THE RAY

TRANSPORTATION + ENERGY SMART POWERED HIGHWAYS

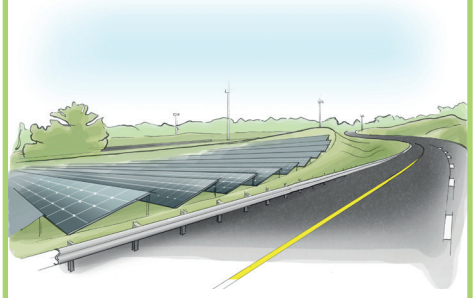
2020

EXECUTIVE SUMMARY

The future of transportation is electric and will increasingly be powered by batteries and fuel cells. In the US, 18.7 million electric vehicles (EVs) are expected to be on the roads by 2030.[1] To enable this electric future, we need to modernize our energy infrastructure – generation and transmission – to deliver exponentially more power to meet unprecedented demand in the transportation sector. It must generate and deliver the power to quickly charge EVs, or generate clean hydrogen, where and when we need it. Our current electricity grid is underpowered for the electric transportation future. Additionally, opportunities exist to significantly increase the climate resiliency of the grid and to develop a national grid by strengthening the interconnections between existing regional grids. As we modernize our grid, we have the opportunity to power it with more renewable energy, and to charge EVs with cost-effective clean energy.

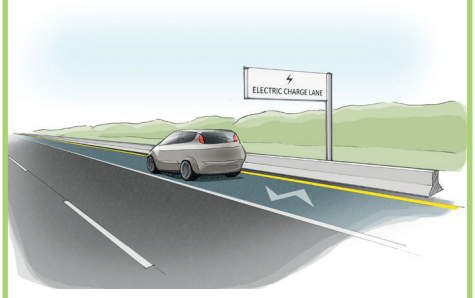
We can accomplish this by making the most of the publicly owned interstate system through three major developments:

Use the state-owned land along our interstates to generate renewable energy.



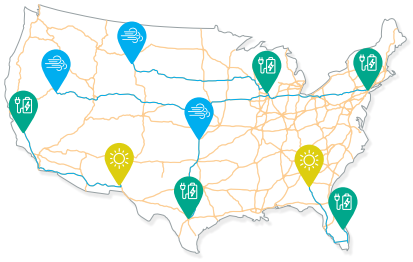
We could generate up to 36 TWh annually just by installing solar panels at interstate interchanges. This is enough to power up to 12 million EVs and represents an opportunity of $4bn annually for State DOTs.[14] This figure could be further increased by installing solar panels along other areas of the right of way (ROW).

Use this renewable energy to charge EVs on the interstate.



Wireless charging lanes and direct current fast chargers allow fast and convenient EV charging. By using the energy close to where it is generated, we create a more efficient system that could improve the financial case for investment in both renewable energy and EV charging infrastructure.

Use our interstate system to build national high-voltage direct-current (HVDC) grid.



Burying HVDC lines along our interstates increases the resiliency of our grid and enables greater use of our solar and wind resources. A truly national grid would create a coast-to-coast market for our nation's abundant renewable resources – much as the original interstate system did for physical goods in the 1950s.

As lower battery costs and new policies continue to increase EV ownership over the next ten years, State DOT revenue from taxes on gasoline and diesel fuel will decline steadily. State DOTs can generate new and diversified sources of revenue and accelerate the transition to an electric future by leveraging the publicly owned asset that is our interstate system.

When we seize these opportunities at scale, we can transform unused land that requires regular maintenance into a more productive area that may also be a new source of revenue for funding infrastructure and initiatives.[15] We can stimulate economic growth and create local jobs. We can accelerate the transition to a smart and electrified transportation system. And we can build energy infrastructure that is more secure and resilient to threats, that is more reliable for our communities and our economy, and that is both cleaner and more cost-efficient.

OUR CURRENT ELECTRICITY GRID IS HOLDING BACK CLEAN MOBILITY

Our electricity grid is a remarkable feat of engineering. It provides reliable power across the country, keeping our lights on and our refrigerators cool 24/7. However, it is not ready for the future of electric vehicles (EVs) and renewable energy.

18.7 million electric vehicles are expected to be on US roads by 2030.[1] Our grid is not ready.

