The Use Cases of (Un)Intended Effects When Interacting Load Modifying Solutions and an Alternative Framework for Their Management and Integration

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ABSTRACT

The energy industry is transitioning with the adoption of electric technologies, renewable generation, and energy efficiency. New rate designs and flexible load management solutions are becoming common alongside stricter building codes. The value of energy is increasingly time and location-dependent, bringing both positive and negative consequences. As more load-modifying solutions emerge, stakeholders must consider their interactions and impacts on the grid, environment, customers, and economy. Understanding and incorporating these effects into decision-making processes is crucial for effective deployment.

In a use-case format, this paper presents empirical results from recent studies highlighting the intended and unanticipated effects of various load-modifying solutions. Following the case studies, the paper provides a valuable framework with key guiding principles to follow when considering the design and deployment of load-modifying interventions. The framework is a valuable resource for utilities, implementers, and policymakers to help them plan and deploy programs that maximize value streams while avoiding adverse effects. The paper emphasizes the need to consider the consequences of different solutions carefully. Finally, the paper highlights the importance of accurate measurement techniques in evaluating program effects.

Introduction

Load modifying opportunities are growing at an unprecedented rate, fueled by emerging sources of load, such as electric vehicles (EVs) and building electrification measures (most prominently represented by heat pumps and heat pump water heaters), as well as the growing adoption of solar and storage technologies. This growth is being propelled by downward cost trends, aggressive federal strategies, and rapid technological advances. Some of the key trends include the following:

- Over the last three years, the US installed over 40 GW of solar PV, fueled largely by the steep and ongoing decrease in the prices of solar modules and inverters, as well as extended federal tax credits (Solar Energy Industries Association 2023).
- Over the last few years, EVs have emerged as a formidable distributed energy resource (DER). Due to the decreasing manufacturing costs of EV batteries, along with improvements in the driving range of EVs and supportive policies from corporate, state, and federal governments (such as the Corporate Average Fuel Economy standards, Clean Vehicle Credits enacted by the Inflation Reduction Act [IRA], and the Clean Air Act), the market share of light-duty EVs has increased exponentially. In 2023 alone, over 1.2 million EVs were sold in the US, representing over 8% of all light-duty vehicles. In comparison, over 4.5 million EVs have been sold since 2010. Myriad efforts are underway to understand EV load flexibility through rate-based solutions and managed

charging programs (Argonne National Laboratory, 2023). Efforts are springing up across the country to test the vehicle-to-grid (V2G) and vehicle-to-home (V2H) capabilities of EVs.

- Building electrification goes hand-in-hand with transportation electrification. With significant potential to mitigate emissions and decarbonize energy supply chains, building electrification has been on the rise in the US. More specifically, the percentage of US homes heated with electricity has increased steadily from 1% in 1950 to 40% in 2020, and the electrification trend continued to intensify, fueled by favorable state and federal policies (Davis 2022). Between 2022 and 2023, multiple states have passed major new laws promoting clean heating through fuel switching (Minnesota Energy Conservation and Optimization Act, Illinois Climate and Equitable Jobs Act, and the Colorado SB21-246, among many others), and the Inflation Reduction Act (IRA) provides a range of financial incentives to encourage individuals and businesses to invest in clean, efficient alternatives for their homes and businesses (Smedick, Golden, and Petersen 2022). For example, in 2022, heat pumps outsold fossil fuel-based heating systems in the US.
- Forecasted estimates across the industry for DER penetration consistently predict the addition of more varied resources to the grid as well as the increasing complexity of resources interacting with one another. These interactions are made possible by the emergence and growth of smart grid and building technologies, ranging from smart thermostats to complex Virtual Power Plants (VPP) capable of aggregating and orchestrating multiple DERs in an automated environment.
- Utilities across the country are pursuing price signals to manage DERs better—and demand in general—in the form of time-varying rates. Some states, like California, opted for a broad TOU defaulting approach, while others, like Oregon, are pursuing a targeted exploration of load-shifting capabilities of time-varying rates. Regardless of approach, across the country, time-varying rates are moving from the periphery to the mainstream of electricity pricing, fueled by the adoption of AMI technology. The arc of price responsiveness shows great promise in the ability of time-varying rates to support flexible load management (Faruqui and Tang, 2023).

As new load-modifying solutions emerge and become more commonplace, utilities and policymakers are faced with sometimes difficult questions of how to best integrate them with one another and how to leverage them in order to support a variety of value streams. At this time, the industry is still striving for and sometimes struggling to understand and assess how the various load-modifying solutions, including DERs, interact as well as how they should be integrated. This paper addresses both areas of uncertainty by:

- Supplementing the existing body of knowledge related to anticipated and unanticipated effects of the load-modifying solutions by presenting several use cases grounded in recent empirical data. The case studies are by no means exhaustive or comprehensive, nor do they reflect all scenarios. Rather, they are useful use cases emerging from recent research and evaluation studies across the country meant to highlight the benefits, risks, and emerging uncertainties related to the integration of the various load-modifying solutions.
- Developing a framework grounded in existing adaptive management frameworks and theories designed to guide and facilitate a more thoughtful, intentional, and measured

integration of load-modifying solutions, taking into account both intentional and unintentional benefits and risks.

