Rural Electric Cooperative Smart Grid Benchmarking Report

Creating value with smart grid applications

September 2021

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Introduction

Background and benchmarking project goals

Members have implemented various smart grid applications with the aim of optimizing their operations through advanced networks, intelligence, automation, and control.

Rural Electric Cooperative Smart Grid Benchmarking Report

Two national cooperatives, CFC and NRTC, collaborated on this comprehensive benchmarking initiative to help our members better anticipate the results of smart grid applications and understand best practices for evaluating and planning for them.

This report consists of four main sections:

1. Prevalence of value streams and applications
2. Application details and results
3. Planning and evaluation processes
4. Funding and financial considerations

Cooperative Principle #6: Cooperation among cooperatives … Thank you to our members

We are grateful to the 60 cooperatives that shared details of their smart grid experience with us. Their participation and experience will benefit other electric cooperatives considering smart grid technologies, helping them make informed decisions.

Survey population and electric cooperative overview

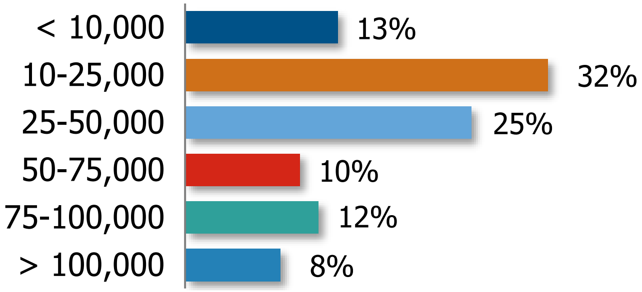
Electric cooperative overview [1]

- Serve over **20 million homes and businesses**
- Own and maintain **2.7 million miles** of distribution lines
- Cover **56% of the nation's landmass**
- **832 distribution cooperatives** deliver electricity and other services to their communities
- **63 generation and transmission** cooperatives provide wholesale power

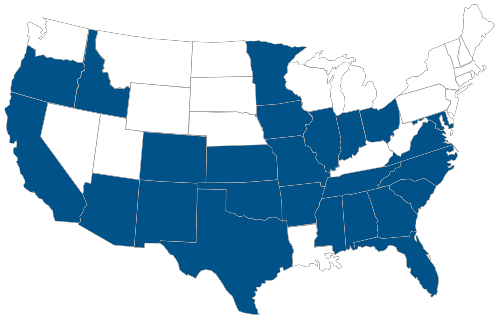
Survey population and methodology

- **60 distribution cooperatives** in **25 states** with diverse characteristics [2]
- At least two cooperatives from each of NRECA's 10 regions
- Members of **various sizes** (as measured by electric meters)
- Members that have **deployed at least two smart grid applications**
- Respondents have deployed an average of more than six smart grid applications; results may not be indicative of the typical cooperative
- Mostly general managers or senior engineering staff

Participants by meter count



Participants by state



Participants by function

(1) Source: Electric Cooperative Fact Sheet, NRECA, July 2021
(2) 50% response rate of 120 members surveyed

Smart grid technologies help meet new demands while optimizing electric operations

New technologies are changing power distribution and creating new demands on electric cooperatives.

Smart grid involves communications and control to an increasing number of end points primarily to:

- **Better respond to end-consumers** and present them with information
- **Better diagnose and respond to outages** and minimize downtime
- Better understand the sources of demand and plan accordingly
- Help design programs to **curtail peak usage** and **optimize load shape over time**
- Analyze and predict equipment failure to **optimize maintenance**

This report provides benchmarking results to help members better anticipate the results of these applications and understand best practices for evaluating and planning for smart grid technologies.

Executive Summary

Key Takeaways

Respondents **very active in smart grid** …

389
Smart grid **applications** deployed by **60 respondents**

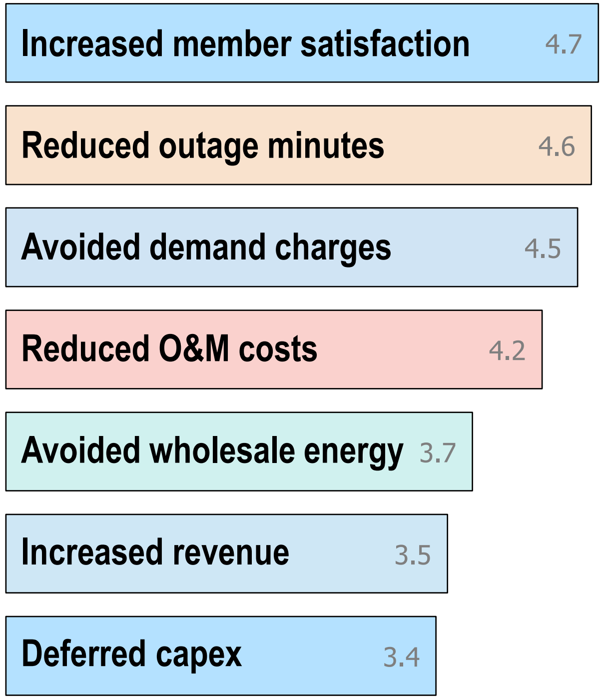
97%
Deployed a **reliability** application

71%
Integrated a **distributed energy resource**

76%
Using an **asset management/ analytics** solution

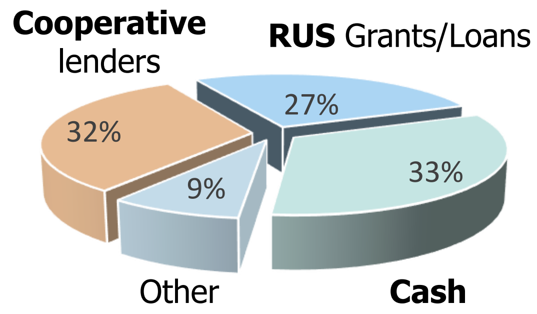
… to help provide **reliable, affordable service** …

Priorities for Value Streams (1-5 scale)

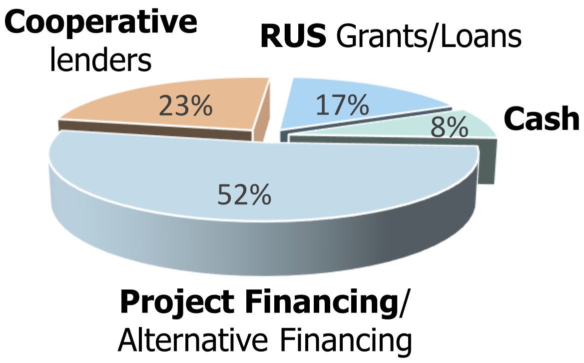


… **funded** by a mix of co-op lenders, RUS and cash

Applications (excluding DER)



Distributed Energy Resources



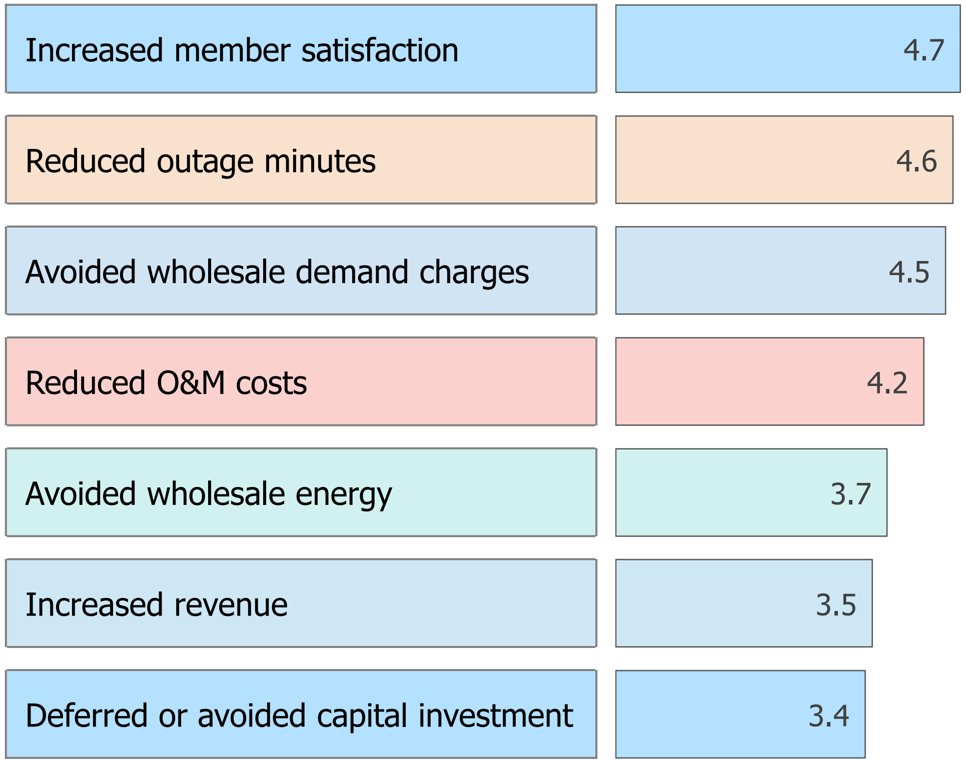
Our members' mission is to provide reliable, affordable service; value streams that further these goals are the most important to cooperatives …

Increased member satisfaction, not surprisingly, ranked as the most important objective for smart grid applications by respondents.

Members achieve this by ensuring that service is:

- **Reliable:** A primary driver of member satisfaction is **reducing the frequency and duration of outages**, which ranked second in importance.
- **Affordable:** **Reducing wholesale demand charges** during peak periods followed closely behind as it materially impacts rates.

Importance of Value Streams



… and cooperatives have deployed several smart grid applications to enable these value steams

Members are deploying applications to better operate their networks and prepare for new demands on their businesses.

- Most respondents have deployed automated metering, outage management systems (OMS), and substation connectivity that form the basic building blocks of smart grid.
- **63%** of respondents have deployed **utility-scale solar**, either directly or through their G&T, as a form of **clean, low-cost energy**.
- Advances in communications technologies are enabling solutions such as **voltage optimization** and **consumer demand response (DR) programs** to reduce peak demand charges.
- **73%** of respondents **have implemented or are planning for electric vehicle (EV) DR programs** to optimize future load.
- Most respondents have deployed substation monitoring, with many moving to advanced equipment health/analytics for substations and downstream assets; broadband networks – mostly fiber – are being deployed to enable these capabilities.

Deployment Status (1)

		Shaded: Deployed	White: Planned
Metering	AMR/AMI (2)	95%	5%
Reliability	OMS (3)	97%	3%
	FLISR (4)	26%	33%
DER (5) Integration	Utility-scale solar	63%	17%
	Utility-scale storage	21%	38%
	Behind-the-meter solar/storage	36%	38%
Load Management	Volt/VAR(6) optimization (VVO)	41%	31%
	Thermostat DR program	24%	33%
	Water heater DR program	36%	26%
	EV DR program	16%	57%
	Real-time load balancing	9%	41%
Asset Management	Equip health/predictive analytics	34%	38%
	Downstream plant health/analytics	19%	21%
	Substation monitoring	74%	17%
Power Quality	Auto. end-of-line voltage regulation	41%	34%
	Automated power factor correction	36%	38%

Shaded: Deployed White: Planned

(1) Includes solutions provided by G&Ts
(2) AMR = automated meter reading,
AMI = automated metering infrastructure
(3) OMS = outage management system
4) FLISR = fault location isolation and service restoration
5) DER = distributed energy resources
6) VAR = Volt-Ampere reactive

nrtc CFC

Smart grid initiatives enable multiple value streams, positive financial returns and increases in member satisfaction

Savings reported across all applications

The chart shows the relative savings reported for each application

- Outage reduction from reliability and asset management solutions saw the highest relative savings followed by demand charge reduction from storage and DR programs.
- Reliability solutions and behind-the-meter solar/storage had the largest reported effect on member satisfaction.
- Reliability solutions, Volt/VAR, utility-scale solar/storage and downstream health/analytics delivered the highest internal rates of return (IRRs).

Members use different business case methodologies

- Different approaches on how to quantify outage reduction and labor savings drove differences in reported investment returns.

Relative value identified by survey responses (1)

		Avoided energy cost	Avoided Demand Charges	Reduced outage minutes	Reduced O&M costs	Avoided/ Deferred Capex	Increased member sat	IRR
Reliability	OMS			●	●		●	●
	FLISR			●	◔		●	◕
DER Inte-gration	Utility-scale solar	◕	◔				◕	◕
	Utility-scale storage	◕	●				◑	●
	Behind-the-meter solar/storage	◔	◔				●	○
Load Mgmt	Volt/VAR optimization (VVO)	◑	◕				◔	●
	Thermostat DR program	◑	◕				◑	◑
	Water heater DR program	◑	●				◔	◕
	EV DR program	◕	●				◕	◑
	Real-time load balancing	◕	◕				○	◑
Asset Mgmt	Equip health/predictive analytics			●	◔	◔	◑	◔
	Downstream health/analytics			●	◕	◔	◕	●
	Substation monitoring			●	◑	◔	◕	◔
Power Quality	Auto. end-of-line voltage reg.	◔	◑		◔	◑	◑	◕
	Automated power factor correct	◕	◑		◑	◑	◔	◔

Lowest → Highest

○ ◔ ◑ ◕ ●

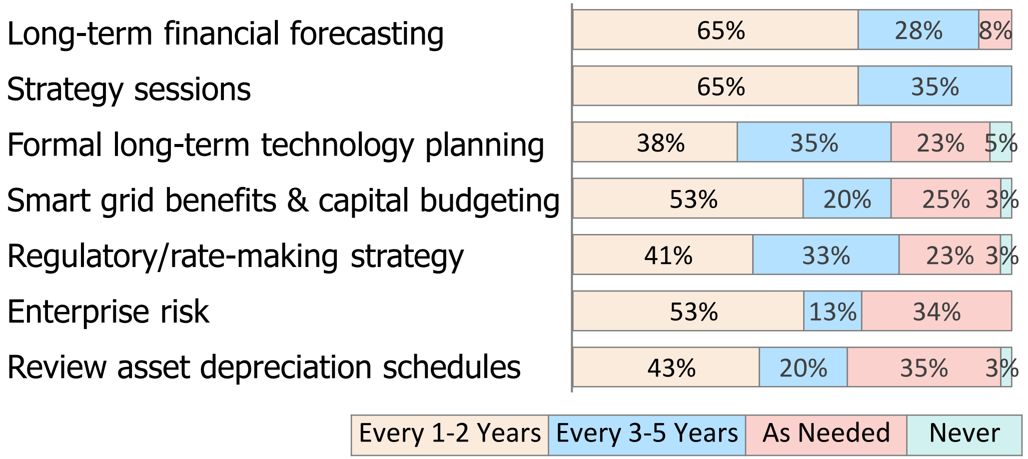
(1) Methodology: Represents relative value of all savings-related value streams, member satisfaction and IRR ranked individually

These forward-looking members generally engage in thorough analyses and thoughtful planning processes and have established sources of funding for projects

Respondents engage in planning exercises regularly.

