U.S. House Energy and Commerce Committee
Subcommittee on Energy, Climate, and Grid Security
"Enhancing America's Grid Security and Resilience"

Responses to Questions for the Record

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The Honorable Richard Hudson:

Witness response:

Thank you, Representative Hudson, for the opportunity to respond to these important questions. The full scope of your questions involves some areas in which I have comparatively little expertise. These include but are not limited to global supply chains, domestic manufacturing, cyber security, and terrorism. I can't address these areas in much depth, but they are important.

1. **What risks to energy transmission and national security are posed when lawmakers pursue policy agendas that rush the electrification of various sectors, like transportation, industry, space heating, and agriculture? How much more serious, or dangerous, would blackouts be in a fully electrified world?**

The last few decades have seen rapid improvement in the functionality and affordability of clean energy technologies, and utilities across the U.S. have increasingly incorporated these into existing systems, largely with success (no significant impacts to reliability). At the same time, there is widespread acknowledgement that policies that target total decarbonization over relatively short time frames present a very different, and much more difficult challenge. A recent report by the North American Electric Reliability Corporation goes one step further, naming state and federal energy policy as one of five major risks for bulk electric power system reliability.[1]

Electrification of "everything" – i.e., significant parts of the transportation sector, along with residential and commercial space heating, and parts of agricultural and industrial energy use—has potential benefits. These include more efficient use of energy (mechanical processes that rely on electricity waste less energy as exhaust heat). If paired with a low-to-zero emission supply of electricity, electrification would also reduce emissions of greenhouse gases and other air pollutants that directly harm human health (e.g., fine particulate matter). There are other potential benefits as well, including opportunities for more sophisticated demand management that could benefit both end-users (e.g., retail consumers and industrial manufacturers).

But alongside these potential benefits, rapid and widespread electrification could pose significant logistical challenges during the initial build-out (i.e., "growing pains"). Even after the electrification process is complete, consumers could face new risks related to more concentrated reliance on electricity in modern life (i.e., "putting all our eggs in one basket").

In general, I view "growing pains" as a temporary and somewhat inevitable part of a transition towards wider electrification (and by extension, decarbonization).

To your point -- the extent of these difficulties would be likely to correlate with the rate of electrification. "Rushing" to electrify without adequate planning could pose more immediate challenges than a more gradual transition.

Examples of electrification "growing pains" that could be felt by system planners, system operators and ultimately customers include:

1. A degradation in load (demand) forecasting skill, especially for the highest "peak" loads, which utilities use as a design target. Utilities estimate demand for electricity using weather forecasts and statistical relationships built from historical observations. From past data, utilities can create models that accurately predict demand in their service areas given information about local air temperature, humidity, wind speeds, day-of-week, and hour-of-day. Once calibrated, these models essentially assume that the relationship between weather and load is static. For example, they assume that on any Thursday afternoon in October that experiences low humidity, and a temperature of 60 degrees F, a utility service area will experience a demand of "X" (fill in the blank) megawatt-hours. Electrification can change these underlying relationships and require utilities to update their models accordingly. For example, as residential consumers increasingly adopt electric heat pumps as a source of home heating, those same Thursday afternoons in October may exhibit higher (e.g., X + 2%) electricity demands.

   Utilities have established procedures for updating their load forecast models to account for these types of technological changes. However, each year utilities may experience only a handful of hours in which extreme conditions (heat or cold) cause demand to reach very high, "peak" levels. This means that utilities have relatively few data points with which to "train" their models to predict load during extreme conditions. Resulting models may work well at predicting load 99% of the time but underperform when predicting consumers' electricity consumption during heat waves and cold snaps.

In particular, electrification of heating could make it more difficult for utilities to predict peak winter loads, and this could mean that some utilities won't build or procure enough capacity to meet demand, and system reliability could decrease.