Use Case 1. The (Un)Intended Energy Benefits of Demand Response

Demand Response (DR) programs have been a part of energy planning for over 40 years. Over time, traditional DR has evolved in concert with the increasing availability of technologies unlocking breadth and depth of customer engagement, coupled with changing regulatory policies to address grid, customer, and climate needs. DR is defined as “changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.” (Federal Energy Regulatory Commission (FERC)). Currently, smart thermostat programs are one of the most common DR offerings on the residential side.

Not surprisingly, peak load curtailment benefits have been the focus of DR programs, and not a lot of attention has been given to the energy-saving impacts that could be achieved through DR interventions. Those impacts, however, are present, even though they are not always explored as part of the load impact evaluations.

An analysis of over two dozen direct load control events leveraging smart thermostats for Ameren Missouri dispatched over the course of the 2019, 2020, 2021, and 2022 Summer seasons and across three distinct device manufacturers (Ameren Missouri 2020, Ameren Missouri 2021, Ameren Missouri 2022) presents strong evidence of positive energy saving achieved by participating customers as a result of DR event dispatch. As can be seen in the figure below, while energy savings range from event to event and device manufacturer to device manufacturer, most of the energy savings are positive. On average, across all events and device manufacturers, energy savings average 0.8 kWh per event day, which represents 2% of the daily HVAC energy consumption. Recent evaluations from other parts of the country show similar impacts. Namely, recent evaluations of PGE’s Smart Thermostat Program show energy savings ranging from 0.86 kWh (Cadmus, 2021) to 1.02 kWh (Cadmus, 2022). Similarly, a recent evaluation of SCE’s Smart Energy Program shows energy savings of 0.62 kWh for the average summer 2021 event. The energy savings are an additional, sometimes anticipated and sometimes not planned for the benefit of DR programs that affect both the grid (permanent load reductions) and the customer (additional bill savings) positively.

The Ameren Missouri smart thermostat impact evaluation results presented in Figure 1 below also show that energy savings increase as event durations increase as well. This is intuitive and not surprising. However, it is also indicative of the potential for even deeper energy savings as a need for longer event durations emerges across the country.

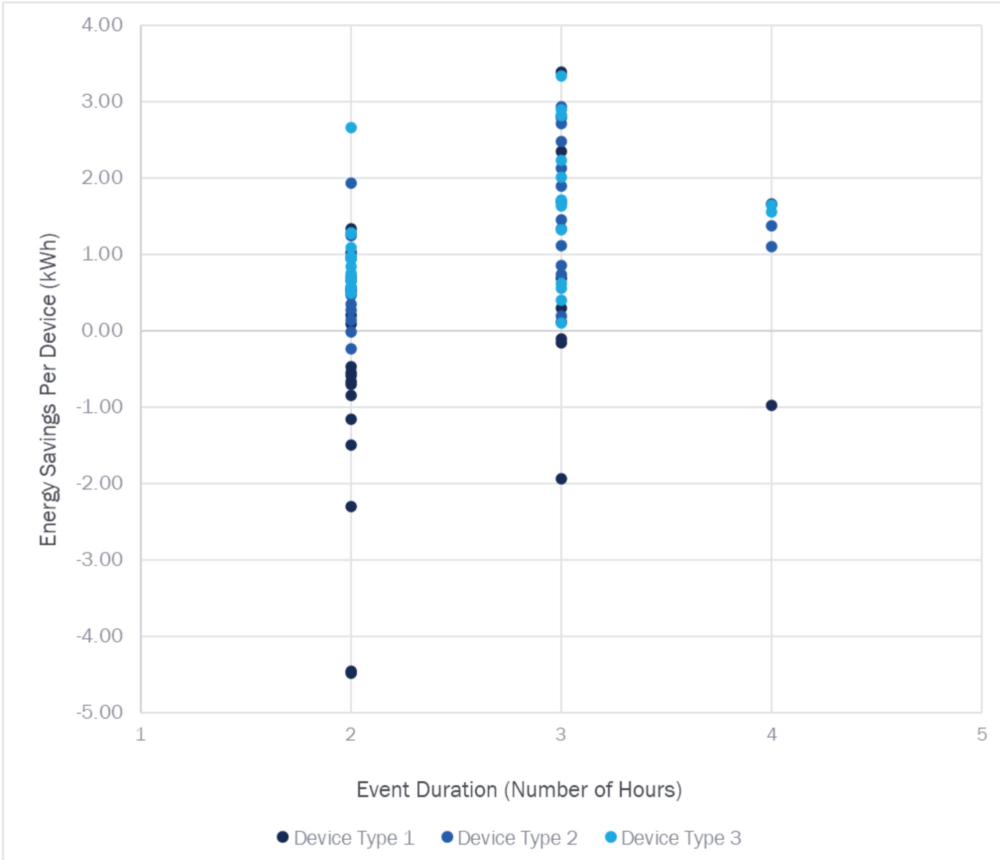


Figure 1. Distribution of Average Per-Device Energy Savings (kWh) by Event Duration