- They often conduct long-term financial forecasting and strategy sessions.
- Respondents run inclusive processes, involving multiple constituents including their senior teams, staff, and boards.

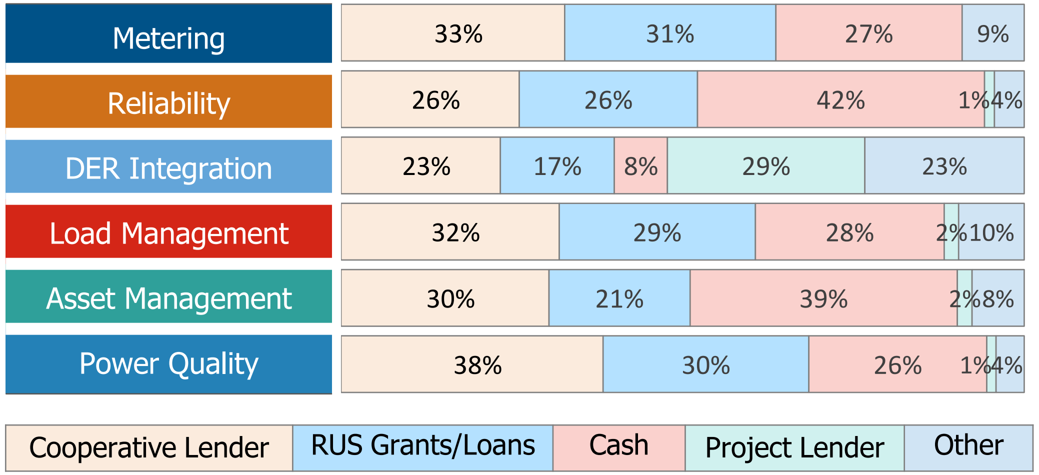
“How often do you revise elements of long-term plans?”



Cooperatives use a variety of sources to fund smart grid projects.

- Cooperative lenders are the most common sources followed by cash and Rural Utilities Service (RUS) grants and loans.
- Cooperatives often use project lenders for DER, often in a power purchase agreement or similar structure where the member pays per MWh.

“How did you fund or plan to fund these technologies?”



Prevalence of Value Streams and Applications

Smart grid unlocks value streams with applications enabled by communications with end points

APPLICATIONS

Metering	AMR/AMI
Reliability & Outage	OMS
	FLISR
DER Integration	Utility-scale solar
	Utility-scale storage
	Behind-the-meter solar/storage
Load Management	Volt/VAR optimization (VVO)
	Consumer DR programs
	Real-time load balancing
Asset Management	Equip health/predictive analytics
	Downstream plant health/analytics
	Substation monitoring
Power Quality	Auto. end-of-line voltage regulation
	Automated power factor correction

ENABLERS

Systems (e.g. CIS [(1)], GIS [(2)], connectivity model)
Assets/End Points
Communications

VALUE STREAMS (BENEFITS)

Avoided wholesale energy cost
Avoided wholesale demand charges
Reduced outage minutes
Reduced operations & maintenance costs
Avoided or deferred capital investment
Increased revenue
Increased member satisfaction

(1) CIS (Customer Information System)
(2) GIS (Geographic Information System)

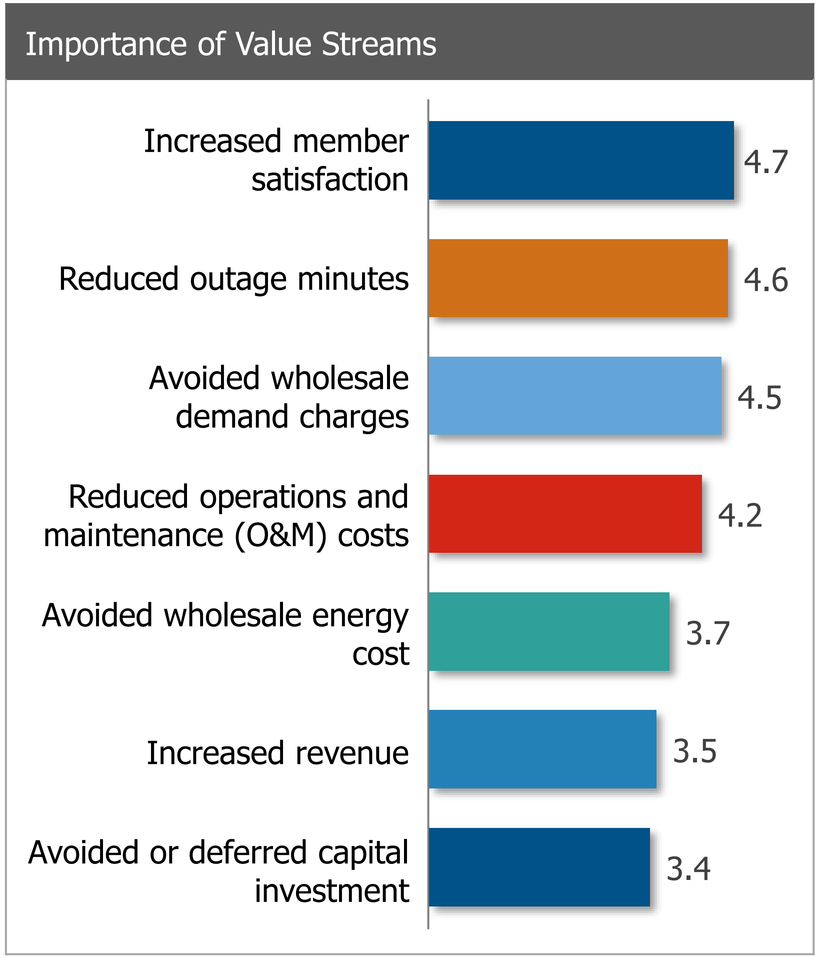
Multiple value streams are important to members; however, value streams that address the core mission of providing reliable, affordable service rated the highest

Smart grid applications can reduce the cost of electricity, increase reliability, reduce costs, and ultimately increase member satisfaction by:

- **Avoided energy cost:** Optimizing the flow of power to reduce the wholesale energy purchases needed to serve the same amount of demand.
- **Avoided demand charges:** Providing optimization tools or programs that incent reduction of peak usage by consumers.
- **Reduced outage minutes:** Providing real-time information to operations and field crews; automating equipment to reduce the frequency and duration of outages.
- **Reduced or deferred costs:** Providing tools or automation to reduce labor costs and taking proactive steps to lower equipment maintenance and replacement costs.
- **Increased member satisfaction:** Members benefit from better service, ease of interaction with their cooperative, access to their usage information, and more.
- Many of these applications also result in **environmental, social, and governance (ESG) benefits** of reduced CO_2 emissions.

Increased member satisfaction and reduced outage minutes ranked as the most important value streams, followed by avoided demand charges.

- As member-owned cooperatives, increased member satisfaction was cited as the most important objective for smart grid applications.
- Service reliability and reduced demand costs followed closely behind.



Respondents asked to rate importance on a 1-5 scale

Respondents have deployed or are planning for several smart grid applications

Most respondents have deployed AMI and OMS.

- These applications form the basis for understanding and responding to usage and outage data.
- More than 75% have had AMI and OMS deployed for at least five years.

Respondents have significant experience in several smart grid categories.

- **Reliability:** In addition to OMS, 59% have either deployed or are planning for FLISR.
- **DER:** 63% have deployed utility-scale solar, either directly or through their G&T.
- **Load management:** DR programs are expanding from water heater load control switches to include thermostats and EVs. The majority are planning for EV DR programs to help mitigate the anticipated EV load growth.
- **Asset management:** Most respondents are using some sort of substation monitoring, with the majority also using or planning for predictive equipment health/analytics solutions.
- **Power quality:** Many are already using power quality (PQ) tools with many more in the planning process.

Category	Application	Deployment Status		
Metering	AMR/AMI	95%		5%
Reliability & Outage	OMS	97%		3%
	FLISR	26%		33%
DER Integration	Utility-scale solar	47%	16%	17%
	Utility-scale storage	12%	9%	38%
	Behind-the-meter solar/storage	34%	2%	38%
Load Management	Volt/VAR optimization (VVO)	41%		31%
	Thermostat DR program	21%	3%	33%
	Water heater DR program	34%	2%	26%
	EV DR program	16%		57%
	Real-time load balancing	7%	2%	41%
Asset Management	Equip health/predictive analytics	28%	7%	38%
	Downstream plant health/analytics	19%		21%
	Substation monitoring	62%	12%	17%
Power Quality	Auto. end-of-line voltage regulation	41%		34%
	Automated power factor correction	36%		38%

Shaded: Deployed | Provided by G&T | White: Planned

Communication to end points and integration with systems are the enablers of smart grid

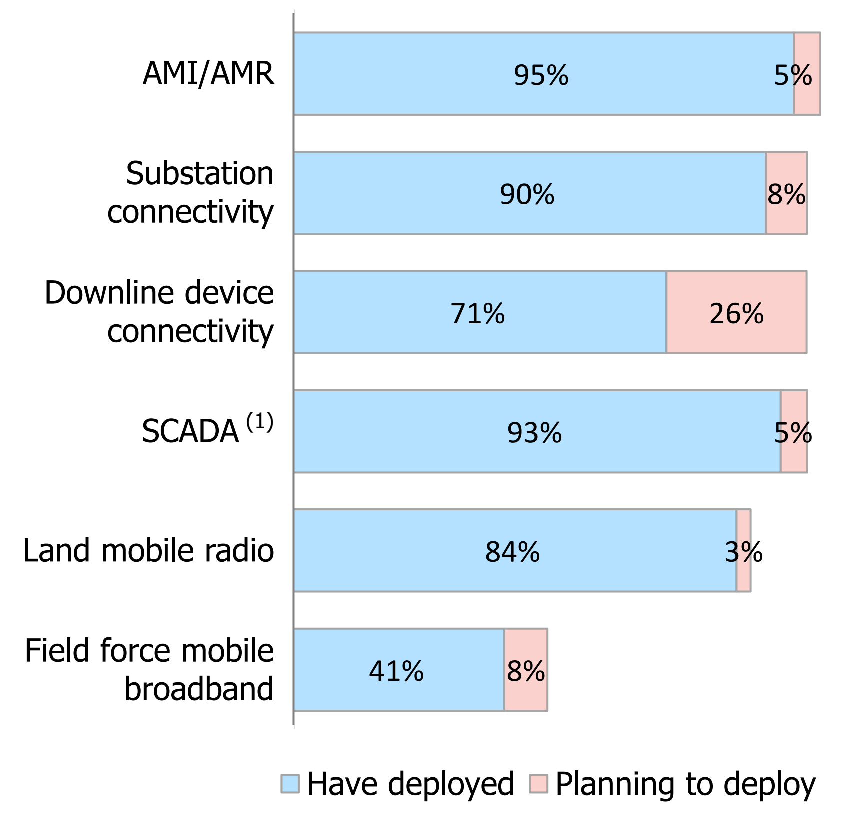
Although this paper focuses on smart grid applications and their value, these benefits could not be achieved without these "enablers."

- **End points, or smart grid assets:** Devices on the distribution network or at member locations. Examples include automated capacitors, switches, voltage regulators, reclosers, and smart meters.
- **Communications networks:** Most smart grid applications need communications networks to operate. A combination of fiber optic and wireless networks connect various assets to transfer operational data and enable control.
- **Systems that store, display, and integrate operational data:** Examples are customer information systems, meter data management (MDM), geographic information systems, and work order management (WOM).

Respondents have largely deployed the networks that enable smart grid.

- **Substation connectivity:** Communications to substations often form a backbone, or wide area network (WAN), that enables other networks and use cases, including consumer broadband.
- While metering networks are fundamental building blocks of smart grid, **most respondents also have communications to downline devices.**
- With the current focus on rural broadband connectivity and grid resilience, members are pushing **advanced networks deeper into their territories** and leveraging them for enhanced smart grid communications.

Communication networks deployed or planned



(1) SCADA = supervisory control and data acquisition

Results

Understanding our results diagrams

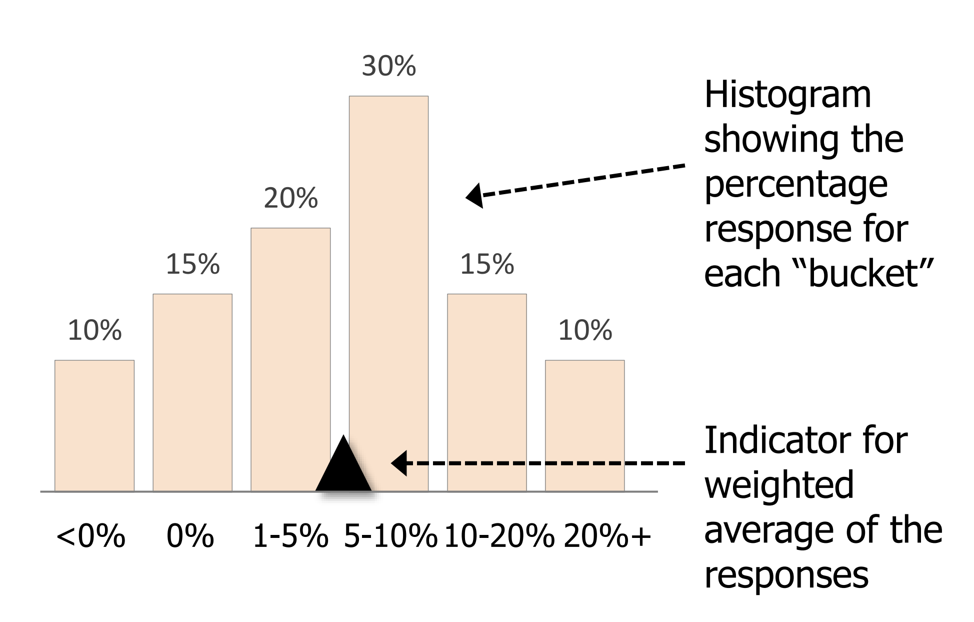
Survey participants quantified the value gained from their smart grid applications, each corresponding to a "value stream."

- The survey asked members to select a "bucket" representing a range of impact.
- Some impacts could be net negative; for example, operations and maintenance cost could *increase* to maintain a certain application that aims to *decrease* another cost.
- Because the impact to member satisfaction is subjective, the survey asked respondents to rate the impact from 1 (none) to 5 (significant).

While we cannot assign an exact average for each value stream, we have included an indicator for the average response.

- For example, if 50% selected 5-10% and 50% selected 10-20%, the indicator is placed between these two "buckets."

Value stream results (chart definition)



Metering: AMI data drives direct results while enabling many other applications

Today's metering networks collect a wider array of data on a more frequent basis, enabling both direct benefits and additional smart grid applications.

