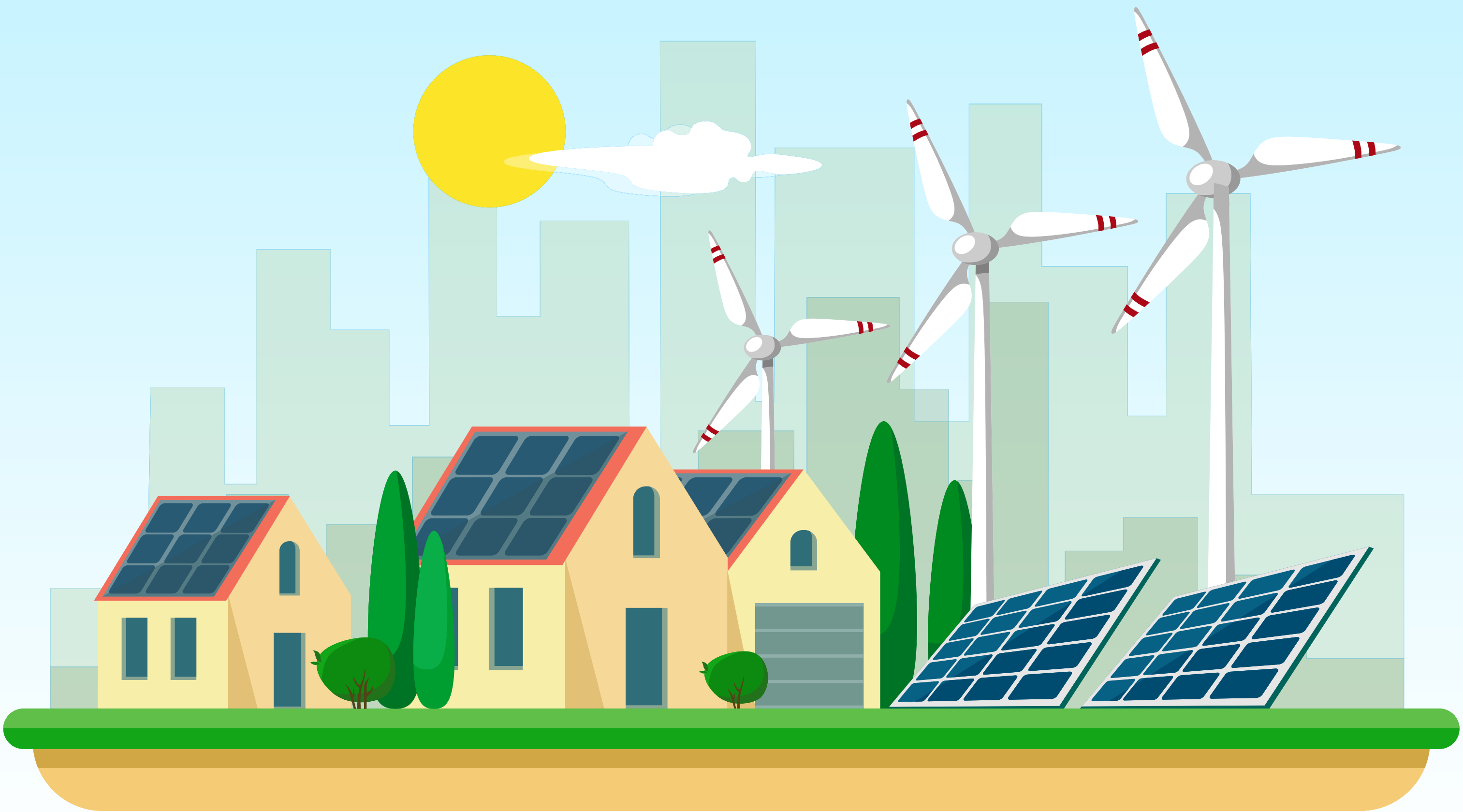

PECAN STREET

Untapped in Texas:
How Solar, EVs and Demand Response Could Fortify the Grid

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PECAN STREET

Pecan Street's mission is to accelerate the transition to clean, low-carbon energy, and integrated water management through innovative technology and policy. Our research, data, and technology expertise give researchers, entrepreneurs, policy-makers, and impact investors the insight they need to change the world.

Our real-world testbed of volunteer research participants is the first of its kind on the planet and has become an international model for conducting energy and resource research and product testing. Our commercialization lab is a world-class proving ground for major corporations and startups alike. And our database, the largest source of disaggregated customer energy data, is used by university researchers and industry-leading companies around the world.

Learn more at pecanstreet.org or email info@pecanstreet.org.

Please direct questions about this paper to Cavan Merski, Data Analyst, at cmerski@pecanstreet.org.

Untapped in Texas: How Solar, EVs and Demand Response Could Fortify the Grid

Data from Pecan Street's network of connected homes during Texas' catastrophic February 2021 freeze illustrate the potential of rooftop solar, electric vehicles, and demand response programs to fortify homes and the grid.

Introduction

Texans will never forget February 2021. Winter Storm Uri crippled the state's natural gas supply and sparked a cascading failure of our electricity system. More than 4 million homes and businesses lost power, many of them for days. More than 700 people died. The Federal Reserve Bank of Dallas estimated the electricity crisis cost the state between $80 and $130 billion.

But Texas isn't alone. Drought-fueled wildfires in California. Hurricanes on the Gulf Coast. Our changing climate is putting unprecedented pressure on our aging grid, and the grid is failing. According to the U.S. Energy Information Administration, the average number of hours American homes endured without electricity in 2020 was double what it was five years ago. And that figure doesn't include Texas' 2021 freeze.

In addition to broad, grid-wide improvements, community and residential solutions can improve efficiency throughout the year and provide an extra layer of protection against crisis-related power outages.

