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Smoothen Chaos - Making Outages a Dimmer Switch

I'm sharing a paper (attached) that I penned with a friend back in December 2019. The summary is that in addition to doing more to make the grid more reliable we should balance our effort by having different systems that enable some function when the main system is down (e.g. batteries, solar). Instead of designing a system that is an off/on switch that we invest to keep in the on position, how might we invest in technologies that turn it into a dimmer switch for more customers?

Additional submitted attachment is included below.

Smoothen Chaos:
Reframing our Approach toward Addressing Public Safety Power Shutoffs (PSPSs)

DISCLAIMER

This paper does not reflect the opinions of any organization affiliated with the authors. It offers frameworks to facilitate clearer conversations about infrastructure service reliability.

PREFACE

This piece is a collaboration between Dr. Asavari Devadiga and Michael Germeraad, former colleagues who both explored questions of infrastructure reliability and design in their graduate research. Our research does not consider planned power shut offs specifically, but concepts from our respective research may provide a helpful perspective to the growing space of PSPS opinions. This paper aims to provide a different framework to spark a dialogue with others who are weighing on how California might smoothen the current chaos of PSPSs.

Dr. Asavari Devadiga's Doctoral Dissertation - "Water When You Need It"
Asavari Devadiga's doctoral research on infrastructure provision in an urban environment accounted for the multiple and dynamic factors of rapid growth, reliability, resilience, and affordability. "Water when you need it" is water available to a user when they need it at the quantity and quality they need – this reframing of reliability applies to different infrastructure services and lends to rethinking of their design and delivery modes. Asavari has actively engaged in the current policy debates around effective planning for climate change at local and regional levels and has delved extensively into the crosscutting areas of urban development, infrastructure, and environment.

Michael Germeraad's Masters Thesis - Methodology for Simplified Lifeline Risk Assessments
Inspired by past cascading infrastructure outages caused by events like earthquakes, Michael Germeraad's thesis explores how lifeline risk assessments can be developed with limited information. The dimensions of infrastructure service outage defined in the thesis as well as the measurement of outage consequences are helpful in framing PSPSs. The research built off a conceptual framework by Hiroyukie Kameda[i].

INTRODUCTION

Power Shutoff and Chaos

In Fall 2019 many households, businesses, and communities in California (particularly in Northern California) were jolted into power shut-offs or Public Safety Power Shutoffs (PSPSs) – a new normal that PG&E admits could happen 15 times a year[ii] and a condition that could last a decade[iii]. Some proactive individuals and institutions had prepared ahead of time[iv], while others were caught scrambling,[v] muddling through possible back-up power measures and realizing their business would close, or their perishable products would spoil. The chaos was felt the greatest by the state's most vulnerable populations whose lives and livelihoods are dependent on essential services.

In Figure 1 below, we depict chaos in terms of service reliability from the past through the present to the future. The recent 2019 fire season marked the start of the new normal where power reliability dropped multiple times. It will take years to improve the reliability of the system, leaving California with the difficult reality of an upcoming decade with PSPS events.

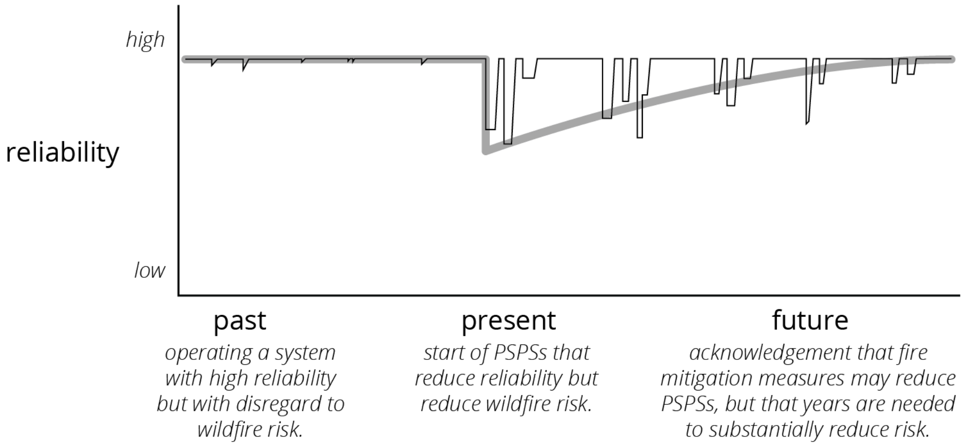

Figure 1. Chaos: Where is the reliability?