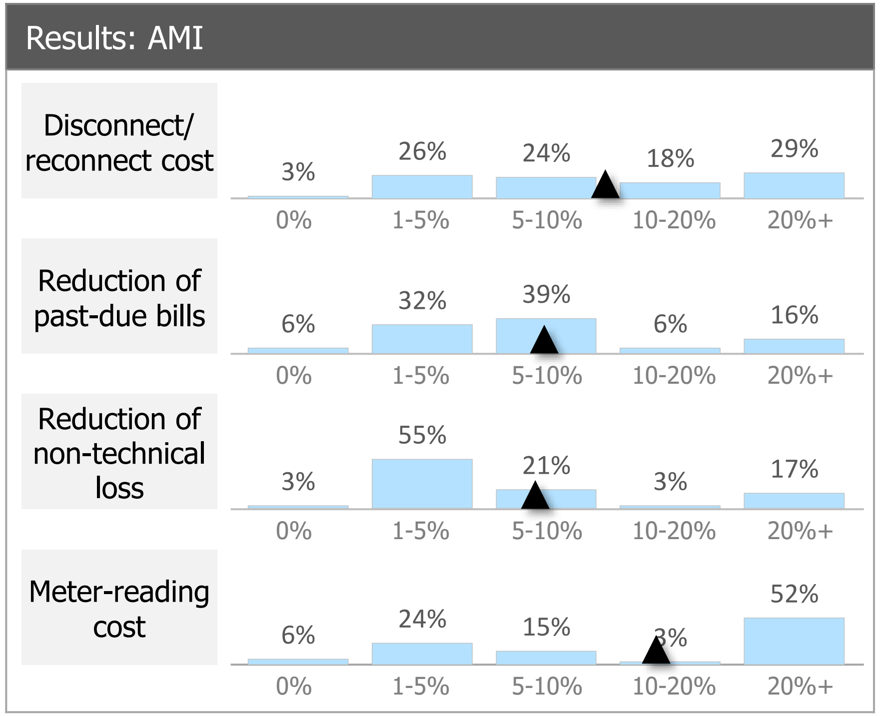
Metering has moved beyond the initial goal of collecting usage data for billing, to collection of more frequent usage data to enable multiple benefits.

- AMI can decrease operating expenses in several ways, including remote connect/disconnect features and reduction of non-technical loss (theft).
- Additionally, AMI supplies the information necessary for several other applications, including outage management, voltage optimization, voltage regulation, and metering at granular time intervals to enable rate modernization.

Respondents report significant savings for expenses directly addressed by AMI.

While noting that AMI data enables other applications, members saw direct benefits:

- The largest direct benefit was meter-reading expense, with half of the respondents reporting a >20% reduction.
- Respondents also report a significant reduction in disconnect/reconnect costs, past-due bills, and non-technical loss.



Reliability/Outage: Outage management system (OMS)

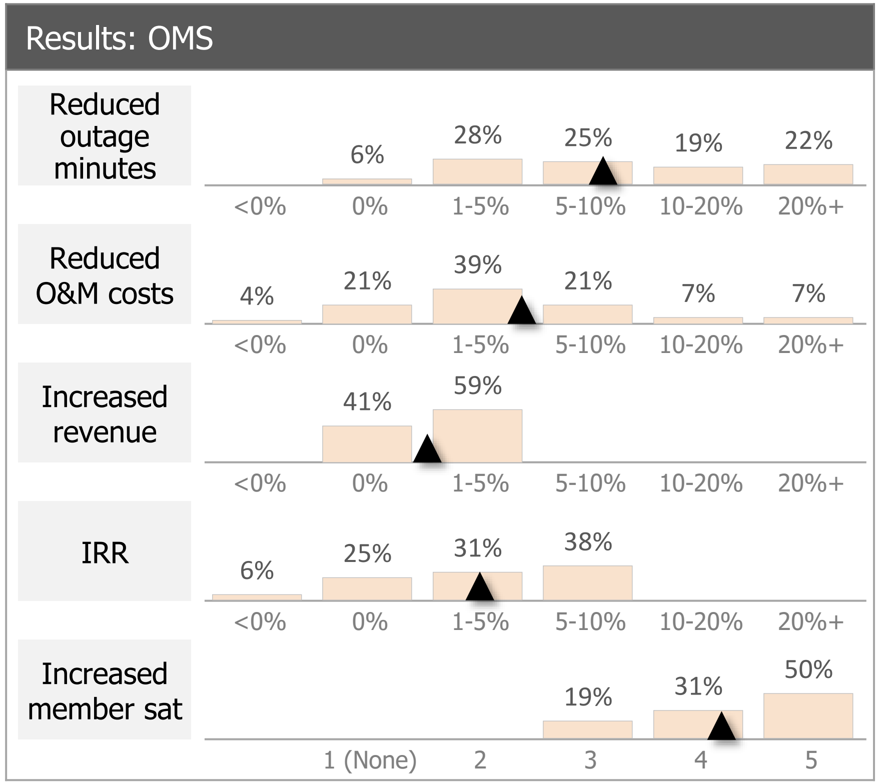
OMS reduces outage duration by displaying and categorizing outages, locating the source of interruptions, and tracking service restoration.

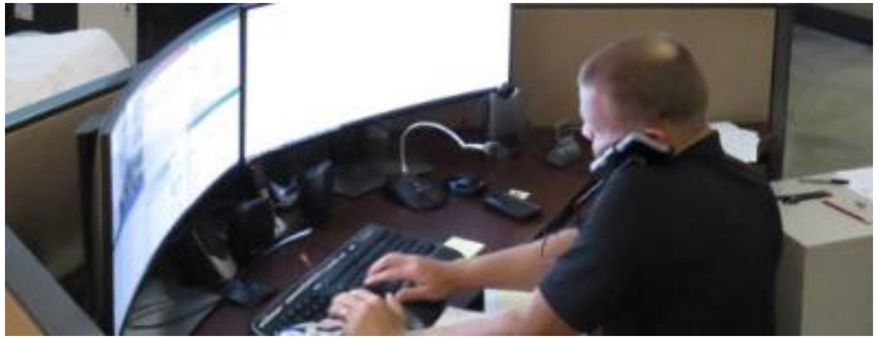
Primary OMS functions include:

- Display of information regarding the size and duration of outages and the source of the equipment that failed.
- Presentation of outage information to consumers, including estimated restoration times.
- Providing repair crews with outage locations and near real-time service restoration information.
- Integration with other systems to achieve these functions including GIS, CIS, IVR, AMI/AMR, SCADA, and LMR. (1)

Reduced outage minutes are the primary OMS value stream.

- Respondents experienced a significant reduction in outage minutes and an associated increase in member satisfaction.
- Respondents also reported a reduction in O&M costs; this is primarily from reduced labor costs due to the efficiency of response.





(1) See the glossary on pages 50-55 for definitions

Reliability/Outage: Fault location, isolation and service restoration (FLISR)

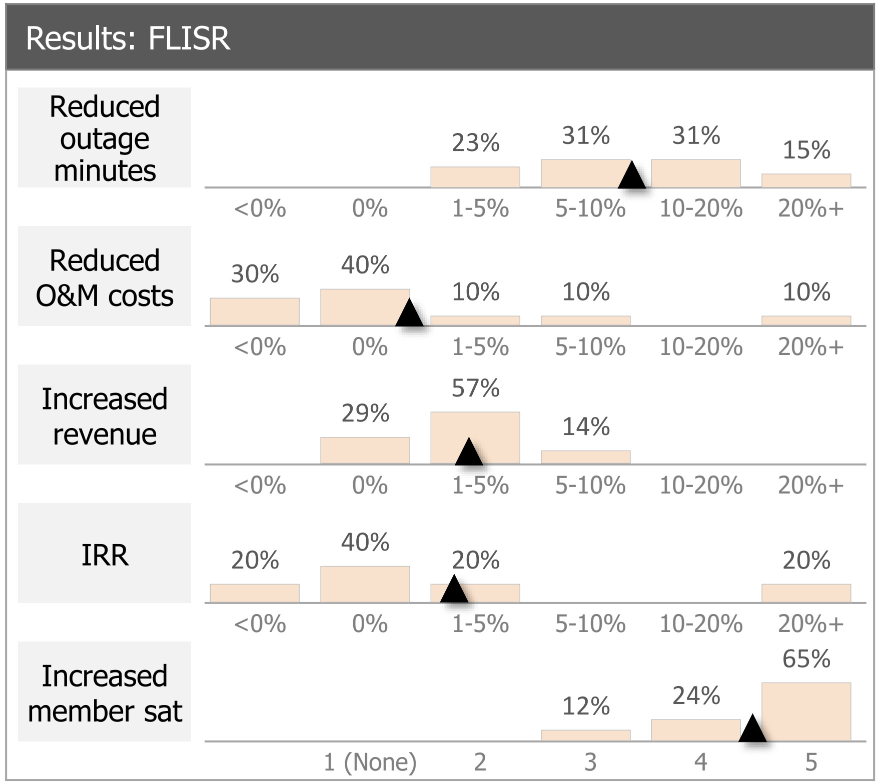
FLISR automatically sectionalizes faults and restores service to remaining consumers by reconfiguring the flow of electricity.

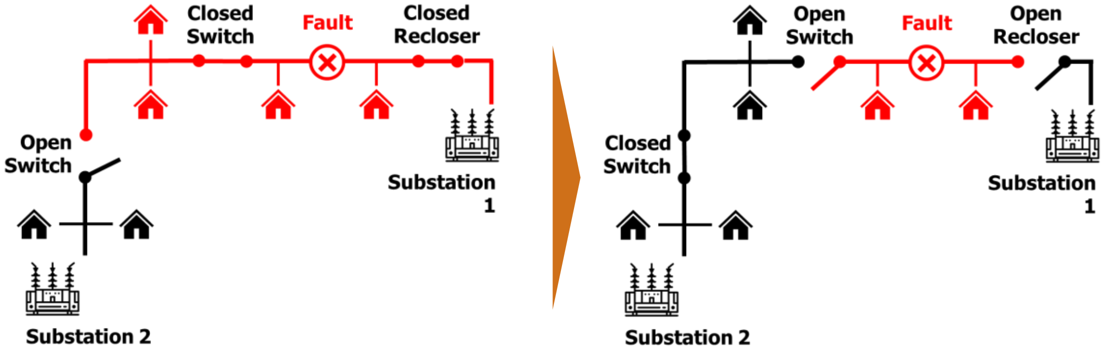
Automated equipment, communications, and software enable the FLISR application.

- The main components are automated substation reclosers and sectionalizing switches with communications modules controlled by FLISR software and SCADA.
- Solution tends to be more effective in more networked distribution scenarios where multiple feeders serve individual service locations.
- The solution can be targeted to areas with high density or key business accounts.
- Can be implemented as fully automatic or manual validation by an operator. Fully automatic actions can take less than one minute, while manual actions may take five minutes or more. [1]

Members identified reduced outage minutes and increased member satisfaction as primary FLISR benefits.

- Respondents reported a significant reduction in outage minutes. In fact, reductions were slightly higher than those reported from OMS.
- However, virtually all respondents have deployed OMS, and it can be assumed that cooperatives likely deployed FLISR with conditions that justified the investment.





(1) "Fault Location, Isolation, and Service Restoration Technologies Reduce Outage Impact and Duration," U.S. Department of Energy, December 2014

Reliability/Outage: Quantifying the impact of reduced outage minutes

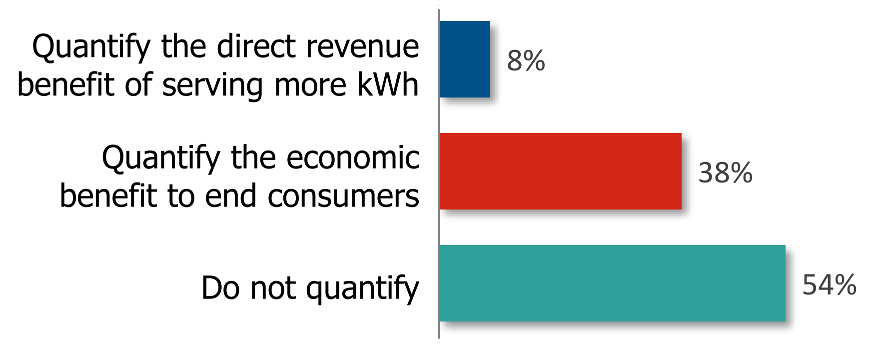
When evaluating the business case for a technology that reduces outage minutes, members can take one of three primary approaches:

- **Quantify the direct revenue benefit:** Multiply the average revenue per kWh by the anticipated kWh saved.
- **Quantify the economic benefit to consumers:** As discussed on the next page, many utilities use tools and econometric models to estimate the "value of service" or, conversely, the cost of outages to end consumers.
- **Do not quantify:** Members can choose to not quantify this impact at all. In this case, the member views the cost of reliability solutions as an investment to further their core mission of providing safe and reliable electricity.

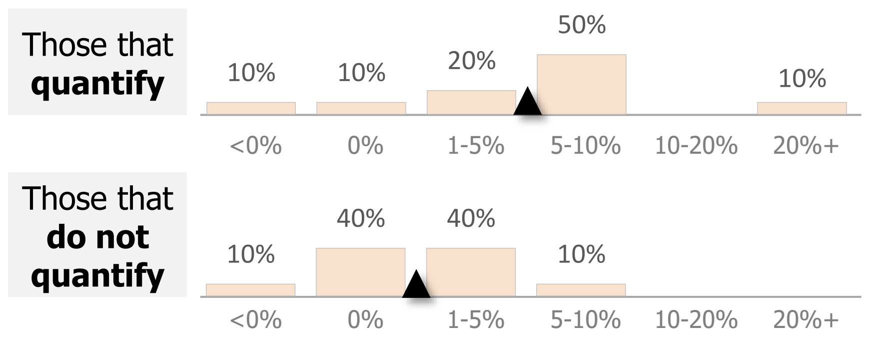
Responses from members reflect a mix of methodologies and a corresponding difference in business case results.

- 54% of respondents do not quantify the financial impact of outages, while 38% quantify the economic impact to end consumers.
- Respondents that quantify the financial or economic benefit reported higher IRR for OMS and FLISR than those that do not.

"How do you quantify the financial benefit of reduced downtime?"



Average IRR for those that quantify financial benefits vs. those that don't (OMS + FLISR)



Reliability/Outage: Quantifying the economic benefit of outage reduction

Researchers have been conducting customer interruption cost (CIC) studies for decades. The U.S. Department of Energy (DOE) has incorporated a set of studies into reliability planning tools. (1)

- Econometric models quantify the value of service (VOS), or the economic impact of interruption to electric service.
- DOE incorporated the results of econometric models covering 34 separate studies representing 100,000 customers into an online tool called the Interruption Cost Estimation (ICE) Calculator.
- The studies quantified the economic value of service to different classes of users (Residential, Small/Medium C&I, Large C&I) and outage characteristics including interruption type, duration, and other conditions such as location (state).

The economic impact of service interruption is significant.

These tools can help quantify how reliability improvements benefit consumers.

