The "Weakest Link" in California's Transition to Load Flexibility: Policy, Coordination, and Regulatory Uncertainty

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ABSTRACT

California is betting on load flexibility (LF), setting a 7-gigawatt load shift target by 2030. While load flexibility is critical for resilience and affordability, many challenges lie ahead. This paper investigates the systemic barriers shaping California's transition to highly dynamic electricity prices and automated load flexibility, with particular attention to the non-technical dimensions of governance, regulation, and market design. While technological development continues at a rapid pace, stakeholders identify policy coordination, regulatory uncertainty, and market misalignment as the "weakest links" in achieving California's 8760 vision of a fully optimized grid. Our research finds broad consensus that these challenges, rather than technical ones, pose the greatest risk to progress. Drawing on 95 interviews with representatives from a range of stakeholder groups, the research explores stakeholders' perspectives on the nature of uncertainties surrounding LF policy, their subsequent implications, and available mitigation pathways. Central questions emerge around how policies are coordinated, how conflicting priorities are reconciled, and how regulatory structures can support rather than delay innovation. Policy uncertainty itself hinders progress by creating a "chicken and egg" problem whereby manufacturers hesitate to develop new load-flexible products until policies provide clarity, while regulators delay reforms pending proven technologies. These governance challenges in turn impact policy design, particularly the debate over default enrollment into dynamic rates. While some view an "opt-out" approach as essential for reaching scale, questions remain about political feasibility and equity protections. This research highlights the stakes of California's policy choices, raising broader questions about whether the state's greatest risks in its energy transition lie not in technical innovation, but in the ongoing challenge of aligning policy, regulation, and market structures.

Introduction and Background

California has identified load flexibility (LF) as a critical resource for achieving building electrification, decarbonization, and grid reliability. The California Energy Commission (CEC) defines LF as "the practice of adjusting load (or energy usage) to match the supply of electricity. Electricity customers with smart devices can automatically shift their energy usage to when electricity is cheaper and cleaner, and use less energy when the grid is under stress or running polluting power plants" (CEC, n.d.). Arguing that continuous LF will maximize renewable utilization, curb rising electricity costs, and reduce greenhouse gas (GHG) emissions, the CEC in

2023 approved an official load shift goal of 7,000 megawatts (MW) by 2030 (CEC, 2023), of which price-responsive automated LF is an integral part.

To make this future a reality, California policymakers are working to establish a system that communicates dynamic retail electricity prices, reflecting the real-time costs of electricity production and delivery, to end-use technologies (e.g., air conditioners, heat pumps, electric vehicle chargers) capable of responding to those prices to balance system needs. These efforts span rate design, technology standards,[1] enrollment mechanisms, and data access protocols, which in turn, shape the technical architecture and market opportunities for utilities, their customers, and the firms that develop enabling technologies and provide load management services.

On the policy side, California has initiated numerous activities to establish the framework for highly dynamic electricity prices and 8760 LF. The Load Management Standards (LMS)[2] require large energy providers in the state to publish hourly prices that can be accessed by California customers and third parties (e.g., aggregators) (CEC, 2024). The state is also developing *flexible demand appliance standards* (FDAS), which will require devices to default to price- and GHG-responsive settings. Both the CEC and the California Public Utilities Commission (CPUC) have critical roles in developing and implementing LMS and FDAS. In parallel, the OpenADR Alliance is updating *OpenADR*, which "standardizes the message format used [by] utilities, ISOs [i.e., independent system operators], and energy management and control systems." OpenADR plays a critical role in facilitating uniform, interoperable, open, and secure communication among actors in the LF ecosystem (OpenADR Alliance, n.d.).

On the research and development side, the CEC funded research to convene actors from across the LF innovation ecosystem to identify, evaluate, develop, fund, and demonstrate cost-effective and reliable load-flexible and flexibility-enabling technologies. Yet as sociotechnical transitions scholarship demonstrates, ambitions such as California's vision for 8760 LF often encounter "regime" resistance from entrenched rules, markets, and institutions that lag technological readiness (Geels, 2004; Geels & Schot, 2007; Verbong & Geels, 2007).

To explore the challenges such friction might pose, a team of social scientists - working in parallel with R&D activities to develop and test LF technologies - explored stakeholder perspectives on the efforts to establish 8760 LF in California. The *stakeholder needs assessments* revealed that policymaking itself - particularly the uncertainty around both the process and its potential outcomes - may be impeding progress towards the goal of a robust LF ecosystem. In the absence of a clear roadmap outlining how and when critical policy decisions will shape the rules of engagement related to LF, stakeholders - whose participation is essential to realizing California's LF vision - face more questions than answers.

Dozens of interviews were conducted with stakeholders from across relevant groups to explore how policy coordination, conflict, and uncertainty, among other topics, are affecting stakeholders' outlooks on and preparations for highly dynamic electricity prices and automated

1 See Outcault, Alston-Stepnitz & Taylor (2024) for full discussion of stakeholder perspectives on the role of standards in establishing a load-flexible ecosystem in California.

