Seeing behind the meter

How electric utilities are adapting to the surge in distributed energy resources

Prepared by OXFORD ECONOMICS

SIEMENS

Introduction

Distribution utilities in North America are working hard to keep up with historic changes taking place in the way electricity is generated, consumed, and monetized. But many companies lack the ability to measure and manage an energy distribution grid impacted by the rapid adoption of electric vehicles, solar panels, and batteries, known as distributed energy resources, or DERs.

One big challenge for utilities is "seeing behind the meter"—a widely used term for understanding the behavior of customer-owned equipment or resources that are not monitored by traditional utility devices. For more than a century, visibility into consumption rates was generally limited to monitoring the amount of electricity an individual home or business pulled from the grid. Now many of those same customers are generating and storing electricity themselves, reshaping demands on the system and creating a new market for selling power back to utilities.

Before the presence of DERs on the grid, energy flow came from only one direction—from the generator to the load. With DERs, the flow can be bi-directional and can change depending on the amount of DERs present and their behavior.

Utilities must now plan for increasingly complex flows of electricity to and from their grids to manage services, operations, and control rates, and compensate customers for the electricity they generate. There are also implications for equitable treatment of low-income customers and the ability to meet sustainability goals.

To better understand how electric utilities in the US and Canada are managing the rapid adoption of behind-the-meter distributed energy resources, Oxford Economics and Siemens surveyed 100 decision-makers from the industry during the fourth quarter of 2023. To complement the survey findings, two in-depth interviews were conducted with Yoh Kawanami, Director of Customer Energy Resources at Hawaiian Electric, and Michael McMaster, Solution Architect for NextGen Grid Management at Siemens.[1]

The research highlights the extent to which utilities are challenged by behind-the-meter DERs—and the benefits they could enjoy if they strategize today for the grid. Among key findings:

- Electric utilities are facing unprecedented growth in the digitalization of customer experience with the adoption of behind-the-meter DERs, and they believe this is the beginning of a potentially longer-term trend.
- Most utilities can quantify the adoption of behind-the-meter DERs, but they lack the requisite detail needed to understand the location and behavior of these resources—both of which are necessary for effective grid management.
- Utilities face a reality in which this limited visibility creates a range of operational challenges, including the ability to conduct interconnection analysis (the data needed to understand the impact of solar installations on the grid) and plan infrastructure upgrades to prevent issues that can hinder grid performance.
- Solutions like demand-side and DER management programs are hard to implement, largely due to hesitation and lack of interest from customers—but utilities that get them right could experience significant benefits, such as reduced costs, increased grid flexibility and resilience, and improved customer satisfaction.

These challenges are garnering the attention of industry leaders around the world. The International Energy Agency (IEA) calls behind-the-meter DERs "largely invisible" and says this opacity makes it nearly impossible for grid operators to monitor and integrate these resources into their grid operations.[2] Implementing the tools and technologies needed to manage this transition from single-directional to bi-directional flows of energy will help utilities and consumers alike to take advantage of the promises of increased DERs on the grid.

1 Note: At the time of his interview for this report, Michael McMaster was employed at Arizona Public Service as DERMS Program Lead (DERMS stands for Distributed Energy Resources Management System). After the conclusion of his interview and before the publication of this report, Mr. McMaster became employed at Siemens as Solution Architect for NextGen Grid Management.

2 Kim, D., & Fischer, A. (2021, September 9). Distributed Energy Resources for Net Zero: An asset or a hassle to the electricity grid? https://www.iea.org/commentaries/distributed-energy-resources-for-net-zero-an-asset-or-a-hassle-to-the-electricity-grid.

The rise of **active energy producers**

Rapidly increasing investments in renewable energy solutions by households, businesses, and communities in the US and Canada are transforming passive energy consumers into active energy producers—also known as **prosumers**—and fundamentally altering the energy market as we know it.

The reasons behind the rise of distributed energy resources are no mystery. Consumers, who have experienced weather-related power outages and increased utility costs, are seizing opportunities to generate their own electricity using sustainable resources like solar or wind. Government incentives such as tax breaks, fee reductions, grants, and rebate programs have also driven investment in DERs, while lowevring their cost.

At the same time, high gasoline prices and heightened awareness of sustainability needs are motivating consumers to reduce their carbon footprint. For example, many consumers are installing battery storage systems or investing in electric vehicles produced by companies like Tesla, whose Model Y recently became the best-selling car in the world.