Energy technology will continue to improve. Yet, we already have the technology to significantly fortify the grid from increasing threats, reduce our reliance on fossil fuel electricity, and reduce electricity-related climate and air pollution.

Using energy data collected from Pecan Street's network of connected homes in Austin during Texas' historic 2021 winter storm, this paper demonstrates that current technology can control demand and better protect families from electricity crises.

Whether Texas leaders will embrace these solutions is another issue completely. In the immediate aftermath of the storm, Gov. Greg Abbott pledged to ensure such a crisis would never again occur. After the state legislature enacted modest reforms during the 87th legislative session, he claimed "everything that needed to be done was done to fix the power grid in Texas."

Though grid experts from around the country pleaded with the governor and legislators to consider solutions like the ones discussed in this paper, none of them were embraced or even seriously considered.

As millions of Texans prepare for the first anniversary of the crisis and pray for a mild winter, we hope a thoughtful discussion of these and other proven solutions will eventually gain traction.

Residential Solar

Beyond its emission benefits, residential solar has significant resilience potential.

Electricity produced by solar PV arrays is an integral part of the transition to low- or no-carbon electricity. U.S. solar PV deployment has grown significantly over the past decade, driven by a combination of declining costs, supportive local policies, and strong federal incentives.

Most utility customers with residential solar panels tie their electricity production directly into the power grid, which allows them to sell power back to the grid and recoup some costs. This comes with a trade-off: because of safety policies and historic permitting requirements, most grid-tied solar homes cannot use their own solar power during a grid outage. If the grid goes dark, so does the home's solar system. For solar to be a reliable crisis tool, this limitation must be addressed, especially as more and more homes will have electric vehicles that can store solar electric. The technical solutions to enable solar homes to stay online during a grid outage event exist; implementing them will requires local permitting changes and educational programming with line workers.

Solar in a Snow Storm

Texas summers are notoriously clear and sunny. But whether residential solar could help improve grid resiliency during a winter storm is an interesting question.

Winter Storm Uri left millions without power in Texas over several days. Cold weather crippled natural gas supply lines and stifled power generation, which led to electricity demand that far exceeded supply. Hundreds of homes in Pecan Street's testbed maintained electricity service during Winter Storm Uri, including 123 with solar panels.

Despite the snow and cloudy weather, the solar panels at these homes produced quite well. Figure 1 shows these homes' average production in the days following the snowfall and power crisis. The average home in our sample produced 69 kWh of power over the five-day period – enough to keep critical circuits like medical devices, cooking appliances, and plug loads functioning through the duration of the outage. If a home relied on a high-efficiency heat pump for heat, 69 kWh would not keep a house toasty, but could provide a level of heat to prevent freezing indoor temperatures.

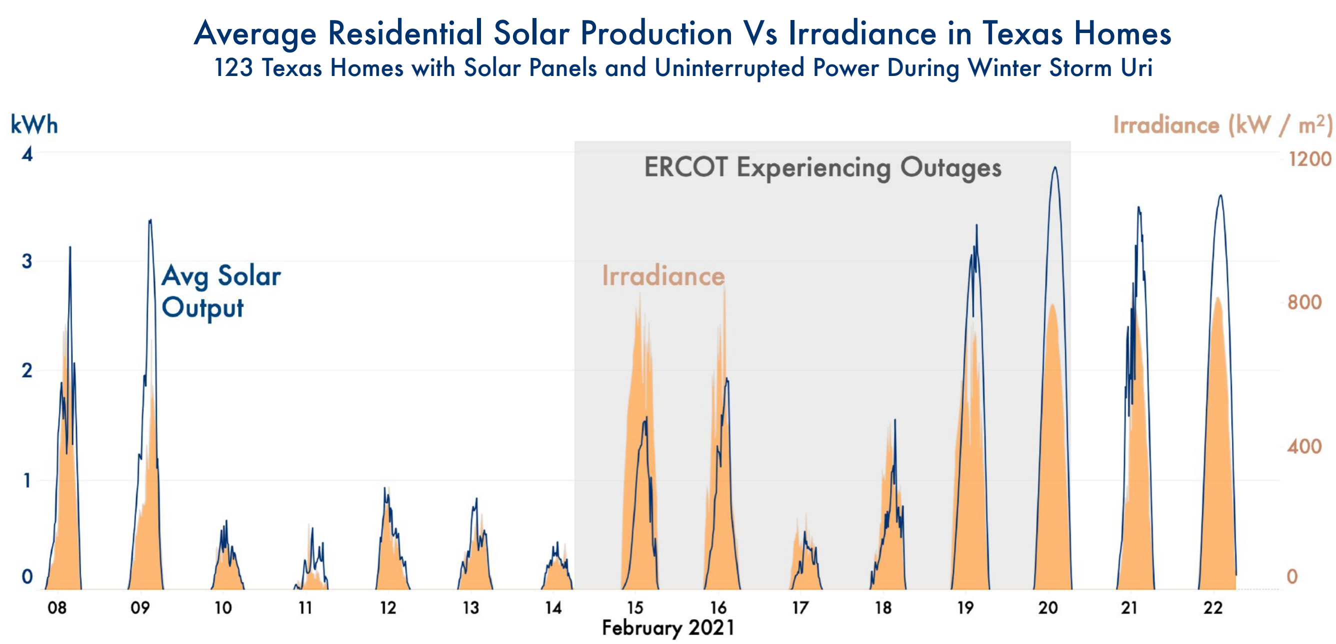

Figure 1.

In the days preceding the storm, low solar generation corresponds to cloudy weather and low solar irradiance. Roughly six inches of snow fell in Austin on Feb. 14. Snow on the panels melted quickly, even in sub-freezing daytime temperatures, and the average solar array in our sample produced 67% of expected production from Feb. 15 to Feb. 20. Solar panels still produce some power when covered in snow. Solar panels also produce power more efficiently in cold weather, which can offset some loss from snow cover.