- VOS is significantly larger than the direct revenue associated with a unit of service (i.e., kWh) in most cases.
- In the example in the chart, VOS for residential is $2.55 per kWh, and VOS for C&I are multiples of that.
- This compares with a direct revenue per kWh, which is typically approximately $0.10 per kWh, but highly dependent on location.

DOE "ICE" tool

ICE CALCULATOR

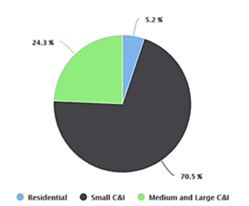
Estimate Interruption Costs

SAIFI	SAIDI	CAIDI	#Residential	#Non-Residential	
5.000	500.0	100.0	10,000	1,000	Alabama

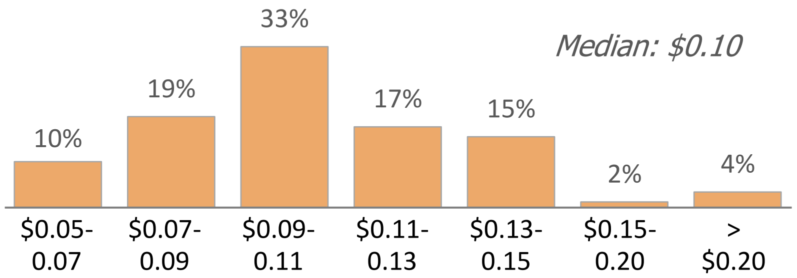
Interruption Cost Estimates

Sector	# of Customers	Cost Per Event (2016$)	Cost Per Average kW (2016$)	Cost Per Unserved kWh (2016$)	Total Cost (2016$)
Residential	10,000	$7.67	$4.25	$2.55	$383,724.21
Small C&I	957	$1,091.37	$133.15	$79.89	$5,222,215.27
Medium and Large C&I	43	$8,365.72	$35.96	$21.58	$1,798,628.99
All Customers	**11,000**	**$134.63**	**$41.27**	**$24.76**	**$7,404,568.47**

Total Cost of Sustained Interruptions by Sector



National sample of co-op volumetric energy charges (2)



(1) www.icecalculator.com/documentation
(2) CFC research based on limited sample of cooperative published rates

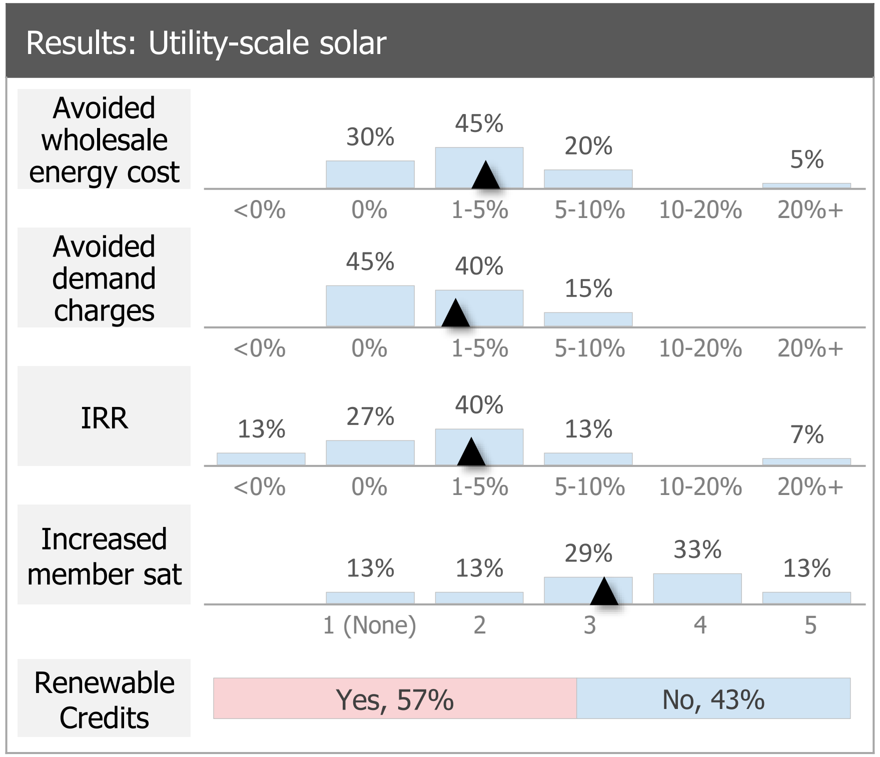
DER Integration: Utility-scale solar

Utility-scale solar generates clean, low-cost energy.

- Generally controlled by the co-op and connected at the distribution system level.
- Can be third-party owned with energy acquired by the cooperative through a power purchase agreement (PPA), where the cooperative pays per MWh.
- If the levelized cost of energy is less than a co-op's wholesale cost, solar may be economically advantageous. It may also reduce demand and transmission charges.
- Solar is non-dispatchable unless paired with storage.

Members identified increased member satisfaction and avoided wholesale cost as the primary benefits of utility-scale solar.

- Respondents indicated that solar projects resulted in increased member satisfaction as their consumer-members may prefer green energy and/or the cost reduction.
- Respondents report lower energy cost (not demand charges) as the primary savings. This is because it is non-dispatchable, i.e., you cannot control when it is generating.
- Solar also can reduce demand charges, typically in summer if generation coincides with periods of peak demand.
- 57% of respondents reported receiving renewable energy credits (RECs) from utility-scale solar (cooperative-controlled).
- State policy may require RECs. Solar also may be a means to improve member satisfaction, with member preferences varying widely across the country.



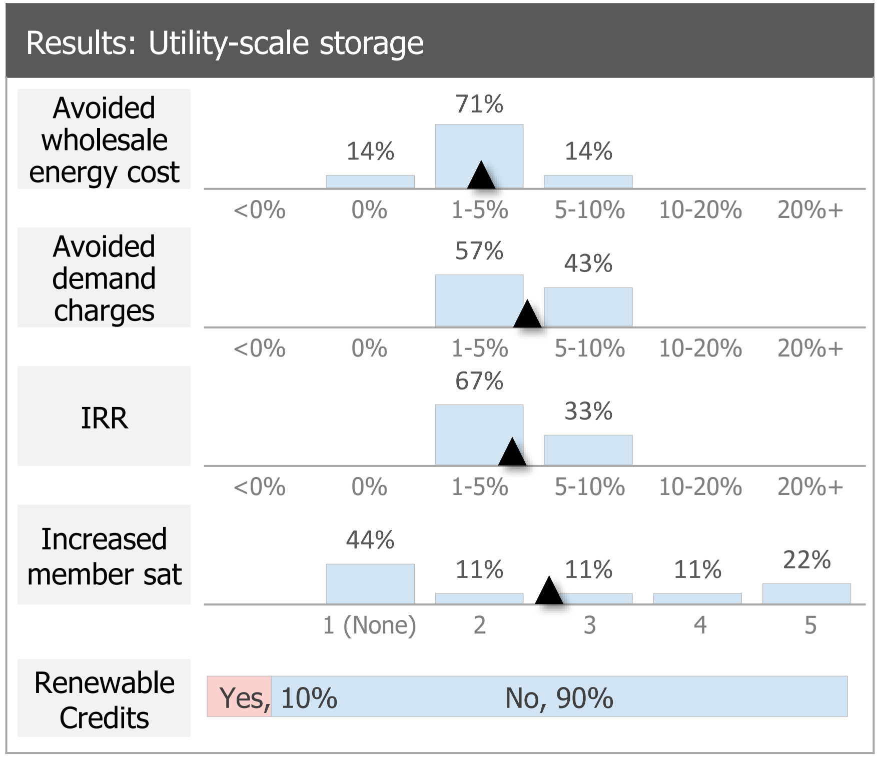
DER Integration: Utility-scale storage

Utility-scale storage provides a dispatchable resource.

- Generally controlled by the cooperative; connected at the distribution system level.
- Developers can offer energy storage as a service via an energy storage service agreement (ESSA), similar to a power purchase agreement.
- Batteries are charged at off-peak times and discharged at selected peak times such as monthly system peaks, G&T annual coincident peak, or market-wide coincident peaks.
- Storage systems are often integrated with SCADA or other control software to optimize charging and discharging.
- Although outside the scope of the survey, some members are utilizing storage to defer capital investment and/or increase resilience.
  - To reduce outage minutes, co-locating storage with critical loads can provide resiliency.
  - To defer capex, placing storage at the end of a capacity-constrained feeder can defer a feeder upgrade.

Utility-scale storage offsets demand costs.

- Respondents cited demand charge reduction as the most critical value stream for energy storage.
- Energy storage is not eligible for RECs in most states.



DER Integration: Behind-the-meter solar/storage

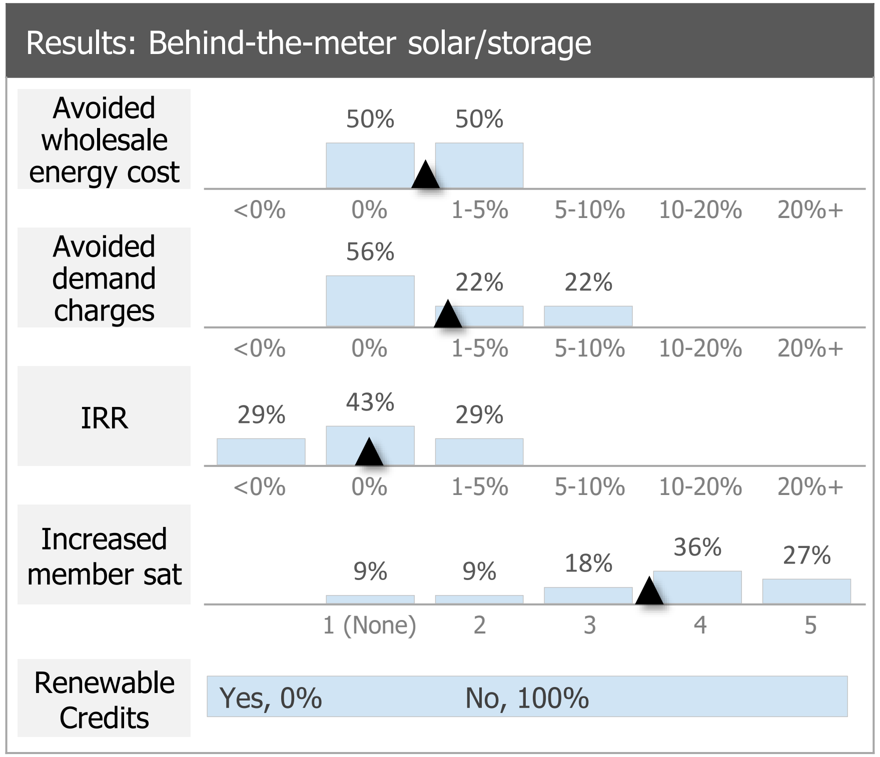
Behind-the-meter (BTM) solar/storage allows consumer-members to offset some of their energy needs with their own on-site resources.

Typically consumer-member-owned, rooftop- and pedestal-mounted solar is increasingly paired with battery energy storage in homes and businesses.

- Storage helps the retail member match their production timeline to the demand of the in-house loads and may offer a short-term power supply backup for the home.
- Arrangements to purchase excess power by the cooperative from the member vary from net metering at retail rates to wholesale purchase at the cooperative’s avoided costs.
- Some retail members may lease solar/storage from a vendor or sign a PPA with a vendor.

Some cooperatives leverage their members’ investments in storage to manage system peak demand, lowering wholesale demand charges.

- Respondents report modest rates of return, with 29% reporting negative IRR.
- Member satisfaction impact from behind-the-meter solar/storage varies, indicating large differences in retail member perceptions of DER across the country.
- Consumers with BTM solar may be eligible for RECs (as opposed to the co-op). Members report that consumers have received them.



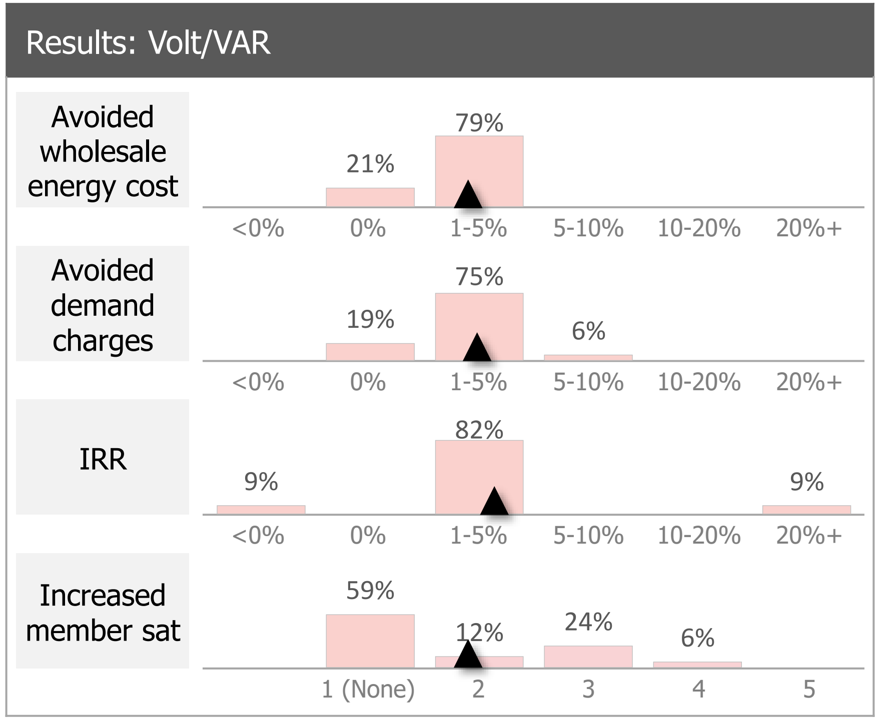
Load Management: Volt/VAR optimization (VVO)

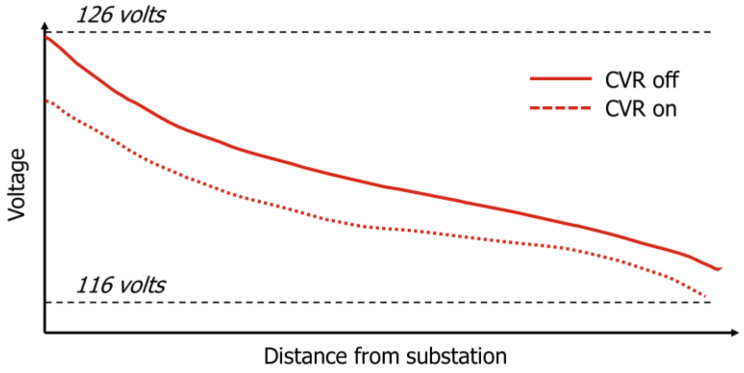
VVO optimizes voltage levels delivered to consumers to reduce energy consumption and demand charges without impact to consumers.