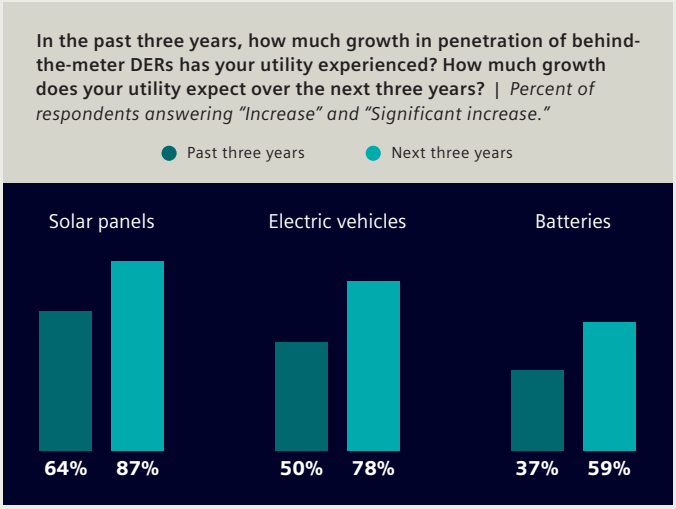
This transition in the energy market brings real opportunities for utilities to tap alternative sources of power, increase the resilience of the grid, and meet sustainability goals. But the lack of behind-the-meter visibility at most companies makes it hard for them to design cost-effective monitoring and repurchase programs and to provide reliable power—crucial elements for maintaining grid stability and customer trust and satisfaction.

At the current rate of electric vehicle adoption, the traditional grid capacity will need to double by 2030. But the grid cannot be built at that rate—it has taken 100 years to enable the capacity available today.

Another issue is that, for both utilities and customers, the cheapest energy to produce is that which they don't generate.

These inefficiencies can be alleviated by the incorporation of behind-the-meter DERs and the use of demand-side resources (products, systems, or strategies that reduce electric load, which reduces the need for additional generation).

Fig. 1 Growth in customer adoption of behind-the-meter solar panels, electric vehicles, and batteries



Furthermore, without visibility, it can be difficult for utilities to identify the source of grid disruptions, including voltage visibility and control issues, back-feeding, and protection and control coordination issues.

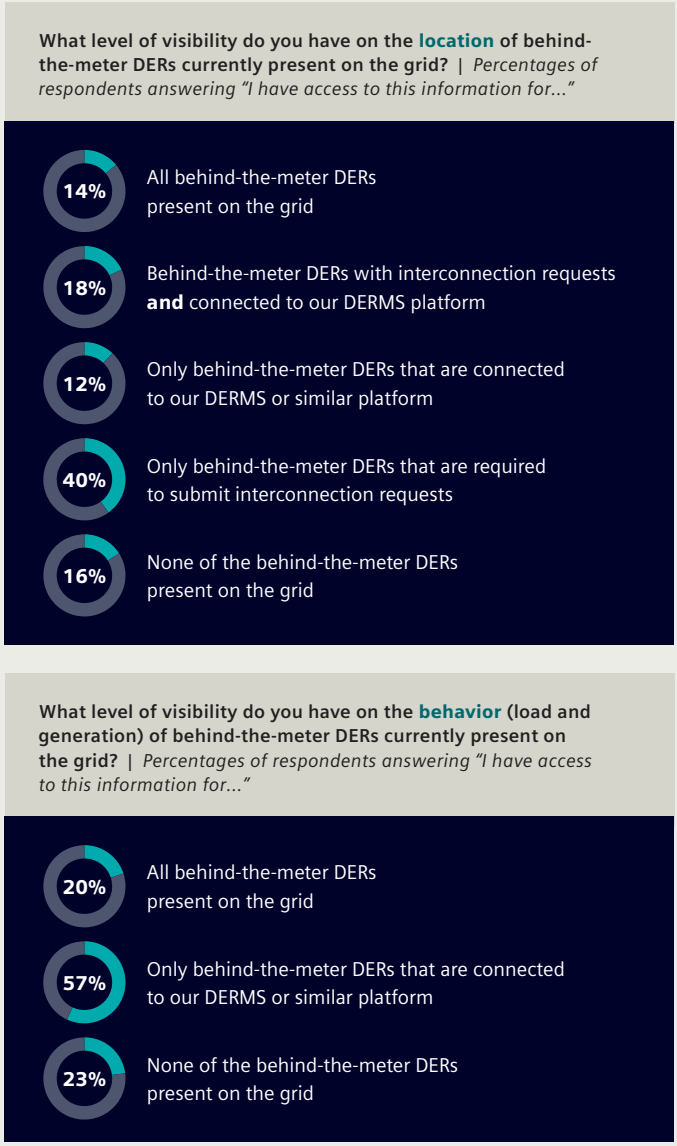
Most utilities surveyed understand the basics of the new energy landscape, like the overall number of DERs on the grid. For example, at least half of the utilities surveyed experienced increases in the adoption of solar panels and electric vehicles over the past three years, and even more anticipate continued growth of these resources, especially for electric vehicles, in the near future. Batteries are gaining popularity as well, with over half of respondents expecting increased penetration in the next three years.

