Is the Grid Ready for Our Electric Future?

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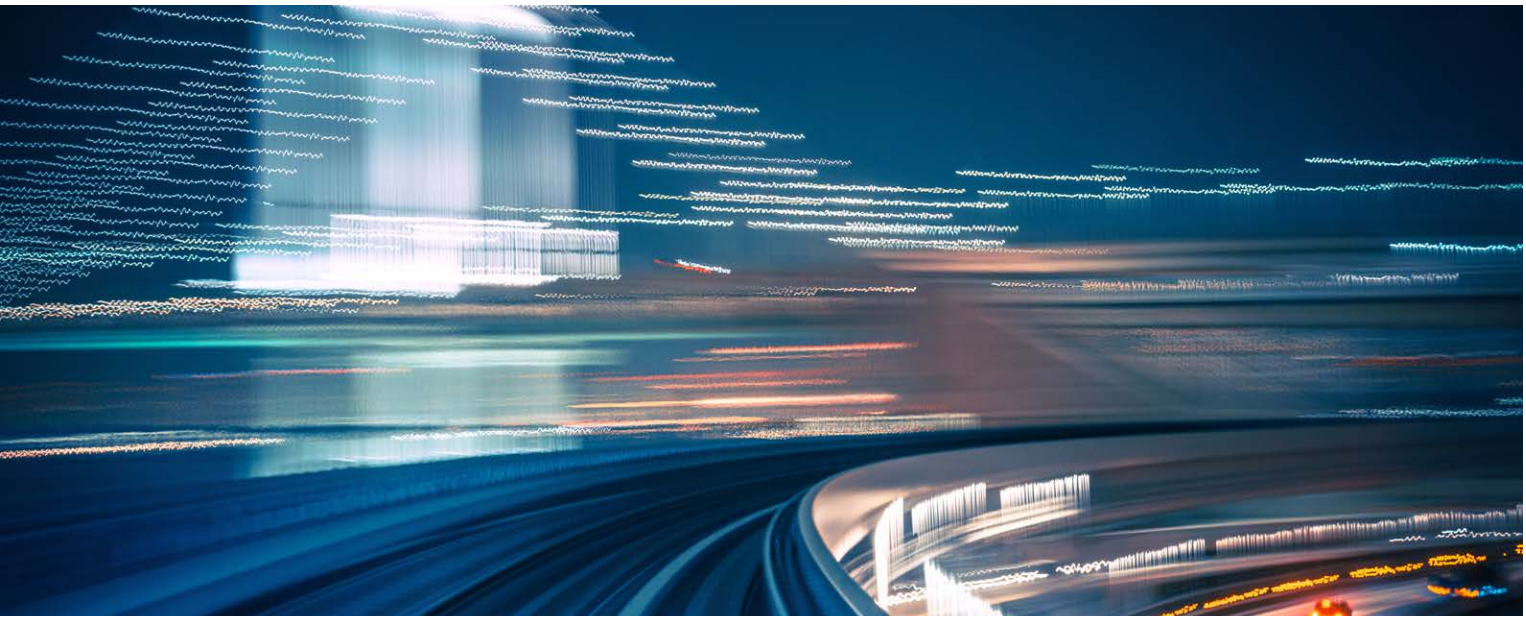


Executive Summary

Our changing climate demands bold action, including a dramatic overhaul of our energy industry and a transformation of the electric grid that powers the United States, which is directly responsible for a quarter of U.S. greenhouse-gas emissions.[1] But climate change alone isn't the only reason we need to reassess the grid.

Our modern world increasingly runs on electrons, from the electric vehicles zooming down roadways to the heat pumps making offices and homes comfortable in summer and winter. More and more, generators source that power from the sun, wind and other renewables. Meanwhile, individual homeowners and businesses deploy micropower generators like solar photovoltaics on their property that connect to the grid all along the distribution system. Sometimes these users pull electricity from the grid, and other times, they push it on. All of this makes for a significantly more complex power system.

“Climate change is happening now, and addressing it requires an upgrade of our energy systems away from fossil fuels," explains J.J. (Jeong Joon) Yu, SK Group Vice Chairman and Chief Executive Officer of PassKey. "It is clear that a cleaner, smarter, more efficient energy grid is good for people and for our planet. That's why we must progress toward our all-electric future through innovations that will help meet the world’s demand for clean and reliable power,” he adds.