It is not national. Our electricity grid is really three separate grids – East, West, and Texas.[2] Referring to the nation's concentrations of renewable energy, such as the Southwest's solar, Ray C. Anderson wrote, "…there is no national 'highway system' of modern, high-voltage, direct-current, low-loss transmission lines to move that infinitely renewable power from where it can be created to where it is needed."[3]

"…there is no national 'highway system' of modern, high-voltage, direct-current, low-loss transmission lines to move that infinitely renewable power from where it can be created to where it is needed." "The parallel with the highways and Ike is obvious." Ray C. Anderson

It is drastically underpowered for EV charging. Our grid reaches most places but without enough power to quickly charge an EV. Installing several fast EV chargers in one place can require an expensive local grid upgrade. For example, a single mega-charger for a Class 8 truck will draw the same amount of power as 1,200 homes. In an electrified future, a truck stop in a rural area will be asked to deliver 10,000-30,000 homes worth of power, although the electric grid may have been built for servicing only a handful of homes and businesses.[4]

It is becoming less efficient and stable. The grid currently loses power 285% more often than it did in 1984.[5] Extreme weather events have contributed to this, as well as unexpected and sudden changes in supply or demand.[6] A modern grid must manage the natural intermittency of renewables, be designed for changing demand profiles, and be resilient to emergencies such as extreme weather, and physical and digital attacks.

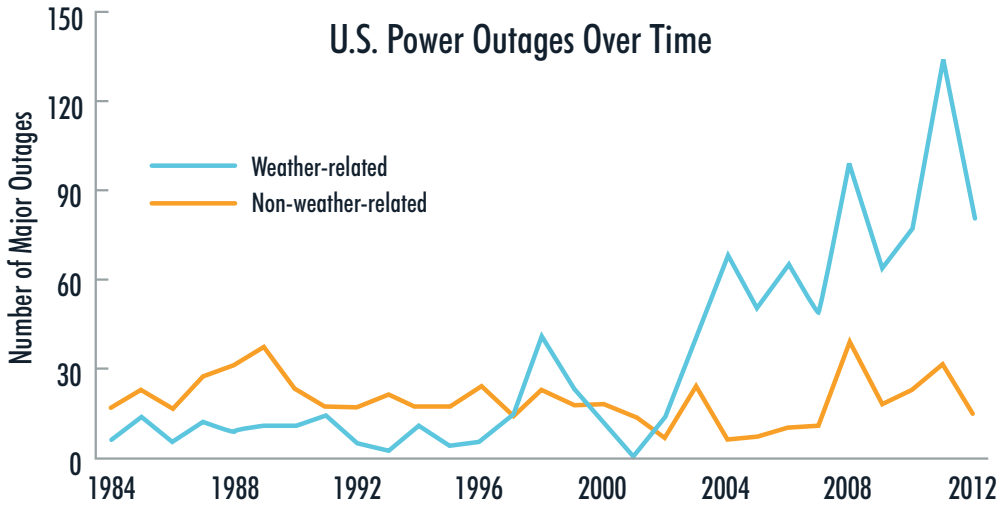


Image reference: Graph courtesy of Climate Central, Kenward, A., & Raja, U. (2014). Blackout: Extreme weather climate change and power outages. Climate central, 10, 1-23.

THE TECHNOLOGIES TO MODERNIZE OUR GRID ARE HERE TODAY

The Southern United States has solar power. The Northwest has hydropower. The Dakotas have wind power. But our grid today, which is mostly alternating current (AC), cannot efficiently transmit this power over long distances. However, a **high-voltage direct current (HVDC)** grid can. When we transmit power further than several hundred miles (the size of a weather system), we can dramatically smooth out natural fluctuations in wind and solar power. During the day it is usually sunny somewhere, and at night it is often windy, which offsets the lack of solar power.

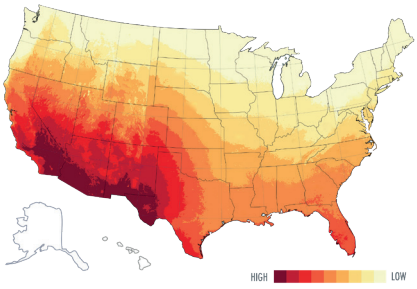
Furthermore, HVDC power lines take up less space than the AC lines that are typically used. They can be buried underground, eliminating the visual disturbance and making the grid more resilient to malicious attacks and extreme weather events.[8,9]

As well as long distance transmission, energy storage can also help to balance the grid and smooth fluctuations in renewable energy. As battery technologies continue to improve, grid-connected **energy storage** is becoming financially viable. Batteries can store intermittent renewable energy, and respond immediately when, for example, a freight truck plugs in to charge.[12]

Studies have also found that installation of a nationwide HVDC transmission system will reduce both electricity costs and carbon emissions.[7,8] But the scale of building a national "HVDC super-highway system" is often likened to the building of the interstate system by President Eisenhower in the 1950s.[8,9]