More granular details, however, are harder to track. The survey data shows a lack of clarity for utilities as they try to understand DERs' location, size, and activity. For example, DER location information is often accessible only for resources that are either connected to grid-management software like distributed energy resource management systems (DERMS) or required to submit interconnection requests to connect to the grid—or, in some cases, both. In fact, 70% of respondents rely solely on interconnection requests and/or integrations with platforms like DERMS to gather information about the location of behind-the-meter DERs. Even though this data is accessible, it remains incomplete because the majority of customers are not enrolled in DER management programs.

"Advanced metering infrastructure data doesn't necessarily give you full visualization of what's generated from that solar system, so we would have to deduce that. We just know what's happening at the meter. But what's happening behind it, like how much solar is being generated or battery is being discharged, we don't have visibility."

Yoh Kawanami
Hawaiian Electric

Fig. 2 Utilities struggle to understand where and how DERs are used by consumers



The survey also shows that more than half (57%) of utilities rely on connections to a platform like DERMS to understand the behavior (e.g., load and generation) of these resources, while nearly one-quarter lack this visibility for all the DERs on the grid. And these solutions may not be enough: the utilities surveyed estimate they are gaining visibility into, on average, 36% of all behind-the-meter DERs present on the grid through connections to their DERMS platform. Though visibility is on the rise, the data is not easily accessible by utilities because it is siloed across different systems.

Operational challenges caused by behind-the-meter DERs are known but difficult to address due to lack of visibility

Utilities are aware that behind-the-meter DERs are impacting the grid, but they only have a high-level overview. The vast majority of those surveyed say they have visibility into the resources' effects on infrastructure, including feeders, transformers, and substations. But Mr. McMaster of Siemens says most of their focus is likely placed on worst-case scenarios like whether DERs disrupt their ability to deliver power to customers.

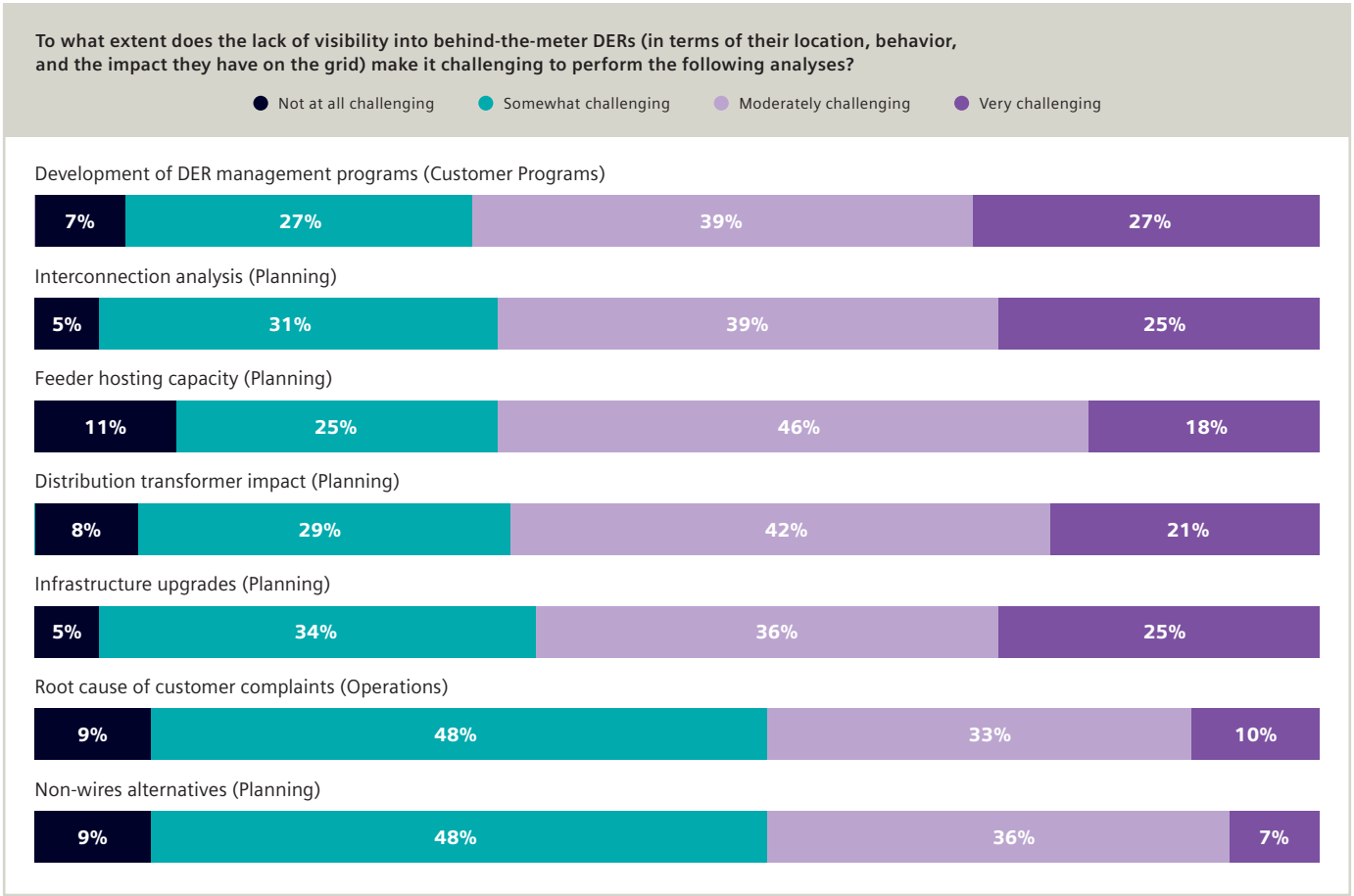
"Just because there's an understanding of the impact doesn't necessarily mean there's an understanding of what the device is doing," he says. Grid insights tend to be more reactive than proactive—in other words, utilities are more focused on making sure these devices do not cause harm to the grid or customers (e.g., through service outages) than truly understanding the opportunities they bring to the table.

