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The Supreme Importance of Reliable and Resilient Electricity

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This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

It's not easy to keep the lights on.

Participants described California's strategy for achieving carbon neutrality by 2045 as "electrify everything and decarbonize the grid". This entails a dramatic increase in electricity production and consumption (two to three times current demand), with widespread implications.

CALIFORNIA'S HISTORY OF BLACKOUTS is familiar to many residents. One reason that Governor Gray Davis was recalled was the 2000/2001 California electricity crisis that included rolling blackouts. Electricity reliability continues to be critically important to California and Californians, and this importance is bound to increase as the state "electrifies everything" on the way to carbon neutrality.

This brief explores the importance and challenges around keeping the grid up and running, and preparing strategically to respond to the inevitable blackouts.

AS EASY AS FLIPPING A SWITCH – THE CHALLENGE OF RELIABILITY

The electrical grid is a truly amazing human invention. It allows people to flip a switch and power their homes and businesses, without a thought as to how it happens. However, much effort, planning, and infrastructure is required to ensure that electricity supply matches electricity demand every second of every day, and that electricity is available wherever and whenever it is needed. This is the challenge of reliability. The new system primarily powered by intermittent energy resources creates new questions for how the grid can deliver electricity reliably on demand.

POWER WHERE YOU NEED IT – INCREASED TRANSMISSION AND DISTRIBUTION

The new system will require new and expanded infrastructure for transmission and distribution systems, carrying power from renewables in remote locations and storage whose properties are very different from current, mostly fossil-fuel based generation. A participant described this as "changing the tires while the car is speeding down the freeway". ***How can California manage substantial changes that will significantly impact both the distribution and transmission systems?***

POWER WHEN YOU NEED IT – SYSTEM RESERVES

Participants pointed out that reliability requires sufficient reserves of on-demand ("firm dispatchable") power to handle sudden spikes in demand. The current system does this with natural gas power plants, geothermal, hydropower, and the Diablo Canyon nuclear-powered plant in California as well as fossil-fired resources in other states. As California moves towards a carbon-neutral future, the fossil-fuel resources that serve this role seem destined to be retired and replaced by intermittent, non-dispatchable renewables whose output is indifferent to demand. ***How will firm dispatchable reserve capacity be provided in the new system?***

RAPID LARGE-SCALE RAMPING TO BACKFILL FOR INTERMITTENT RENEWABLES

Participants pointed out the significant and growing issue that occurs every day as the sun goes down, when solar generation drops off just as evening demand picks up. Keeping the lights on requires the availability of utility-scale electricity sources that can rapidly be brought to bear to provide large quantities of power. Similarly, should the wind suddenly stop blowing the system must be ready to "turn on a dime" and quickly provide other sources of electricity. ***How will California provide flexible, rapid-response electricity supply at large scale?***

THE EMERGING NEED FOR STORAGE

Participants broadly perceived that, should generation become primarily or exclusively renewables, storage will be the key to resource adequacy because sometimes "the sun doesn't shine and the wind doesn't blow." Participants believed that utility-scale storage will be of particular importance. In addition, there might be some system benefits to distributed storage (e.g., electric vehicles and behind-the-meter battery storage that is coupled to rooftop solar), although grid operators currently do not have the technology that can access these possible storage resources. ***How will California system operators analyze, site, build, and manage large-scale storage on the grid and on distributed systems?***

In addition to the short-term storage which provides a buffer for the vagaries of sun and wind, participants indicated that long-term storage must play an important role in order to handle extended periods of either high demand (e.g., a lengthy heatwave) and/or low renewables supply (e.g., excessive clouds, or low winds in winter time). ***Are California and the country adequately investing in the development of long-term storage technologies?***

VEHICLE BATTERIES FOR FIRM POWER

Some participants discussed the possibility of using vehicle batteries as a source of firm dispatchable electricity supply during times of shortage. However, it is uncertain whether EV manufacturers will warranty their batteries for frequent cycling for supporting grid electricity shortfalls. ***What role should vehicle batteries play in reliability planning and assessment?***

In addition, there is a risk that if a blackout were to occur after the vehicle battery has been partly or fully discharged, the vehicle will be less effective for transportation. This might discourage users from allowing their vehicle batteries to be used to support the grid, which in turn might make the grid less reliable. ***How might electricity reliability concerns affect enrollment in programs to use car batteries as a grid resource?***

PUBLIC SAFETY POWER SHUTOFFS (PSPS) DUE TO INCREASED WILDFIRE THREAT AND INTENSITY

Due to climate change, California has seen a significant increase in the magnitude and intensity of wildfires. Once rare wildland megafires now occur with increasing frequency. Wildland fire risk conditions routinely lead to public safety power shutoffs. These events, which are predictably unpredictable, can last for many days. Some regions of the state are experiencing relatively frequent PSPSs. Some participants suggested that self-sustaining microgrids in certain areas might be wise. ***How can the state ensure reliable electricity supply during wildfire season?***

RELIABLE PROVISION OF GRID SERVICES

Many participants recognized that "reliability" includes not only sufficient energy, but also the provision of other grid services that stabilize and condition power. ***How can grid services be maintained as the grid moves from a central-station firm power model to one that must embrace distributed generation and intermittent resources?***

NEW COMPLEXITY REQUIRES NEW THINKING

The new system brings new uncertainties and coordination needs. The need for new and improved models, analytical methods, policies, and regulations that need to be implemented will be considerable. ***How will California understand, model, analyze, and run the new system?***

DISRUPTION HAPPENS – THE CHALLENGE OF RESILIENCY

The previous section discussed reliability, which is the challenge of matching electricity supply to demand, everywhere, all the time. Reliability requires careful attention even when everything is going well. However, sometimes things don't go well and the system experiences a disruptive event (e.g., falling tree, mechanical failure, computer glitch, etc.). We need to take steps so that when a disruptive event does occur, we can avoid a blackout or at least minimize the extent of its harm. This challenge is called resiliency.