2 The 2022 Load Management Standards Rulemaking established the foundation for more variable retail electricity rates, requiring utilities to "develop and offer customers at least one retail electricity rate that changes at least hourly" (CEC, 2022). The policy aims to promote grid reliability, curb rising electricity costs, encourage utilization of renewable energy resources, and reduce greenhouse gas emissions.

LF. Findings from those interviews were initially reported in Outcault, et al. (2023a; 2023b). This paper builds on those findings to explore in-depth stakeholders' perspectives on the nature of uncertainties surrounding LF policy, their subsequent implications, and available mitigation pathways.

Methodology

Data were collected through two rounds of semi-structured interviews with four stakeholder groups: (1) developers of load-flexible and flexibility-enabling technologies ("technology providers"); (2) "energy service providers" including investor-owned utilities, community choice aggregators, and firms that provide load management energy services for the purpose of grid support; (3) large commercial customers; and (4) energy/environmental interest groups. Table 1 summarizes the breakdown by stakeholder group and year. Interviewees were recruited from the professional network of the wider research team. Interview protocols were developed for each round to ensure consistency and flexibility (protocols can be found in Outcault et al., 2023a & 2023b). The specific questions asked and their precise wording were slightly tailored to each stakeholder group as needed to ensure relevance and accurate interpretation.

Table 1. Respondents (n=95) by stakeholder group and year

	Year 1	Year 2	Total
Technology providers	12	21	**33**
Energy service providers	15	16	**31**
Large commercial customers	0	19	**19**
Energy/environmental interest groups	0	12	**12**

The first round of interviews, conducted in Aug-Sept 2022, focused exclusively on project partners, affiliates, and members of the Technical Advisory Committee. Interview questions explored the topics of electricity rates, stakeholder value propositions, barriers to the transition to dynamic prices, and technical aspects of communications technologies. Interviews were completed with 27 stakeholders representing 21 different organizations and two stakeholder groups (technology providers and energy service providers).

The second round of interviews, conducted Jun-Sept 2023, aimed at a broader representation of stakeholders, i.e., beyond project partners. The interview protocol was informed by input collected from members of the project team and other experts through a Delphi panel.[3] The resulting interview protocol included questions related to California's vision

[3] The Delphi technique is a scientific method used for iterative, structured group (i.e., panel) communication to gain consensus-driven insights into current or future challenges when information is limited (see Beiderbeck et al., 2021). More information on the methods and results of the Delphi panel used are reported in Outcault, et al., 2023a.

for LF, policies and standards, technology development, customer issues, and organizational changes needed to prepare for dynamic prices and devices that optimize responses to them. A total of 53 interviews were completed with 68 individuals who collectively represented 50 organizations and all four stakeholder groups.

Two members of the research team independently coded all interview transcripts to ensure thoroughness and reliability. During this process, a detailed codebook was constructed based on emerging themes and subthemes. Codes established included 11 parent codes: customers, device/appliance, economics, energy history, key players, policy, social/environmental, priority/need/constraint, technology characteristics and technology/intelligences, and "other." Each parent code had associated child codes. For instance, the parent code "policy" included: building codes, demand response, energy efficiency, goals, load flexibility, mandates, pilots, programs, standards, and time of use. Across all categories, a total of 86 child codes were created.

Analysis was conducted using NVivo qualitative analysis software. Queries were executed to identify interview transcript segments that met specific criteria, such as the presence of one or more codes, keywords, or technical terms. The retrieved text segments were then analyzed by researchers to interpret patterns and insights. In some cases, open-ended responses were grouped (pile sorted) and coded, and instances were counted to illustrate the frequency of a particular perspective or sentiment.

Results

Analysis revealed four key areas of uncertainty: (1) How will rate design evolve? (2) What technology standards will be established, how, and when? (3) Do policymakers have the commitment and capacity to implement the LF vision? and (4) When will there be clarity on the prevailing uncertainties? These patterns emerged from analysis of both direct accounts from stakeholders describing their own experiences and perspectives, as well as indirect insights from participants speaking about the opportunities and challenges faced by other stakeholder groups. Together, these perspectives provide a more comprehensive view of perceived barriers and priorities across the system. The results are organized according to those four questions, synthesizing stakeholder perspectives on and consequences of those unknowns, and options for addressing them.

How Will Rate Design Evolve?

Stakeholders expressed doubt, concern, and confusion about the future directions of rate design as it relates to dynamic electricity prices. Topics identified included timescale, input parameters, and customer participation.

Timescale. Stakeholders noted that pricing more granular than hourly increments would offer more precision for maintaining system balance, but would be more costly to implement. As one stakeholder noted, "You get more granularity with 5-minute [pricing], but is it worth it? Do the complexity and the cost go through the roof when you get that much data?"

In addition, several interviewees highlighted practical and institutional constraints that will shape what is feasible in practice. Utilities described legacy billing processes as a major barrier to implementing sub-hourly or highly customized rates. They noted that reprogramming customer information and billing systems to support multiple, highly granular tariffs is a multi-year and expensive undertaking that would require explicit cost recovery of the associated utility costs. Furthermore, stakeholders emphasized that LF devices' ability to respond to sub-hourly prices is not well understood, with several citing potential damage to HVAC equipment from frequent cycling.