Behind-the-meter DERs create major operational issues for a majority of the surveyed electric utilities, which also must contend with a power grid that can be prohibitively costly to upgrade and digitize. Nearly three-quarters of utilities say customer adoption of behind-the-meter DERs creates operational challenges, including:

- 59% Voltage visibility and control issues
- 49% Back-feeding
- 42% Protection and control coordination issues
- 39% Distribution transformer and conductor overloads
- 24% Masked or hidden loads

These issues can materially impact a utility's ability to allocate resources effectively. Roughly two-thirds of utilities say limited visibility makes it challenging for them to develop DER management programs; conduct interconnection analysis; or plan feeder hosting capacity, distribution transformer impact, and infrastructure updates. A vast majority of utilities surveyed (91%) also struggle to identify the root cause of customer complaints or plan non-wire alternatives.

Fig. 3 Operational challenges are driven by limited visibility behind the meter



Optimizing the grid through **demand-side and DER management programs**

The ongoing decentralization of electric power generation creates challenges. Both utilities and their customers must adapt to a new culture and a more nuanced relationship than the simple provider-user dynamic that has prevailed since the grid was first built more than a century ago. The payoff for both providers and consumers should include reduced costs, increased security and reliability of the grid, and opportunities to innovate for a greener future and achieve sustainability goals.

Mr. McMaster says the growth of behind-the-meter DERs could be a net positive. "In some ways, it can be beneficial, where effective use of demand response can help shift the load outside of the peak where it would be fairly costly and fairly difficult on the system as a whole."

Utilities can help control the demand for electricity by implementing **demand-side management programs**, which incentivize customers to modify their energy consumption patterns during peak hours or reduce their overall energy consumption. These programs include energy efficiency investments, time-variant pricing (e.g., time-of-use rates), and demand response programs.

More than two-thirds (69%) of the utilities in our survey are currently implementing demand-side management programs—and nearly all of them plan to expand their programs within the next five years.

DER management—the monitoring and analysis of data collected—is also crucial for grid visibility but more difficult to achieve: only 37% of respondents say they are currently implementing DER management programs. Meanwhile, the vast majority of respondents who are not currently implementing DER management programs do not expect to have these programs operational for another three to five years.

