation of the role of the end customer, several paradigm shifts are converging with the goal of reshaping the future of the energy industry. The role of smart metering in enabling this transition is critical and absolute. While the first-generation of smart meters have helped to nudge the industry in this direction, the development of second-generation smart meters sets the stage for a rapid acceleration in achieving these goals.

This Guidehouse Insights white paper explores the emerging market for next-generation smart meters. It discusses:

- The evolution of smart meters from a source of data to sophisticated edge-based computing devices
- How advanced analytics and artificial intelligence (AI) applications are being more seamlessly embedded into the advanced metering infrastructure (AMI) hardware and software operating at the grid edge
- The enhanced value proposition in providing real-time, relevant, and actionable insights to customers and grid operators.
- The role of major smart meter manufacturers and analytics providers in enabling these transformations, including Landis+Gyr, Itron, Sense, and others.

Evolution of Smart Metering

An electric meter was originally designed to provide utilities with a simple number—the amount of electric power that flowed through the meter each month. However, the development of new technology and miniaturization of computing power enabled the transformation of electric meter systems into connected networks of intelligent edge computing devices, fully equipped with onboard sensors, computers, and communications capabilities.

Although smart meters vary significantly in their capabilities, for the purposes of this white paper, a smart meter includes the following capabilities:

- Integrated onboard data storage and processing, enabling energy readings at frequent intervals—at least once hourly but often at 15-minute or even more frequent intervals
- Integrated, two-way communications between the meter and a utility's headend IT systems, enabling remote reading and control (remote disconnect-reconnect) of the meter

Sophisticated next-generation devices, such as Landis+Gyr Revelo, deliver high frequency, high resolution waveform data for utilities and grid operators.

Although these definitions establish baseline technology requirements, advanced smart meters have evolved beyond these rudimentary capabilities. Devices can now measure and monitor the voltage and current waveforms, in addition to total energy, current, and voltage, and can capture these measurements thousands of times per second. This enhanced data availability and resolution is foundational to the enablement of inside-the-meter analytics capabilities that are discussed throughout this white paper.

The Rise of Second-Generation Metering

Nearly all smart meters installed across the globe still classify as first-generation devices. These smart meters lack the technical requirements (sufficient computation, memory, programmability) and data capture capabilities (high resolution waveform data) to constitute second-generation or next-generation devices. Although these embedded capabilities have been a constant source of product evolution since the dawn of AMI, it is only recently that industry-leading manufacturers, such as Landis+Gyr and Itron, have achieved a paradigm-shift-level progression in smart meter technology.

Utilities are constantly searching for ways to create value from their smart meter deployments. While interval data generated by first-generation smart meters has been a valuable input for an array of static and descriptive analytics use cases, the value of certain use cases is hindered by inherent technological limitations. The development of more sophisticated smart meters was born out of the need to provide customers and grid operators with more detailed, real-time information behind-the-meter (BTM) to manage the burgeoning complexities of a more dynamic energy ecosystem. From optimizing the grid through higher levels of situational awareness to more effectively engaging with their customers, many of the macrotrends utilities have chased for years now come a bit easier with the development of second-generation smart meters.

After developing specialized hardware that could be deployed inside electric panels to deliver real-time data streams, Sense and others are now working with meter manufacturers in order to deploy these technologies at scale, as its more logical to embed this functionality into existing infrastructure at the home; more specifically, at the meter.

The ability to capture high resolution current and voltage waveform data, which was previously only possible with additional hardware, is revolutionary. The analysis of waveform data enables device and pattern recognition capabilities in real time, capabilities that are not available with existing on-premise or cloud-based architectures. High resolution waveform data and edge computing enable new applications to be run inside the meter itself.

From Data Source to Edge-Based Computing Device

It’s been established that the next generation of smart meters can capture massive amounts of data across several parameters (i.e., current and voltage waveform data). The question then becomes, so what? This treasure trove of data is essentially useless if not properly acted upon; the underutilization of smart meter data in helping customers make their homes smarter and more efficient, as well as the underinvestment in analytics, is something that has plagued the utility industry for years.

However, these barriers erode when presented with next-generation smart meters, such as Landis+Gyr’s Revelo and Itron’s Riva Distributed Intelligence (DI) meters. Improvements in device functionality, along with open ecosystems of analytics partners, creates an architecture in which utilities and their customers can benefit from real-time, actionable insights from intuitive touchpoints (e.g., smartphones, home assistants). Rather than smart meters operating only as a data source, which have been their primary function since the invention of electromechanical meters in the 1800s, the next generation of smart meters can operate as truly sophisticated edge computing devices.