We currently have a few HVDC links in our grid, such as the Pacific DC Intertie line that connects the Northwest's hydropower with Southern California.[10] But there are no East–West links and no national network. Political and logistical hurdles associated with dealing with multiple utilities, state governments, and landowners are getting in the way of new HVDC lines.[11]

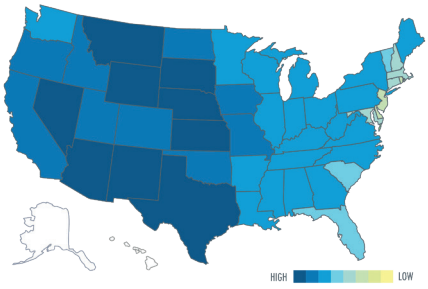
Solar Potential



Global Horizontal Solar Irradiance: Annual average daily total solar resource. Image adapted from NREL.

Image reference: *Sengupta, M., Y. Xie, A. Lopez, A. Habte, G. Maclaurin, and J. Shelby. 2018. "The National Solar Radiation Data Base (NSRDB)." Renewable and Sustainable Energy Reviews 89 (June): 51-60.*

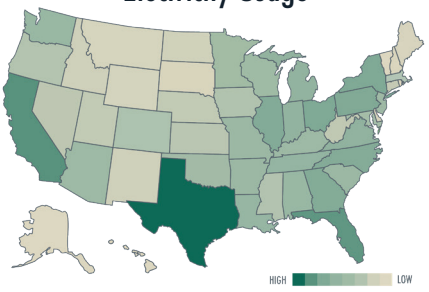
Wind Potential



U.S. Potential wind capacity at 80 meters. Image adapted from WINDExchange

Image reference: *WIND Exchange, "U.S. Installed and Potential Wind Power Capacity and Generation", U.S. Department of Energy, Site visited August 2020, https://windexchange.energy.gov/maps-data/321*

Electricity Usage



Electricity sales to ultimate customers in 2018

Data reference: *U.S. Energy Information Administration. Electric Power Annual 2018. Indepedendent Statistics & Analysis U.S. Department of Energy. Washington D.C. 2019, https://www.eia.gov/electricity/annual/pdf/epa.pdf (accessed September, 2020)*

By investing in a truly national grid, we can smooth out the intermittency of renewables, optimize the location of renewable energy projects and move electricity from where it's created to where it's needed.

OUR INTERSTATES COULD BE OUR FUTURE ENERGY SYSTEM

1. USE THE STATE-OWNED LAND ALONGSIDE OUR INTERSTATES TO GENERATE RENEWABLE ENERGY.

Our interstates are built on state-owned land known as the right of way (ROW). The ROW typically includes interchanges, medians, exits, and rest areas that the State DOT must maintain at substantial cost.[13] In work commissioned by The Ray, the Webber Energy Group at UT Austin has estimated that installation of solar panels at interstate exits could generate up to 36 TWh of solar power each year. This is enough to power up to 12 million EVs annually[14] and is just the beginning. Even more power could be generated by leveraging other areas along the interstates for solar development, such as rest stops, visitor centers, and parking facilities.