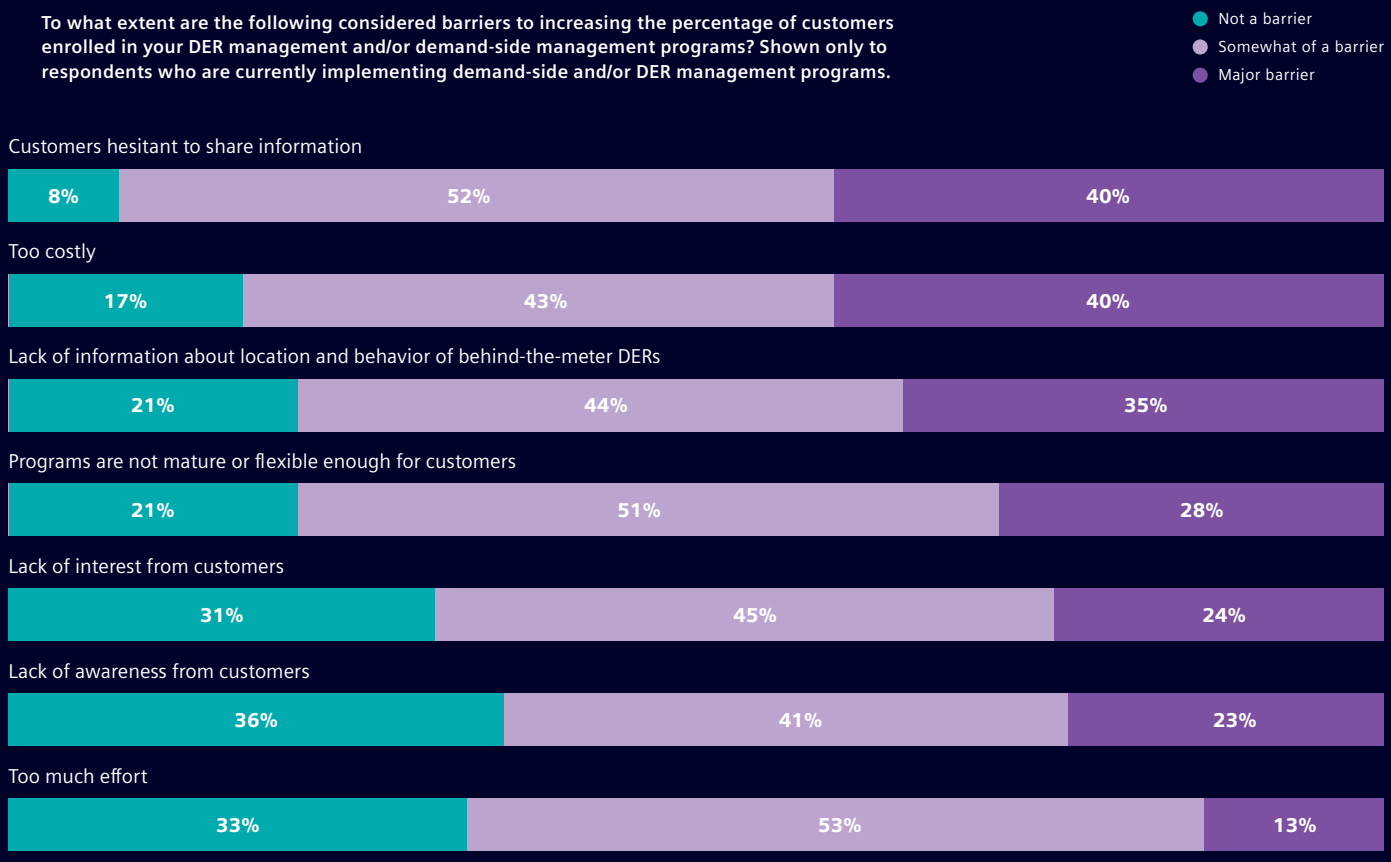
DER management involves the communication and management by grid operators of groups of DERs to deliver grid services and balance demand with supply, which is only possible when customers opt in and allow their utility to manage their DERs. But getting customers to enroll is, according to Mr. Kawanami, the hard part. This might explain why utilities estimate that, on average, only 35% of their customer base participates in their DER management programs—a notable drop from the 54% average participation

rate for the incentive-based demand-side management programs. Increasing enrollment in both demand-side and DER management programs is key for increasing visibility behind the meter.

Mr. McMaster explains some of the challenges utilities face when building a two-way partnership with their customers. For example, asking customers to share information about their consumption habits, and at times even change those habits, might not give utilities the predictable outcomes they need. "Utilities have to rely a lot on reliability, and customers obviously want privacy," he says. "Customers have their livelihoods, their smart resources, and their electric vehicle better be charged when they need it. All these other utility programs that might help with the bill are nice, but they also need to not inconvenience their daily routine."

According to the survey, customer hesitation to share information is one of the top barriers to increasing enrollment in DER and demand-side management programs, along with other challenges such as cost and limited visibility behind the meter. A majority of respondents say they also struggle with enrollment due to a lack of customer interest and awareness.

Fig. 4 Customer hesitation and cost are top barriers to management program participation