To summarize, three capabilities are required to turn smart meters into powerful edge computing devices:

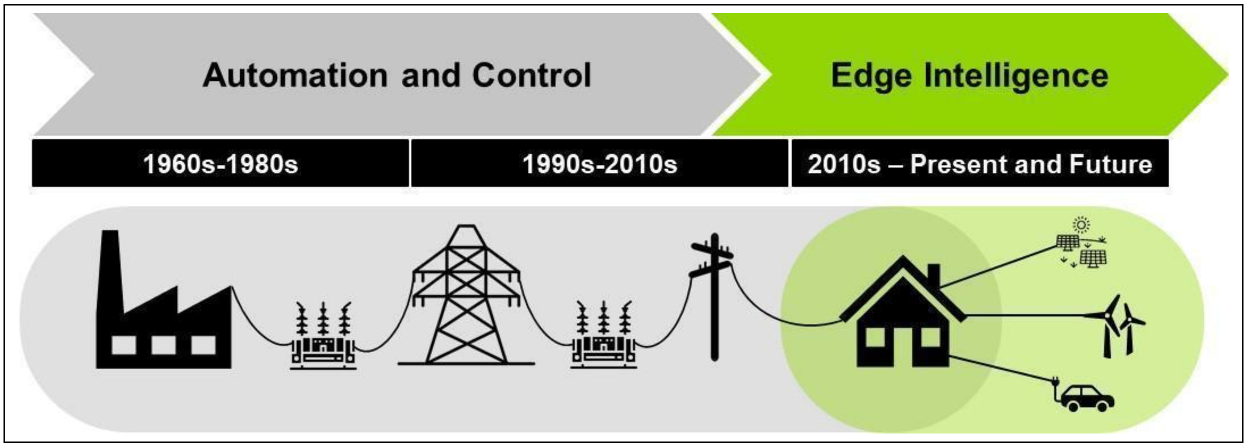
1. High resolution waveform data with sample rates capable of enabling real-time device identification (at least 15,000 samples per second).
2. Edge computing in the meter itself that has access to the raw data stream.
3. Low latency networking via Wi-Fi or cellular to support real-time consumer experiences (with delays within one or two seconds).

Enabling the Next Generation of Energy Analytics

Prior to the technological advancements led by Landis+Gyr and Itron, there was little to no value in performing smart meter analytics at the edge, i.e., inside-the-meter, as the same insights could be generated by performing this analysis in the back office. The current set of smart meter analytics solutions on the market primarily use low resolution data and static reporting techniques to deliver descriptive insights. This has fostered a perception across the industry that these types of solutions provide limited operational value for utilities and their customers. However, the metering foundation discussed throughout this white paper debunks these traditional lines of thinking and redefines the potential value of smart meter analytics moving forward.

The newest generation of smart meters provides a viable solution to the computing and data resolution issues that have inhibited the adoption of inside-the-meter analytics, and true edge computing, to date. Figure 1 illustrates the extension of monitoring and control capabilities across transmission and distribution networks, culminating in the proliferation of distributed intelligence at the grid edge.

Figure 1. The Evolution of Grid Intelligence



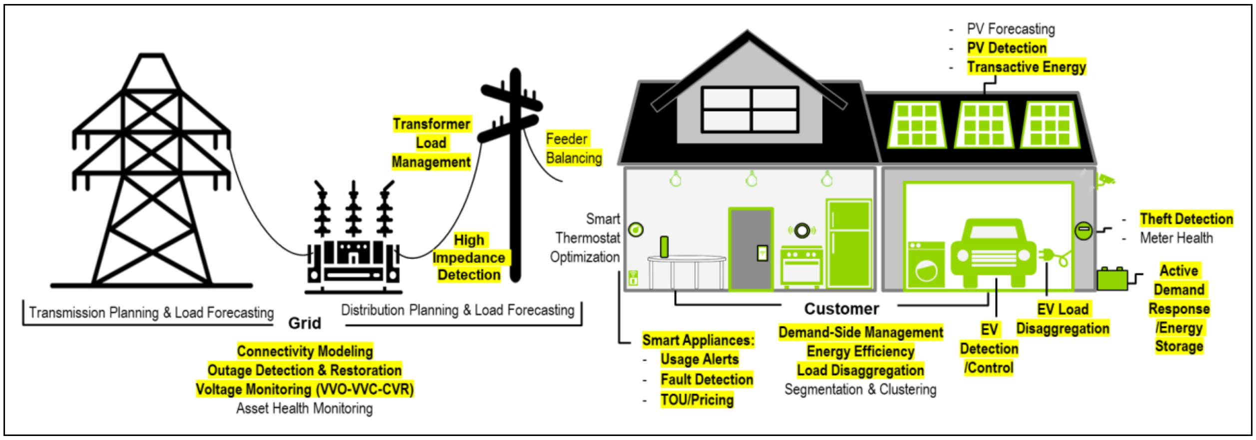
(Sources: Guidehouse Insights)