Several participants questioned whether "super dynamic" (e.g., 5-minute interval) pricing is actually desirable, arguing that most of the system benefits could be captured with simpler, more predictable time-variant structures. They suggested that hourly may be "good enough" to achieve 80-90% of the grid value while avoiding the confusion and implementation burden associated with very high-frequency price changes.

Input parameters. Details about how rates will be designed remain unknown, leaving stakeholders to speculate. Some contended that rates will reflect the underlying costs - both fiscal and environmental - of providing electricity at a given time, eliminating cross-temporal subsidies inherent in the current rate design (where off-peak rates subsidize on-peak rates). Others noted that marginal emissions (i.e., the change in emissions with a small change in electricity load) may be an input factor in rate design. As one stakeholder noted, marginal costs and carbon emissions are not perfectly aligned, which will require that rate design prioritize either affordability or decarbonization goals.

Stakeholders also wondered how the transition to highly dynamic prices would navigate other efforts related to rate design, including the "dysfunctional" net energy metering system, recovering wildfire mitigation and liability costs, bill protection measures, income-based utility billing, and the proposed policy for flat-fee utility billing. The following quote illustrates one such potential conflict whose resolution is uncertain:

> *You're gonna have these dynamic rates that are gonna make energy more expensive when it really should be, and cheaper when it should be, but then you throw in this curveball of like a fixed charge that reduces the ability for anybody to have price variation between the high points and the low points. It is gonna decimate rate flexibility.*

Finally, some stakeholders warned that dynamic rates could interact with broader investment choices in ways that are misaligned with policy goals, pointing to what they described as a "grotesque misalignment of investment" in which the state devotes substantial resources to supply-side assets while under-investing in demand-side capabilities that dynamic pricing is intended to unlock.

Customer participation. Stakeholders noted that a large differential between on- and off-peak rates will be necessary to gain customer interest and ensure their sacrifice is adequately compensated. Stakeholders emphasized that rate design should also reflect the value that load-flexible customers provide to the grid (e.g., reduced generation capacity, reduced need for transmission and distribution infrastructure upgrades) and their opportunity cost for doing so. One technology provider asserted that "it matters that the tariff reflects financially to the customer what it is that we're trying to accomplish." He argued that utility bill savings should reflect the potential convenience, comfort, and control customers relinquish when providing LF.

Small, frequently changing margins could easily be masked in automated algorithms and ignored by customers.

Stakeholders also warned that the uncertainty associated with highly dynamic prices will be problematic for some customers. Shadow billing (showing customers what they would have paid under an alternative rate) was viewed as a potentially useful trust-building tool, but some utility representatives reported that it is costly to administer and that many customers either do not notice the additional information or find it too confusing to influence their behavior. The challenge will be, as one stakeholder put it, "figuring out the right …level [to] shift customer behavior enough to be aligned with the goals, but also, not expose them to that volatility." A large differential that rewards participants will punish those who cannot participate, as these quotes depict:

> *There's no way to have high differences in rates that don't punish non-participants… because rewarding participants is the point, so I definitely understand the need to balance it.*
>
> *You want that high price to send the market [a signal], but you also don't want that high price to penalize people who can't change their behavior.*
>
> *If you change the entire rate structure for everybody based on the assumption that people have load management, you're going to get some pretty ugly results for non-participants.*

Against this backdrop, stakeholders argued that enrollment design will be just as important as the rate structure itself. Many argued that an opt-in model for dynamic pricing is unworkable at scale, citing high transaction costs and historically low enrollment rates. Instead, they favored making dynamic tariffs the default (i.e., opt-out) in order to reach broad participation and realize system benefits. Some also proposed linking participation in dynamic rate programs to eligibility for other benefits, such as electrification rebates or solar incentives, so that public investments in distributed resources are paired with grid-beneficial behavior. Interviewees also emphasized that - to maintain customer participation - automation and price response must never compromise the core service that a device provides: Algorithms should not prioritize bill savings over keeping critical medical equipment running, maintaining safe and comfortable indoor conditions, or ensuring that an EV has adequate charge for an emergency.

Perspectives on customer participation in LF were uniquely informed by large commercial customers' previous experiences with DR programs. One higher education campus reported saving $60,000 in electricity costs and earning $270,000 in incentives during a 2022 heatwave by leveraging thermal storage, demonstrating the financial potential of participation. Other campuses described being eligible for programs that incentivized load shifting to absorb excess solar generation, but the benefits were tempered by operational challenges, including underutilized systems due to limited staff training. School districts reported mixed and sometimes negative experiences, including "summer discount" programs that curtailed air conditioning during extreme heat, occasionally during critical periods such as state testing in one case, and instances where districts incurred significant financial penalties after overriding automated controls in response to occupant discomfort. Healthcare stakeholders emphasized the primacy of reliability, describing investments in battery storage and participation in emergency response efforts, including deploying diesel generation during grid crises under temporary regulatory exemptions. Government and public facility managers highlighted challenges with automated controls that compromised occupant comfort, as well as lingering mistrust stemming from billing errors and data inconsistencies. In the agricultural sector, early pilots in dynamic pricing for pumping loads showed promise in attracting participation through automation incentives, but persistent gaps in real-time data access limited the ability to demonstrate value to customers.