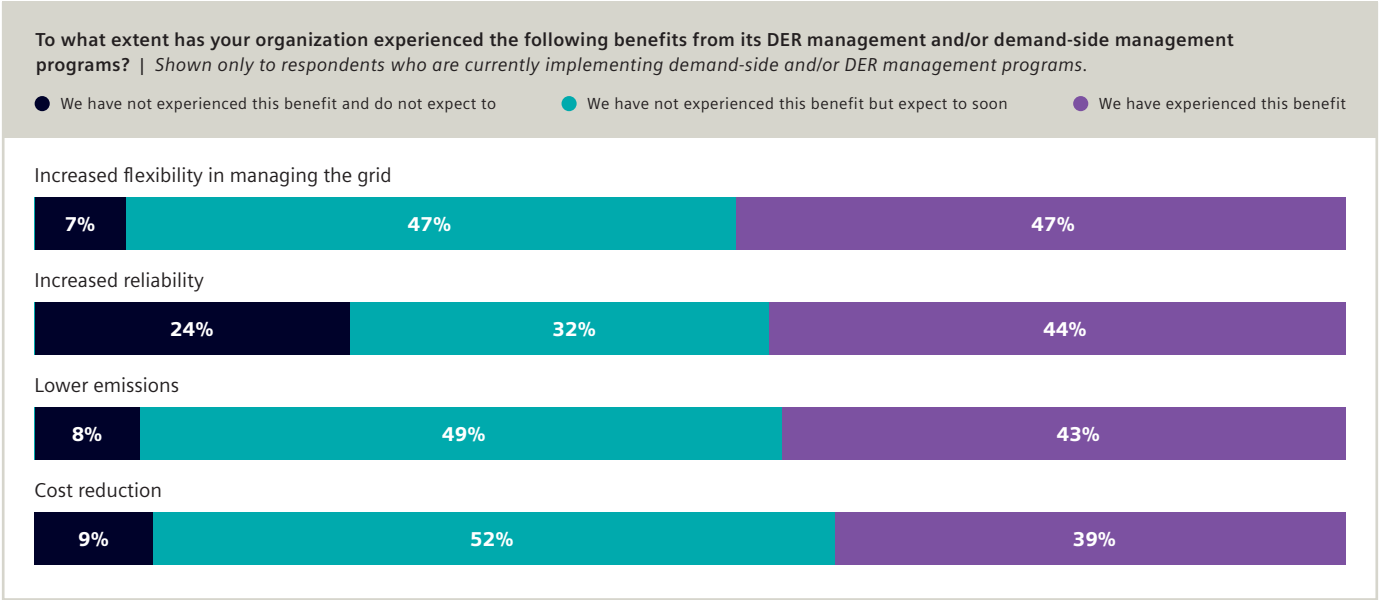


One way to address the friction between data collection and privacy, says Mr. McMaster, is to gather usage and preference profiles that include information on when customers are comfortable with utilities controlling their DERs and when they are not. Prosumers may feel comfortable with sharing their energy consumption and production information, if it doesn't interfere with their routine—that is the challenge, says Mr. McMaster.

Bridging this gap might require reframing the customer-utility relationship from an impersonal, transactional one to a collaborative one that can help maintain low costs while protecting the environment, says Mr. McMaster. There is a paradigm shift that must occur to change customer perception of utility companies: they are not solely billing companies; instead, they are willing to collaborate with consumers to help achieve a common goal.

The benefits of management programs are clear: many utilities have already experienced increased flexibility in managing the grid, increased reliability, lower emissions, and cost reductions as a result of their demand-side or DER management programs. The remainder of respondents say they are optimistic and expect to see these benefits soon. While some express doubts about the programs' ability to increase the reliability of electricity transmission, few feel the same way about other benefits.

Fig. 5 Demand-side and DER management programs help utilities manage the grid more effectively



SIDEBAR:

The social component of DER management

The rising penetration of behind-the-meter DERs impacts more than just grid management and operations: it can also lead to more complicated billing processes that result in societal inequities.

Customers who participate in demand-side and DER management programs can sell the energy produced by their solar panels to utilities or charge their electric vehicles outside peak consumption hours to reduce their utility bills. These incentives might improve the stability of the grid and ease the management of behind-the-meter DERs—but they do not benefit everyone. Existing business models at utility companies may mean that decreasing bills for some customers requires increasing bills for others, an act that often hits communities that cannot afford sustainable energy solutions hardest.

"The more solar you install, someone else is going to have to pay for what's not been paid by the solar customer," says Mr. Kawanami of Hawaiian Electric. "And that's inequity. Because the people that can afford it are able to drop their bill, and people that can't afford it are now paying more to compensate for that."

To combat these inequities, Hawaiian Electric, Hawaii's largest electricity supplier, is focused on developing programs that are available and fair for everyone. In fact, Mr. Kawanami says inequities are already emerging, given that a substantial part of the market already has solar installed. This, he adds, is why it is so important to design a program that makes sure all customers win—not only those who invest in clean solutions.

Arizona Public Service, Mr. McMaster's previous employer, has these inequities on its radar as well. "Our commission had us release rebates for batteries, which was very good for customer adoption, but can prove to be a challenge to target multi-family dwelling customers," he says.

He mentions alternative options, such as the Country Acres Solar Project pioneered by the community-owned, not-for-profit Sacramento Municipal Utility District (SMUD) in California. The utility's initiative will create enough commercial solar energy and battery storage generation to power more than 80,000 homes per year. "Customers get the relief on the billing impact without needing to have the upfront income or real estate to put in a battery or invest in electric vehicles," says Mr. McMaster.