It is also important to address the presence of negative energy savings in Figure 1. Negative energy savings are increases in energy consumption as a result of DR events. They typically occur as a result of home preconditioning occurring prior to event dispatch to maximize participant comfort and minimize overrides. While pre-conditioning of participant homes is typical as part of the event dispatch, pre-conditioning routines can vary dramatically by device manufacturer, program implementer, and utility. In the case of Ameren Missouri, one of the three device manufacturers (Device Type 1 dark blue dots in Figure 1) pursued aggressive pre-conditioning routines, thus driving energy savings to be negative for a large share of events, reaching as much as -4.46 kWh or 21% of the daily HVAC load. While these aggressive pre-conditioning strategies are intended to deepen peak load reductions during event hours at the expense of increasing the load overall, they can lead to unintended negative customer experiences in terms of comfort and increased bills. If negative savings of -4.46 kWh per event were to persist throughout the event season across all events, customers could stand to incur in terms of increased energy bills an equivalent of a quarter of the participant seasonal incentive.[1]

If we were to remove devices with aggressive pre-conditioning strategies, energy savings achieved through event dispatch average 1.22 kWh per event day per device for an average

[1] Assumed 10 events, $25 in seasonal incentives, and 13.7 cents/kwh energy charge which is the current charge for customers on Ameren Missouri's flat rate.

Ameren Missouri smart thermostat program participant – 4% of the daily HVAC load. As can be seen in Figure 1, energy savings can reach up to 2.93 kWh for Ameren, Missouri – 12% of the daily HVAC load.

These learnings suggest that carefully curating the event durations and pre-conditioning strategies can allow DR programs to deliver additional energy conservation benefits to the system even with a relatively limited number of events.

However, the number of DR events that can be dispatched over the course of the season is limited, either by temperature triggers or by contractual stipulations preventing the dispatch of more than a certain number of event hours in a season. In order to harvest additional energy savings, Ameren Missouri integrated smart thermostat optimization on non-event days for customers participating in their DR program. While this optimization was performed on participants of just one device manufacturer, the results are illustrative of what is possible in terms of energy savings when smart thermostat energy optimization is stacked harmoniously on non-event days over the course of the event season. Such energy optimization occurs during evening hours and includes small setpoint adjustments that may not be noticeable to participants but that result in detectable and positive energy conservation benefits on non-event days. The 2022 evaluation results show a 1.57 kWh in energy savings, equaling an 8% reduction in daily HVAC load (Ameren Missouri, 2022). Figure 2 below shows the baseline and the actual average daily energy consumption on non-event days.

Combining average event day energy savings of 1.22 kWh per day with the non-event optimization-driven energy savings of 1.57 kWh per day and extrapolating them over the entire event season, an average program participant can stand to save over 235 kWh or over $32 additional dollars in bill reductions due to energy saving interventions effectively incorporated as part of the direct load control strategy.[2]

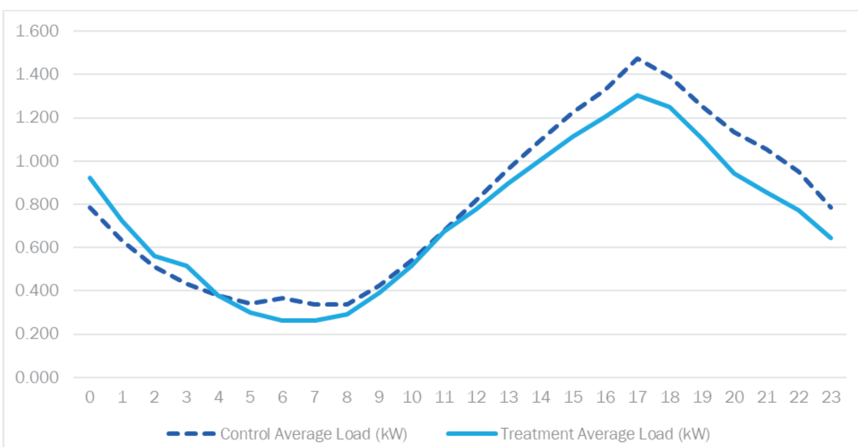


Figure 2. Energy Savings Benefits Achieved through Setpoint Optimization on Non-Event Days.

Use Case 2. The (Un)Intended Impacts of Transportation Electrification Activities

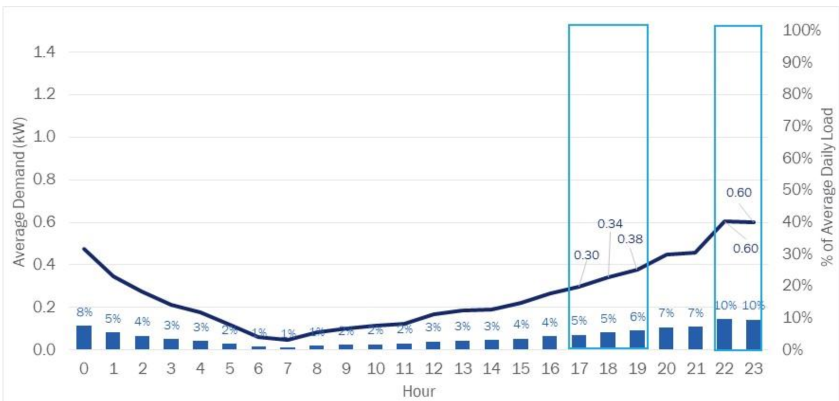
The growing presence of electric vehicles presents opportunities and challenges for utilities. Left uncontrolled, EV load can create new peak conditions and present a threat to the distribution system. Increasingly, utilities have been piloting a variety of EV load management