What Technology Standards Will Be Established, How, and When?

Uncertainty about technology standards related to LF and associated communications capabilities - what they will be and when they will be enacted - was nearly universally acknowledged as stifling progress towards achieving a robust LF ecosystem. One stakeholder explained, “It makes it hard to be an early adopter because every building designer has to pick something. They're gonna put it in their building, and they hope it still works in five years.” Stakeholders explained that “really clear requirements of what's necessary to be a load-flexible compatible device [are] important.” Otherwise, “If we end up with every vendor having their own proprietary protocols and trying to make that work, forget about it.”

Supply-side initiatives, such as mandated standards from regulators, are seen as essential because they create market demand by requiring OEMs to produce LF-compliant products, while simultaneously ensuring interoperability by enforcing common protocols across vendors. This top-down approach is viewed as necessary to build a market for LF devices. Several respondents urged California policymakers to make strides towards establishing standards for LF technologies.

Standardization and security of data access and APIs. Beyond the existence of standards on paper, stakeholders described the lack of consistent, real-time access to devices and customer data as a primary bottleneck. Large non-residential customers, including affordable housing developers and school districts, described how single meters covering diverse loads make it nearly impossible to respond to price signals or understand system-level consumption, while submetering individual systems was often prohibitively expensive. In response, stakeholders pointed to solutions such as smart panels and submetering requirements, as well as ad hoc approaches like installing current transformers to isolate device-level “power signatures,” though these introduce additional complexity in data management.

Other stakeholder groups echoed the need for more granular data; many participants advocated for a shift away from utility meter data toward direct device telemetry, which can provide real-time, high-resolution data suitable for optimization and measurement, in contrast to delayed or inconsistent utility data streams. They noted that existing efforts such as Green Button are implemented differently by each utility, forcing third parties to develop custom workarounds instead of relying on a uniform interface. Several argued that the next generation of standards must specify the actual data fields and telemetry required for LF (e.g., state of charge, power consumption, or operating mode). Numerous stakeholders also stressed the importance of ensuring that APIs are broadly accessible (i.e., free or low-cost), rather than “pay-to-play,” so that smaller entities like aggregators or CCAs can participate on equal footing and are not kept "out of the game."

Large commercial customers highlighted cybersecurity requirements as a non-negotiable dimension of standard-setting. For some, meeting internal cybersecurity protocols is a “go/no go” condition for connecting equipment to networks or participating in LF programs. If standards cannot guarantee secure communication, these customers simply cannot enroll their loads, regardless of potential economic or environmental benefits.

Software versus hardware. Stakeholders also expressed a preference for standards that target software rather than hardware. Some manufacturers cautioned that mandating specific physical ports (e.g., connector types) can be "technology limiting,” locking in designs that may become obsolete and adding redundant hardware to products. One manufacturer explained:

> *If the standard says you must put on a blue box that allows the algorithm to run on it, then that hinders the ability to implement something at a more efficient cost... Standardizing on the cloud typically works better versus standardizing on a port that is on a water heater. I think that's too prescriptive.*

Instead, stakeholders urged policymakers to focus on communication “language” (e.g., OpenADR or IEEE2030.5) and allow greater flexibility in how devices achieve connectivity (e.g., embedded hardware, add-on dongles, or cloud-based integration) so that standards can evolve with the technology without stranding installed equipment.

Outcome-based versus prescriptive standards. At present, for many LF devices, it is unclear whether outcome-based or prescriptive standards will be enacted. Stakeholders expressed a range of views on what kind of standards should guide LF technologies, some wary of premature or overly rigid rules and others insisting that mandates will ultimately be necessary to drive participation. Most stakeholders advocated for “intent-based” or “outcome-based” standards – where clear definitions outline the intended functions of certain technologies without being too prescriptive. Several stakeholders argued that such an approach “give[s] flexibility that can sometimes spur innovation and creativity in how to get there, [which] can also result in products and solutions that go beyond the expected [with] our standards-based targets.”

Although most stakeholders advocated for outcome-based standards, many pointed to shortcomings of this approach. Some warned that outcomes-based standards can lead to inconsistent interpretation and implementation. Others argued that at this nascent stage, “standards are kind of getting in the way of innovation from the implementation side of things.” At the opposite end of the spectrum, some cautioned that voluntary standards would not be enough to drive market alignment or achieve the LF vision. As one said, “If you make [LF capabilities] optional, then you may not get all these device makers to come along with you and meet the goal or achieve the vision.” A few went further, emphasizing that “mandated it has to be” to adequately stimulate the market.

Stakeholder engagement. Precisely how standards will be developed - and in particular, if it will involve stakeholder participation - is another area of uncertainty.