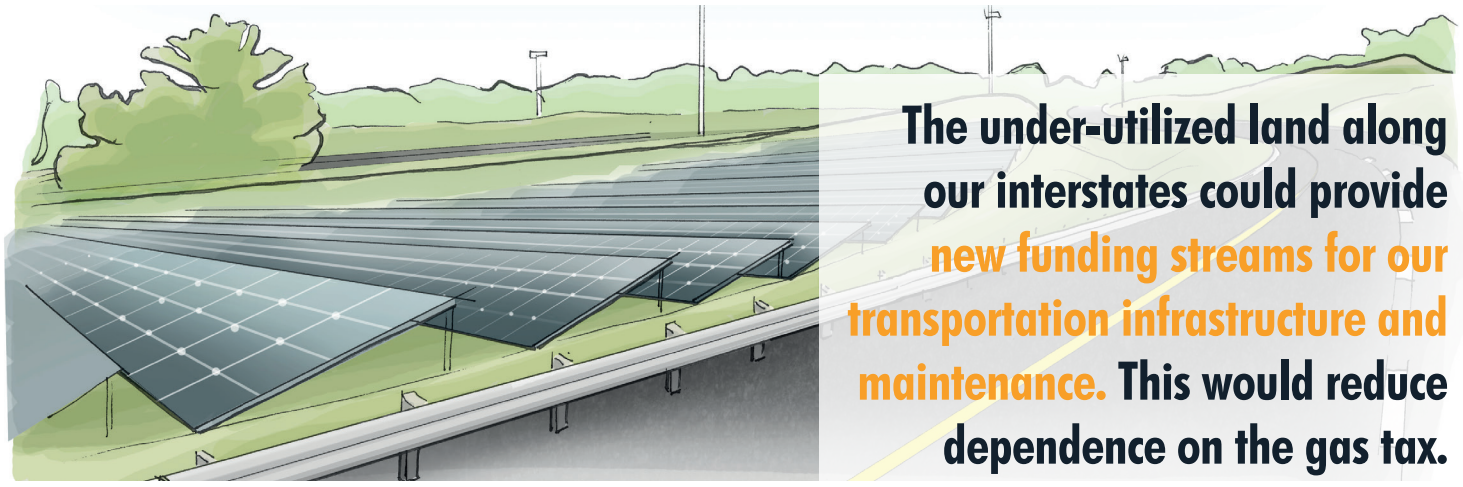
The Ray and Georgia Power have demonstrated this potential with the Southeast's first ROW solar project. The one-megawatt installation includes nearly 2,600 high-efficiency solar panels behind a safety setback from the travel lanes, crash barrier, and safety fencing at Exit 14 on Interstate 85 in Georgia.[16] Solar power can also be incorporated into roadside noise barriers,[17] or even on the road surface itself.[18]

Today's interstate roadside is unsuitable for farming due to contamination from road debris, pollution, and stormwater run-off. Using this land to host renewable energy infrastructure has the potential to reduce pressure to turn existing arable and ecologically sensitive land over to solar farms. And ROW land is usually closer to an existing suitable grid connection, even before we've built a next-generation grid along our highways.

Furthermore, the cost of wind and solar power is approaching the cost of electricity from the grid ('grid parity') in many states. Renewables are outcompeting most fossil fuels on cost on the open market[19], while also offering better resiliency, reliability, and security,[20] and the financial case for renewable energy projects is getting better and better.

We desperately need to invest in our crumbling infrastructure. States have typically relied on the gas tax or road tolls to fund transportation infrastructure. But revenue from the gas tax will decline as EVs become more common. Other revenue alternatives include annual fees for EV drivers, congestion pricing, and a road usage charge.

But we're currently missing an opportunity. Our states have an increasingly valuable asset that they are not using – ROW land. If they harness this land to generate renewable energy, they can generate new revenue streams from land fees, negotiate lower energy costs, and benefit from renewable energy credits. This new revenue could help fund modernized transportation infrastructure and maintenance and reduce the need to raise other taxes on transportation.



Putting solar panels on the ROW could generate enough energy to power 12 million EVs annually

2. USE THIS RENEWABLE ENERGY TO CHARGE EVs.

We can use this renewable energy right there on the interstate, to charge EVs through wireless charging lanes and fast chargers at exits and rest areas. We can also use it to generate hydrogen through electrolysis and store it in batteries to create resilient local microgrids. We build a more efficient system where energy is used close to where it is generated and improve the financial case for investments in renewable energy, EV charging, and hydrogen infrastructure.

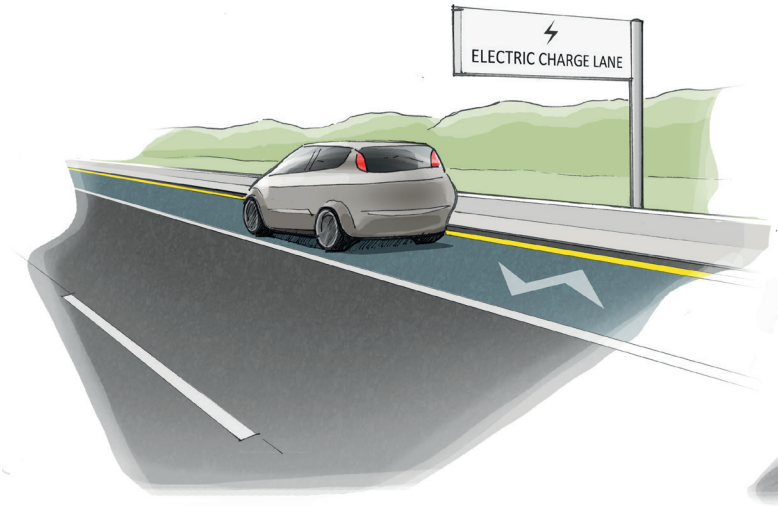
Less need for local grid upgrades. We can install fast EV chargers and wireless charging lanes, powered by ROW energy and storage, without costly and commercially complex upgrades to the local grid.[21]