- Because of feeder voltage drop, utilities need to provide higher voltage to consumers closer to a substation than to members toward the end of the line.
- VVO uses conservation voltage reduction (CVR) techniques to reduce voltage requirements while maintaining acceptable voltage (e.g., 120 V +/- 5%) for all consumers.
- VVO improves phase balancing and reactive power compensation to optimize voltage and reactive power flows. This reduces real & reactive power consumption.
- Automated capacitors and voltage regulators along with usage data from AMI and software are needed to implement VVO.
- The solution tends to be more effective where the cost of power and demand charges are high and density is low (longer lines lead to more loss).

Most respondents report reduction in energy and demand cost of 1%-5%.

- These results are consistent with the goals of the application, where a low single-digit reduction in energy consumption can be achieved without noticeable consumer impact.
- Interestingly, some members report modest increases in member satisfaction, perhaps due to cost savings or reduction in carbon.





US DOE, https://etap.com/product/volt-var-optimization-control

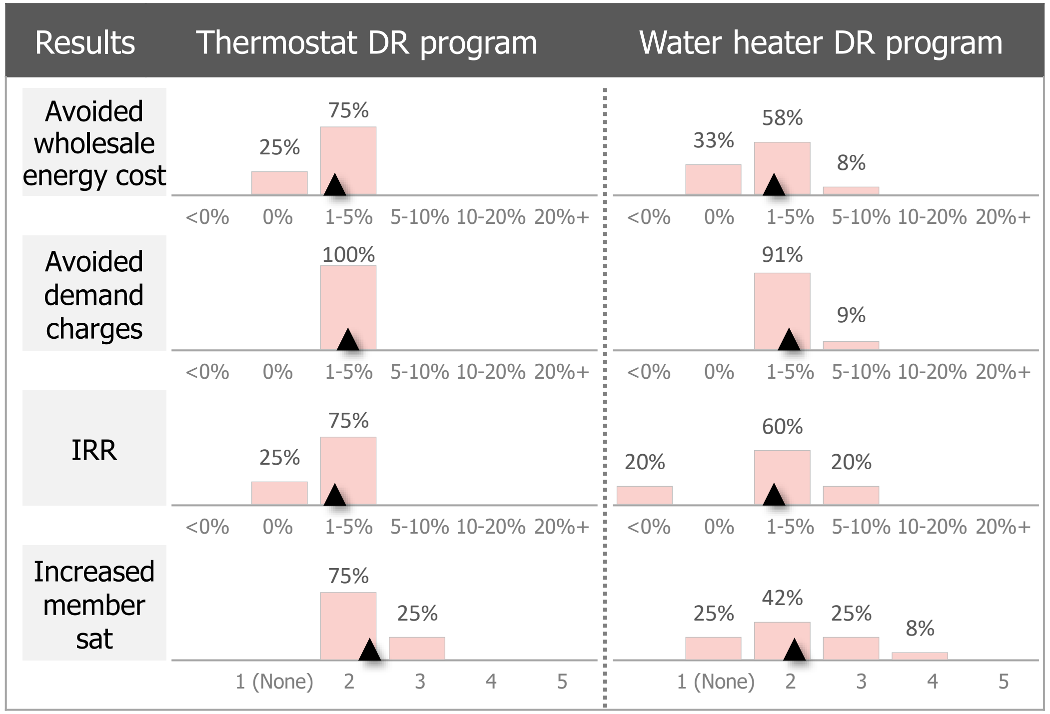
Load Management: DR programs – thermostats and water heaters

Demand response (DR) programs incent end consumers to curtail usage during peak periods.

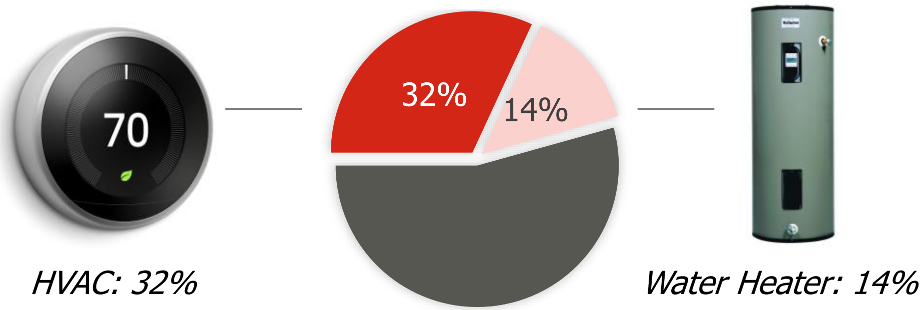
- DR programs usually involve a utility providing incentives such as discounted or free consumer equipment and periodic rebates.
- Historically, DR has involved control via one-way load control switches.
- However, with current communications technologies, utilities can control behind-the-meter assets, while also better understanding results and presenting information on savings to consumers.
- With the advent of smart thermostats, consumer DR programs can address 46% of residential electricity use, between HVAC and water heaters. (1)
- Programs can also be tailored to C&I members to incent time shifting of heavy demand. (For example, in agriculture, irrigation control.)

Smart thermostats and water heaters reduce demand charges while improving member satisfaction.

- Members will most always have a demand charge element of their wholesale pricing structure. DR programs address this cost.
- Some wholesale rate structures also have different pricing during different times of the day. If a cooperative employs time-of-use (TOU) rates, programs can be extended to time shifting of usage.



Residential Electricity Use (1)



(1) Source: www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php

Load Management: DR programs – electric vehicles

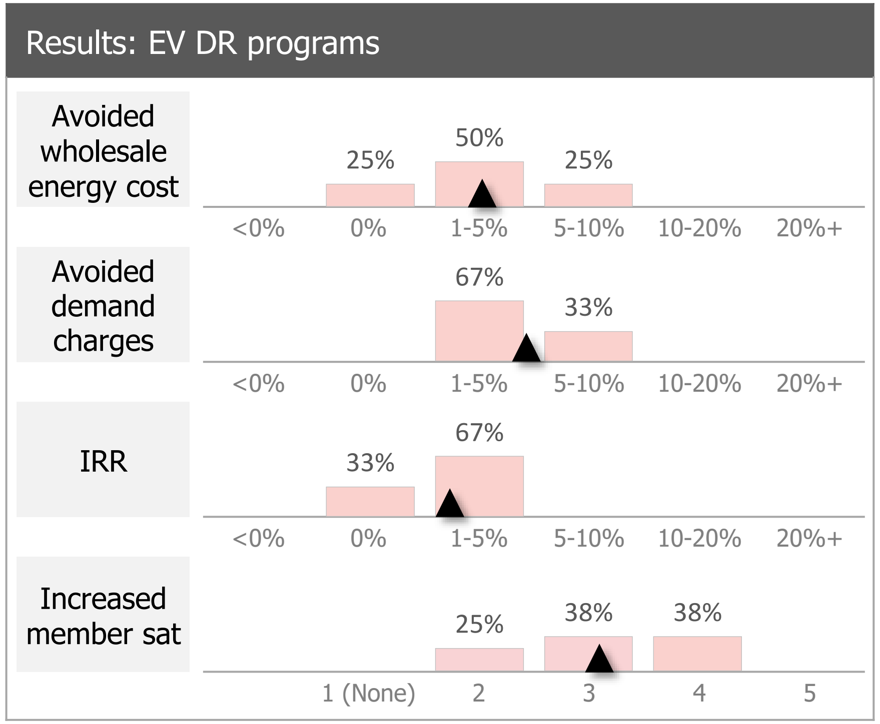
While EV adoption will provide new revenue streams for members, optimizing this significant additional load will be critical.

- EV DR programs incent end consumers to charge vehicles during off-peak hours, enabled by rate mechanisms and/or direct control.
- Studies have shown that each EV increases a household's energy consumption by 20%-50% and demand by 70%-130%. (1)
- 80%-90% of EV charging happens at home (2) with Level 2 chargers peaking at 5-10 kW. Without control signals, EVs can significantly increase evening peaks.
- EV adoption can be clustered (localized). Even with EV TOU rates, clustered EV charging could stress local grid equipment such as transformers.

Although these programs are mostly new, members are seeing benefits.

- 89% of respondents with EV DR programs started their programs within the last two years.
- Those with EV programs report energy cost and demand charge reduction and increased member satisfaction.

(1) "Electric Vehicles Are a Multibillion-Dollar Opportunity for Utilities," Boston Consulting Group, April 2019
(2) "Electric Vehicle Charging Implications for Utility Ratemaking in Colorado," NREL, March 2019



Avg. Household Demand (1)	W/O EV	WITH EV	Change
Energy Demand (MWh)	6-14	9-17	+20-50%
Capacity Demand (kW)	6-12	14-20	+70-130%

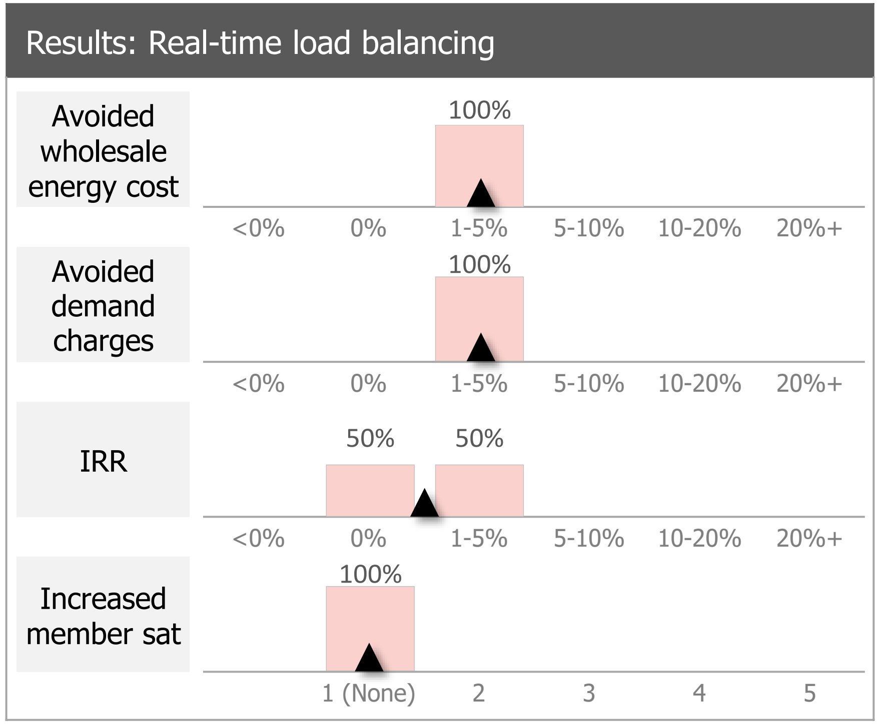
Load Management: Real-time load balancing

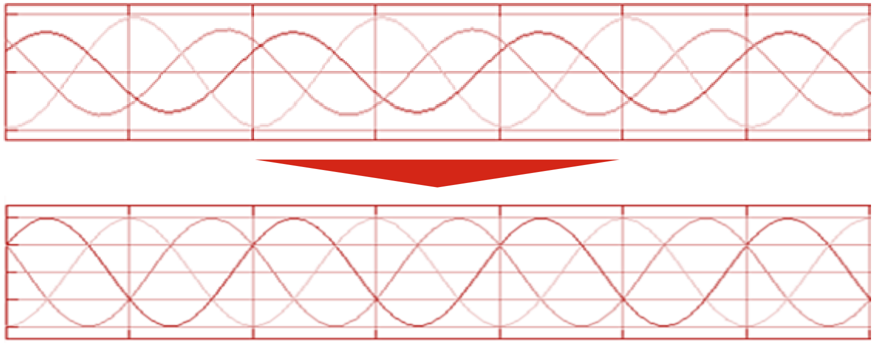
Real-time load balancing optimizes the amount of power draw on each incoming phase to reduce neutral currents and protect infrastructure.

- Unbalanced electrical load causes multiple issues, including increased line losses and associated increased wholesale energy costs.
- Unbalanced load also can decrease equipment life and capacity.
- Real-time load balancing automatically calculates and corrects for load balancing across the phases.
- This reduces neutral line currents and reduces peak demand charges related to imbalanced phases.

Respondents that have implemented load balancing are seeing reduced wholesale power costs.

- Members reported reduced wholesale energy and demand costs.
- Most report no increase in member satisfaction as consumers are generally unaware that the solution has been implemented.





Smart Grid Technologies: Generally, not causing rate changes

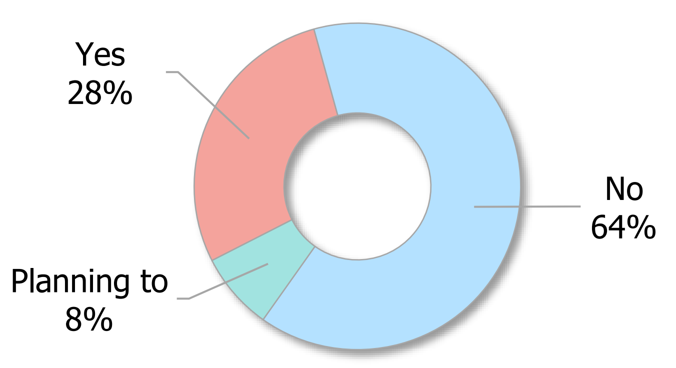
Aligning rates with smart grid opportunities can increase savings.

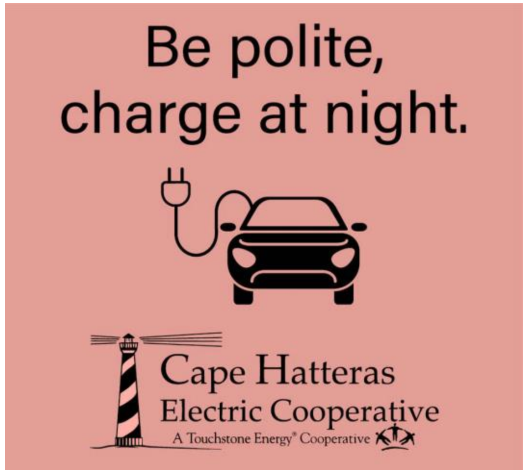
- Changes in rate design are generally driven by changes in the cost structure that members face. Appropriate rate designs meet the cooperative's revenue requirement and equitably align revenue with costs.
- Rate design changes, like TOU or a demand component, may create savings opportunities from smart grid technologies for the cooperative, its members, or both.
- For example, TOU rates can encourage consumer-members to charge their EVs during off-peak times and save themselves and their cooperative money.

Smart grid implementations did not impact most respondents' rates.

- 64% of respondents have not changed rates to enable savings from smart grid technologies.
- 36% have implemented rate changes or are planning to do so.

"Have you changed your rate structure to enable savings from these (smart grid) technologies?"