SK and its operating companies have set out a bold plan that commits us to advance the communities where we do business by creating both economic and social value.[2] To meet this ambition, we are investing in cleantech, life sciences, semiconductor and green companies across the U.S. Our investments will total more than $50 billion by the end of 2025, increasing the number of U.S. employees from 4,000 in 2021 to more than 20,000 by 2025.[3]

The Grid Is Warning Us

There was nothing out of the ordinary in Odessa, Texas, on May 9, 2021. It was a seasonable 75 degrees Fahrenheit. It wasn't raining, and the wind wasn't blowing especially hard. But anyone who has spent time around a power plant knows that issues can occur even on a good day when the sun is shining.

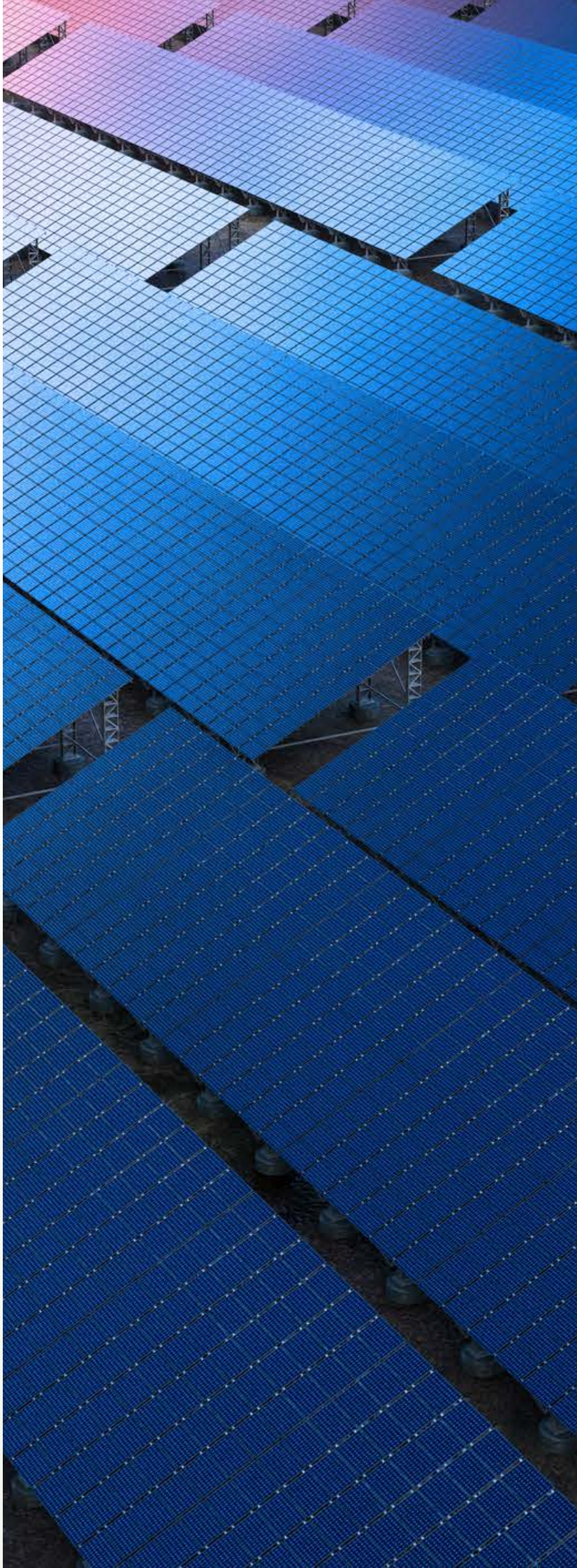
At 11:21 am, a faulty piece of equipment tripped a circuit breaker at a natural gas-fueled plant outside town.[4] Generators are prepared for such events, and the system reduced power output by only 192 megawatts before it recovered within fractions of a second.

But then something else happened that nobody expected from such a run-of-the-mill fault. Solar photovoltaic and wind generators connected to the grid up to 200 miles away from the initial fault started reducing their power output. At the height of the disruption, the renewable sources reduced the power they were feeding the grid by more than 1 gigawatt, enough electricity to power hundreds of thousands of homes. In the end, the system quickly resolved the disturbance, but the unexpected event raised enough alarms to trigger investigations by Texas power authorities and the industry's oversight body, the North American Electric Reliability Corporation (NERC).