Solar in a Hurricane

The potential for solar power to provide emergency grid resiliency is more profound in the summer. Six months after Uri, Hurricane Ida struck Louisiana and other Gulf states and left more than one million people without power. Damage to the power distribution grid was so extensive that 200,000 people in Louisiana did not have power more than two weeks after the storm made land-fall.

All the while, there was abundant sunshine in Louisiana. Homes in Pecan Street's Austin testbed are only 32 miles north of New Orleans, which means both cities receive almost the same amount of daylight. Figure 2 shows that a sample of 176 homes in Austin produced an average of 21.7 kWh per day following the storm.

The sweltering heat posed a threat to the elderly and people who lived alone or had pre-existing health conditions. With the correct solar integration, homes without electricity could have remained cool and supported vulnerable residents with power while the grid distribution system was repaired.

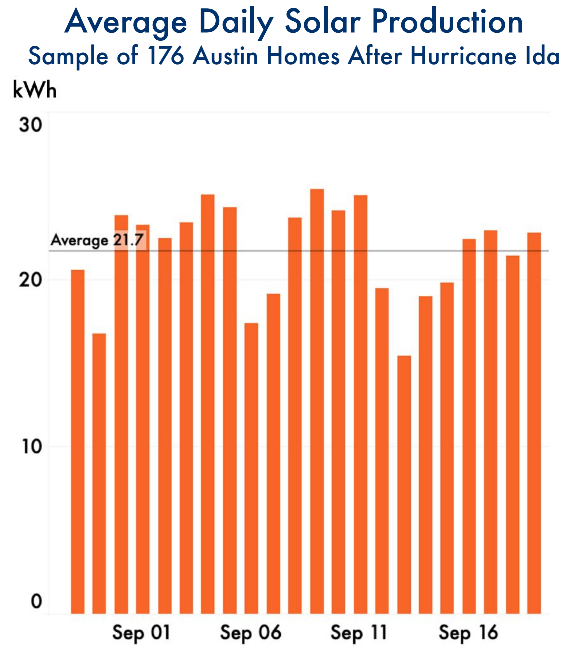

Figure 2.

Solar panels are extremely durable and often withstand major storm conditions like hail and hurricane-force winds. They are so securely fastened to roofs that it's [more likely for the roof to fail in a storm] than the solar panels.

As more homes incorporate solar, battery storage, and demand-side management, they can become more resilient to grid outages by producing backup power for longer periods of time.

Electric Vehicles

Residential EV charging is frequent, fast, and flexible. All of these features are good for the grid.

Electric vehicles have gone mainstream. Every major manufacturer offers fully electric or plug-in hybrid models. Ford has released all-electric versions of its two most iconic models – the F-150 truck and the Mustang. Ford and GM have each announced roadmaps to full electrification. For proponents of electric transportation and climate action, this shift is a positive but overdue indication that the auto industry is moving toward an all-electric future.

Despite this momentum, the electric vehicle transition is normally pigeonholed into two narratives.

1. Electric vehicles virtually eliminate on-road climate and air pollution and, if charged with renewable energy, can eliminate a driver's auto climate footprint.

2. Charging millions of new electric vehicles will be a challenge for utilities, customers and grid operators.

Both are true and important. Electrifying the transportation sector is a critical piece of a comprehensive climate strategy, and it will require significant investment and upgrades to the electric system.

Yet, both narratives miss the grid benefit. A fleet of millions of electric vehicles, if we plan strategically, could become critical assets within our electric system that stabilize demand, integrate more renewable energy, empower customers, and even provide daily and emergency back-up power for homes, businesses, and communities.

Pecan Street analyzed data from EV households in our research network to illuminate key trends and behaviors. The results tell an important story about how their vehicles could provide critical supplemental power during an outage.

EV Drivers Charge Frequently

Even as new EV drivers join Pecan Street's research network, our participants' charging behavior remains consistent.

Figure 3 shows the distribution of more than 197,000 EV charge cycles between 2015-2021. Notably, 77% of EV charge cycles were under 10kWh, which roughly equates to 30 miles of range. This pattern has held even as EV battery capacities have increased to the 60-100 kWh range, suggesting that drivers prefer shorter, more frequent charging sessions. For short-range EVs and plug-in hybrids, customers deplete and replenish regularly. For long-range EVs, customers charge frequently to remain well-charged.

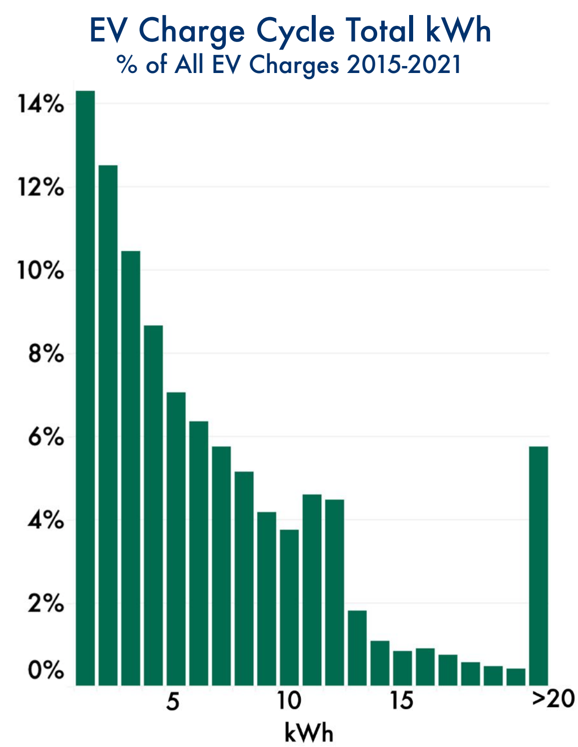

Figure 3.