> *The dialogue is critical. The more dialogue you have with the industries, the easier it's gonna be to see the true path of how to get there. Whereas if you try to prepare a mandate or a standard with minimal industry input or feedback, that's going to be problematic.*

One stakeholder cited as a cautionary tale an example of a nonsensical standard (for pool pumps) created without industry input. In addition to OEMs, many respondents emphasized that technology standards will not succeed without corresponding attention to the stakeholders who specify, install, and operate LF equipment. Stakeholders observed that even sophisticated "smart" systems are frequently disabled, overridden, or left uncommissioned because building operators and contractors do not fully understand how they work or how to maintain them. As one stakeholder explained:

> *My maintenance staff [are] not trained to handle and fix a lot of this intelligent equipment. We have to outsource it. And in a lot of places, [facilities staff are] just not equipped to handle that stuff. So when it goes down, oftentimes it just gets bypassed.*

Sentiments like this led to calls for stronger commissioning requirements, mechanical acceptance testing to ensure devices function as designed, and standardized training or certification for those responsible for keeping LF capable systems functional over time.

Alignment with incentive programs and other policies. With standards not yet set, another area of uncertainty is how future standards will align with those of other jurisdictions (e.g., other states, federal policies). The prospect of conflicting standards is problematic, especially for technology providers, as this quote indicates:

> *We want national standards, not something that's California-specific. That's going to be really hard for us…So, whatever standards you use, make sure they're kind of a national standard that we have to comply with, as opposed to trying to do something really unique for California.*

Many stakeholders underscored that standards have the greatest impact when they are tied directly to financial incentives. They noted that manufacturers are much more likely to retool product lines for the California market when meeting a specific standard is a prerequisite for state rebates or utility incentive programs. In their view, using incentive eligibility as the "carrot" to accompany the "stick" of standards is a critical mechanism for aligning market behavior with policy goals.

Until more is known about the technology standards California will require of LF technologies, some technology providers are pursuing multiple potential compliance tracks. As one stakeholder noted: "We are attempting to fit as many standards into our product offerings as we can, unfortunately, to address the very fragmented market that it is today." They track building codes and product certifications across the United States and try to develop products that are compliant in multiple markets. This, they note, is costly and not all OEMs can afford to do this, restricting the number of market entrants.

Enforcement and third-party certification. Several stakeholders asserted that the current problem is not the absence of standards but the absence of meaningful compliance. They pointed out that requirements such as automated demand response (ADR) provisions in existing codes are "already on the books" yet are often ignored in practice. One stakeholder explained, "California's done things like put ADR requirements in the Title 24 building code and that's great. But no one implements it. No one." In response, many stakeholders advocated for third-party testing and certification rather than self-certification, noting that devices may be labeled as compliant on paper while failing to perform as expected when called upon by the grid. One stakeholder shared that their "most successful projects [were] ones where a third-party commissioning outfit has come in and run the equipment through its paces... holding the contractors more responsible." In stakeholders' view, credible certification regimes are essential for ensuring that standards translate into reliable LF performance in the field.

Do Policymakers Have the Commitment and Capacity to Implement the LF vision?

Stakeholders expressed concern around the degree of policymaker commitment and institutional capacity for implementation. Topics included political commitment and institutional capacity.

Political commitment. Stakeholders wonder how committed policymakers are to the LF vision. Continual changes in the direction of energy policy – emphasizing efficiency, then net-zero, then LF - create doubt about the state's commitment to highly dynamic prices and automated LF, while some stakeholders worry that a focus on dynamic rates could weaken attention to energy efficiency, electrification, and decarbonization.

Stakeholders questioned whether California policymakers have the political will to make the decisions required to implement highly dynamic prices and automated LF, particularly as it relates to rate design and customer enrollment. Stakeholders acknowledged that policymakers would face heavy criticism if they adopted a rate design that offers potentially large bill savings to those who enroll in dynamic rates, while excluding those who cannot participate. Defaulting all customers into dynamic rates was thought by most stakeholders to be the only way to ensure broad participation and minimal impacts on participants, but many doubted whether policymakers would have the political will to adopt such an approach. Others noted that "not everybody is on the same page of what [the vision] would actually look like and how it would be implemented."

Several participants went further, arguing that the core problem is not only political risk aversion, but a lack of confidence in demand-side resources and corresponding misalignment of public investment. One stakeholder pointed out that billions of dollars have been allocated to nuclear life extensions and large-scale storage projects, while far less has been directed towards the "architects" of demand-side programs (i.e., state agency leadership, staff, and energy policy experts who are responsible for designing and advocating for LF and DR frameworks in California). They contended that California has effectively abandoned its historic "merit order" for acquiring cost-effective demand-side resources before committing to more expensive supply-side options. They interpret this shift as evidence that policymakers might not truly believe that LF can deliver at scale.

Some stakeholders expressed concern that dynamic pricing is being treated as a long-running "experiment" without clear metrics for success or transparency about distributional risks. In their view, the absence of visible optimism about automation's potential to manage complexity on behalf of customers, paired with limited attention to the risk of bill volatility or "shock" (especially for vulnerable customers), reinforces doubts about policymakers' genuine commitment to the LF vision.