Grid resiliency has many aspects, and there are many ways to think about it. In this brief, we use a resiliency framework developed by the Pacific Northwest National Laboratory which proposes that resiliency comprises actions taken to prepare for disruption; to operate at some level during disruption; and to restore the grid promptly after disruption.

PREPARE – KEEP BLACKOUTS LOCAL

Participants pointed out that in the past, there have been many instances where a local blackout due to local problems spread quickly to other areas. Participants indicate that it is possible to establish a robust transmission system to stop blackout "contagion." However, a robust grid must be purposefully built. Participants also observed that micro-grids can be helpful in this regard. ***How will California ensure a robust grid that can localize blackouts?***

PREPARE - ELECTRIC VEHICLES DURING BLACKOUTS

Decarbonization requires that vehicular transportation be electrified or use "green" hydrogen in fuel cell vehicles. During a blackout, electrical vehicles won't be able to charge. To the extent that hydrogen for fuel cell vehicles is made close to the time of consumption, hydrogen supplies might quickly dwindle.
How can electric vehicles be re-energized in the event of electricity outages?

How can vehicle hydrogen fuel be provisioned in the event of electricity outages?

PREPARE - DEFENDING AGAINST CYBER THREATS

Participants identified cyber security as an important risk to system reliability. They pointed out that decarbonization is "tech heavy" and more technology means more risk. They identified distributed systems as having many vulnerabilities (access points), including solar inverters, smart buildings, and smart grids. Participants also identified communications and control systems as points of cyber vulnerability. ***How will California provide a systematic and robust defense against cyber attacks?***

OPERATE – CRITICAL INFRASTRUCTURE

California will need to ensure that critical infrastructure, including hospitals, emergency first responders, and public safety radio nets will be able to operate when the grid has gone offline. Participants suggested several solutions to this challenge, including microgrids for critical infrastructure locations, new forms of long-term storage, and/or the use of fossil-fired generators. ***In a carbon neutral future, what will be the best strategies for ensuring that critical infrastructure is maintained and responsive during a blackout?***

OPERATE – SUSTAINABILITY OF DISTRIBUTED BACKUP POWER FOR LONG OUTAGES.

Most blackouts are of short duration, a few hours. As we have seen recently in California, some blackouts can last for days. Currently, easily-refueled fossil-fuel generators are the usual backup, but these will presumably become less prevalent during the transition to net zero carbon. ***How will distributed backup power be provided during blackouts?***

Backups could be in the form of battery storage, or hydrogen fuel cells. If backups are based on batteries, reenergizing during a lengthy blackout will pose a challenge. ***How will battery and fuel cell backups be re-energized during blackouts?***

It is too soon to say how important hydrogen and hydrogen fuel cells will be to the energy transition. It is likewise too soon to say how hydrogen will be provisioned (manufactured and transported). To the extent that hydrogen provision is dependent on electricity (e.g., electrolysis) hydrogen supplies could dwindle rapidly during a blackout. ***How will hydrogen backups be provisioned with hydrogen during blackouts?***

RESTORE - GRID INFRASTRUCTURE

The national grid is one of the most complex machines ever devised, and the California energy transition increases its complexity. The new grid with its attendant complexities and communications channels may be challenging to get back up and running after a blackout, especially if there is substantial damage to distributed generation (e.g., residential solar inverters), storage, or communication networks. ***Are there adequate technologies, systems, and regulations to enable rapid start-up from any grid outage?***

RESTORE – WEATHER-CAUSED BLACKOUTS

In a changing climate, weather impacts are likely to include severe wildfires, torrential rains and flooding, high winds, and extreme heat. These present challenges to reliability, but they also present challenges to recovery. It is possible that careful pre-planning and investment could make recovery more rapid than now. ***Can California develop mechanisms so the new system can recover quickly from weather-caused blackouts?***

Can the changing grid be hardened to protect it from a variety of threats?

RESTORE – CYBER ATTACKS

Cyber attacks can take many forms. Recovery can be a challenge. Some cyber-attacks include extortion demands and a rapid decision on whether to meet those demands can affect the time to recovery. ***Can California develop mechanisms to recover quickly from likely cyber attacks?***

All Our Eggs Are in One Basket

This brief highlights some of the risks and challenges of transitioning from the current energy system to an all-electric system that is based on renewables. California's strategy of "electrifying everything" entails at least a doubling of electricity usage, with pretty much everything (transportation, building heating, industry, commerce) running on electricity. This represents a massive bet on electrical reliability and resiliency.

California's strategy of "decarbonizing the grid" entails retirement of significant amounts of firm, dispatchable fossil fuel generation and its replacement by intermittent, non-dispatchable renewables, buffered by storage. This is a massive bet on the state's ability to site, design, build, and operate a type of system never before undertaken at this scale.

The goal of carbon neutrality may be a pathway for reducing a diversified and broad portfolio of energy resources to a less-diversified and narrower portfolio of electricity resources powered by renewables and storage. ***Is an integrated system that has multiple energy sources more resilient than a system that is purely electrical, or purely renewables?***

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