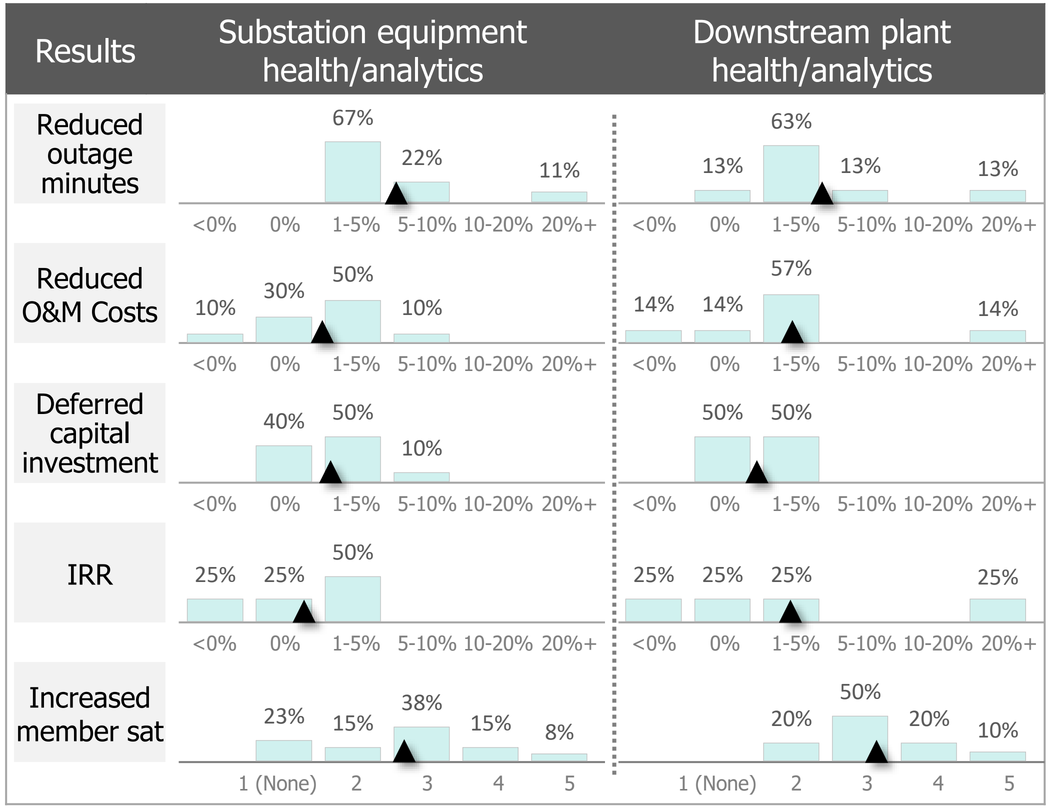
Asset Management: Equipment health/analytics—substations and downstream plant

Equipment health/analytics solutions monitor current status and predict future maintenance or replacement needs.

- These solutions can reduce outage minutes, extend asset lives, and reduce maintenance costs.
- Analytic solutions compare real-time sensor data to normal operating ranges to predict potential failures. Examples include temperature signatures, vibrations, and dissolved gases.
- O&M costs may be reduced with targeted O&M activities instead of blanketing the fleet of equipment with identical maintenance schedules.

Outcomes for operating costs and capital investment varied.

- All members report some reduction in outage minutes from substation equipment health/analytics.
- While most respondents experienced decreases in O&M costs for both substation and downstream, others saw cost increases.
- Rates of return varied widely, including 25% of members reporting negative rates of return.
- Respondents benefited from deferred capital investment due to the ability to target equipment replacements based on actual condition rather than just equipment age.



Asset Management: Substation monitoring including video surveillance

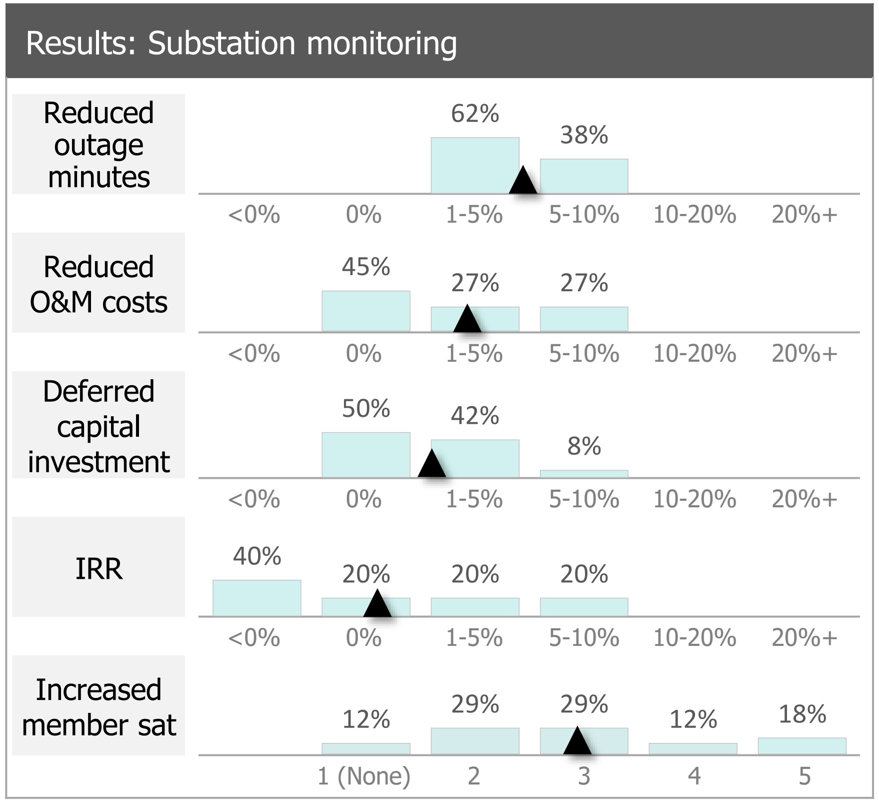
Members implement video surveillance of substations to reduce outage minutes and increase member satisfaction.

For this application, improving service to members is the higher priority over financial considerations.

- Members report that reducing outage minutes is the biggest factor in substation video surveillance.
- Increased member satisfaction, perhaps as a result of lower outage minutes, is also an important factor.
- Substation monitoring may create more benefits if the substation is in a remote location.

Cost reduction and rates of return are not the reason for member investment in substation video surveillance.

- Majority of respondents experienced zero or negative rates of return on their investment in substation video surveillance.
- Most members report zero reduction in O&M costs and capital investment.



Quantifying Financial Benefits: Labor savings

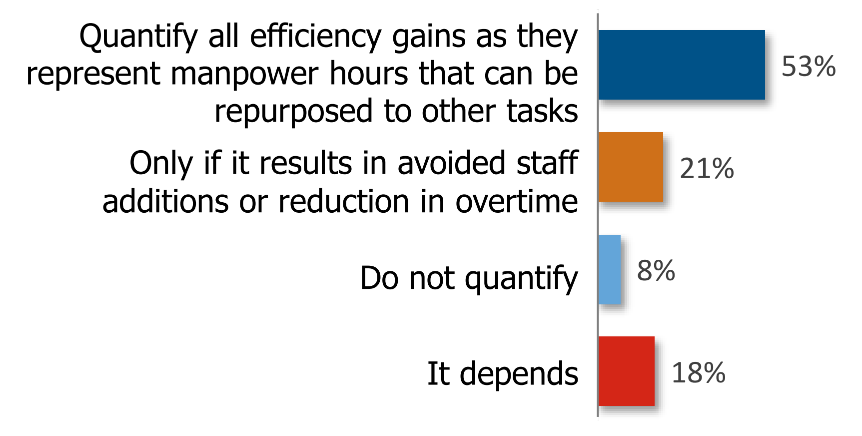
When developing a business case, members decide how to quantify the impact of efficiency gains.

- Technology provides ways to automate or reduce the time necessary to complete tasks, reducing required staff hours.
- The most **direct savings** result when efficiency tools lead to avoided staff additions.
- **Efficiency gains** may also allow members to repurpose staff hours to other productive work. There are different philosophies on how and whether to quantify this.

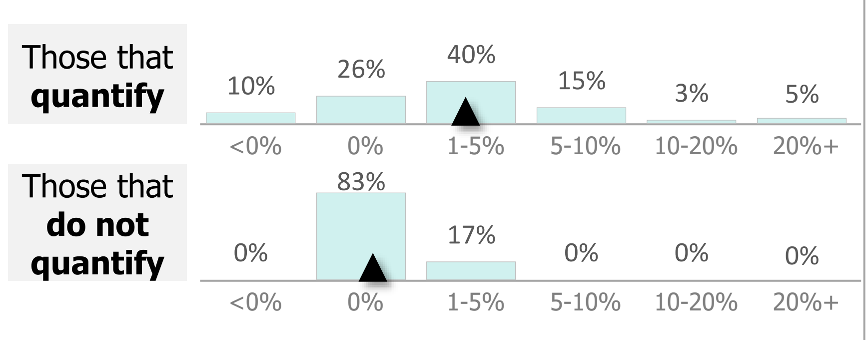
Respondents use a mix of methodologies and see a corresponding difference in business case results.

- 53% of members report calculating labor savings inclusive of labor efficiency gains, even when staff is not reduced.
- Those quantifying all labor efficiency gains reported higher IRRs for applications aimed at reducing O&M cost.

"For labor savings, how do you quantify efficiency gains in your business case?"



Average IRR for those that quantify labor savings vs. those that do not *



* For those applications with O&M savings quantified as value streams

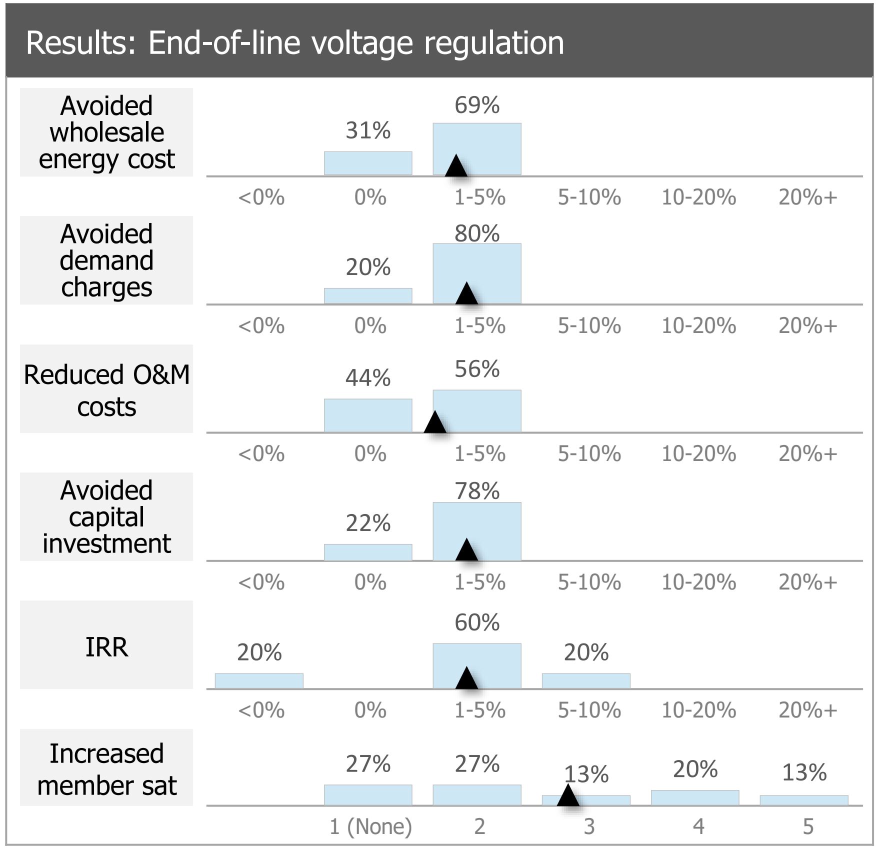
Power Quality: Voltage regulation

Voltage regulation delivers more consistent electricity to consumers by preventing sags, surges, and brown-outs, while lowering operating costs.

- Control equipment varies the voltage at strategic locations along a feeder based on near real-time data to keep voltage within pre-set limits.
- Voltage regulation can be a lower-cost alternative to upgrading feeders to maintain adequate voltage when load growth is compromising the feeder voltage profile.
- The application also can solve problems with low voltage at the end of long feeders.
- Voltage regulation is most advantageous for members that have commercial or industrial loads with process control equipment or other voltage-sensitive loads.

Voltage regulation enables multiple value streams.

- Most respondents saw benefits including avoided power costs, O&M savings, and avoided capital investments.
- Most respondents reported increases in member satisfaction. This may be because voltage regulation delivers more consistent power. C&I customers are most likely to notice this benefit.



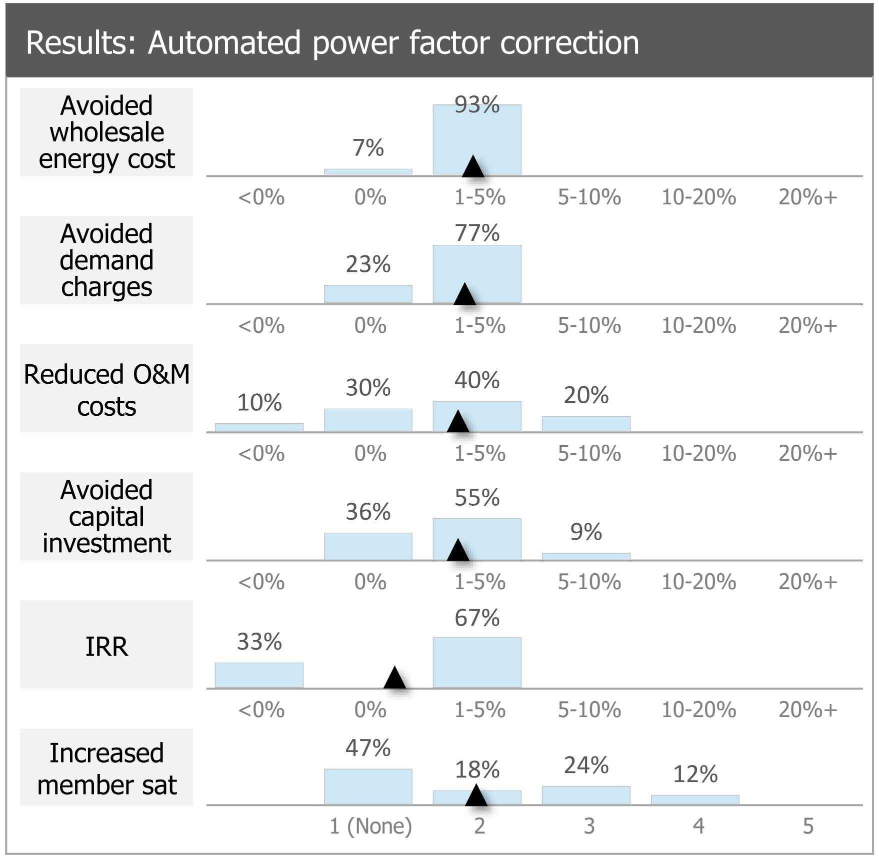
Power Quality: Automated power factor correction

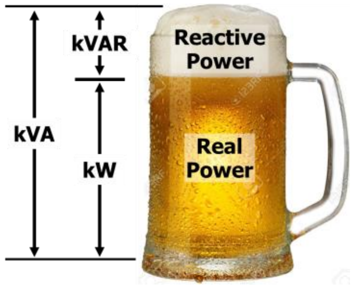
Power factor correction lowers operating costs by reducing the cost to deliver the same amount of electricity.