Less than 6% of all charging sessions recorded since 2015 resulted in more than 20kWh of charge (approximately 60 miles of range). In other words, EV drivers are not sucking the grid dry every day. Most of them sip here and sip there; major charging sessions are few and far between.

Charging is Getting Faster

New EV batteries are not only larger, but they can also charge faster. Home charging speed is limited by two factors. First is the amount of power the charger can send to the car, which is a function of the voltage and amperage of the charger. A 220 volt / 48 amp home charger can produce 11.5 kW. Some home chargers can use more than 48 amps – an 80 amp charger can produce 19kW and would fully charge an empty Mustang Mach-E in 4 hours.

The second factor is how quickly the EV battery can accept power. As with chargers, not all EVs are equal, but charging rates are increasing across the board. This is not only a convenience for EV owners; it means EV charging load can be flexed more easily from one time of day to another, away from high demand periods and toward low demand periods or when clean grid electricity is plentiful. Moreover, faster charging means EVs are more likely to be fully charged when an emergency arises and can recharge more quickly during intermittent grid service. If a weather disaster is forecasted days in advance, as Uri was, people can charge their EV batteries quickly, long before the crisis arrives.

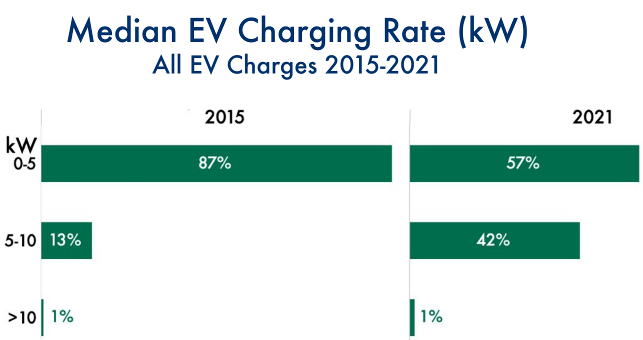

Figure 4.

Charging Times are Flexible

The high speed and frequency of charging could result in EVs becoming the most flexible load in the home. Because daily charging is dominant and drivers routinely use 20% or less of the battery capacity, most drivers do not need immediate or long charging sessions.

EVs and Level 2 chargers include technology that allows owners to schedule when to charge. In the future, this basic functionality could be expanded to allow utilities to limit charging during grid emergencies or schedule charging sessions, for example, overnight, that would optimize the use of clean energy. In areas where utilities offer time-of-use rates, customers could set cost thresholds for charging. As bi-directional chargers emerge, this connectivity could allow EV owners to dispatch energy to the grid when payback prices are highest.

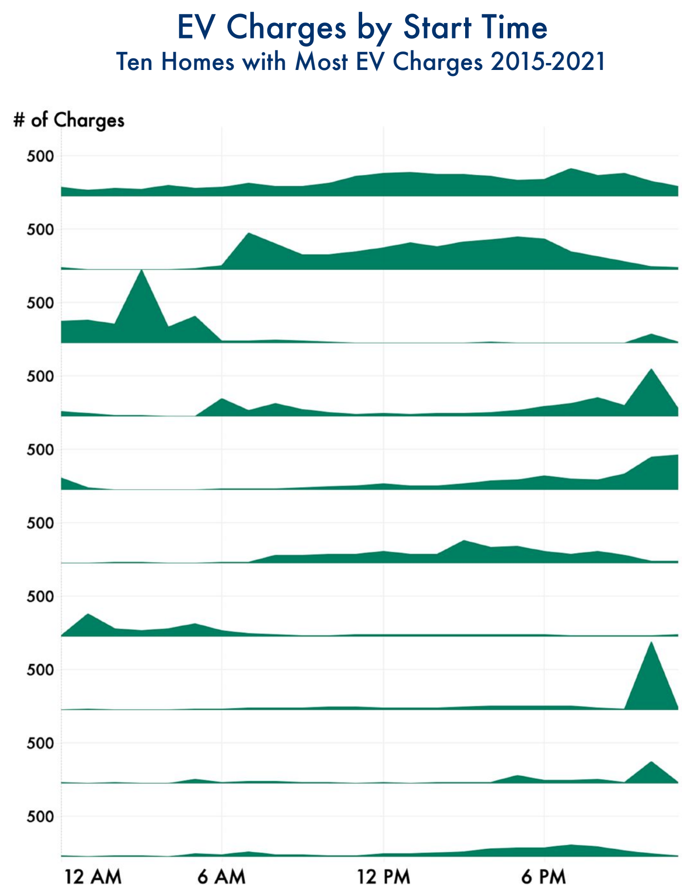

Figure 5.

EV Drivers Want to Support the Grid

EV charging in our testbed homes that maintained power during Winter Storm Uri was 40% lower than the two weeks before and after the event. This suggests most cars were sufficiently charged leading into the unexpected grid outage and that drivers did not "panic charge." Perhaps they heeded ERCOTs' pleas to conserve electricity during this emergency event. Regardless, EV drivers didn't hoard electricity or place undue stress on the grid.

Moreover, early Pecan Street research suggests that EV owners' charging behavior is very elastic, especially when presented with incentives. Volunteers were enrolled in a simulated time-of-use rate plan and were sent text alerts of simulated peak demand periods. Not only did drivers postpone charging sessions when alerted, a significant number programmed their cars to only charge after midnight, when the simulated price was lowest.