[2] Assumes event season from May through September, 10 event days and the rest non-event days, and 13.7 cents/kwh energy charge which is the current charge for customers on Ameren Missouri's flat rate.

programs to address these threats. However, pursuing multiple EV load management solutions at the same time can limit program benefits if care is not taken in program design. Stacking those solutions in a way that is complimentary and sequential as opposed to contemporaneous can present an opportunity. A managed charging pilot in the Pacific Northwest demonstrates that multiple EV load management strategies can be successfully deployed with thoughtful program design (PGE 2023 Transportation Electrification Plan report). The PGE Pilot enrolled customers into one of two load management groups, depending on whether customers were also on a whole home TOU rate. The Pilot also randomly assigned customers to an unmanaged control group, which provides a baseline to assess the impacts of managed charging, the TOU rate, and the stacking of both interventions.

When the EV charging load is unmanaged, the TOU rate is effective at shifting the charging load from peak hours of 5pm-9pm to off-peak hours, as can be seen in the graphs below.

Non-TOU Participant Unmanaged Charging Load (Summer 2022)



TOU Participant Unmanaged Charging Load (Summer 2022)

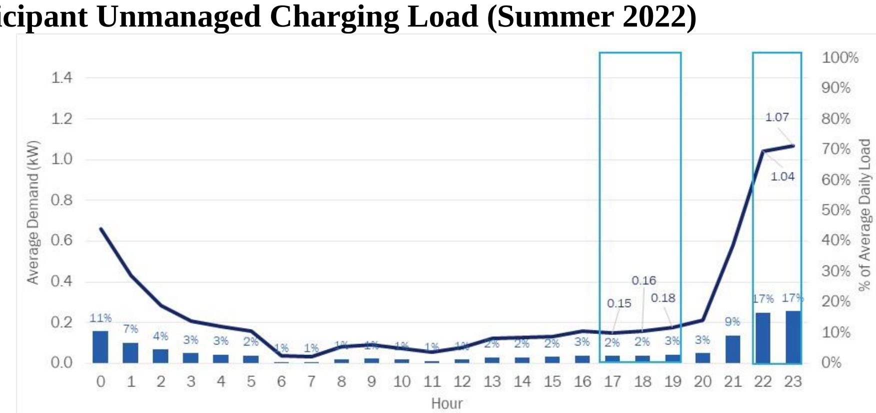
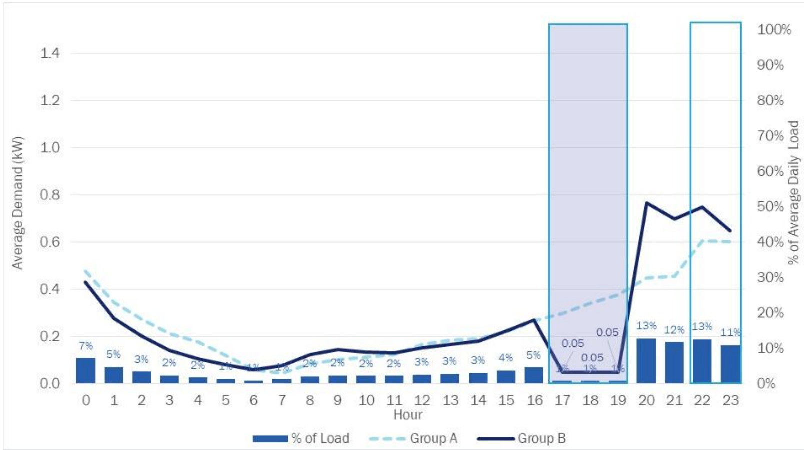


Figure 4. Unmanaged Charging Load With and Without TOU Rate.

Managed charging interventions, however, are also highly effective at shaping participants' charging load both during the hours coincident with the TOU peak as well as during the hours following the peak.

Non-TOU Participant Managed Charging Load During Hours 5-8 PM (Summer 2022)



Non-TOU Participant Unmanaged Charging Load During Hours 10-11 PM (Summer 2022)