The PSPSs highlight the vulnerability of the electric grid (supply-side and quality of infrastructure) and the reliability of its service (infrastructure service). They also raise questions about the actions that should be taken in the near and long term to avert the large economic losses from the PSPSs[vi] and hardship that outages bring.

While California grapples with an evolving energy system being pressured by climate change, renewable source targets, and new governance structures, is there a way to smoothen the chaos? If we are to face more PSPSs, how do we prepare ourselves for failing power service and many other associated services? Do we have to face PSPSs forever or can we avoid the chaos?

Lessons from the Past

2019 was a shock for Californians, but utility disruptions are not new. Water service disruption following the 1995 Kobe, Japan earthquake offers a helpful frame for how utilities thought about and redesigned their system after weathering the shock. It offers insights on how utilities can consider service disruption.

Following the 1995 Kobe earthquake, water service was disrupted for weeks: 3 weeks after the earthquake, 25% of the residents were still without water; 5 weeks after the earthquake, 10% of residents were without water. During the water outage, the Kobe Municipal Water Supply tracked customer calls. Over the first four weeks, emotions changed from inquiry, to complaints, to anger, and then desperation. The utility recognized that those who were without water service for longer than four weeks had excessive difficulties.

Following the restoration of service, the Kobe Municipal Water Supply designed their system to match the acceptance curves of their customers and adopted new design criteria to provide water service to all customers within four weeks following a future earthquake (Kameda, 2000; Germeraad, 2015).

"People can stand lifeline disruptions for some period... but as a reduced level of supply is sustained, their demand will increase and the individual users' acceptance curve will decrease with time" (Kameda, 2000).

REDEFINING RELIABILITY

The purpose of this paper is to question if high reliability should be defined by 24/7 supply-oriented service, or instead be reframed by focusing on the service experienced by the users (citizens, including consumers). **We reframe infrastructure service reliability from the users' side.** Service is when you get it. "Water when you need it" (Devadiga, 2014; 2019)[vii] is when users receive water in the quantity and quality they need and when they need it. The concept translates to any infrastructure service. Specifically, we consider the PSPS impacts in terms of four service levels or dimensions: quantity, quality, time, and space (Germeraad, 2015).

PSPS and Infrastructure Service

Most Californians have experienced roughly two decades of highly reliable power supply. In recent years interruption was fairly limited to short and contained outages caused by winter storms or equipment malfunction. Most of the time, Californians received 100% of the power they desired (quantity and quality), 99.9% of the time (see Figure 2, first row). This has been the status quo for many over at least the past two decades.

		Time	**Quantity**	
Past *(recent decade)*	regular conditions	99.9%	100%	
	outage conditions	0.01%	0%	
Present *(w/ 2019 PSPS)*	regular conditions	98%	100%	
	outage conditions	2%	0%	The present condition can be improved two different ways:
Future 1 *(24/7/365)*	regular conditions	99.9%	100%	
	outage conditions	0.01%	0%	**Future 1.** Reducing the frequency and length of outages, "reducing the two."
Future 2 *(hybrid approach)*	regular conditions	98%	100%	
	outage conditions	2%	> 0%	**Future 2.** Increasing the quantity of power during disruptions, "increasing the zero."

*For the purpose of this paper, we use a minimal outage condition occurring 0.01% of the time in the past and then increase to 2% of the time in 2019. These numbers are used to reflect general concepts.