A higher price for our renewable energy. The value of electricity delivered to an EV at high power or on the move is significantly higher than the wholesale cost of electricity on the grid.[22] Of course, the delivery requires additional infrastructure investments, but companies are starting to realize that providing this value-added service to EV owners could, in the future, be a more attractive investment than grid-connected renewables.[24]

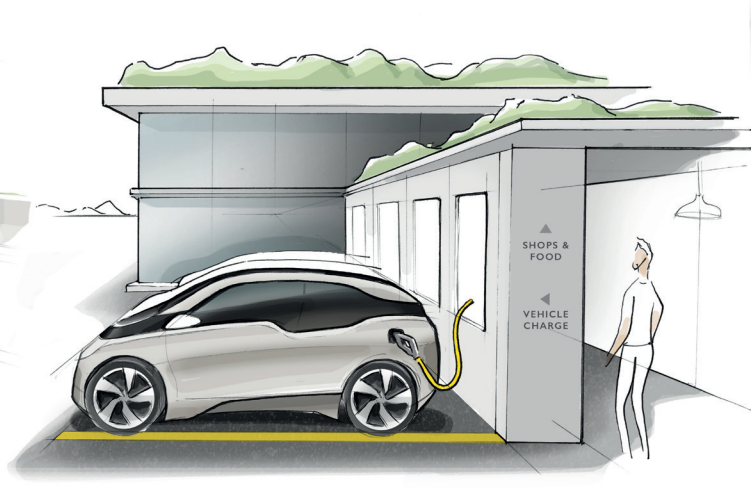
Charging EVs with renewable energy makes both economic and environmental sense.

A more efficient system. The electricity generated travels a short distance, reducing transmission losses. Solar panels generate direct current – EVs need direct current to charge quickly. Research is ongoing into highly efficient EV-charging microgrids, which connect solar panels directly to EV chargers with no use of alternating current, reducing conversion losses.[23]

Companies in the UK have recognized the commercial opportunity of building renewable energy microgrids for charging EVs. They are investing in 'electric forecourts' that offer a 'totally new customer-focused charging, retail, and services offering'.[24] The investment will include fast EV chargers, solar power generation, and energy storage. Revenue will come from EV charging and retail, among other services, and from using the storage capacity to provide flexibility services to the grid. These subsidy-free ventures are expected to undercut the charging price of competing facilities that are simply connected to the grid.[24]