Where use cases demand real-time intelligence, such as notifying a customer that they have activated an appliance or electric vehicle (EV) during a higher priced time interval or sending real-time notifications regarding detected faults and anomalies, the logical solution is to tap into analytics engines on the meter itself. Moving raw, high resolution waveform data through the cloud would be cost-prohibitive, with latency constraints further deflating the relative value of these respective use cases.

Growing List of Grid and Customer Applications

This section discusses the primary applications used to deliver inside-the-meter intelligence to utilities and their customers. Figure 2 illustrates the wide range of smart meter analytics applications that have been developed to date, while highlighting the subset of use cases that can be supported inside-the-meter.

Figure 2. Inside-the-Meter Intelligence Applications



(Sources: Guidehouse Insights)

Although the list of available localized analytics applications spans several segments, the impact of these next-generation devices in enhancing home automation & energy management and grid management are discussed in more detail below.

Home Automation and Energy Management (BTM)

Smart meters have proved valuable tools for utilities in engaging with their customers since the dawn of home energy reports. Many utilities already offer their customers daily or monthly energy usage information and insights regarding their bill. Yet the majority of these applications have focused on engaging customers from a solely energy management perspective rather than the broader position of overall intelligence for the home. This is largely due to the data resolution constraints of first-generation smart meters and the latency constraints of traditional on-premise and cloud-based analytics architectures. Embedding AI-powered algorithms into next-generation smart meters enables new capabilities around device recognition, real-time usage tracking, and proactive notifications, that support greater benefits around home automation, customer experience, energy management, and more.

To support this broader range of customer- and home-oriented use cases, advanced solutions providers such as Sense use high resolution energy monitoring and machine learning algorithms to provide detailed real-time insights into how devices are being used right now. Customers can watch on an app as they turn on and off the stove or plug and unplug devices, seeing in real time how these actions translate into energy consumption; the app can also provide alerts, for example, if the stove has been left on too long, promoting safety benefits.

This high resolution, real-time approach to delivering customer insights has been proven to facilitate higher levels of customer engagement over traditional home energy management (HEM) methods. Interacting and engaging with customers in real time can also facilitate benefits on the utility side of the meter, including enabling new channels for energy efficiency resource procurement, enhancing demand flexibility for demand response (DR) programs, and facilitating tighter integration and control of new electrified loads (e.g., EVs) on behalf of customers. These sophisticated platforms create a bridge between consumers and utilities at the intersection of the smart home and the grid.

Grid Management and Optimization (Front-of-the-Meter)

High resolution waveform data streams and edge-based computing can also be leveraged to support a broad range of asset- and network-oriented use cases.

With the development of AI-based connectivity modeling algorithms, new location-based (spatial) analytics can deliver near-real-time visibility of network connectivity across meters, transformers, and feeders, based on smart meter data. For example, Landis+Gyr and Itron second-generation devices offer connectivity information and electrical location for every smart meter on the network. These enhanced spatial capabilities (i.e., connectivity information) work in concert with high resolution waveform data streams to facilitate new and improved grid management applications. This information can be used to help grid operators pinpoint outages for quicker power restoration, geolocate unpredictable loads, identify and integrate distributed energy resources, and detect voltage and other power anomalies.

One of the major enablers of these upstream applications is waveform analysis. Emerging localized analytics algorithms can examine waveform data captured by smart meters to identify power quality characteristics both BTM and in front-of-the-meter (FTM). The combination of waveform analysis, connectivity information, and peer-to-peer communications enables grid operators to understand, with a high degree of accuracy, the when (has an outage occurred?), where (location on the distribution system), and what (fault type) of fault occurrences. This allows utilities and grid operators to know what type of crew to roll out and facilitates higher mobile workforce efficiencies and enhanced asset and outage management practices. Customers simultaneously benefit from quicker power restoration and minimized outage times.