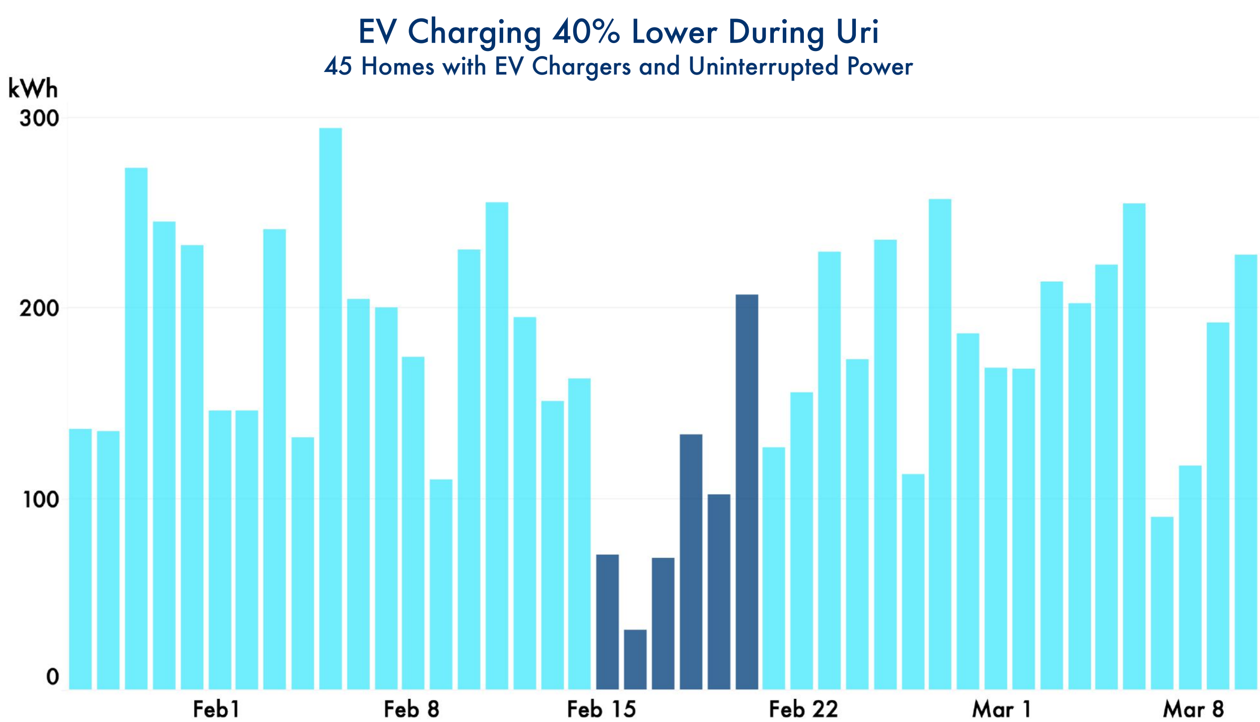

Figure 6.

EV Battery Potential in Grid Outage

Today, very few homes are equipped to use an EV's large battery to power home appliances; none of Pecan Street's networked homes are. As EV-to-home technology is now being introduced, however, it's useful to hypothesize how EVs could have met their owners' electricity needs during a crisis outage. To do so, we examined the electricity use of homes in our network that maintained power during Winter Storm Uri.

Figure 7 shows the home backup potential of different EV batteries if they had been integrated into the average home in our testbed, which consumed 32.3 kWH per day during the storm. Consumption was higher in the first three days when temperatures were the lowest, but remained consistent throughout the week.

Naturally, electric cars with larger batteries would keep a home powered for longer periods of time. The forthcoming Ford F-150 Lightning, for example, has a 133-kWH battery and could provide almost four days of average power use for a home. Additionally, if a house can reduce demand to only critical loads during emergencies, backup power would last even longer.

All EV batteries are large enough to provide significant backup power support, and the larger a battery is, the more valuable it will be during a grid outage. If the battery is combined with solar generation and/or demand management, the EV can provide significant resiliency support to individual homes and to the grid.

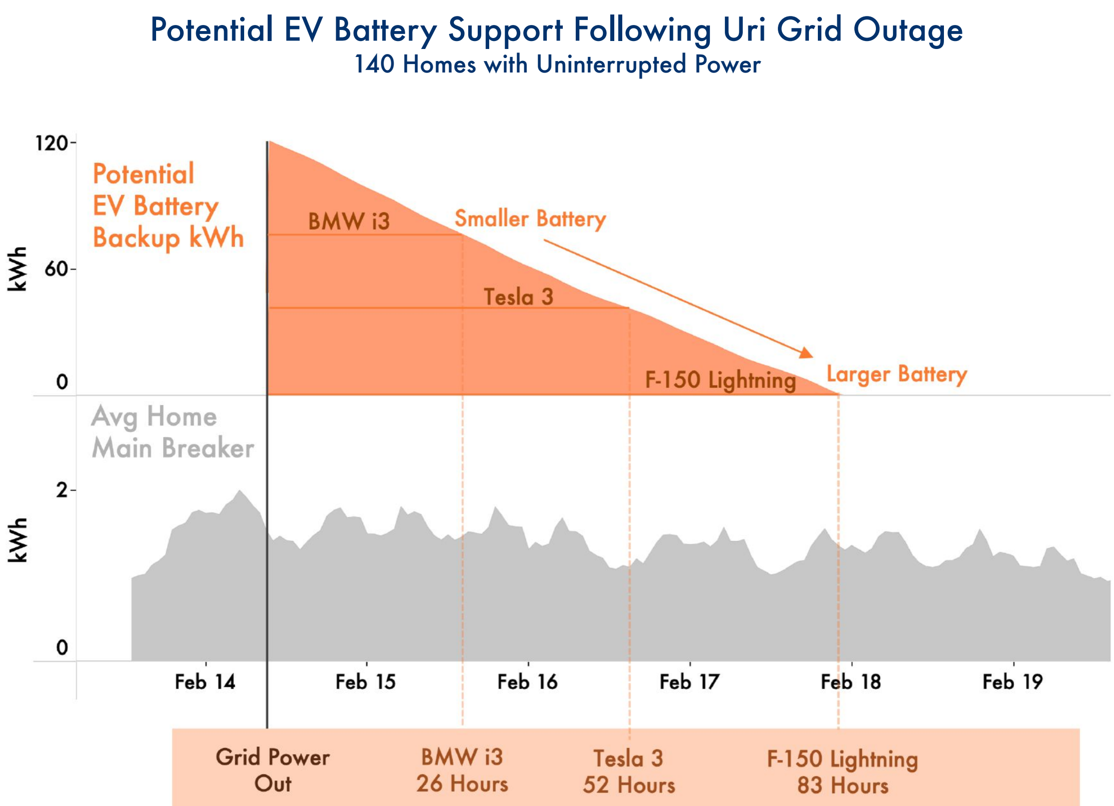

Figure 7.