Officials were concerned with the so-called "Odessa Disturbance" because it was just one of multiple cascading renewable power generation reduction events they've recorded in recent years as alternative sources of electricity have plugged into the grid. Their fear? The current U.S. electrical system is unprepared to bring large amounts of renewable electricity generation online and provide the electricity needed for a future where more of our machines get their power from renewables than fossil fuels.

Warning signs about the insufficiency of the grid now seem to crop up regularly. More glaring alarms occurred in the summer of 2022 when electricity imbalances peaked in several Western states. In September, California's independent system operator recorded a spot price—what it cost at the moment to buy electricity for immediate delivery—that briefly rose from an average of below $100 per megawatt hour to an unsustainable $2,000 per megawatt-hour. And in July, Texas's market saw price skyrocket to an incredible $5,000 per megawatt-hour.

The move away from fossil fuels in favor of zero-emission renewables, including wind and solar power, is critically needed. Without these clean-energy resources operating at scale, curbing emissions at levels required to meet global climate targets becomes nearly impossible. In the short term, though, the transition will create challenges. That's why we need practical, near-term solutions alongside the long-term grid innovation and infrastructure buildout that is already underway to boost the capacity and resilience of the country's electrical system.



Renewables & EV Adoption: Two Growing Trends Challenging The U.S. Power Grid.

SOLAR & WIND GROWTH

Renewable energy stands as a contender to be the "primary source for new electricity generation"[5] by 2050 according to the U.S. Energy Information Administration.

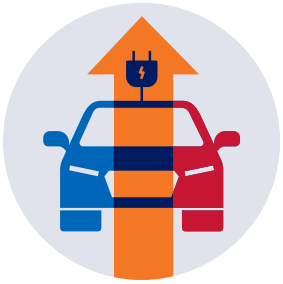
EV ADOPTION RATE

As renewables grow, electric vehicle adoption is forecasted to have a **60%** share of all global new car sales by 2030.

GIGAWATT CAPACITY BY 2050

404.25

Projected amount of gigawatt capacity coming from wind energy by 2050.[6]



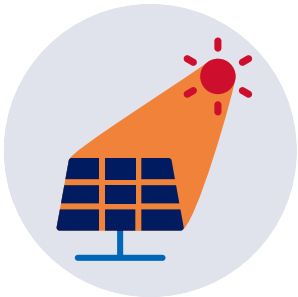
ESTIMATED EV FLEET SIZE BY 2030

300 Million

In less than a decade, the International Energy Agency projects electric vehicles could account for 60% of all new car sales.[7]

U.S. SOLAR CAPACITY IS PROJECTED TO **QUADRUPLE** OVER THE NEXT **TEN YEARS**[8]

Solar energy represents America's fastest-growing power source, accounting for more than 40% of all new electricity generating capacity.



Electricity: A Powerful Tool to Cleanse Sectors of Emissions

Scientists warn that climate change's impacts are happening faster than initially thought and the window to keep global warming below 1.5 degrees Celsius, the limit above which consequences will likely be much more severe, has all but closed.[9] Many communities may soon lose the ability to adapt if countries and companies refuse to act in earnest. In the U.S., any serious effort to stem greenhouse gas (GHG) emissions must focus on transportation, electricity generation and powering and heating buildings, which account for 65% of all GHGs.[10]

But there are more and more reasons to hope that the country is getting serious about moving beyond fossil fuels and addressing climate change. Increasing renewable power generation, adoption of electricity-powered building systems and growing sales of electric vehicles (EV) suggest that a pivot away from fossil fuels is within reach.