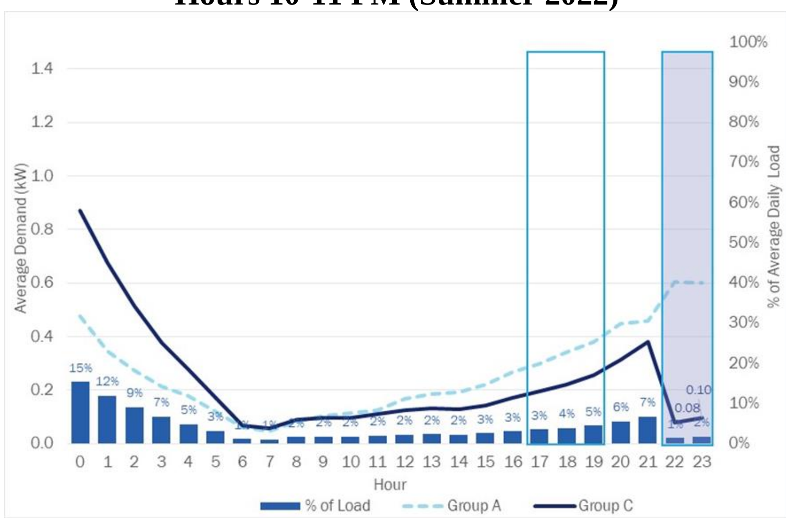


Figure 5. Managed Charging at Different Hours of the Day

Together, managed charging and TOU interventions targeting the same set of hours may not deliver enough incremental benefit; however, staggered in time, they can target different hours of the day, beneficially shaping the charging load.

Use Case 3. The (Un)Intended Impacts of Energy Conservation

Solar energy is one of the fastest-growing renewable energy sources in the US, according to the Department of Energy (Department of Energy). The United States installed 17.0 GWac (20.2 GWdc) of PV in 2022, ending the year with 110.1 GWac (140.6 GWdc) of cumulative PV installations (NREL). California represents the largest solar market in the United States. As of September 2023, solar technologies accounted for 28% of the state's electricity output, including rooftop and grid-scale PV systems, as well as concentrated solar plants (SEIA). California's investment in energy efficiency programs is set to continue on an aggressive pathway. More specifically, The California Public Utilities Commission (CPUC) has approved a budget of $4.3 billion for energy efficiency initiatives from 2024 to 2027. Additionally, there is a forecasted budget of $4.6 billion for the period from 2028 to 2031 (CPUC).

Energy impact evaluations have traditionally excluded customers with solar generation in order to isolate program effects. Opinion Dynamics' recent impact evaluation study for the GoGreen Home Energy Financing Program (Opinion Dynamics, 2024), however, not only included customers with solar but explored energy savings in that segment separately in an effort to understand any differences in energy savings achieved within this customer segment. The analysis showed that participating customers with solar were more likely to achieve positive electric energy savings than those without solar. In addition, solar customers achieved considerably higher energy savings than those without solar. Notably, participants with solar pursue larger projects as well as a higher percentage of projects with weather-sensitive measures. The patterns persist even after controlling for climate zones and, therefore, weather. Solar participants are considerably less likely to be located in disadvantaged communities. It is possible and even likely that the current sociodemographic composition of the customers with solar influences the extent of energy savings achieved and that as the presence of solar in California homes continues to increase, the energy savings impacts may change. However, it is important to consider the following possible consequences:

- In the near term, increased engagement of solar customers in energy conservation is likely to deliver higher energy conservation impacts, thus delivering a range of grid benefits, including peak demand reductions, infrastructure improvements, and environmental benefits.
- By doing so, solar customers will be making available excess solar generation capacity that the California Grid will have to absorb and host.
- Given existing economic disparities among customers with and without solar – the median income of residential solar adopters in CA is higher than that of the general population (LBNL) – deeper energy conservation impacts are likely to pose equity considerations.

Figure 6. GoGreen Homes Energy Savings Analysis Results

Use Case 4. The (Un)intended Customer Bill Impacts from Building Electrification

Buildings contribute to about one-third of greenhouse gas emissions in the United States, and as such, widespread building electrification will be required to meet decarbonization goals (EPA 2022). State policies, utility programs, and federal funding, such as the Inflation Reduction Act (IRA), have been designed to help support this important goal. These efforts typically focus on the societal benefits of widespread building decarbonization and may imply that building electrification, such as adopting heat pump technology, is universally beneficial to individual residential households. Indeed, research shows that many households would experience reduced energy costs by adopting heat pumps and other efficient electric technologies (Nadel and Fadali, 2022). However, there is variation in both the upfront and ongoing costs and savings associated with building decarbonization for residential households, influenced by regional factors, including climate patterns, differences in energy prices between fuels, electric grid capacity, and rate structure, and by individual factors such as baseline fuel, building age, complementary upgrades like solar PV adoption and weatherization, and household income (Billimoria, Henchen, Guccione, and Louis-Prescott 2018; Fadali, Waite, and Mooney 2024; Kahn-Lang, Miller, Satchwell, and Present 2024; Nadel and Fadali 2022; Yim and Subramanian, 2023). This variation and the corresponding risks to consumers have important implications for customer outcomes and decision-making and should be a more central part of the discussion if we are to achieve decarbonization goals while also minimizing unintended consequences for consumers.

Residential customers are aware of and concerned about the high up-front costs of electrification and the potential for increased energy bills, and these are leading barriers to widespread market adoption. In a study with California homeowners in 2023, those who were aware of heat pumps but had not installed one cited the possibility of increased utility bills as a top barrier, with over half (58%) stating that the chance of increased utility bills was a major or moderate barrier to adoption. The only barriers greater than bill concerns were also cost-related: the upfront costs of the technology and the potential for associated upgrades to their home's wiring or electrical panel (Loomis and Steiner, 2024). This is particularly illuminating given that building electrification is likely less financially risky for Californians than for homeowners in the Midwest and Northeastern parts of the country (Kahn-Lang, Miller, Satchwell, and Present, 2024; Nadel and Fadali, 2022).