Whether policymakers would strictly enforce LF policies and standards was another open question stakeholders noted. "We really have to follow through. We have to get the right people making sure that on the built environment side, that these buildings are really working and performing the way they should perform."

Institutional Capacity. Stakeholders questioned whether public institutions have sufficient staffing, technical expertise, and organizational alignment to implement the envisioned changes. Several noted that agencies lack the "capacity - whether that's actual like staff and volume or expertise - to implement the desired vision." They warned that even well-crafted policies could stall without enough personnel to translate them into programs, rules, and enforcement. At the same time, with many ongoing developments in California energy policy, stakeholders were uncertain how LF policies would interact with other initiatives. Similarly, numerous stakeholders highlighted overlapping jurisdiction among several state agencies (e.g., CPUC, CEC, CAISO), noting that it is unclear how these distributed entities will coordinate, how conflicts will be resolved, and whether this fragmentation will further constrain the state's ability to deliver a coherent LF policy framework.

When will there be Clarity on the Prevailing Uncertainties?

Stakeholders expressed another layer of uncertainty on top of the aforementioned concerns, regarding the expected timeframe for resolving uncertainties. As one said:

> *To the best of my knowledge, [policies] aren't necessarily pointed at a very specific goal at the moment. [Something like] "X percent of California customers enroll in real-time energy pricing by 2030." That to me is the [challenge].*

Of particular concern was the tension surrounding when price-responsive technologies and relevant rate structures would be introduced relative to each other. While several stakeholders initially described this as a "chicken-and-egg problem," their accounts more precisely reflect a multi-sided coordination challenge spanning manufacturers, utilities, aggregators, and customers. Technology providers do not want to invest in making their products ready to receive highly dynamic prices if the rate structure does not yet exist; without a rate structure that encourages load-flexible behavior change, there's no financial incentive for customers to buy price-responsive technologies.

This dynamic is further complicated by what stakeholders described as a three-way standoff. OEMs report that many devices are already technically capable of responding to external signals but lack utility or aggregator programs to activate them, while utilities and aggregators are hesitant to launch such programs without a critical mass of compatible hardware already deployed. In parallel, manufacturers, particularly in sectors such as electric vehicles, often view grid integration as peripheral to their core business and are reluctant to invest in additional research and development without a clear policy signal, such as a "grand unifying vision" or legislated timelines that reduce market uncertainty. Adding LF functionality often increases device costs, creating a price premium that is difficult to justify when expected customer savings are minimal, often described as "pennies to nickels" per day with LF, and zero before it is introduced. As a result, even where technologies are technically feasible, stakeholders emphasized that there is limited "market pull," as most customers are not actively demanding, or even aware of, these capabilities.

Some stakeholders noted that until dynamic rates are introduced, manufacturers may have difficulty recovering the premium they would need to charge for load-flexible technologies. However, even then, getting a return on their investment depends on sufficient customer adoption, which presupposes customer demand, despite little evidence to date that it will emerge. Together, these dynamics suggest that progress across rate design, technology development, and customer enrollment must occur in parallel rather than sequentially, reinforcing uncertainty about when, and how, the system will reach scale.

This timing challenge is compounded by structural barriers within utilities, which one stakeholder described as "slow-moving cruise ships," unable to pivot quickly. Utility billing systems, as noted in previous sections, are "archaic" and reprogramming them for sub-hourly dynamic rates could take 3-5 years, in addition to tens of millions of dollars for IT staffing. Manufacturers emphasized that financial incentives alone will not suffice; they need "legislated dates" to justify R&D cycles, citing LEDs as proof that mandated timelines, rather than voluntary market signals, drive investment and cost declines.

For businesses to justify investing in developing load-flexible technologies, they must perceive a clear business case for doing so. They need evidence that sufficient demand for their products and services will emerge in response to California policymaking. "We have to see a path to monetization for us to invest. That path has to involve scale. It can't be bespoke little efforts." For some - across stakeholder groups - data access is "the beginning and end" of the problem. Third-party aggregators lack real-time, billing-quality data to verify device performance, blocking the business case for dynamic pricing ecosystems. Similarly, international manufacturers hesitate to develop "specialized California products" without assurance of national alignment on protocols like OpenADR or IEEE 2030.5.

As a result, stakeholders expressed confusion and concern about how the timing conundrum will be resolved, as illustrated in this quote:

> *There's been a really challenging chicken and egg situation with smart grid or flexible demand deployments in general, where manufacturers don't build in the capabilities, or the devices don't ship with the capabilities enabled or present at all, because there aren't a lot of utility programs that would use them. So it's not worth doing. And the utilities aren't running programs because there aren't devices to go talk to.*

Stakeholders reported two different approaches to dealing with the uncertain timing of California's policy decisions: "hedging their bets" and "wait-and-see." *Hedging their bets* companies have already proactively incorporated multiple communications technologies to ensure an early advantage in the market. Meanwhile, a stakeholder described the reasoning behind the *wait-and-see* approach:

> *There's a sense that this huge thing is coming, but [it's] not clear what form it's going to take and what the rules are going to be and what the details are. As a company, how do you prepare for that? You wait.*

Many stakeholders, particularly capital-constrained entities like school districts, described the vision as feeling “too theoretical” and insisted there be pilot studies demonstrating the feasibility and benefits of dynamic prices and automated LF before committing resources. In this environment of prolonged uncertainty, some stakeholders suggested offering manufacturers financial incentives for early-stage products as a bridge, but most emphasized that tangible proof from field tests, not just policy signals, is what will finally resolve the wait-and-see stance and unlock investment.