On the power supply side, the U.S. Energy Information Administration (EIA) projects that renewables will generate more than 44% of U.S. electricity by 2050.[11] Around 57% of the country's total capacity addition (approximately 1,000 gigawatts) will come from renewables between now and then. As just one example of the broader trend, in 2022 and 2023 alone, power project developers and operators told the agency they planned to add 51 gigawatts of solar power and battery storage projects to the U.S. grid[12]. And the EIA reports that it's now considerably cheaper to build and operate solar photovoltaic plants than any other source, with onshore wind and natural gas competing for second place.[13] Meanwhile, 95 gigawatts of coal-based electricity capacity have been retired since 2011, and that trend will continue.[14]

But those projections aren't enough to keep global temperature rise at or below 1.5 degrees Celsius. In its most recent World Energy Outlook, the International Energy Agency says renewables' share of global electricity production will need to jump from 28% in 2020 to 61% in 2030 and 84% by 2040.[15] Closer to home, meanwhile, it will take considerably more work to achieve the U.S. government's stated goal of decarbonizing the grid by 2035. According to the U.S. Department of Energy's Solar Futures Study, there will need to be up to 1,000 gigawatts of solar alone deployed by then, which would produce up to 40% of electricity demand. But in 2020, a mere 76 gigawatts of electricity came from solar projects.[16] The DoE study assumes the rest of the decarbonized supply will come from wind, nuclear, hydroelectric, biopower and geothermal electricity production.

On the electricity demand side, automakers are ramping up production to meet the unexpectedly high consumer desire for EVs, a trend at least partially triggered by volatile and costly gasoline prices. A recent forecast projected that number will reach 26.4 million in 2030.[17] If achieved, the EV fleet will represent 10% of all cars and light trucks in service in 2030. Further, EVs will account for 32% of all car and light truck sales annually when the next decade begins.

Meanwhile, commercial and residential buildings – another major GHG source – are rapidly switching from natural propane- and oil-fired furnaces, boilers, cooking ranges and water heaters to high-efficiency electric innovations like air-source heat pumps, induction cooktops and heat-pump hot water systems. A McKinsey analysis found that electric heat pumps could comprise around 90% of new heating unit sales by 2050, compared with 35 percent in 2022.[18] The result could be a cut of 3 gigatons of carbon dioxide emissions. At that point, electric appliances would provide 61% of space heating, 52% of water heating and 94% of cooking services in the buildings sector.[19]

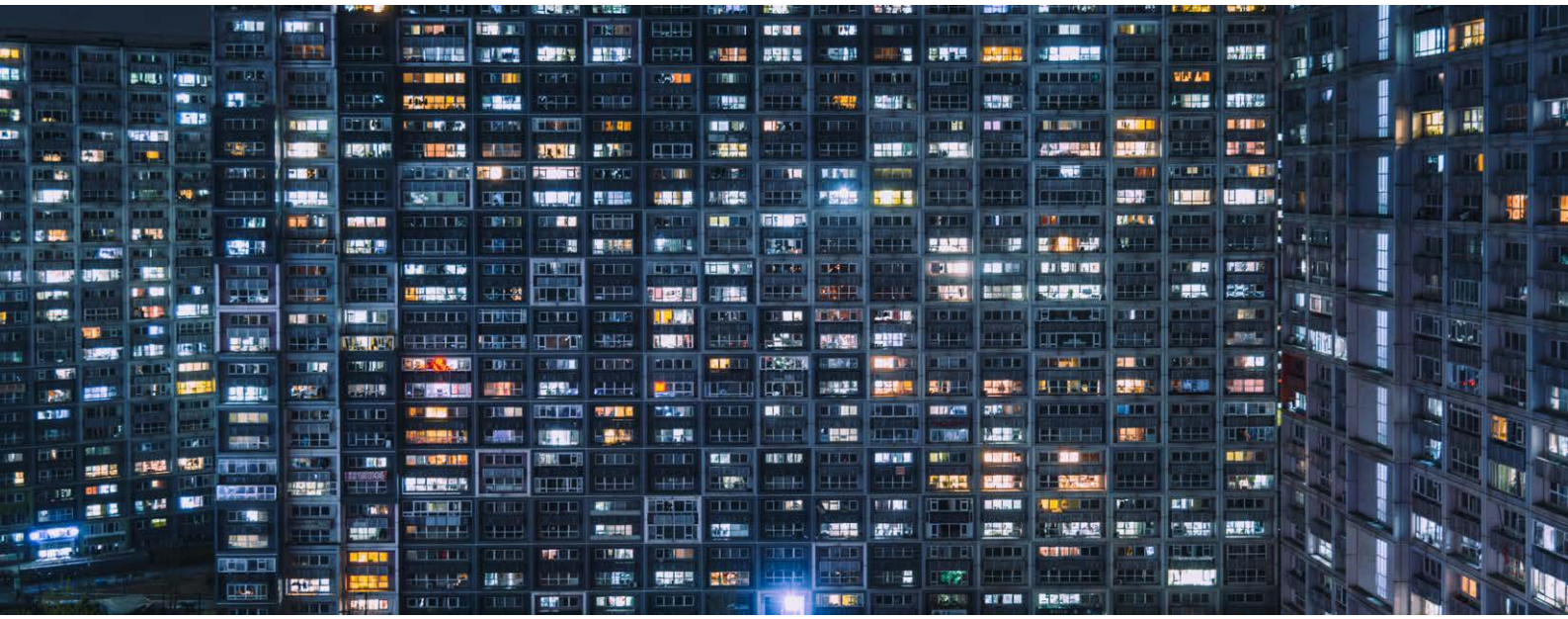
The Power Paradox: Increasing Electricity Demand and Its Challenges