Even among customers who save money on their energy bills following electrification, bill impacts tend to be modest. Recent research from the Lawrence Berkeley National Lab (LBNL) examined residential customer bill impacts from energy efficiency, distributed solar PV, and building electrification to simulate impacts across regions, rates, and building types, showing that customer bill impacts from investments in these areas result in bill savings of less than 2% for most customers and maximum bill savings of 6%. While all customers in the Southwest and Great Plains utilities they studied would experience bill savings when electrifying their home on a volumetric rate, about half would experience a bill increase in the Midwest and Northeast due to the higher price of electricity compared to fossil fuels. In the Midwest, despite a 61% decrease in median energy consumption, the median energy bill would be 3% higher following electrification (Kahn-Lang, Miller, Satchwell, and Present 2024).

Research with customers who have recently electrified their homes provides insights into customer experience and perceptions of how the upgrades influenced their bills. Among California TECH participants who received a heat pump, fewer than half (41%) reported that their combined monthly electric and gas utility bills decreased. Consistent with other research, a variety of factors affected perceived customer bill impacts in both positive and negative directions, including the presence of solar PV, utility rate changes, weatherization completed around the time of the heat pump installation, and whether the customer had air conditioning before installing the heat pump. Most of the customers who experienced reduced bills (57%) also had solar PV. Those customers with air conditioning before installing the heat pump were more likely to experience a decrease in their bills compared to customers without air conditioning prior to the upgrade (46% vs. 29%, Steiner and Loomis, 2023).

One tool for utilities and policymakers who want to manage the increased load associated with widespread electrification while helping customers manage their bills is time-varying rates (Billimoria, Henchen, Guccione, and Louis-Prescott, 2018; Yim and Subramanian, 2023). Pacific Gas & Electric recently introduced the E-ELEC rate, which is available to customers who charge an electric vehicle at home, have battery storage, or use an electric heat pump for water heating or space conditioning (Pacific Gas & Electric 2024). While it is intuitive that time-varying rates would be effective for helping utilities and grid operators manage new peaks from electrification, corresponding benefits do not universally or automatically extend to individual households. For example, LBNL found no consistent relationship between flat versus time-based rate designs and customer bills across a range of scenarios involving energy efficiency, solar PV, and building electrification. While time-based rates did not typically lead to substantial bill increases, they also do not lead to the kind of bill savings that would financially motivate customers to shift to off-peak hours, and temporal variation in pricing was less predictive of customer bill outcomes than retail volumetric rate differences (Kahn-Lang, Miller, Satchwell, and Present 2024). While enabling technology may help customers to achieve the best outcomes possible given the rates available from their utility, contractors are still learning to recommend and install equipment with time-of-use controls that support customers' ability to optimize their new equipment under a time-varying rate (Loomis and Steiner, 2024). Aligning individual incentives and outcomes with available technology and societal outcomes will be important for maximizing the effectiveness of rates as widespread electrification continues to put pressure on both individual customer energy bills and the grid.

FLEX Framework for Adaptive Management of Load-Modifying Solutions

The market trends, along with the aforementioned case studies, illustrate that the emerging multi-DER landscape is characterized by complex, highly uncertain relationships, extensive interdependencies, and unpredictable externalities. Given the intricate nature of these relationships and interdependencies in a rapidly evolving field, we draw on established decision-making theories and frameworks to propose a new framework. This framework comprises guiding principles and a process flow designed to facilitate a more thoughtful, intentional, and measured integration of load-modifying solutions, taking into account both intentional and unintentional benefits and risks.

The following key theories and frameworks were used and adapted to present a foundation for the framework below:

- Cynefin framework. Originally developed by Dave Snowden & Cynthia Kurtz from 1999 to 2005. It is a useful framework for describing and understanding complex environments through a sense-making model, and it provides solutions for how to deal with challenges and situations (Sensemaker.com). The framework establishes five domains ranging from Obvious to Chaos and offers a pathway to assessing, understanding, and solving challenges in each. Within this framework, the current state of the DER space lands at the juncture of the "Complicated" and "Complex" domains, each described by a cause-and-effect relationship. The "Complicated" domain within the framework is described by the environment where "cause and effect can only be perceived partially or in retrospect, but cannot be fully understood in advance, and many different actors modify the system and each other." Decisions within this domain are based on sensing, analyzing, and responding to the situation(s) based on existing good practice (rather than best practice). Within the "Complex" domain, the "relationship between the cause and effect can only be perceived partially or in retrospect, and experimentation is required to make sense of it all." Within this domain, experimentation is required to find answers (decisions), and as such, probing is first required, then sensing of the situation, then responding to it.