Discussion and Conclusion

The findings from this study reveal a fundamental tension in California’s 8760 LF ambitions: While stakeholders across sectors endorse the technical vision, they consistently identify institutional and regulatory gaps, not technological barriers, as the binding constraint on progress. The following discussion synthesizes the four uncertainties presented above into broader themes and highlights their implications for policy coordination.

Institutional Capacity as the “Weakest Link”

A core insight from the interviews is that governance fragmentation, regulatory uncertainty, and institutional inertia form the critical bottleneck. Stakeholders emphasized that technologies capable of load management already exist or are near commercialization, yet deployment at scale awaits unresolved rate structures, enforceable standards, upgrades to utility billing systems that can support dynamic rates, and clarity on enrollment mechanisms. This dynamic has left the LF ecosystem in a holding pattern, as manufacturers “hedge bets” or await pilot proof points and utilities move at “cruise ship” speed.

This pattern echoes socio-technical transitions literature where technological innovation outpaces entrenched rules, markets, and institutions (Geels & Schot, 2007; Verbong & Geels, 2007). In California, the incumbent regulatory architecture, characterized by overlapping agency jurisdictions (e.g., CPUC, CEC, CAISO) and risk-averse policymaking, impedes the rapid, synchronized reforms that 8760 LF demands. Stakeholders warn that even well-designed policies falter without adequate staffing, technical expertise, and inter-agency collaboration to operationalize them, while inadequate workforce preparation (e.g., training for installers, commissioning agents, and maintenance personnel) leads to standards non-compliance. These findings suggest the governance architecture itself may require recalibration, not merely policy refinement, to align institutional capacity with LF ambitions.

The “Chicken-and-Egg” Problem as a Coordination Failure

The dynamic articulated by stakeholders—where manufacturers await finalized rate structures while regulators await proven technologies—reflects a broader coordination failure across the load flexibility ecosystem. Rather than a single “chicken-and-egg” dilemma, stakeholders described a set of interdependent barriers that must be addressed in an ordered but overlapping sequence.

First, enabling policy signals, particularly rate structures and program rules, must be sufficiently defined to indicate how value will be created and captured. Without this foundation, manufacturers and service providers lack a clear target for product development or investment. Second, technology development and standardization must advance to the point where devices can reliably respond to those signals at scale. This includes not only technical capability, but also interoperability, cybersecurity, and cost considerations that determine whether such technologies can be widely deployed. Third, market formation depends on achieving meaningful customer adoption, which in turn requires demonstrated value, manageable complexity, and trust in both pricing structures and automation. Without sufficient enrollment, neither utilities nor aggregators can justify launching or scaling programs.

Critically, stakeholders emphasized that these steps cannot unfold in a strictly linear fashion. Each depends on credible progress in the others, creating a coordination challenge in which rational hesitation by individual actors leads to collective delay. This impasse is further compounded by the diverse incentives, risk tolerances, and time horizons across institutions, including state agencies (e.g., CEC, CPUC, CAISO), utilities, manufacturers, aggregators, and end users. In this context, stakeholders pointed to the absence of a shared focal point to align expectations and investment. Several identified "legislated dates" or similarly binding policy milestones as potential mechanisms to resolve this coordination problem. By establishing clear timelines for implementation, such policies could function as credible commitment devices, reducing uncertainty, synchronizing market actors, and catalyzing investment, similar to the role federal LED efficiency standards played in accelerating industry-wide transformation.

The Opt-out Dilemma and the Politics of Default Enrollment

The opt-in versus opt-out debate reveals a deeper tension between achieving scale and safeguarding equity, a recurring challenge in energy transition governance. Stakeholders uniformly recognized the inadequacy of an opt-in approach to system-wide LF, yet expressed acute awareness of the distributional risks: Default enrollment would expose inflexible customers, often lower-income households without access to responsive technologies, to rates optimized for those who can participate.

Proposed mitigations remain contested. Linking electrification rebates to dynamic rate enrollment risks excluding the households most in need of such support, while bill protections blunt the very price signals intended to drive flexibility. Stakeholders' skepticism about policymakers' political will reflects broader patterns in regulatory decision-making, where measures yielding diffuse grid benefits but concentrated costs encounter formidable resistance. Overcoming this impasse demands not only refined rate design, but also deliberate strategies for public trust-building and transparent risk communication.