With the increasing adoption of electrically powered machines that replace those that operate on fossil fuel combustion and a steadily growing share of renewable power generation, market forces now guarantee that the country has begun an irreversible and essential shift in how electricity is produced and consumed. And recent federal legislation meant to incentivize infrastructure, renewable energy and energy-efficiency improvement projects from the individual consumer up to big industrial players will put wind in the sails of the electrification revolution already underway. The result will trigger a wholesale transformation of U.S. energy infrastructure and the broader economy that relies on it.

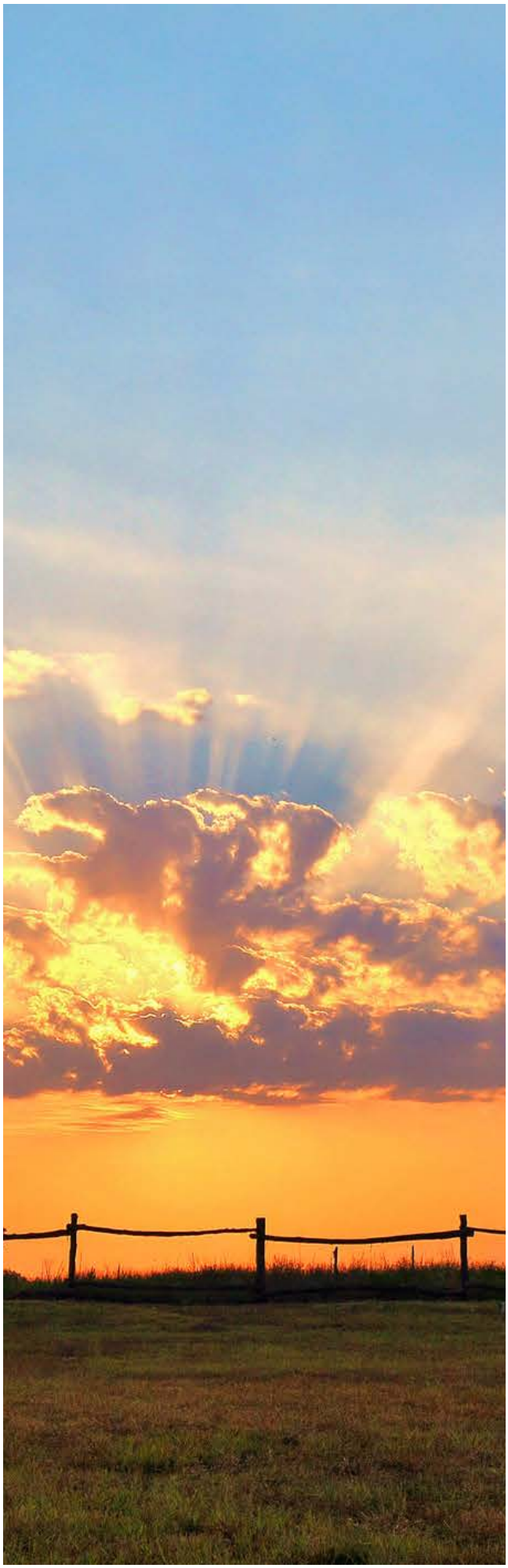
But there's an important consideration to take into account with the significant improvements in GHG emissions, air quality and energy security that electrification will afford. All those efficient electric machines coming online in the transportation and buildings sectors will need more power than is currently available through the grid. Electricity's share of all energy consumption will need to double–up from 20 to 40%–by 2050, and widespread electrification will increase total U.S. electricity consumption by as much as 38% by 2050.[20,21] The power generation industry requires significant upgrades and expansion to meet the country's movement to mass electrification.