- Adaptive management theory and framework. Developed by C.S. "Buzz" Holling and Carl Walters in the late 1970s and early 1980s as part of the work in ecological and natural resource management. This framework was later adopted by the US Department of the Interior as a technical guide for adaptive management approaches. Adaptive management framework promotes flexible decision-making that can be adjusted in the face of uncertainty while emphasizing careful monitoring and real-time learning of outcomes in order to advance scientific understanding and adjust policies or operations as part of the iterative learning process.
- Systems Thinking framework. It is a powerful framework for understanding and managing complexity. This framework features a holistic approach to understanding and managing complex systems and focuses on the relationships and interactions between the components of a system, as opposed to viewing those components in isolation. The key principles associated with the Systems Thinking Framework are 1) recognition of interconnectedness of all parts of the system, 2) acknowledges the importance of feedback loops, 3) emphasis on looking at the system as a whole rather than focusing on individual components, 4) understanding that the system as a whole can exhibit properties not evident from each of the parts, 5) definition of the system boundaries and 6) identification of the impactful components of the system where small changes can lead to deep impacts.

The proposed framework prioritizes the following tenets that are critical given the current state of the integration of load-modifying solutions into the grid and society:

- Recognizes interconnectedness and interdependence of the various load-modifying solutions.
- Recognizes inherent uncertainty and lack of knowledge.
- Recognizes continuous and rapid change that the technology, the grid, and the customers are undergoing.
- Encourages strategies that are flexible and can be adjusted based on feedback and changing circumstances, as well as iterative processes that allow for experimentation, learning, and refinement over time.
- Emphasizes stakeholder engagement to ensure diverse perspectives and depth of understanding.
- Encourages experimentation and data-driven decision-making.

The figure below provides a visual depiction of the framework. It is comprised of four key steps – Formulate-Link-Engage-Experiment, with monitoring and evaluation being an embedded part of the process. The arrows in the framework indicate the iterative and cyclical nature of the process with a focus on learning and iteration. Following the graphic, we provide a summary of considerations for each of the steps. This framework can prove useful to the utilities, policymakers, technology providers, regulators, and other stakeholders working to integrate load-modifying solutions into the grid, homes, businesses, and society in general.

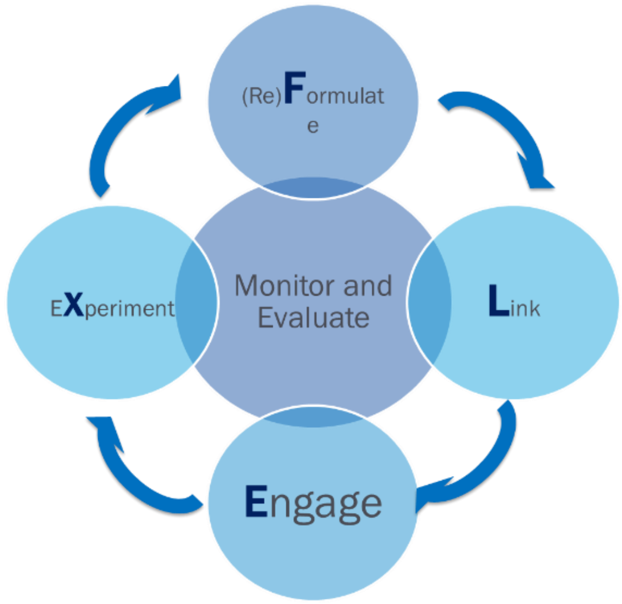


Figure 7. FLEX Framework Overview

Step	Considerations
Formulate	This step includes identifying and defining a load-modifying solutions /suite of solutions and determining the targeted impacts, benefit streams, and anticipated goals and outcomes. This step also involves holistically considering all possible areas of impact and projecting the consequences of incorporating load-modifying solutions on other adjacent areas such as the grid, the environment, and the customer (including experiences, bills, comfort, health, and other areas of influence). Multidimensionality is common when it comes to load-modifying solutions and the areas of their impact. As such, sensitivity analysis can help assess the various areas of impact associated with a specific load-modifying solution against one another and help zero in on a set of critical considerations that impact the desired outcomes further. As part of this step, it is also important to document the areas of uncertainty associated with the impacts of a resource, as that can serve as valuable input in the further steps in the process, such as engagement, experimentation, and monitoring. This step can help achieve deeper explicitness and purpose associated with the load-modifying solutions integration.
Link	This step involves taking a broader view and placing the load-modifying solution(s) in the context of existing solutions and resources with similar and differing benefits. It also involves carefully considering the effects of incorporating multiple solutions into a single ecosystem (e.g., solar, storage, rates, and event-based DR). In conjunction with that, this step includes formulating the market engagement process (who will be targeted, who needs to be engaged, etc.), including market actors, technology providers, and end-use customers. In the case of end-use customers, special consideration should be given to the choice environment that is currently available to them as it relates to the load modifying opportunities and whether restriction-based (this but not that) vs. option (this and this) driven vs. journey based (this before that) approach is appropriate. In addition to considering the current interactions and engagements, this step involves considering projecting the consequences of future possible interactions and engagements, including the emergence of other known load-modifying solutions that may present a meaningful threat to the target resource’s stream of benefits (e.g., change to demand response benefits with the introduction of default time of use rates) or a tangible threat to customer experience (e.g., confusion and decay in engagement).