Figure 2. Comparing Conceptual Regular and Outage Conditions: Past, Present and Possible Future Scenarios

In the present, those that live in higher frequency PSPS shut off zones are likely living in a situation where they operate in two circumstances (Figure 2, Present): say, 98% of the time they receive 100% of the power they desire, but 2% of the time they have 0% of the power they need, hence face chaos (Figure 1).

Reframing the Goals

Many are asking the question of how we can get back to the earlier state of 100% service, 100% (or 99.9%) of the time (Figure 2, Future 1). The current discourse points to the goal of reducing the service loss of 2%-time to zero and restoring regular conditions to 100%. That is a great goal to have, but we know delayed infrastructure maintenance, increasing frequencies of PSPSs, and higher wildfire risks may make achieving the goal expensive and time consuming.

With this changed reality as our primary motivation, we reorient the goals toward increasing "the 0%" quantity service during outages and smoothening the chaos. We acknowledge that outages will occur. We recognize that in addition to maintaining the current systems, we will need to innovate and create new designs - both infrastructural and institutional. Going beyond only reducing the 2% outage times, we will need to improve the service levels over 0% during the outages. Do we then continue to have the traditional designs and conventional, large infrastructure systems?

As we examine the different possible scenarios in Figure 2, instead of focusing only on 100% of service, 100% of the time (Future 1), we broaden our focus to considering the individual service levels or dimensions of quantity, quality, time, and space. We argue for a more nuanced, hybrid approach that advances these goals that may be more quickly implemented and more cost effective (Figure 2, Future 2) in the near-term. The longer-term supply-side planning of hardening the centralized supply-side system aiming to reduce PSPSs or outages (Figure 2, Future 1) may continue in conjunction. However, as we discuss below, the renewed framework of the "hybrid approach"[vii] offers many opportunities for huge value gains for users and advances a new way of thinking.

A NEW WAY OF THINKING

Exploring a "Hybrid Approach"

Large portions of the state are grappling with the reality that 2% of the time they may be without any power. Instead of only focusing strategies on reducing the 2% value, we recommend considering a hybrid approach that also prioritizes strategies that capitalize on the quantity, quality, and spatial dimensions of outages. This approach allows us to particularly address the near term, urgent needs while long term planning is in process. When confronting the reality of an outage, altering these dimensions can influence the ability of a user to gracefully get through an outage.

Quantity. Think about the average California household. When they are in a blackout with 0% of their regular power, they cannot charge or power anything. If they had 10% of their regular power (e.g., 60 watts compared to none) they might be able to derive some utility, e.g., charge cell phones, turn on a single light, or power their refrigerator so as not to lose all their food. The point being, the difference in acceptance and ability to humanely get through an outage can be reduced significantly by having some power. Figure 3 shows how some users might receive great shares of value or utility with very limited power (e.g. average family), while others might require mostly full power to have any value (e.g. factory).