While a subset of second-generation smart meters promotes near-real-time data capture capabilities, sophisticated next-generation devices, such as Landis+Gyr Revelo, go beyond sub-second in delivering high resolution waveform data streams. While it may seem like a trivial distinction to some, this delineation can have a significant impact on the accuracy and level of insights delivered to grid operators responsible for management and control at the grid edge.

Inside-the-Meter Intelligence to Become the Norm

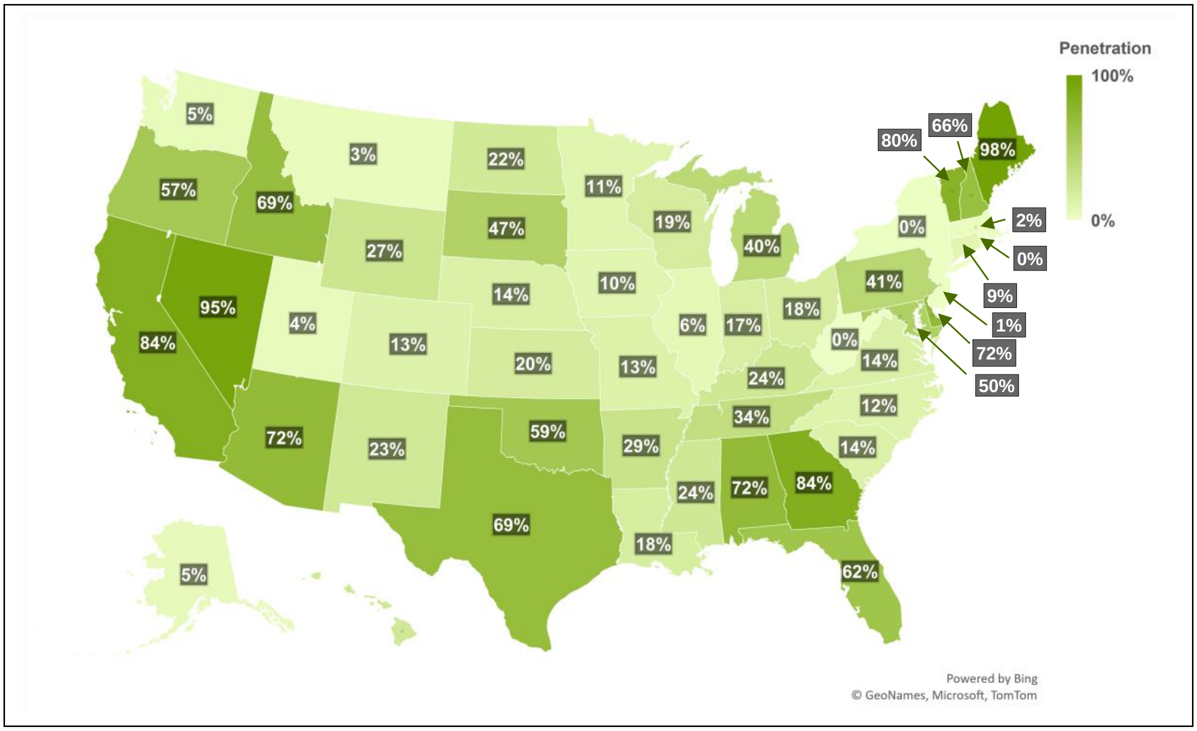
The transition to inside-the-meter analytics is reminiscent of the transformation witnessed in the telecom space with the proliferation of smartphone devices. That sector saw a radical and rapid transition from consumers using phones the way they had been for decades, to using smartphones as computation and application platforms. For example, if a consumer had wanted a music player or navigation system, they would need to purchase a separate piece of hardware to perform that specialized function; with the emergence of smartphones, an entire new market for applications was created due to transformational improvements in device architectures and capabilities. The same can and should happen with energy infrastructure, with the electric meter sitting at the heart of this paradigm shift.

The share of second-generation smart meters in the US is expected to grow from approximately 4% in 2021 to more than 25% by 2030.

Although the market for second-generation smart meters is still nascent, it is not expected to remain so for very long. Industry-leading smart meter manufacturers, such as Landis+Gyr and Itron, have shifted their strategies to promote next-generation devices as their newest flagship offerings. Supplemented by the negligible difference in price between first- and second-generation smart meters, along with the host of benefits and value potential highlighted earlier, it's logical to expect the next wave of smart meter upgrades to primarily involve second-generation smart meters. The combination of supply- and demand-side drivers position these sophisticated devices for overwhelming success moving forward.