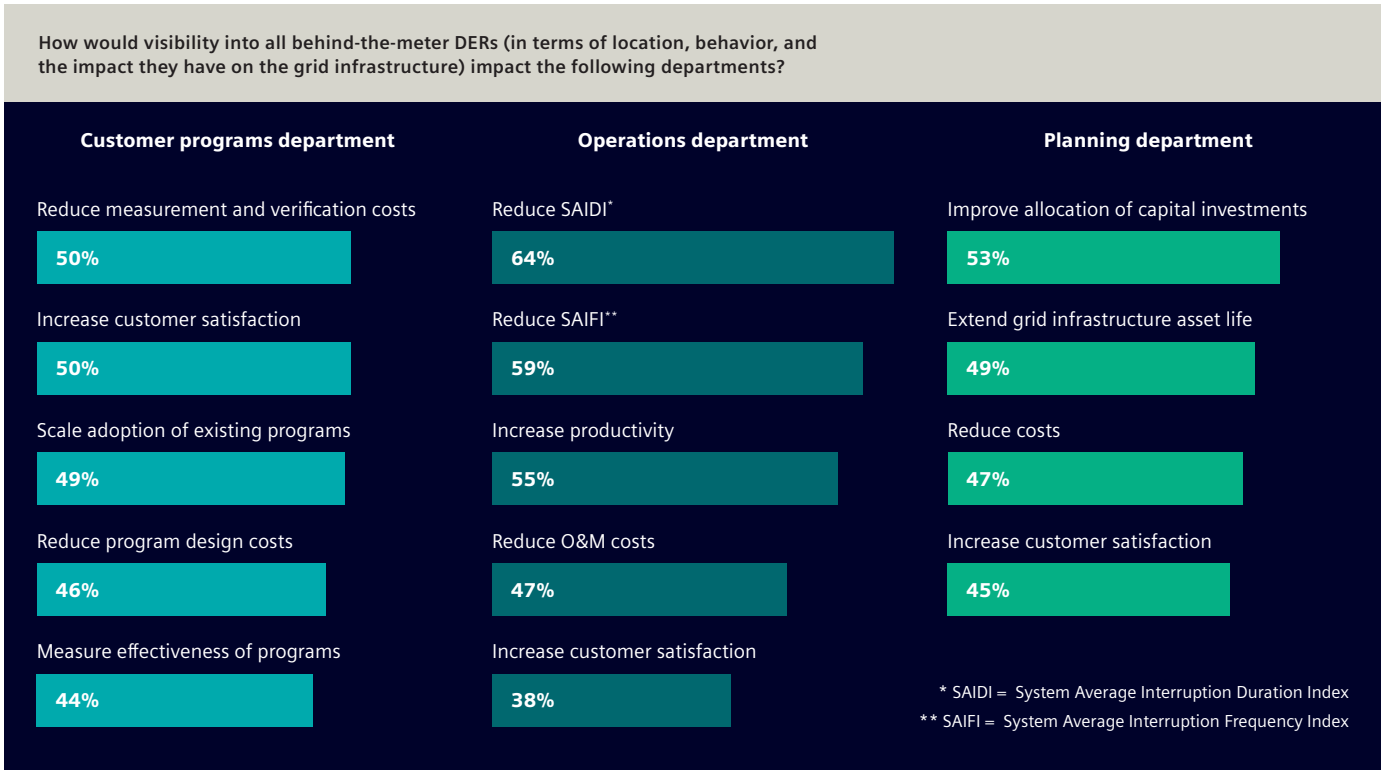
The tension between equity and green options is a persistent issue, but awareness of the challenge is a vital first step for utilities to manage behind-the-meter DERs and deepen the relationship with their customers.

The future of the grid relies on **visibility**

Increased visibility behind the meter could lead to a broad range of benefits for utilities, especially in their operations, planning, and customer programs departments.

For example, more than half of respondents expect visibility into the behavior and location of all behind-the-meter DERs to benefit their operations department by reducing their SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) metrics and increasing productivity. Planning departments could experience improvements in the allocation of capital investments, leading to extensions in grid infrastructure asset life, reductions in costs, and increased customer satisfaction rates.

Fig. 6. Visibility into behind-the-meter DERs could improve planning, operations, and customer programs



Leveraging artificial intelligence to improve grid management

Dealing with disruptions driven by the influx of behind-the-meter DERs requires methodical planning, updated processes, and new technologies.

In order to achieve its commitment to 100% clean and carbon-free electricity by 2050, Arizona Public Service has deployed a wide range of programs across different DER asset classes. But the utility is also interested in the potential of harnessing new technologies to aid in the visibility and management of these resources. "I think the long-term solution is going to involve pushing some intelligence toward the edge, but you have to choose between telemetry and AI. The former tends to be fairly costly, but if you talk to any utility, the moment you talk about intelligence, algorithms, or AI, that's a little bit outside of our normal comfort zone," says Mr. McMaster. "Going to that proactive side is a little bit outside of what utilities are used to investing in."