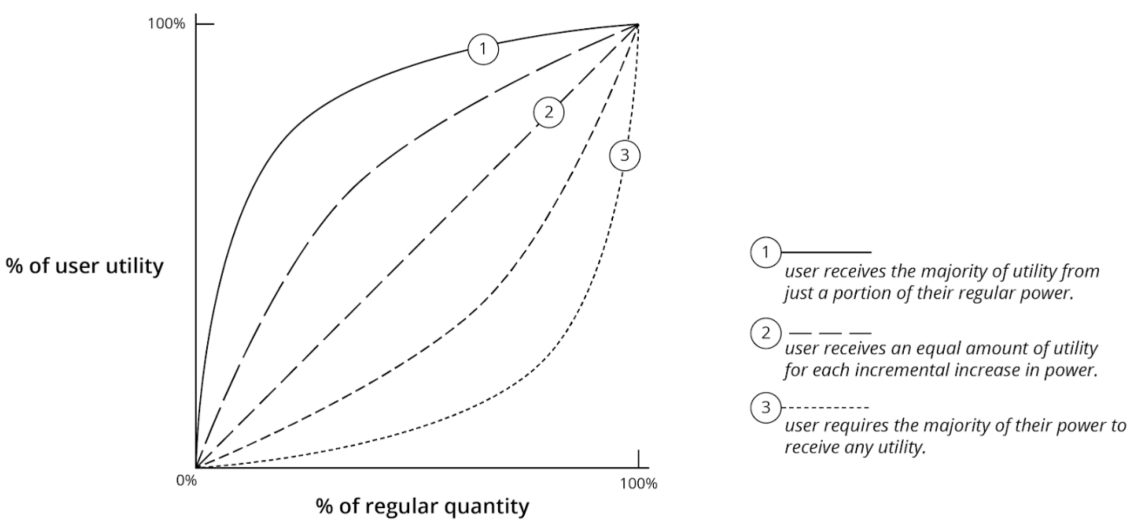

Figure 3: Conceptual User Utility Curve

Time. The 24/7 supply paradigm drives most infrastructure system reliability design. However from the users' perspective, service is about receiving or having access to the power when they need it. It may be that some users may derive maximum utility if they receive power only for a few hours in a day or for a certain duration..

Quality. Quality as a dimension for electricity can be framed by stability of the power supply. Does the power fluctuate (high peaks and lows) or is it stable? Depending on the user the quality of power can be important or insignificant. Many businesses may not operate if the power stability is poor, while a homeowner may be fine to use power, even if stable for a short duration.

Space (access). Outages occur over areas. When thinking about the spatial impact of an outage, for many users there is a difference between being in a large blackout zone versus a small one. For example, if a family is without power in their home, but can go a few blocks to gain access to power and other services they may be more able to withstand an outage, than if their entire community is without power. Here it is about a user's distance from the nearest point of functioning infrastructure.

Space (unique user conditions). Each user has a unique outage acceptance relationship between the four dimensions (Figure 3). Some at-risk users might require uninterrupted power supply for life-safety needs, while others may be only inconvenienced by multiple days without power. Similarly, the socio-economic conditions of each user will influence the impact of an outage and the choices an individual has to lessen impacts.

Lastly, these four dimensions are interdependent. As the condition of any dimension changes, the relationship of the user with the other dimensions and their overall acceptance can change.

Applying the "Hybrid Approach"

We can apply the hybrid approach using currently available solutions such as smart inverters that enable the use of rooftop solar systems during power disruptions. Most older rooftop solar installations do not provide power when the grid is shut down; however, newer inverter technologies allow for a rooftop solar system to operate independently of the grid.

An Example Hybrid Approach for a Family. Let's assume a rooftop solar array produces 50% of the power a home needs during the day, and 0% of the power a home needs during the night. By offering a homeowner the ability to have 50% of the power they need for 50% of the day within their home the ability to withstand a multi-day grid outage gracefully may go up dramatically. Food that would have otherwise spoiled would stay cool from a refrigerator that runs 8 hours of each day and small items may be charged during the day. In addition to this single home being more able to withstand a grid outage, the benefits may extend to neighbors who may be able to charge a cell phone or lantern, or store critical medication.

This strategy does not alter the length of the outage, but it increases the quantity of power supply to a value above 0% of a moderate quality, intermittent power for half of the day. Finally, this strategy provides the homeowner with power in their home, and depending on their community cohesion, enables a change in the spatial access to power for neighbors, nearby family members, or other people in their network. The hybrid approach provides a framework for how distributed solutions like smart solar, solar + storage or microgrids might be designed with all four dimensions in mind.

An Example Hybrid Approach for a Water Utility. Critical services like water and wastewater service rely on electricity – when a power outage occurs the outage can cascade across systems causing water or wastewater service outages. Imagine, a water utility that services a community with a reservoir, pumps and distribution pipes. In the event of grid failure, the water utility might use a generator to power the pumps so service remains uninterrupted through gravity-fed distribution lines. This can happen only if the utility has planned in advance for emergency purposes and allocated resources (manpower, funds, etc.) toward mobilizing the appropriate mechanisms (e.g., generators) to come into play when needed.