The evolution in smart meter technology is also quite timely; when examining the smart meter landscape across North America and Western Europe, there is a massive base of smart meters set for upgrade and replacement over the coming decade. This is due to the initial surge in smart meter installations experienced during the late 2000s and early 2010s; subsidies offered under the US Smart Grid Investment Grant and European Union (EU) Directives programs beginning in 2009 galvanized the US and European smart meter markets. Figure 3 illustrates this in the form of a US heatmap of early-stage smart meter penetration, with several states already reaching more than 50% customer penetration by the end of 2013.

Figure 3. Smart Meter Penetration, US: 2013



(Source: Guidehouse Insights)

Although vendor specifications typically cite the lifespan of smart meters at 20 years, this is largely overestimated, as technology obsolescence and security issues are forcing replacement rates between 12 and 15 years. Based on a jurisdiction scan of Guidehouse Insights' *Global AMI Tracker*, shown in Table 1, the average lifespan of first-generation smart meter deployments is approximately ~12 years. Several factors will ultimately determine meter lifespans, such as weather conditions, availability of new technologies, analytics roadmaps, and communications requirements.

Table 1. Smart Meter Lifespans by Utility

Region & Utility	Logo	Meter Lifetime	Key Insights
North America	**N/A**	**Years**	**Description**
Arizona Public Service	aps	2 - 7 Years	Arizona Public Service installed its first-generation smart meters between 2007 and 2014. The utility began deploying second-generation smart meters as early as 2 years following the initial deployment (e.g., Sedona, Verde Valley), while some meters were replaced after 7 years (Phoenix area).
EnergyUnited	EnergyUnited	~10 Years	EnergyUnited installed its first-generation smart meters between 2009 and 2012. The utility began deploying smart meters as part of its second-generation upgrade deployment in September 2020.
GreyStone Power	GreyStone	~13 Years	GreyStone Power installed its first-generation smart meters in 2007. The utility is deploying smart meters as part of its second-generation upgrade deployment from 2020-2023.
Pedernales Electric	PEC	~17 Years	Pedernales Electric installed its first-generation smart meters beginning in 2003. The utility is deploying Aclara smart meters as part of its second-generation upgrade deployment that began in 2021.
PPL Electric	ppl	~12 Years	PPL Electric finished its initial AMI deployment in 2004. The smart meter replacement project began in December 2016 and was completed in 2019.
Salt River Project	SRP	~11 Years	SRP completed its first-generation smart meter deployment in 2013. The utility is set to complete its second-generation upgrade deployment in 2024.
Western Europe	**N/A**	**Years**	**Description**
Enel – Italy	enel	~15 Years	Enel installed its first-generation smart meters between 2001 and 2006. The utility began deploying Enel smart meters as part of its second-generation upgrade deployment in 2017.
E.ON – Sweden	e.on	~10 Years	E.ON installed its first-generation smart meters between 2006 and 2009. The utility began deploying Landis+Gyr smart meters as part of its second-generation upgrade deployment in July 2019.
Ellevio – Sweden	ELLEVIO	~12 Years	Ellevio installed its first-generation smart meters between 2007 and 2009. The utility began deploying Sagemcom smart meters as part of its second-generation upgrade deployment in September 2020.
Vattenfall – Sweden	VATTENFALL	~15 Years	Vattenfall completed its first-generation smart meter deployment in 2008. The utility began deploying smart meters as part of a two-phase second-generation upgrade project; set for completion in 2022 and 2025, respectively.
Elenia – Finland	ELENIA	~15 Years	Elenia installed its first-generation smart meters between 2004 and 2008. The utility began deploying Aidon smart meters as part of its second-generation upgrade deployment in mid-2020.

(Source: Guidehouse Insights)

In the US, approximately 37 million smart meters will be 12 years old or more by 2023, and nearly 65 million by the end of 2027.

This implies that over the course of the next decade, the US, as well as pockets of Western Europe, will experience a similar surge in upgrade and replacement projects, reminiscent of the first wave of smart meter installations during the 2010s. This anticipated upgrade trend is already playing out in some areas, with a growing number of utilities having selected or installed next-generation devices as part of their second-generation smart meter deployments.