Mr. McMaster sees plenty of opportunities for AI, including the current wave of highly accessible generative AI applications, to transform processes and ease the transition to green energy. Uses of the technology for the utility industry include real-time data management and modeling, customer engagement and communication, regulatory compliance, and solution development.

The long-term goal, as these technologies are developed and utility companies add capabilities to adopt them, is a future in which generative AI is used to manage behind-the-meter DERs and mitigate grid issues with precision and efficiency not yet available today.

Where to go from here

The complexities introduced by the rapid adoption of behind-the-meter DERs are not insurmountable. Gaining actionable insights into the opportunities and challenges these resources bring can help utilities better manage the grid, reducing costs for themselves and their customers and improving grid resilience—all while accelerating progress on sustainability goals.

Based on the findings from the survey and expert interviews, utilities can prepare for ongoing changes to the energy market and gain visibility behind the meter in the following ways:

Invest in the technologies that boost visibility behind the meter—a necessity for utilities to successfully navigate the energy transition and future-proof the grid.

Most utilities can expect a significant increase in the customer adoption of solar panels, electric vehicles, and batteries over the coming years. But tracking this growth is not enough. Utilities must invest in the tools required to build a more accurate model of the distribution grid and better visualize the location, behavior, and impacts of behind-the-meter DERs. Advanced technologies, like those enabled by artificial intelligence, can take data modeling and solution development to the next level.

Prioritize strategies like demand-side and DER management programs for increased flexibility behind the meter.

Implementing and expanding these programs is crucial for understanding and managing customer-owned DERs, resulting in increased reliability, stability, and security of the grid. The time to start planning is now: the utilities making use of demand-side and DER management programs are already experiencing lower emissions, reduced costs, and increased flexibility in managing the grid—or expect to in the near future.

Strengthen customer trust to boost participation in management programs.

The utility-customer relationship is changing as energy consumers transform into energy prosumers. With a deeper understanding of their customers' needs and preferences, utilities can develop transparent policies and practices that reduce barriers to program enrollment, including customers' lack of interest and hesitation to share information.

About Siemens Smart Infrastructure

Siemens Smart Infrastructure (SI) is shaping the market for intelligent, adaptive infrastructure for today and the future. It addresses the pressing challenges of urbanization and climate change by connecting energy systems, buildings, and industries. SI provides customers with a comprehensive end-to-end portfolio from a single source—with products, systems, solutions, and services from the point of power generation all the way to consumption. With an increasingly digitized ecosystem, it helps customers thrive and communities progress while contributing toward protecting the planet. Siemens Smart Infrastructure has its global headquarters in Zug, Switzerland. As of September 30, 2023, the business had around 75,000 employees worldwide.

About Oxford Economics

Oxford Economics is a leader in global forecasting and quantitative analysis. Our worldwide client base comprises more than 1,500 international corporations, financial institutions, government organizations, and universities. Headquartered in Oxford, with offices around the world, we employ more than 600 people, including over 450 economists, industry experts, and business editors. Our best-in-class global economic and industry models and analytical tools give us an unmatched ability to forecast external market trends and assess their economic, social, and business impact.

About the research

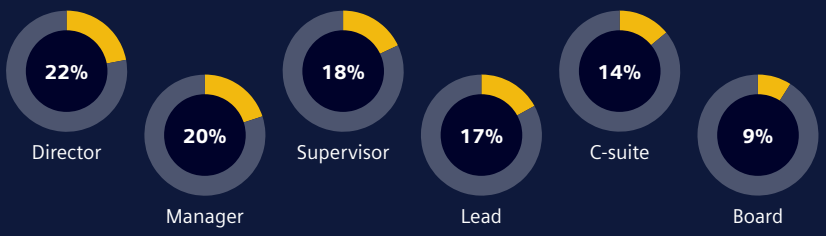
Oxford Economics partnered with Siemens to survey 100 decision-makers from electric utilities in the United States and Canada to better understand the challenges and opportunities their organizations face as the adoption of behind-the-meter DERs continues to rise. The survey was conducted using computer-assisted telephone interviewing (CATI) methods and fielded in October 2023.

Respondent breakdown

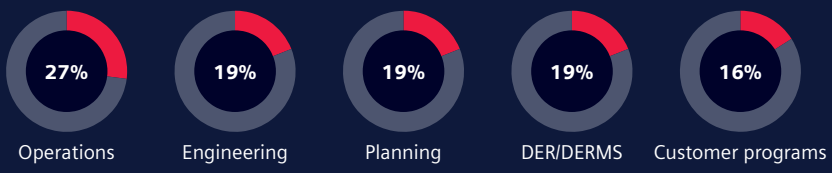
Country:

Distribution utility type:

Level of seniority:



Role:



Utility size (number of customers):