"The current U.S. power grid, similar to other advanced countries, was built a long time ago under the assumption that demand would be predictable and supply would come from centralized, dispatchable fossil fuel generators," says Doctor Kyungyeol Song, Ph.D., Chief Operating Officer of PassKey. "If demand was predicted to increase, you had a coal or gas plant that could produce more electricity. But now, you can't just start making more electricity from a solar farm if the sun isn't out."

That's just one issue from the supply side's increasing share of renewably produced electricity. The demand side brings a whole portfolio of challenges that threaten to throw off the balance between supply and demand. As one example of demand-side growth, EV charging will increase each household's peak electricity demand by up to 270%. In its current state, the grid, which is already outdated and saturated in many U.S. cities, will be unable to meet such a spike in demand.



Without grid innovation and modernization, catastrophic failures could plunge large areas of many key states in the U.S. into blackouts. Grid instability is not a distant threat the U.S. might face at some unknown point in the future; NERC's most recent summer reliability assessment warned that more than two-thirds of the U.S. was under blackout risk due to grid problems. If the American grid is already stressed, the situation will become more severe in a future where more climate change-induced heatwaves and droughts combine with more machines needing electricity from clean, decarbonized-but intermittent-power sources like solar and wind. Without meaningful, focused action, rolling blackouts could leave hospitals, homes and businesses without power and EVs stranded when electrons stop flowing.



"It's obvious from the recent events and price spikes in California and Texas that the U.S. is already suffering from a power-grid crisis," says Dr. Song. "Without considering a fundamental solution to improve grid stability, the current and vital push for renewable energy and electric vehicles could exacerbate these strains further, especially as the effects of climate change create more frequent and devastating natural disasters."

Some challenges facing the grid today will grow more acute without upgrading the grid so that it includes the following solutions[22]:

- **Urgent need to deploy power storage at scale.** Renewables are very different from fossil-powered generation. The sun isn't always shining, and the wind isn't constantly blowing. Alternative sources like solar photovoltaics are deployed not just as large, centralized plants like the old grid model dictated but are also distributed in parking lots and residential rooftops. They may feed their variable capacity into the grid anywhere along the line, from transmission to end users. And sometimes, buildings with these installations pull power from the grid, while other times, they put power into it.

  This two-way, distributed power generation and consumption create a significantly more complex operating environment. In order to accommodate more renewables on the grid and to avoid power instability, more grid-scale power storage should be deployed and reach scale as soon as possible.

- **Battery materials bottleneck.** A recent McKinsey report sees eight times as much demand for lithium, the metal at the core of modern EV and grid batteries, by 2030.[23] EV battery demand will drive the market and make competition for the critical material fierce for grid-scale battery makers. Since better alternatives to lithium-ion energy storage are still in the R&D stage, large, accelerated supply-chain investment in acquiring lithium must start now to meet the need for batteries, including utility-scale energy storage solutions.

- **Modernizing an aging grid.** Some components of the national grid are over 100 years old, far past the 50-year lifespan of most equipment that comprises it.[24] An energy infrastructure survey by the U.S. Department of Energy found that 70% of power transformers are 25 years or older, 60% of circuit breakers are 30 years or older, and 70% of transmission lines are 25 years or older.[25] This old equipment can lead to problems in its own right, but when more intense climate change-induced hurricanes, wildfires and other disasters appear, it’s a recipe for outages. One recent investigation found that the number of power outages has doubled in the past six years compared to the previous six.[26]

Mass electrification will demand a higher capacity and more reliable electricity supply to keep the grid operating. The current system needs to modernize to avoid disturbances like what the industry saw in last year's Odessa, Texas, event from becoming catastrophic failures.

Necessity Becomes the Mother of Grid Modernization

SK E&S's Dr. Song says companies and governments around the world are adopting net-zero goals at an incredible pace. That is precisely why his company is offering PassKey, a potent innovation to make tomorrow's grid more nimble and reliable while producing fewer emissions through renewables. PassKey is unique in connecting Energy Storage Systems (ESS) that can store renewable generated power with artificial intelligence (AI). The AI algorithms predict supply and demand and optimize power across the grid to intelligently shuttle electricity where it's needed when it's needed.