- Inductive loads associated with motors are present at virtually all member locations, but the most impactful inductive loads are at industrial locations.
- Having large inductive loads increases current flow down the feeder by increasing reactive power flows. This can result in higher losses, more wholesale energy cost to support the same load, and the need for higher capacity feeders.
- Power factor correction offsets the reactive power from inductive loads and improves system efficiency; this is achieved by monitoring in real time and adjusting the amount of capacitive load to balance inductive loads.

Power factor correction projects create mostly financial benefits.

- Most respondents saw savings in both wholesale energy charges and wholesale demand charges.
- The majority of respondents saw reduced O&M costs.
- More than half of the respondents saw member satisfaction improvement, likely as the result of lower retail electricity bills.





Difficulty of deploying applications

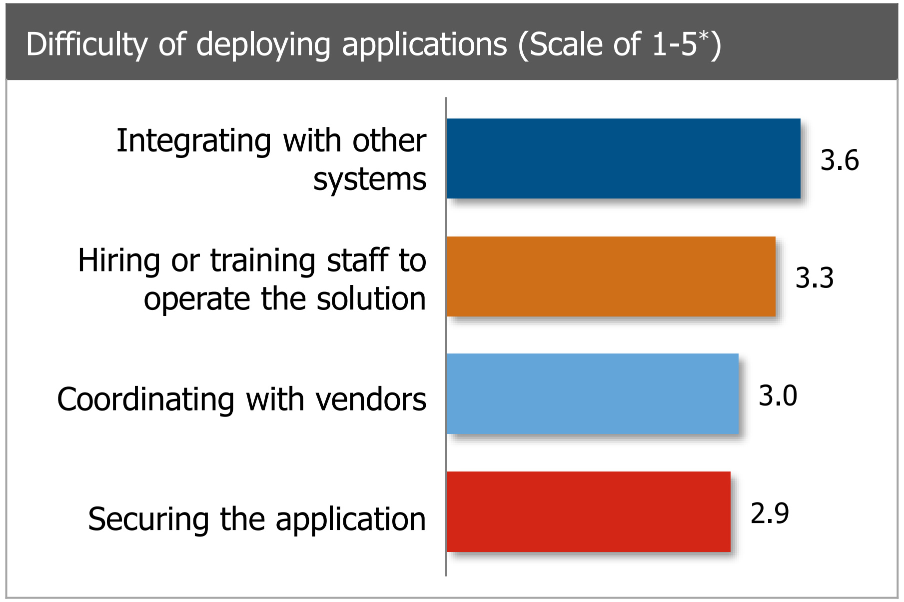
Smart grid applications require systems integration, hiring or training employees, and coordinating with vendors.

Integration with pre-existing systems such as SCADA systems, metering systems, communications networks, and geographic information systems creates challenges.

- Existing systems at the cooperative may not be standards-based. Communications protocols must be compatible.
- Existing or new staff must be trained to operate and maintain these applications.
- Departments at the cooperative need to understand where to retrieve and display information from new systems in order to perform their function.

Respondents view integration with other systems as the most difficult challenge when implementing new smart grid applications.

- Developing a trained workforce through new hires or training existing staff also proved challenging to respondents.



* 1: Least difficult, 5: Most difficult

Planning and Evaluation Processes

Long-Term Planning: Timing

Cooperatives engage in a family of long-term planning processes to manage their evolving business needs.

The need for periodic plan updates may be driven by:

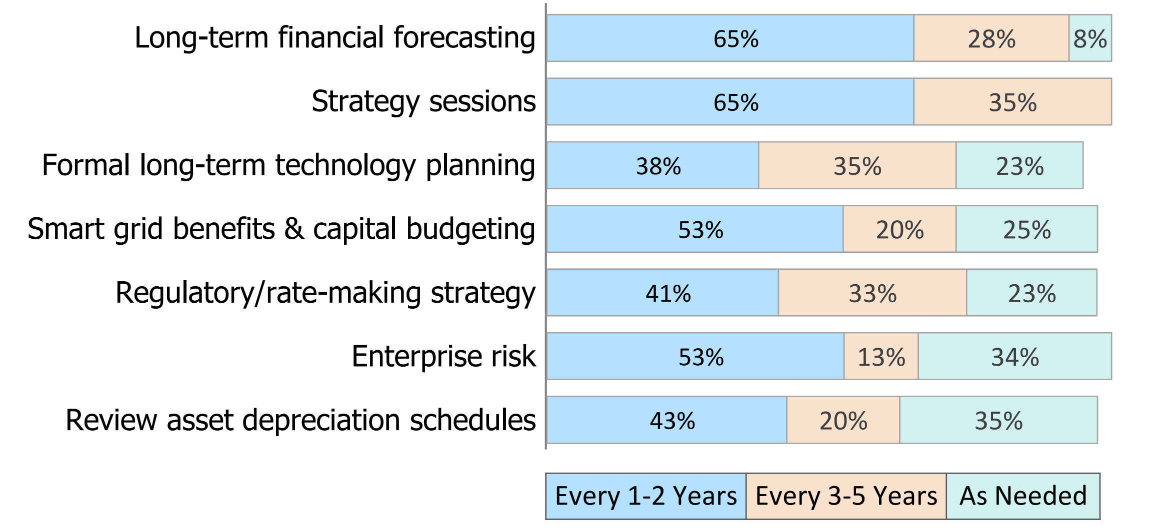
- Technology changes
- Evolving member expectations
- Changing market and business conditions

Strategic planning and financial forecasting are foundational.

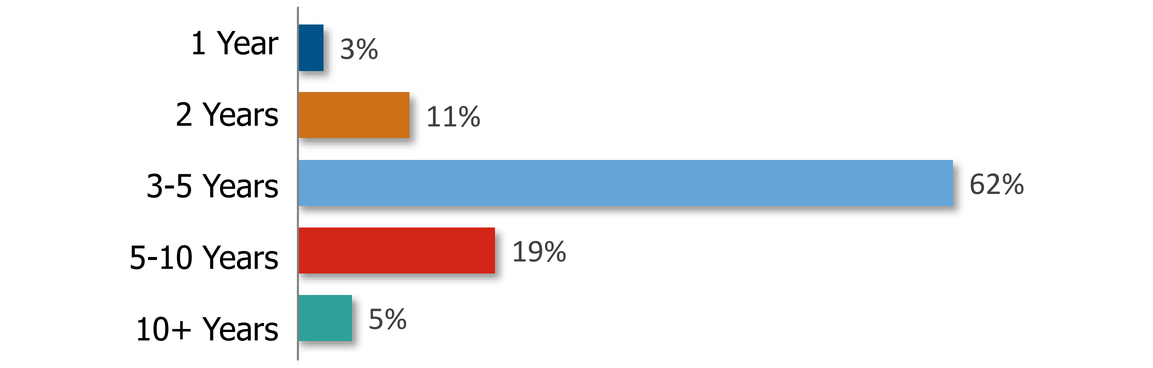
Respondents engaged in strategic planning and financial forecasting more frequently and on more definitive schedules than other planning activities.

- All respondents had a definitive periodic schedule for strategic planning, with one to two years being most common.
- 93% of respondents update long-term financial forecasts on a definitive schedule, usually on a one- or two-year cycle.
- 23% or more of respondents perform other plan updates, including formal technology planning, as needed instead of on a pre-determined schedule. However, a plurality revisited all long-term planning documents on a one- to two-year cycle.

"How often do you significantly revise these elements of long-term plans?"



"What is the term of these plans?"



Long-Term Planning: Reasons for engaging in planning activities

Internal and external factors motivate planning activities.

- Regulators and lenders require a small number of planning documents as a matter of compliance.
- Boards require a larger number of documents as a matter of good governance.
- Executive leadership teams institute a full set of planning documents as a matter of good management.

Boards and management drive most planning activities.

- Lenders and boards of directors are equally interested in long-term financial forecasting. 65% of respondents report them as reasons for these plans.
- Board requirements drive strategy sessions.
- There was a significant "other" response. Most of them cited internal management practices–their executive leadership team's desire to articulate their technology vision as opposed to being required by their board, lender, or regulator.

Reasons for engaging in planning activities	Regulatory requirement	Lender requirement	Board requirement	Other
Long-term financial forecasting	8%	65%	65%	18%
Strategy sessions	0%	8%	70%	23%
Formal long-term technology planning	3%	15%	38%	38%
Smart grid benefits and capital budgeting	3%	10%	48%	38%
Regulatory advisory & rate-making strategy	18%	23%	58%	25%
Enterprise risk	3%	8%	45%	30%

Regulatory/Lender Compliance

Good Governance

Good Management

Long-Term Planning: Importance of stakeholder groups

Stakeholder involvement

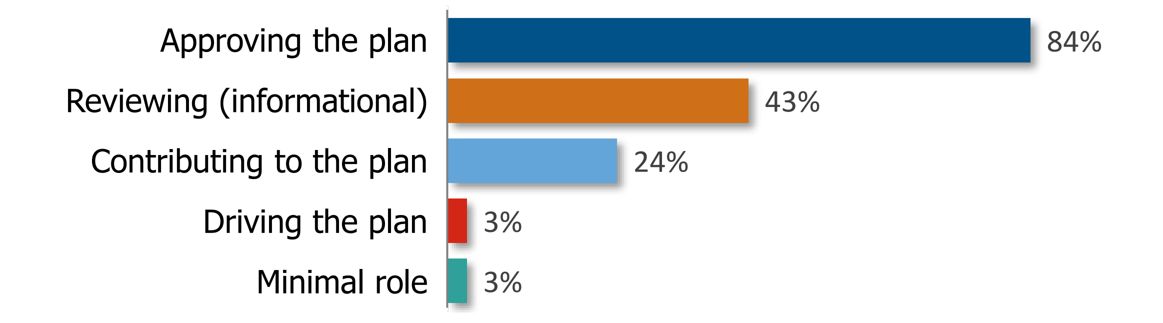
- Respondents describe senior leadership as playing the central role in all long-term planning.
- General staff participation is more important in technology planning and smart grid planning as compared with other planning documents, indicating a need for detailed subject-matter expertise for technology planning.

Board involvement in long-term planning

- Boards of directors predominantly approve plans created by senior staff with assistance from other stakeholders.

Importance of stakeholders in planning*	Board of Directors	G&T or power supplier	Members	Sr. Lead-ership	General Staff
Long-term financial forecasting	3.8	3.1	2.6	4.9	3.0
Strategy sessions	4.3	2.5	2.8	4.9	3.3
Formal long-term technology planning	3.1	2.4	2.8	4.8	3.6
Smart grid benefits and capital budgeting	3.6	2.5	2.8	4.8	3.5
Regulatory advisory & rate-making strategy	4.2	3.3	3.1	4.8	3.1
Enterprise risk	3.7	2.6	2.7	4.7	3.2
Review asset depreciation schedules	2.3	1.7	1.9	4.3	2.9

"How active is your board in long-term planning?"



* On a 1-5 scale

Technology evaluation

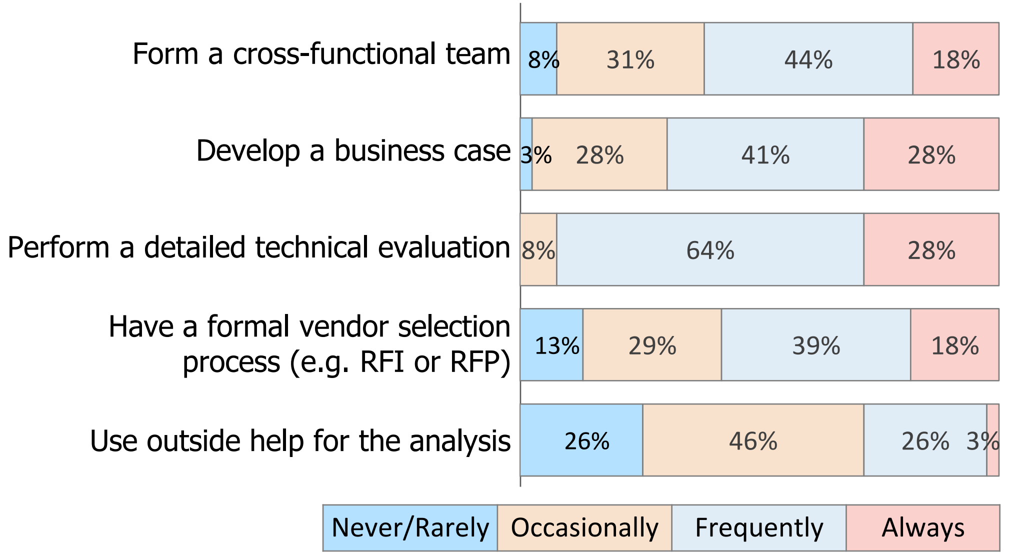
Members are analyzing new technologies, but the approach depends on the application.

- **Technical evaluation:** Respondents performed technology evaluation most often. Typical steps include understanding use cases, evaluating solutions and vendors, and how to integrate with existing systems.
- **Business case:** Respondents' second most frequent activity; typically involves understanding the cost of various vendor solutions, implementation options, tradeoffs, and the associated benefits.
- **Form a cross-functional team:** Most respondents do this to some extent, depending on the application. For example, an outage application can affect multiple functions, including member services, engineering, field operations, dispatchers, and others.
- **Formal vendor selection process**, e.g., request for proposals (RFP): The level of cost and complexity of a given project will dictate whether to engage in a formal process.
- **Use outside help:** Members report using consulting resources, likely determined by whether internal expertise and/or bandwidth is available.

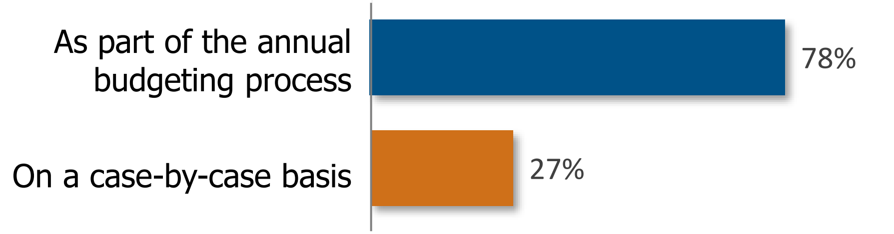
Most respondents allocate funding for these technologies as part of their annual budgeting process.

- This again is likely determined by the size of the project.