Standards, Interoperability, and the Risk of Fragmentation

Stakeholder views on technology standards expose a familiar tension between the need for regulatory clarity and the hazards of premature technological lock-in. They strongly favored outcome-based standards that specify functional performance without mandating particular hardware or protocols, yet readily acknowledged the pitfalls of this approach, including inconsistent implementation, free-riding, and compliance ambiguity, which already plague existing ADR requirements in California's building codes.

Stakeholders consistently emphasized the need for granular, device- or circuit-level data, noting that aggregate "whole home" or master meter data is insufficient for effective load management. However, several barriers persist, including concerns about privacy and cybersecurity, limitations in IT infrastructure (e.g., restrictions on connected devices), and manufacturer control over proprietary data access, all of which constrain the scalability of granular data solutions.

A preference for flexible, software- and cloud-centric approaches over rigid hardware specifications reflects acute awareness of rapid technological evolution - standards tied to physical ports risk rapid obsolescence. Insistence on third-party certification and robust enforcement reveals profound skepticism toward self-reported compliance. The persistent gap between standards "on the books" and standards in operation underscores the central finding that implementation capacity, rather than policy ambition, constitutes the critical limitation.

Jurisdictional fragmentation compounds this challenge. Manufacturers developing devices for multiple markets face crippling costs when California pursues bespoke standards rather than aligning with those established elsewhere. While the state's market heft confers leverage, a patchwork regulatory landscape threatens to deter precisely the investment LF demands.

Differences by Stakeholder Group

Stakeholders across groups identified a range of interrelated barriers to implementing load flexibility, spanning technical, economic, behavioral, and institutional dimensions. Technology and service providers emphasized challenges related to feasibility, particularly limited access to high-quality, real-time utility meter data, which they described as essential for load forecasting and verifying customer savings, alongside concerns that overly prescriptive hardware standards could constrain innovation and increase costs; they also highlighted uncertainty around viable business models, noting that aggregation and customer acquisition costs often outweigh the modest grid value of individual devices. Residential and small business stakeholders focused on complexity, comfort, and financial risk, expressing concern that dynamic pricing could exacerbate confusion and "price anxiety," while offering insufficient savings to justify discomfort or behavioral changes, and raising apprehension about loss of control over household devices without clear override options. Institutional and large commercial customers, including schools and hospitals, underscored the primacy of reliability and operational continuity, pointing to mission-critical constraints, split incentives within organizations, and limited financial and technical capacity as key barriers to participation. Equity-focused stakeholders highlighted structural inequities, including the digital divide, renter limitations, and inflexible work schedules, warning that dynamic pricing could function as a "hidden tax" on those least able to adapt. Finally, local governments identified administrative and regulatory challenges, including complex permitting processes and fragmented policy landscapes across state agencies, which together hinder coherent planning and slow adoption.

Policy Implications

These findings yield concrete implications for California policymakers (and those in other jurisdictions) pursuing 8760 LF ambitions:

- ***Credible policy and market commitments are needed to align actors.*** Stakeholders emphasized that binding timelines, interoperable standards, and incentive-linked policies led by regulators and operationalized by utilities, are necessary to coordinate investment across manufacturers, aggregators, and customers. Without alignment between standards and incentives, actors delay, reinforcing stasis; credible commitments combining mandates, incentives, and timelines are therefore essential to unlock system-wide investment in LF technologies.
- ***Institutional capacity must support policy infrastructure.*** Addressing staffing shortages, inter-agency fragmentation, legacy billing constraints, and workforce training gaps are not administrative footnotes, but foundational preconditions. Without deliberate capacity-building - such as enforcement mechanisms, coordination protocols, and commissioning standards - even policy mandates risk remaining aspirational requirements that, in stakeholders' words, exist "on the books" but not in practice.
- ***Process transparency reduces uncertainty.*** Stakeholder uncertainty stems not solely from confusion about policy substance, but also from opaque development timelines and decision pathways. Articulating clear milestones, feedback loops, and resolutions could itself convert generalized uncertainty and apprehension into actionable foresight.

There is general consensus that California's 8760 LF vision will be technically feasible, but stakeholders warn there are significant institutional headwinds. Uncertainty about how policy conundrums will be resolved has stymied progress, but policymakers hold the power to interrupt this holding pattern through credible commitments (e.g., legislated dates, default enrollment), capacity investments (e.g., staffing, workforce training, billing modernization), and transparent processes. Stakeholders highlighted several priority areas for transparency, including tariff design and billing logic (e.g., simplifying rate structures and enabling predictable customer cost outcomes), grid readiness and infrastructure planning (e.g., clarifying local capacity and responsibility for upgrade costs), state agency coordination (e.g., articulating a coherent, unified implementation roadmap), impact verification (e.g., publicly reporting real-time grid and emissions outcomes), and data access (e.g., establishing open, non-proprietary APIs for device and meter data). The path forward demands broad stakeholder engagement and collaboration beyond the project team's policy-proximate networks whose voices are represented here. Future efforts to expand this dialogue could validate the cross-sector concerns identified in this research, reveal latent barriers, and illuminate pathways to synchronized action that can support California's LF ambitions.

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