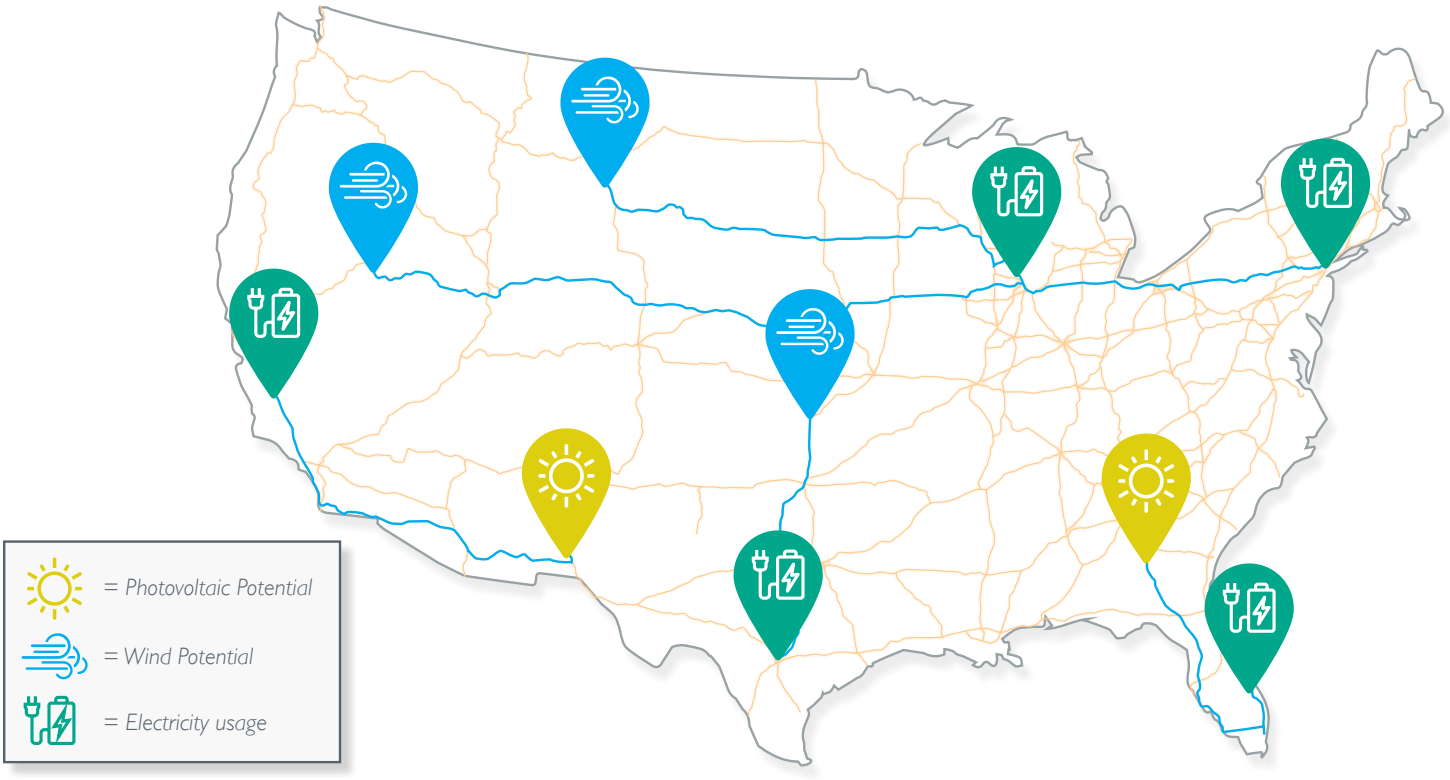


Wireless charging lanes will charge vehicles on the move.



Next-generation fast chargers will recharge an EV in just a few minutes.

3. USE OUR INTERSTATE SYSTEM TO BUILD A NATIONAL HIGH-VOLTAGE DIRECT-CURRENT (HVDC) GRID.



One of the main barriers to a national HVDC transmission network is the complex planning process and the need to negotiate with multiple landowners. **Our interstates could enable a national HVDC grid:**

- The interstate system is **national**. It is a natural grid system because it was built to **connect** communities where we live and work – and need energy ('points of demand').
- **Buried** HVDC cables along the state-owned ROW would avoid negotiations with multiple landowners, eliminate any visual disturbance, and make the grid more resilient to malicious attacks and extreme weather.[8,9]
- The ROW has the potential to generate significant amounts of **renewable energy** that could be fed into the modernized grid.[14]
- DC power conversion from large voltages to smaller, more usable voltages, is advancing rapidly, driven by developments in solid-state devices. Branching off of regional and coast-to-coast HVDC transmission lines with converter stations will support multiple DC systems along the interstate system – renewable energy generation on the ROW; the fast-charging of electric trucks and vehicles; powering the production of hydrogen for fuel cells; and battery storage. Policies that support and enable HVDC transmission must anticipate and accommodate future DC power-conversion technology and the localized integration of resources it will enable.

A national HVDC grid would create a coast-to-coast market for our nation's abundant renewable resources, much as the original interstate system did for physical goods in the 1950s. It would supply our cities with renewable energy through a system that naturally connects them. It would support the electrification of our transportation system. And the deployment of HVDC grid in the ROW could provide yet another revenue-generating opportunity for State DOTs who negotiate a land fee or pursue other arrangements, like a resource share.[15]

Our interstates could be our future energy system. More powerful. More efficient. Resilient to extreme weather.

EVERYONE WINS FROM THE CLEAN MOBILITY REVOLUTION

Our country and our states

- We transform the interchanges, medians, exits, and rest areas of our interstates from a liability that requires regular maintenance into a valuable asset that generates new revenue – and more transportation funding – for our states.
- We generate revenue from ROW land to help State DOTs diversify their income portfolios and make up for some of the lost revenue from the gas tax as EVs are adopted. This revenue can be used to help fund infrastructure modernization and maintenance.
- We enable the trade of our abundant renewable resources across the nation.
- We reduce our dependence on fossil fuels.