When evaluating a significant new technology do you:



"What is the process for allocating budget for these technologies?" (1)



(1) Total is >100% as some chose both answers

Funding and Financial Considerations

Business case and financial considerations

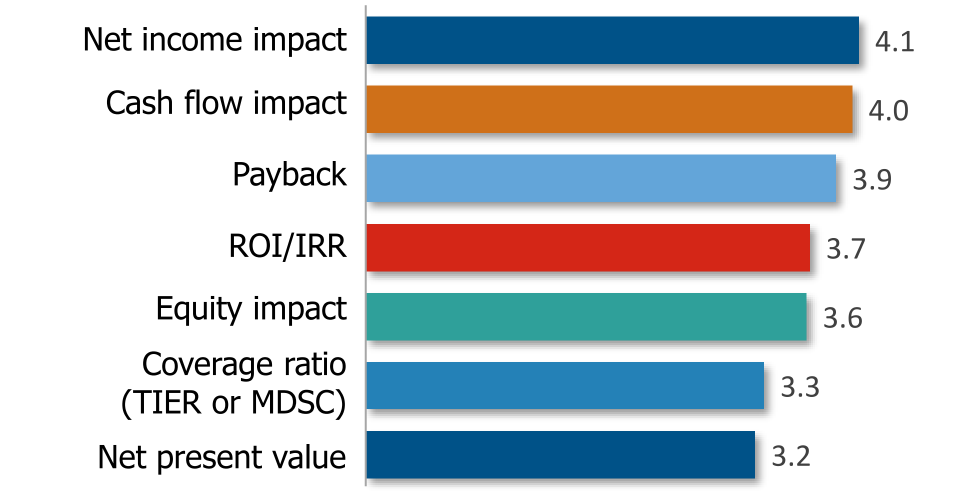
Members consider several measures when evaluating the financial impact of new technologies.

- **Net income:** Used the most by respondents and defined as revenue less operating expenses, depreciation, interest, and taxes. It is of particular interest to electric cooperatives as it is the basis for determining consumer-member rates.
- **Cash flow:** Cited second by respondents, cash flow is the net amount of cash transferred into and out of a business in a given period. This does not include depreciation and other non-cash items.
- **Payback:** This measure is the amount of time it takes to recoup an investment, sometimes known as a break-even period.
- **Return on investment (ROI) and internal rate of return (IRR)** gauge the profitability of an investment.
- **Equity impact** is the change in the amount of equity on the balance sheet.

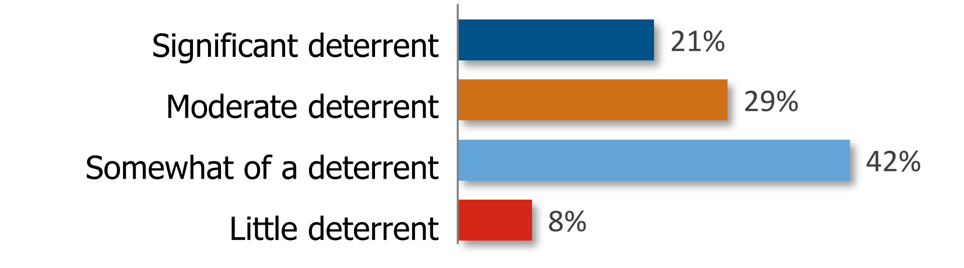
Depreciation of existing technologies is a consideration for members.

- Depreciation is a non-cash item that, especially for entities with low to no taxes, has little effect on cash flow.
- If technologies are replaced sooner than their determined useful life, the assets need to be written off, impacting net income and equity.
- Roughly half of respondents cited this as a significant or moderate deterrent to investing in a more current technology.

How often do you consider the following metrics when evaluating a business case for a specific technology?



If you desire to replace an existing technology with a more current technology, but the existing is not yet depreciated, how does this impact your decision making?



Funding

Cooperatives have access to traditional and new funding sources for smart grid implementations.

- Traditional investments in plant combine cash from operations with loans from a cooperative lender and/or RUS.
- Project financing is a non-traditional option when the smart grid project has a revenue stream that acts as the collateral for a loan from a project lender.
- PPAs are contracts between the project developer/owner and the power purchaser that enable the ability to collateralize the future revenue stream.

Funding models vary with project type.

- Metering, load management, asset management, and power quality projects generally follow the traditional cooperative financing model.
- DER integration projects use much more project lending with PPAs.
- Outage management and substation monitoring tend to use cash from operations.

How did you fund or plan to fund these investments/technologies?

Category	Technology	Cooperative Lender	RUS Grants/Loans	Cash	Project Lender (e.g., PPA)	Other
Metering	AMR/AMI	33%	31%	27%		9%
Reliability & Outage Management	OMS	22%	22%	54%		2%
Reliability & Outage Management	FLISR	32%	32%	25%	4%	7%
DER Integration	Utility-scale solar	21%	13%	11%	34%	21%
DER Integration	Utility-scale storage	25%	14%	4%	32%	25%
DER Integration	Behind-the-meter solar/storage	25%	25%	8%	17%	25%
Load Management	Volt/VAR optimization (VVO)	29%	32%	29%	3%	8%
Load Management	DR programs	29%	21%	38%		12%
Load Management	Real-time load balancing	41%	36%	9%	5%	9%
Asset Management	Equip health/predictive analytics	30%	22%	37%	4%	7%
Asset Management	Downstream plant health/analytics	30%	22%	33%	4%	11%
Asset Management	Substation monitoring	32%	18%	45%		5%
Power Quality	Auto. end-of-line voltage reg.	39%	32%	24%		5%
Power Quality	Auto. power factor correction	37%	29%	29%	3%	3...

Acknowledgements

Thank you for reviewing the "Rural Electric Cooperative Smart Grid Benchmarking Report." This document covers a wide range of topics, and we hope that you will benefit from these data and analyses.

A deep expression of gratitude to the participating 60 electric cooperatives. We asked them to share a lot of detailed information about their smart grid strategy, investments, and results. Their willingness to do so made this report possible. Thank you for your commitment to helping other cooperatives enhance their smart grid strategies and deploy these applications.

CFC and NRTC were pleased to collaborate on this effort. Cooperative principles guide everything we do, and this was a wonderful opportunity for us to embody the spirit of Cooperative Principle 6. More importantly, it's what our shared members deserve–their national organizations working together for them. We look forward to more efforts like this, both between our cooperatives and with other like-minded organizations.

CFC and NRTC look forward to continuing the smart grid conversation with our electric cooperative members, helping to evaluate technologies and technology investments that hold promise for you, your members, and the communities you serve.

Contacts and team acknowledgements

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About NRTC: NRTC is a technology cooperative, owned by the ~1,500 electric and telephone members that we serve. We help our members evaluate, build, and manage Broadband, Smart Grid, and Mobile networks.

About CFC: Created and owned by America's electric cooperative network, CFC—a nonprofit finance cooperative with $30 billion in assets—provides unparalleled industry expertise, flexibility and responsiveness to serve the needs of almost 1,000 member-owners.

Appendix

Appendix: Smart grid applications deployed and timing of deployment

Deployment Timeframe		Deployment Status	Timing of deployment: 5+ years ago	Timing of deployment: 3-5 years	Timing of deployment: 1-2 years	Timing of deployment: <1 year	Timeline for future deployment: Next 12 months	Timeline for future deployment: 1-2 years	Timeline for future deployment: 3-5 years	Timeline for future deployment: 5+ years	Timeline for future deployment: Un-defined
Metering	AMR/AMI	95% 5%	75%	14%	9%	2%	33%	33%	33%	0%	0%
Reliability & Outage Management	OMS	97% 3%	79%	16%	4%	2%	50%	0%	0%	0%	50%
	FLISR	26% 33%	67%	13%	20%	0%	21%	16%	32%	0%	32%
DER Integration	Utility-scale solar	47% 16% 17%	37%	56%	4%	4%	20%	30%	20%	0%	30%
	Utility-scale storage	12% 9% 38%	0%	14%	29%	57%	18%	18%	27%	0%	36%
	Behind-the-meter solar/storage	34% 2% 38%	55%	25%	10%	10%	9%	27%	23%	9%	32%
Load Management	Volt/VAR optimization (VVO)	41% 31%	58%	29%	13%	0%	22%	28%	22%	0%	28%
	Thermostat DR program	21% 3% 33%	25%	50%	8%	17%	5%	37%	11%	5%	42%
	Water heater DR program	34% 2% 26%	90%	10%	0%	0%	7%	40%	7%	0%	47%
	EV DR program	16% 57%	0%	11%	67%	22%	12%	24%	24%	3%	36%
	Real-time load balancing	7% 2% 41%	100%	0%	0%	0%	0%	8%	33%	4%	54%
Asset Management	Equip health/predictive analytics	28% 7% 38%	38%	38%	25%	0%	0%	27%	45%	0%	27%
	Downstream plant health/analytics	19% 21%	64%	18%	18%	0%	0%	8%	33%	0%	58%
	Substation monitoring	62% 12% 17%	86%	8%	3%	3%	10%	40%	40%	0%	10%
Power Quality	Auto. end-of-line voltage reg.	41% 34%	58%	25%	13%	4%	0%	30%	25%	10%	35%
	Auto. power factor correction	36% 38%	67%	29%	5%	0%	0%	18%	27%	5%	50%

Deployed | Provided by G&T | White: Planned

Application definitions

CATEGORIES	APPLICATIONS	DEFINITION
Metering	1. Automatic meter reading (AMR)/ advanced metering infrastructure (AMI)	AMR/AMI: Meters that use communications to collect electricity usage and related information from consumers and to deliver information to consumers. AMI: Enables collection of additional information more frequently to enable a range of benefits beyond the mostly meter-reading and billing functions of AMR.
Reliability and Outage Management	2. Outage management system (OMS)	System used to assist in power restoration; typically pulls in data from other systems to group and display outages and locate the source of the interruption among other functions.
	3. Fault location isolation and service restoration (FLISR)	Automatic sectionalizing, circuit reconfiguration, and restoration. Coordination of field devices, software, and communications to automatically determine the location of a fault and rapidly reconfigure the flow of electricity to avoid outages.
Distributed Energy Resources (DER) Integration	4. Utility-scale solar	Large solar facilities deployed by a utility or G&T to generate power (as opposed to behind-the-meter facilities used by end consumers to offset retail supply); generally 1 MW or greater.
	5. Utility-scale storage	Conversion of electrical energy into a stored form that can later be converted back into electrical energy when needed; generally 1 MW or greater.
	6. Behind-the-meter solar/storage	Solar and/or storage solutions deployed by a residential or C&I member.

Application definitions

CATEGORIES	APPLICATIONS	DEFINITION
Load Management	7. Volt/VAR optimization (VVO)	Optimization of system-wide voltage levels and reactive power flow to reduce system losses, peak demand, or energy consumption using conservation voltage reduction (CVR) techniques.
	8. Consumer demand response (DR) programs	Programs that seek to reduce peak demand by incenting end consumers to participate in a program to curtail usage during periods of peak demand.
	9. Real-time load balancing	Balances the power draw on each incoming phase to eliminate neutral currents and protect infrastructure. Performs automatic calculation and correction for load balancing across the phases in real time. Reduces neutral line currents and eliminates peak demand charges related to imbalanced phases.
Asset Management	10. Equipment health monitoring/ predictive analytics (substation)	System that measures and communicates equipment health and maintenance characteristics, including temperature, dissolved gas, and loading. Can generate alarms and suggest an optimal schedule for replacement.
	11. Downstream utility plant health/analytics	Solutions that monitor and measure utility assets such as poles (pole tilt monitors), vegetation, and advanced inspection techniques for other assets and equipment.
	12. Substation monitoring	Solutions can be similar to the above, but also include video monitoring.
Power Quality	13. Automated end-of-line voltage regulation	Solutions provide a steady and reliable output voltage regardless of voltage fluctuations at the input, preventing sags, surges, and brown-outs from harming electronics. Control equipment varies the voltage at the supply end of a feeder or at the load end and controls the current in the line by changing the power factor.
	14. Automated power factor correction	Correcting the excess reactive power generated by inductive loads in the industry. Improves efficiency of the system by reducing losses and apparent power demand charges.

Value stream definitions

VALUE STREAMS	DEFINITION
1. Avoided wholesale energy cost	Avoided general wholesale energy costs (any charges from power provider(s) for delivering energy).
2. Avoided wholesale demand charges	Avoided peak and coincident peak demand charges from the energy supplier and related charges including transmission charges and capacity charges, if they are functions of system demand.
3. Reduced outage minutes	Reduced frequency and/or duration (faster restoration) of outages. Usually quantified as a reduction in SAIDI (system average interruption duration index).
4. Reduced operations and maintenance (O&M) costs	Reduction in the labor and parts costs to operate the grid.
5. Avoided or deferred capital investment	Deferred or avoided replacement of assets by reducing the load and stress on the elements and/or more accurately determining replacement schedules via analytics.
6. Increased revenue	Additional member revenue from added energy sales or new services.
7. Increased member satisfaction	Benefits members see from having greater service reliability, ease of interacting with their cooperative, access to their usage information, etc.

Additional definitions (1 of 2)

Backbone (substation connectivity): High-bandwidth, low-latency data connection, enabled by wired or wireless technology, that connects systemically important infrastructure; this is most often substations for electric cooperatives.

Behind-the-meter: On the consumer's side of the meter, typically inside the residence or building.

C&I: Commercial and industrial consumers.

CIS: Customer information system–software that enables billing and member service business processes.

CIC: Customer interruption cost–also known as value of service (VOS), the economic impact of interruption to electric service.

Coverage ratio: A ratio that measures interest coverage such as TIER (times interest earned ratio) and debt service coverage (DSC) ratio.

DER connectivity/control: Connectivity and control of distributed energy resources such as solar, consumer-sited devices, energy storage, and electric vehicles.

Disconnect/reconnect cost: The cost of disconnecting or reconnecting service. Without this function in smart meters, this would need to be done manually at a member location.

Downline plant: Feeders and equipment between the substation and meters at the member service locations

EV: Electric vehicles.

Field force mobile broadband: Systems that improve efficiency of a field service team or fleet by providing real-time consumer and operational data.

Additional definitions (2 of 2)

GIS: Geographic information system– a system that places utility assets on maps.

IRR: Internal rate of return–a metric used to gauge the profitability of investments; the discount rate at which the present value of future cash flows is zero.

IVR: interactive voice response phone application.

Land mobile radio (LMR): Secure, instant communications systems to field staff and vehicles in mission-critical environments such as public safety and utilities; has one-to-one and one-to-many capabilities and often push-to-talk.

Non-technical loss: Energy that is consumed but not billed, typically due to theft or errors.

PPA: In this report, a PPA, or power purchase agreement involves a developer that installs an energy system, retains ownership, and sells the power generated from the system, typically at a fixed rate.

RUS: Rural Utilities Service, an operating unit of the USDA rural development agency of the U.S. Department of Agriculture.

SCADA: Supervisory control and data acquisition – systems used to monitor and control plant or equipment; typically comprising controllers, software, and communications.

Smart grid endpoints: Devices on a smart grid network such as meters, reclosers, and sensors.

Substation connectivity: Secure, two-way connectivity to utility substations.

VOS: Value of service – also known as customer interruption cost (CIC), the economic impact of interruption to electric service.