Demand Response

Better connectivity between homes, individual appliances, and utilities or third-party companies has opened the door for more demand-side management of flexible loads.

Demand management programs have helped utilities match electric generation with demand for decades. For residential customers, demand management has traditionally focused on heavy loads that run during peak electric grid demand, most notably air conditioning.

Many utilities enroll customers in demand management programs to make small thermostat adjustments which, in aggregate, provide crucial relief to grid generation resources operating near maximum capacity. Various forms of demand management can also help integrate renewable electricity generation into the power grid by flexing or throttling home power use to match patterns of renewable generation.

Some energy experts – especially those in the natural gas industry – have warned of dire grid consequences of the increase of high-load technologies like electric vehicles and the trend toward replacing residential natural gas appliances like heaters, water heaters, and cooking ranges with electric alternatives. Indeed, EVs and increased electrification will increase electricity use and, if the trend is ignored, overall peak grid demand.

But all doomsday assessments fail to recognize the fundamental differences between older and newer appliances.

EVs are a completely new residential electricity use and among the biggest individual residential loads while charging. But the combination of load flexibility and EV's internet connectivity make them the perfect candidate for demand response programs.

Technology advancements also make other essential residential appliances new candidates for demand management programs. Considering all that it takes to include an appliance in demand response programs is an internet connection, everything from electric water heaters to electric clothes dryers could be part of a utility's demand response program. Below we outline some important demand management opportunities presented by individual uses that are currently left untapped by most Texas utilities.

Demand Response Opportunities	Description
Electric Vehicle Charging	An intermittent and flexible load that could power a home in the event of a grid disruption.
Heating and Air	Small changes in thermostat temperatures have minimal comfort impacts but can aggregate to large demand-side reductions during peak demand. Two-way heat pumps that cool and heat homes often have electric resistance backup strips to provide maximum heat when outside temperatures plunge. Limiting and synchronizing electric resistance heat modes can provide demand response functionality.
Electricity Metering Infrastructure	Advances in electric metering can help flexible loads that can be shifted to off-peak hours.
Electric Water Heaters	Hybrid water heaters heat water slowly in heat-pump mode and quickly in resistance heat mode. A heat-pump-only mode could provide demand response. Hot water temperature settings could be reduced during peak demand periods.
Electric Clothes Dryer	A significant but not critical load, they are useful candidates for demand response programs.
Pool Pumps and Heaters	WiFi-connected control systems are standard for new pools and replacements. Water circulation and heating for pools and spas can be shed or flexed depending on grid and weather conditions.

Sheddable Load During Uri

Winter Storm Uri affected hundreds of homes in Pecan Street's Texas network.

Analyzing these homes' electric loads reveals two challenges for demand-side management that are instructive for future events.

First, it will be important for a home to focus power on critical loads to ration backup power. Many homes in our network ran appliances like clothes washers and dryers, dishwashers, pool pumps, and hot tubs during the storm – non-critical loads that added to or, at the very least, didn't help the grid situation. Each large but non-critical load that is eliminated, shifted, or staggered during a crisis can shed significant demand. Figure 7 shows that, though some non-critical loads were reduced during Uri, reducing them to zero could have saved 15% more electricity at an average home during the week of the storm.

Secondly, homes must run critical loads as efficiently as possible to maximize their limited backup power supplies. This is true especially as electric appliances replace those powered by fossil fuels.

Average Daily Non-Critical Load

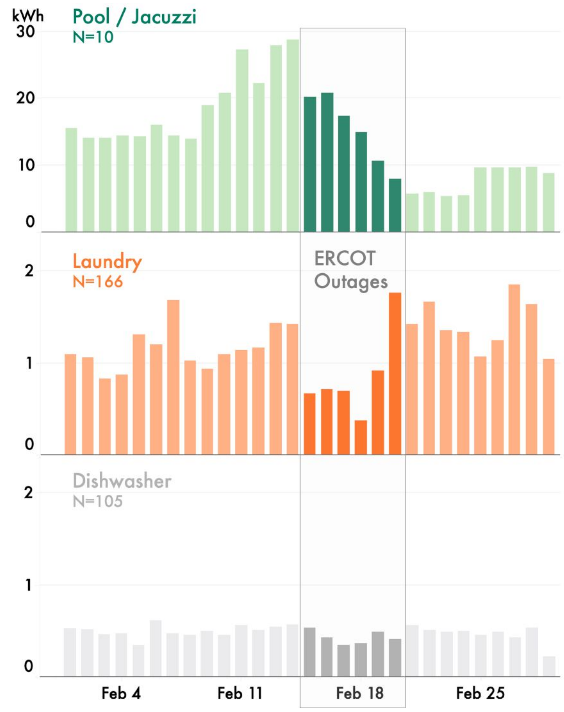

Figure 8.

Figure 9 compares two homes with two-way heat pumps for space heating. The heating load of the condenser and the backup resistance heat are broken out during the week of the storm. As the outside temperature got colder near Feb. 12, the resistance heat was activated to support the heat pump. When the temperature dropped lower on Feb. 14, the condenser in the first home turned off completely to save power. This is an effective energy-saving tactic that eliminated 1-2kW drawn by the condenser when the resistance heat is engaged and actively heating the home. Resistance heat is effective at low temperatures, but it produces higher power loads and should be used as sparingly as possible. Adjusting heat pumps and water heaters to run in heat pump-only mode as much as possible can also lower total power consumption.