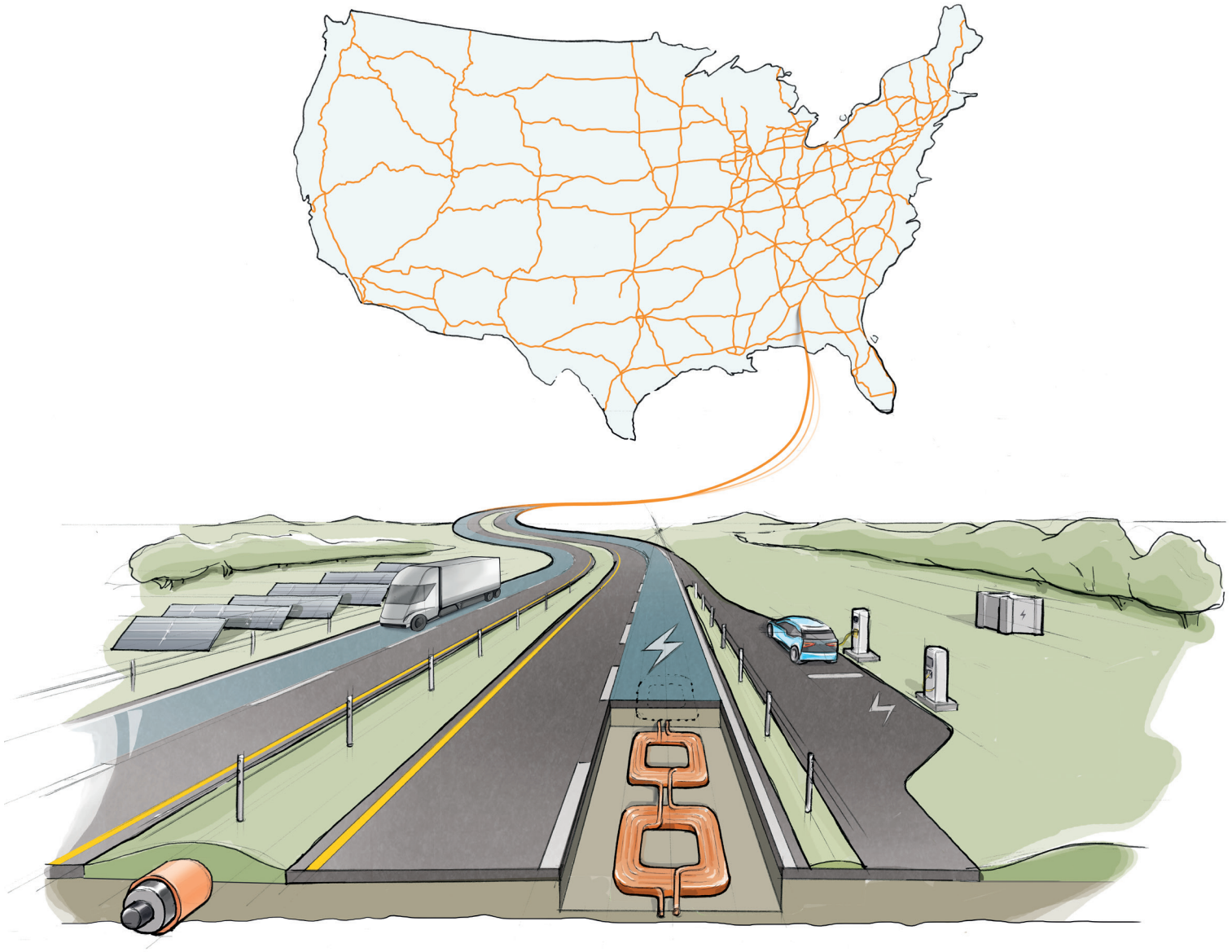
Investors and entrepreneurs

- We improve the financial case for investments in renewable energy and accelerate the energy transition.
- We enable a host of business opportunities, from the EV owner who can profit by selling their battery capacity to the grid, to the large-scale energy investor, to the entrepreneur providing value-added services alongside "electric forecourts" like those being developed in the UK.[24]

Everyone

- We enable convenient electric travel across the country.
- We decrease the pressure to develop arable and ecologically sensitive land into solar farms.
- We power our transportation system with clean, local and renewable energy.
- We reduce air pollution (which shortens life expectancy).[25]
- We create economic growth, and local jobs in the production and installation of renewable energy and EV charging infrastructure.
- We facilitate the decarbonization of transportation and energy.
- We create a more stable, secure, and efficient electricity grid that we can rely on.
- We connect our communities with clean and renewable energy.

VISION OF SMART POWERED HIGHWAYS



LET'S DRIVE THE ELECTRIC FUTURE.

THE CLEAN MOBILITY REVOLUTION IS HAPPENING IN GEORGIA

Georgia is a sunny state. Here, solar energy is booming through market forces.