Planning for one emergency generator is one thing but it is a solution that often does not scale for a larger blackout and service areas; for longer PSPS durations; or for hilly areas that might require energy intensive pumping. In terms of quality of service, the hybrid approach would aid in maintaining the service per the user needs and incorporate efficiencies in deliveries. The hybrid approach would employ diverse and distributed supply sources for service and not rely only on one, single source or only centralized systems. It would also invest in use efficiencies, so less water is needed for the same task. Depending on what the water is being used for, on-site recycled or gray water may be used for nonpotable purposes. Not all water needs to be treated to drinking water standards or not all power needs to come from the central grid. Systematic and advance planning for such diverse sources, modes of delivery, and institutional mechanisms under the hybrid approach would ensure sustained "service when you need it". This demand-side planning may in fact also feed successfully into the longer-term goals of reducing the outage times to less than 2% and innovating toward resilience.

Further, more recently with increased homeless populations with no ready access to piped water in certain parts of California, it is incumbent upon the municipality or utility to deliver water in new ways. Here, the capacities (technical, institutional, financial, governing authority, etc.) of a utility or a municipality become critical and affect these decisions. The local jurisdictions (Cities and Counties) can play and have played an important role in facilitating or coordinating to ensure service (e.g., using common areas for shared services such as emergency shelters, public libraries). The hybrid approach leverages the combined capacities to deliver service for the diverse users and spatial conditions.

PSPSs are Just One More Reason to Invest in Decentralized Systems. The hybrid approach also address challenges beyond PSPS. Decentralized water technologies and designs such as water-efficient appliances, rooftop rain gardens, and onsite wastewater treatment and resource recovery are the key to enhancing the performance of aging centralized systems, and to assuring adequate water supplies and healthy ecosystems into the future (Nelson, 2008). Decentralized technologies however are still at the margins of engineering practice, and construction of big-pipe water, stormwater, and wastewater infrastructure continues (Nelson, 2008, p.11; Devadiga, 2014, p.32). Gleick (2003, p. 277) has proposed an alternative approach, dubbed the "soft" path that relies on centralized infrastructure but complements it with investment in decentralized facilities, efficient technologies, and human capital. This approach strives to improve the overall productivity of water use rather than seek endless sources of new supply. It delivers diverse water services matched to the users' needs and works with water users at local and community scales (Devadiga, 2014; p. 31). This thinking extends to other essential networked infrastructure services such as power, communications and sewage.

Why Consider the "Hybrid Approach"

We need reliable service and fast. Centralized systems have helped achieve economies of scale in service connectivity and consistency in continuous service. However, the costs of both building and maintaining them in the long term, not to mention the recent breakdowns resulting in chaos continue to prove the need for new thinking. The hybrid approach redefines service reliability from a user perspective. It is geared toward achieving the goal of “water when you need it” or “service when you need it” through a combination of physical and institutional aspects to ensure an acceptable level of service. This approach decouples the modes of delivery and the service delivered and accounts for quantity, quality, time, space, and diversity of users. It can be a combination of centralized and decentralized systems and involves not only the physical delivery modes but also institutional mechanisms to ensure that service is delivered as intended.

WRAP UP AND QUESTIONS FOR THE READER

We believe our value proposition of translating our past research to the PSPSs is in providing a framework for discussion in two ways: one, having people acknowledge what their goals of a future state are will support greater understanding and two, talking and thinking about how different solutions to the challenge affect or do not affect the four dimensions can help people articulate how strategies address the challenge. With that framing we have a few leading questions for you:

1. Was there a concept or framing that you found most helpful?
2. Did reading this spark a new idea, or offer a helpful reframing of an existing one? What was it?
3. Do you think equal resource should be used to “increase the zero” service by improving power quantity, quality, time, and space/access during outages instead only reducing outage likelihood?

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