2. A second example of possible "growing pains" that could accompany rapid, widespread electrification are inadequate supply chains. Supply chain issues for mined aluminum, copper, battery grade lithium, nickel, and cobalt are well documented, and the U.S. has limited domestic manufacturing capabilities for certain electrical quality steels, large (bulk power) transformers, and distribution transformers (the latter a key component in the electrification of transportation).[2,3] High prices for these mined resources and manufactured products should eventually encourage additional investment in production capacity, and the federal government has some mechanisms it could use to try to increase domestic manufacturing capabilities in this area. But some supply chain issues may extend beyond the influence of U.S. policy and represent a persistent vulnerability.

3. A third potential source of "growing pains" is sub-optimal (i.e., economically inefficient, or financially risky) investment in new infrastructure and technologies. For example, a variety of factors lead to the significant decrease in the cost of solar photovoltaic panels experienced over the period 2000-2015. These factors include improved materials and technology, more efficient supply chains, improved financing options, and economies of scale. Due to the patchwork (state-by-state) nature of energy and climate policy in the U.S.,

> early adopters (e.g., states like California that legislatively mandated renewable energy production quotas for electric utilities) played an instrumental role in driving down prices of clean energy technologies for other states.
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> However, early adopters of solar (and by extension, consumers in early adoption states) have typically paid a steep premium, because state governments mandated that utilities invest early in technologies that then quickly declined in cost. Later adopters of solar who employed a "wait and see" approach prolonged their state's reliance on fossil fuel generation but kept prices low for consumers by avoiding higher technology procurement costs. I know that some electric utilities and state utility commissions are aware of this dynamic and try to strategically incorporate it into their decision-making processes.

The second part of your first question above asks about reliability and security risks in a fully electrified U.S. economy. There are some serious risks related to the widespread integration and behavior of new, dynamic loads. For example, very large fleets of charging electric vehicles may have the potential to exacerbate temporary, infrequent disturbances that originate in the bulk power system; if these issues are not adequately addressed, they could cause widespread reliability impacts.[4]

Other risks full electrification relate to a concentrated reliance on electricity in modern life (i.e., "putting all our eggs in one basket"). I am concerned about the inadvertent consequences of full electrification in part because the grid is already facing several growing reliability challenges: the age of the power grid, the increased exposure of the power grid to cyber security threats, our increasing reliance on less predictable generation technologies, and the projected impacts of more frequent and severe storms and extreme heat caused by climate change.

While it is possible and perhaps even likely that the power grid will become less reliable over the next few decades, it is not yet clear whether blackouts in an expanded or fully electrified world will be more costly and/or more dangerous. But it is definitely a risk. This is an area of active research in my group, and at national labs and other universities across the U.S.

In particular, I worry that we don't fully understand the potential for reduced mobility of vulnerable communities during blackouts if we largely electrify light duty transportation in the U.S. Mobility is a key resilience tool that can allow people to move out of a hazardous area and/or an area with interrupted electricity service to find safety and resources. Even today, there are significant, existing challenges related to mobility that can make it difficult for vulnerable communities (especially low-income households) to prepare for, survive, and recover from natural disasters.[5] In a fully electrified world, it is possible that this key lifeline (the ability to pack up a car and leave an area impacted by a natural disaster) could be further out of reach for some communities. To my knowledge, this is an issue that has received relatively little attention.

I am aware of (but have not personally been involved in) a large body of research suggesting electric vehicles could be a source of resiliency during prolonged outages. Hypothetically, vehicle owners could use energy stored in vehicle batteries to temporarily (over many hours or days) power life-saving equipment (lights, refrigeration, medical equipment). In certain cases, this capability could reduce some of the need for mobility during disasters.

Few electric vehicles purchased in the U.S. currently come with these capabilities, which require additional bi-directional charging infrastructure. Partnerships between auto manufacturers and electric utilities are exploring the potential benefits (and consequences) of more widespread use of vehicle-to-home and vehicle-to-grid power transfer capabilities. In the short term, it seems likely that adoption of these capabilities will be concentrated in more affluent communities, the same as electric vehicle ownership (and to some extent, ownership of home solar and storage systems). If these technologies are to serve a useful role in disaster management and community resilience, they would need to be more widely accessible, and their use approved and guided by electric utilities and community leaders.