Internal system heater settings can also be adjusted to avoid triggering resistance heat and to reduce the power consumption from heaters or hybrid water heaters. These variable-run modes can be governed by demand management software or manually at each individual unit, depending on the scenario. Such control would not only reduce a home's grid load, it would extend the back-up capability of battery systems for homes that have them.

These system operation changes may reduce the system's capability to hit a particular set point for comfort, but they would enable operation to avoid extremes while providing potentially critical grid services. ERCOT rules and state laws, however, prevent controlled loads from participating in such programs. As recently as 2021, a market report commissioned by the Public Utility Commission of Texas (PUCT) concluded: "While REPs have the ability to offer time-of-use and energy management products for residential customers, residential load response remains a critical and unrepresented resource in the market…The existing market rules and protocols do not permit nor encourage residential participation, leaving these resources inaccessible to ERCOT. "

This inability to access the market hasn't changed since the major rules around loads as resources were enacted in 2014. Comments around NPRR555 in August of 2013 identified these as limitations and have proved prophetic.

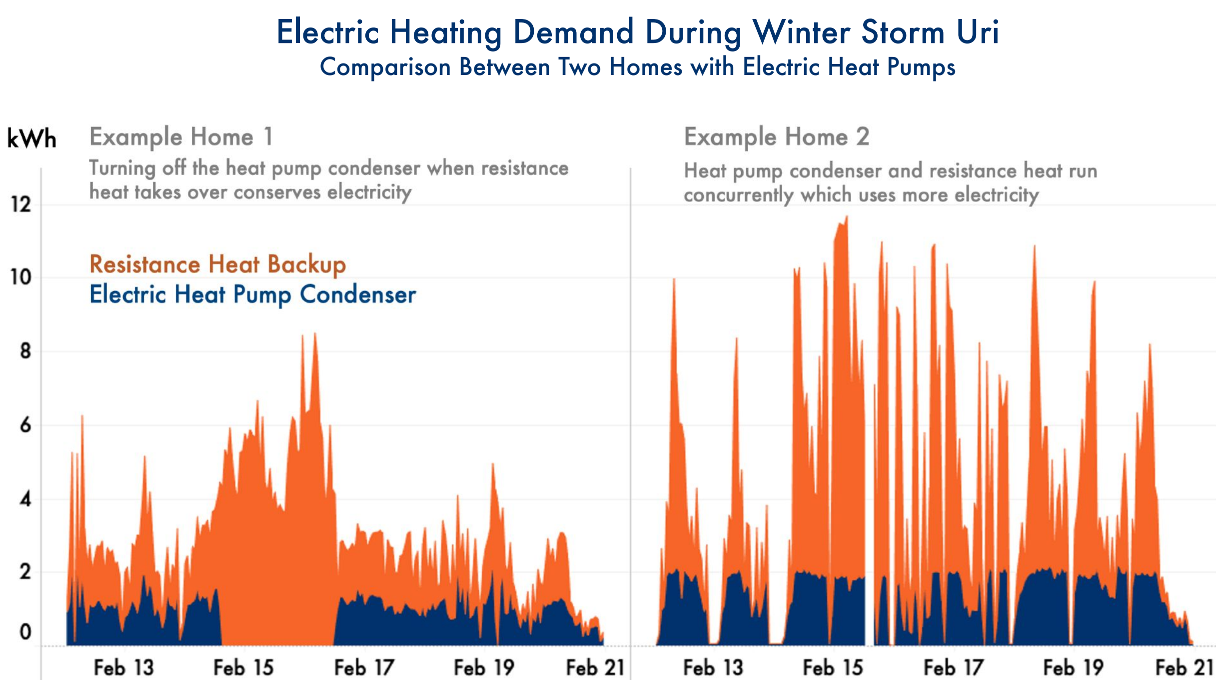

Figure 9.

Discussion

Imagine a scenario where the individual concepts discussed here were integrated and leveraged to increase resiliency for individual customers and the broader grid.

- Homes with solar or solar+storage could operate independently during power outages
- Electric vehicles could seamlessly provide backup power to a home or back to the grid during peak demand periods or energy crises
- Electric vehicle charging, electric dryers, and other appliances could be part of demand response programs that automatically and invisibly reduce demand during peak demand periods or energy crises
- Appliance manufacturers optimize their products, like two-way heat pumps, to deploy conservation algorithms automatically during energy crises
- And customers, importantly, are in control of the entire suite of solutions. They have access to and can share any of the energy data necessary to deploy these ideas with any company they choose

These are not far-out, futuristic scenarios; the technology to implement all of them exists today, and energy experts have been urging Texas leaders to implement them.

But they're complicated. It would be nearly impossible for a residential electricity customer to piece together the various ingredients required to execute the ideas presented here. Moreover, our grid is not equipped to take advantage of these tools.

#1. We Need Technology and Data Standards

All of the scenarios outlined here require two assets that don't exist today:

- Technology and communication standards (APIs, etc.) that allow the various pieces of these systems to work together seamlessly, and
- Standards that address customers' access to the data their home or products produce.

Both voids continue to stifle innovation and adoption. Tesla plugs don't work on Nissan Leafs. Ford's electric Mustang doesn't talk to solar inverters. Ford is marketing vehicle-to-home electricity flow for its F-150 Lightning, but no manufacturers are required to allow it, and some manufacturer warranties specifically prohibit it. The longer these various industries continue to innovate only within their own supply chain, the longer it will take for their products to have any real community-wide electricity benefit.

#2. We Need to Reduce Costs and Address Equity

None of these solutions are cheap. In addition to slowing innovation and adoption, generally, the high cost of these solutions has the potential to shut out large portions of the community that would most immediately benefit from more efficient and resilient homes.