Vendor Approaches to Inside-the-Meter Analytics

At the forefront of this transformation are a combination of smart meter manufacturers and growing ecosystems of analytics providers. These companies have been early movers in the development of enabling technologies and have continued to innovate in their quest for market leadership. Among smart meter manufacturers, two major providers have led the way, Landis+Gyr and Itron:

- **Landis+Gyr** is making inroads in the space with its Revelo line of smart meters. Combining edge computing and waveform data processing technologies, Landis+Gyr's next-generation meters enable real-time pattern recognition of energy delivery, including HEM, fault identification, and safety-based use cases. The ability to capture not just sub-second data streams but high resolution waveform data is a key differentiating feature that positions Landis+Gyr and its analytics providers for success moving forward. The company has attracted a flurry of second-generation smart meter wins over the course of 2020 and 2021, including 1.7 million meters in National Grid's New York service area.

- **Itron** has been developing its portfolio of inside-the-meter applications for nearly a decade. In October 2014, Itron released Riva, its open distributed computing platform. Now branded

Distributed Intelligence (DI), this platform supports applications for meter bypass detection, location awareness, high impedance detection, residential neutral fault detection, transformer load management, solar awareness, active premise load shedding, and many others. More than four million Itron Riva DI meters have been deployed to date with nearly four million licensed applications in use.

While next-generation smart meters provide the enabling hardware behind inside-the-meter intelligence, the development of AI-enabled software applications has been led by open ecosystems of analytics partners. There are a growing number of innovative companies operating across the continuum of inside-the-meter application development, including Sense, Grid4C, and Utilidata, among others.

Sense has worked with Landis+Gyr to embed its high resolution processing software application into Revelo meters; this follows Landis+Gyr's purchase of a small equity stake in the company in January 2019. Sense pioneered working with high resolution waveform data streams and delivering real-time insights through its flagship home energy monitors. But where Sense has historically relied upon additional hardware for high resolution data capture, under the Landis+Gyr partnership, the company now offers embedded analytics applications that can be activated on any Landis+Gyr Revelo meter, without the additional hardware expense. In such a nascent space, Sense is unique in its ability to bring proven expertise to the table in leveraging high resolution waveform data streams across energy, current, and voltage, for the delivery of real-time, actionable insights to drive customer engagement.

Grid4C, meanwhile, is embedding its GridEdgeAI software within Itron's Riva equipment to help customers monitor appliance-level usage and issue proactive notifications. Similarly, Landis+Gyr partnered with Utilidata to deploy energy optimization software within Revelo meters, enabling several grid-based use cases (e.g., fault detection, feeder monitoring).

Conclusion

Ultimately, the stage is set for the proliferation of second-generation smart meters over the next decade and beyond. In terms of market demand, the negligible price difference between first- and second-generation devices, supported by the array of benefits highlighted throughout this white paper, makes these sophisticated smart meters the clear and logical choice for both new and replacement projects moving forward. In terms of market supply, aggressive development and strategic marketing from leading smart meter manufacturers, complemented by rich and growing ecosystems of impressive analytics partners, is forcibly nudging the smart meter market in the direction of next-generation technologies.

The value proposition behind smart meter deployments has yet to be fully realized. Immediate benefits around workforce optimization, billing accuracy, and outage detection represent the tip of the iceberg in potential value creation. This paradigm shift in edge computing functions to not only deliver enhanced benefits to utilities and their customers, but also supports larger climate and decarbonization goals. From using high resolution data from the edge to assist in the deployment and management of new electric loads (namely EVs) to leveraging real-time customer experiences for better calibration of demand- and supply-side resources, the value stacking potential of inside-the-meter intelligence permeates all facets of the energy ecosystem. The edge intelligence enabled by next-generation metering technologies provides real-time visibility to unprecedented data streams to deliver value both BTM and FTM—helping utilities, customers, and society-at-large to better manage energy for a brighter future.[1]

[1] Revelo Meters Overview, Landis+Gyr, https://www.landisgyr.com/product/revelo-meters.

Acronym and Abbreviation List

AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
BTM	Behind-the-Meter
DI	Distributed Intelligence
DR	Demand Response
EU	European Union
EV	Electric Vehicle
FTM	Front-of-the-Meter
HEM	Home Energy Management
IT	Information Technology
US	United States

Table of Contents

Scope of Study

Guidehouse Insights prepared this white paper, commissioned by Sense, to explore how innovative applications of advanced analytics and AI are helping utilities maximize the value of their AMI investments. It provides an overview of smart meter analytics and discusses the evolution of more sophisticated architectures operating at the grid edge, helping provide more timely, relevant, and actionable insights for customers and grid operators.

Published 3Q 2022