2. **What concerns do you have with expanding the electrification of various sectors, like transportation, industry, space heating, and agriculture, while the federal government, states, and utilities lack an understanding of the potential for impacts on emergency management and infrastructure development?**

My answer to this question borrows somewhat from my response above.

Emergency management services will have to evolve to respond to new and growing threats over the next few decades. A major risk will be more frequent and severe weather extremes.

Over the past 20 years, more than 80% of major power outages (affecting at least 50,000 people) were caused by extreme weather. In order, the most damaging weather events to the grid have been from: severe thunderstorms (rain, wind, lightning); winter weather (extreme cold, snow, ice, freezing rain); hurricanes and tropical storms (wind and flooding); extreme heat; and wildfires.

Outages were significantly higher over the period 2010-2020 than they were over the period 2000-2010. Moving forward, and on a region-by-region basis, we can confidently expect a range of effects from climate change, some of which threaten grid reliability, public health, and economic output.

With adequate planning, there are some aspects of widespread electrification that could enhance emergency management services during disasters. As noted above, there are (as of today, mostly hypothetical) benefits that could be drawn from the use of electric car batteries during and/or after extreme events. This technology may not be widely available in the short term due to higher costs, but it is possible that strategic investments in these technologies by emergency management services could prove valuable (e.g., fleets of Ford 150 Lightnings could be used as mobile generators to power emergency resource stations across a community).

But there are scenarios in which widespread electrification could create new challenges for emergency management services. I stated above my concerns about the potential for reduced mobility of vulnerable communities during blackouts if we largely electrify light duty transportation in the U.S. Mobility is a key resilience tool that can allow people to move out of a hazardous area and/or an area with interrupted electricity service to find safety and resources. Even today, there are significant, existing challenges related to mobility that can make it difficult for vulnerable communities (especially low-income households) to prepare for, survive, and recover from natural disasters.[5] In a fully electrified world, it is possible that this key lifeline (the ability to pack up a car and leave an area impacted by a natural disaster) could be further out of reach for some communities. To my knowledge, this is an issue that has received relatively little attention.

If widespread light duty vehicle electrification alters mobility during blackouts, then it could increase the demand for emergency services during disasters, further stretching resources and potentially reducing the scope and effectiveness of services possible.

Likewise, if widespread electrification contributes to an increase frequency or severity in electricity service disruptions (which is possible, especially during a rapid transition[5]), it could increase the demand for emergency services.

In addition, to the extent that electrification more firmly links electricity reliability with the reliability of other critical services beyond transportation (e.g., water and sanitation, building heat, food and fuel availability), it is likely that this would magnify the public health impacts associated with blackouts. But this is an area of uncertainty that needs to be better explored (and planned for), ideally through coordinated analysis by stakeholders and decision-makers across these multiple sectors. I think the federal government could play a useful role in encouraging and organizing these planning efforts across the country, but they would be best led by utilities, state and local governments, and community/business partners.

I hope these responses are useful. Please do not hesitate to ask if I can be of any help in the future.

References:

1. https://www.nerc.com/comm/RISC/Related%20Files%20DL/RISC_ERO_Priorities_Report_2023_Board_Approved_Aug_17_2023.pdf

2. https://www.energy.gov/sites/default/files/2022-12/The%20Supply%20Chain%20Crisis%20Facing%20the%20Nations%20Electric%20Grid_12.12.22.pdf
3. https://www.mckinsey.com/industries/oil-and-gas/our-insights/could-supply-chain-issues-derail-the-energy-transition
4. https://esg.wharton.upenn.edu/engagement/digital-dialogues/improving-disaster-recovery/
5. https://www.nerc.com/comm/RSTC/Documents/Grid_Friendly_EV_Charging_Recommendations.pdf