"The target to reach net-zero emissions by 2050 is mission impossible without energy storage and artificial intelligence," Dr. Song explains. "For customers, achieving net zero usually causes inconvenience and increased costs. Our mission at PassKey is to achieve both targets simultaneously accelerating the push to net zero and providing convenient, affordable electricity to customers. Many people think that these two goals conflict with each other, but we believe PassKey's business models and technologies can achieve both."

Because SK E&S sees energy storage as an essential block in the foundation of tomorrow's grid, the company has made significant investments in the technology throughout U.S. markets, including taking majority ownership of Key Capture Energy in 2021.[27] The New York-based company builds and operates standalone energy storage projects, now boasting more than 5+ gigawatts of capacity in development, construction or in operations. Its leaders aim to have more than one gigawatt of battery storage operating across the U.S. by 2024.

PassKey's novel solution to modernizing the grid circumvents some of the expensive costs and labor of upgrading transmission lines. The system's software ensures that ever-growing loads of solar and wind power are reliably and efficiently distributed to consumers using existing grid infrastructure.

And decreasing the investment in the physical parts of the grid means that PassKey is a much more quickly deployable solution than having to go into the field to build new transmission and distribution lines.

"Our ultimate solution should be to upgrade the entire grid, but in reality, that is going to take a very long time to accomplish across the country. So, what should we do as a practical alternative? Our power solution can quickly ramp up and meet this gap by minimizing grid upgrades and provide affordable and convenient electricity services to end customers."

- Kyungyeol Song, Ph.D., COO of PassKey.

Keeping Up With EV Evolution In The Not-Too-Distant Future.

THE CURRENT CONTEXT

The U.S. grid relies more and more on electrons emitted by intermittent resources like solar and wind power which poses a challenge in the near future now that electric vehicle adoption is peaking.

SOLUTIONS POWERED BY TECHNOLOGY

To improve grid reliability, PassKey offers a solution that combines the use of **Energy Storage Systems (ESS)** powered with the latest technology in **AI** to predict the best times to offload and store power from renewables, ensuring EV fleets can recharge their batteries without overstressing the grid.

Applied to electric vehicles, PassKey's smart charging solution could allow large EV fleets to charge their batteries with clean power at the lowest possible prices, without overstressing the grid even during peak hours. So much so that EverCharge, an EV charging company PassKey acquired last year, recently partnered with car rental company Avis Budget Group to deploy EV charging stations at the George Bush Intercontinental Airport in Houston. EverCharge's unique AI-powered stations can analyze the charging patterns of EVs to intelligently allocate available power based on the individual vehicle's need. Following the launch at the Houston airport, Avis Budget Group and EverCharge plan to extend their partnership to additional U.S. airports this year.

Besides PassKey and longer-term infrastructure upgrades to power lines and equipment, Dr. Song says there are two other critical components in which to invest. The first of these is microgrids, the interconnected, distributed electrical networks of loads and clean, decarbonized power generators that can act independently from the broader grid and boost reliability and resilience against wider disturbances.[28]

The second is battery technology development. Current lithium-ion batteries can usually only discharge reliably for four hours with a full charge. Developing longer duration batteries that can last for eight hours or even a day before recharging would significantly improve the utility of renewably sourced power.

The U.S. grid is an extremely complex system. Modernizing and preparing it to supply significantly more electricity demands a multi-pronged approach. We must combine the research, development and deployment of technologies like PassKey's power solution.

"Adding more and more renewables and EVs without modernizing the grid through better design, energy storage and AI could undermine the important shift to an emissions-free electric grid," Dr. Song says. "It will make demand supply balancing much more challenging and exacerbate existing grid instability."

Such a scenario can be avoided with innovations like the one developed by PassKey. Working in concert, that and other grid innovations will put the U.S. and the world on the road to a better all-electric future. This will supercharge the deployment of a green economy, help citizens attain a higher quality of life and, through electrification, take a significant step toward addressing climate change. It's a major effort, and SK and SK E&S are committed to meeting this better future by developing solutions that make our aspirations for a stronger tomorrow a reality.

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