Step	Considerations
Engage	This step involves incorporating relevant stakeholders in the decision-making process and identifying points and areas of collaboration to support load-modifying solutions integration and deployment. Stakeholders include people and organizations who use, influence, and have an interest, or "stake," in a given resource. Stakeholder engagement can help support deeper coordination of existing flexible load solutions, further deepen and inform an understanding of linkages, and coordinate any monitoring and measurement to ensure that the complexity of the interactions is proactively anticipated and addressed. Stakeholder engagement can also support better understanding and identifying ways to reduce tension points among stakeholders. Understanding the points of tension and incorporating them in the decision-making process can help enhance an understanding of the flexible load resource benefits and improve its integration into a broader ecosystem of flexible load solutions.
Experiment	This step involves both the implementation/deployment and experimentation as part of the flexible load resource deployment process. When advancing flexible load solutions, emphasizing the implementation process that focuses on learning while doing, learning can be accelerated when there are opportunities to experiment and test the hypothesized benefits as well as externalities of a flexible load resource. Such approaches as replication, randomization, and control can help lead to more rapid identification of issues frequently on a smaller scale before a broad-based launch.
Monitor and Evaluate	Monitoring and evaluation is the step cutting across all of the above steps and including, first and foremost, periodic or ideally continuous assessment of the flexible load resource performance against the pre-defined objectives and performance metrics, theory-driven working hypotheses, and pre-existing assumptions. This step also involves continued assessment of the market and tracking of the policy, customer, technology, and grid metrics to ensure that impactful information on changes in the market dynamics is considered and, if needed, incorporated into the decisions related to the flexible resource value streams, deployment, or integration with other resources. The monitoring and evaluation process should be designed at the outset and informed by the key considerations, decisions, knowledge, and uncertainties determined through the previous steps. Real-time and developmentally focused evaluation and measurement can enhance early learning and facilitate mid-course corrections.

Table 1. FLEX Framework Steps and Considerations

Implications for Evaluation, Measurement, and Verification

Incorporating multiple load-modifying interventions as part of the load management strategy has important implications for evaluation, measurement, and verification. Developing baselines free of non-routine events and unrelated to the intervention source of load changes has been a challenge for evaluation professionals for decades, and it has only been exacerbated by the emergence of DERs and multiple load-modifying interventions. Consider a hypothetical example presented in the figure below with multiple DERs in play, including Direct Load Control (DLC) DR events that shed load during event hours but also increase load due to pre-conditioning and snapback outside of event hours, layered on top of TOU price signals that encourage customers to shift load to off-peak hours, with managed charging interventions overlapping some but potentially not all of the hours, while adoption of energy-efficient technologies drives permanent load shed and beneficial electrification of homes and vehicles drives increases in electric load. Isolating the sources of the load modifying signals, adequately controlling for each, and thoughtfully attributing them to the sources of the interventions will require careful planning – engaging EM&V professionals early to craft appropriate measurement design to ensure evaluability of each individual intervention as well as their (un)intended benefits and costs, be it through experimental design or other techniques available at the EM&V

professional's disposal will allow for more effective and successful integration of DERs into the grid while ensuring positive customer engagement and experience.

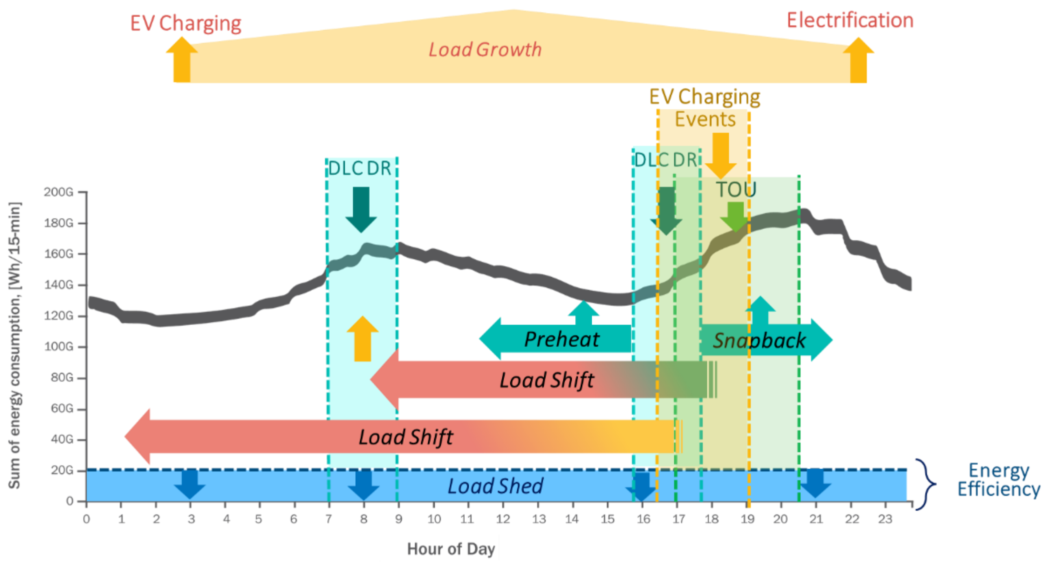


Figure 8. Conceptual Example of Load Modifying Interventions Administered Together

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