This is already occurring within the solar industry due to high up-front costs and long investment payback periods, despite the fact that low-income families and multi-family structures would realize significant resiliency benefits from rooftop or community solar.

#3. We Need a 21st Century Grid that Extends into the Home

The need for a better network of electric vehicle chargers has received a lot of attention. And because more electric vehicles will produce community-wide benefits, this has been discussed as a national infrastructure need, not just an individual driver need.

Because we know that smarter and more efficient homes are better for the grid, we need to think about home energy upgrades the same way: they're part of the energy infrastructure.

Upgrading a home to support a V2G system or creating "critical load circuits" could cost thousands of dollars. Wiring solar panels so they can power a home during a blackout is illegal in most places. Given the benefits these solutions can provide, they deserve a priority position in the public debate about what features and capabilities the "future grid" will have, what real-life implications they will create for customers, and who will pay for them.

#4. We Need Forward-Thinking Energy Policy

Few industries are as affected by policy as energy. Texas' heavy reliance on coal, in the past, and natural gas, more recently, is not a result of unadulterated capitalism. Texas policy has favored fossil fuel energy for decades, and with the exception of the success of Texas wind, state policies are still stuck in last century's thinking that we always need more energy supply and should pull it out of the ground and burn it.

A forward thinking approach to energy policy would not only improve the environment, clean the air, and ease pressure on the grid, it would create thousands of new jobs.

Supply and Demand are Equally Important

When it comes to managing and planning for electricity supply and demand, Texas focuses nearly exclusively on supply: more power plants, more gigawatts. For decades, scores of experts have urged the state to deploy aggressive demand-side strategies. In the summer of 2021, a coalition of former PUCT and Federal Energy Regulatory Commission (FERC) commissioners and advisors released a detailed technical report outlining how demand-side management could fortify the grid. In the legislative session that followed the winter storm, not a single demand response solution was passed.

New Energy Solutions Should not be Political Scapegoats

While Texas was freezing, Gov. Greg Abbott told Fox News that the power crisis was caused by frozen wind turbines (this has been thoroughly debunked: the primary cause of the crisis was an embarrassing failure of the natural gas system). Though Gov. Abbott eventually backtracked, his knee-jerk "blame wind" response is indicative of how new energy technologies like solar, wind and even electric vehicles are attacked for political points. In the recent Texas legislative session, for example, lawmakers pushed a bill that would have charged EV drivers an annual fee between $190 and $240, an extra $150 for driving more than 9,000 miles a year, and $10 a year for a "charging infrastructure advisory council." Why? EVs don't generate gas tax revenue, so many politicians pedal the idea that EVs, like wind, are causing problems rather than solving them.

This thinking fails to recognize the enormous benefits that modern energy technology can provide. The Texas Emissions Reduction Plan (TERP), for example, collects more than $200 million a year in fees to help replace old, very dirty diesel buses and trucks with newer, less dirty diesel models. Why not use those existing funds for electric replacements that have zero tail-pipe emissions and save households thousands of dollars a year in avoided gas and car maintenance costs? EV's don't require oil changes, and their electric motors are easier and more cost-efficient to maintain over time. Dozens of electric vehicle companies, including Tesla, have set up shop in Texas to seize this remarkable opportunity, yet Texas political leaders still withhold the unbridled support they have offered the fossil fuel industry for years.

Texans Deserve the Same Energy Freedom Shown to Fossil Fuel Companies

The deregulation of Texas' electricity market hasn't been perfect. But it has been successful in keeping electricity costs low and providing customers a level of market freedom. That freedom, however, has not extended far beyond the ability to choose your utility.

For example, unlike Texas utilities, those governed by FERC are required to allow residential customers who install energy storage systems to tie them to the grid, be compensated for the power they provide, and install technology that allows them to stay "powered" during an outage. There's no such customer protection in Texas. It took until 2021 for the state to prohibit homeowner associations from banning solar panels in their neighborhoods, despite decades of lobbying from customer rights groups. The state was quick, however, to prohibit cities, counties, and other municipalities from banning fracking operations in their communities.

#5. We Need Genuine Energy Leadership

All of these needs add up to one big one: leadership from elected officials who will put the security of Texans ahead of politics. We need leaders that will demand, design, and deploy fair policies that truly improve the grid and create new economic opportunities for Texans.

Unlike mass-market products, like iPhones, that have easily demonstrable customer benefits that spark incredible market share in a short period of time, home resilience products face a tougher adoption curve. They're expensive. They benefit the community as much as they benefit the customer. And at their core, they strengthen a system most customers think should be strong enough without having to upgrade their homes. If we want companies to make these products, they need to know there will be customers who will buy them.

Growth in this industry will be inhibited until our state policies stop favoring natural gas over smart clean energy and demand-side solutions. Unfortunately in Texas, the utilities, elected officials, and regulators who have the power to drive this transition have shown little urgency or enthusiasm for such solutions. They seem to forget that Texas' global leadership in wind power started with a legislative mandate, which signaled to the world that Texas was committed to wind and open for business. In doing so, Texas kick-started a national industry that now employs more Americans than the generation of nuclear, coal, natural gas, or hydroelectric energy.

While the snow was still on the ground in February, elected officials, including former governor Rick Perry, touted Texas' independent grid. In fact, our grid independence would allow us to make upgrades and changes to quickly integrate innovative solutions. It's a unique asset that renewable energy advocates have argued for decades could speed our transition to a more reliable, resilient, affordable, and cleaner grid. But for Perry and other politicians, our grid independence has been used more as a cudgel against Washington than as tool for the genuine improvement that Texans deserve.

We are desperate for true energy leadership. The person, company, or entity that steps up to fill this leadership void will be a hero on both sides of the political aisle and to future generations of Texans who won't have to pray for warm winters.