Hanwha Q CELLS has opened a solar panel assembly plant in Georgia, and SK Innovation has opened a lithium ion battery factory.[27,28] The benefits of these ventures are already being felt in the region. Hanwha Q CELLS' new plant is reducing lead times for the state's numerous solar projects and is allowing solar panels to be purchased tariff free.[29] And both projects create thousands of new jobs, but also attract other suppliers to the region.[28]

The boom in renewable energy is attracting big businesses to the state, including companies like Facebook, Johnson & Johnson, and Walmart.[30,31] They have found that in Georgia, they can meet their clean energy commitments and look after their bottom lines. These solar projects and businesses boost tax revenues and support our public services.[31]

"We have to have access to 100% renewable energy for our facilities. If we're unable to achieve that, we won't locate in that region" — Paul Clements, director of energy and infrastructure at Facebook

And we could do even better. Many of our current solar projects are built on farmland. But the unused land at our interstate exits in Georgia has the potential to generate over 1.2 TWh, representing a $140 million per year opportunity.[14] The state owns this land. The revenue it could generate would help Georgia DOT to diversify its income streams for funding ambitious transportation projects, like the Interstate 75 truck-only lanes.

We would also create a range of opportunities for local investors and entrepreneurs. Investments in solar power. Investments in charging infrastructure. Retail opportunities at 'electric forecourts'. And jobs in installing and maintaining our renewable energy infrastructure.[31]

Georgia has a vibrant community of innovators supporting the transition to an electric future. Georgia Tech is advancing smart grids, developing new technologies for energy generation and energy storage, and optimizing the economics of clean energy.

*Georgia has an **abundance of solar energy**. If we invest in it, the benefits just keep coming. We can **attract business** to the state. We can create **local jobs**. We can build a more **reliable grid** and benefit from **affordable, renewable power**. We can make Georgia the **best state in the US to own an EV.** We create a more robust and **diverse economy**. **Georgia has the potential to lead the world in the clean mobility revolution. Let's make it happen.***

The Ray is a 501(c)3 nonprofit foundation and an 18-mile corridor of I-85 in southwest Georgia that provides a proving ground for the evolving ideas and technologies that will transform our transportation infrastructure. Zero carbon. Zero waste. Zero deaths. Visit theray.org for more information.

@TheRayHighway

#DriveTheFuture #RideTheRay

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Our current electricity grid is holding back the clean mobility revolution

1. A 2018 report produced by the Edison Electric Institute predicts the number of EVs on the road in the USA by 2030 to be 18.7 million, or approximately 7% of all vehicles. The report also suggests that around 9.6 million charging ports will be required to support this level of EV uptake. Cooper, Adam; Schefter, Kellen, *Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030*, Washington, D.C.: Edison Electric Institute, Nov 2018.

2. The current continental US electricity grid consists of three interconnections: The Eastern Interconnection consisting of 36 balancing authorities, The Western Interconnection consisting of 37 balancing authorities and the Electric Reliability Council of Texas (ERCOT) consisting of a single balancing authority. Hoff, Sara, "U.S. electric system is made up of interconnections and balancing authorities", *Today in Energy,* 20 July 2016, https://www.eia.gov/todayinenergy/detail.php?id=27152.

3. "Our current grid limits where renewable energy can be generated and transported, and making changes to the existing grid means dealing with multiple stakeholders from state and local governments, as well as individual property owners." *Anderson, Ray. Confessions of a Radical Industrialist: How Interface proved that you can build a successful business without destroying the planet. Random House, 2010.*

4. Putnam, M. (2020). *NextGen Highways: Co-Locating the Transport of Vehicles, Energy, and Information* [White paper]. NGI Consulting. https://19fgew3zyb632ma8181lw82b-wpengine.netdna-ssl.com/wp-content/uploads/2020/09/NextGen-Highways-Sept-22nd.pdf

5. A 2016 report from The Lexington Institute found that the USA has more blackouts each year than other developed countries and loses power 285% more often today that it did in 1984. Barrett, J. M.. *Challenges and requirements for tomorrow's electrical power grid.* Arlington, VA: Lexington Institute, June 2016. https://www.lexingtoninstitute.org/wp-content/uploads/2016/09/Tomorrows-Electrical-Power-Grid.pdf.

6. A 2014 report from the NREL showed that the number of weather-related power outages has been increasing (on average) for the past two decades. NREL, *Distributed Solar PV for Electricity System Resiliency: Policy and Regulatory Considerations.* Denver, CO: NREL, Nov 2014. https://www.nrel.gov/docs/fy15osti/62631.pdf.

The technologies to modernize our grid are here today

7. A 2016 article published in Nature Climate Change found that the proportion of renewables could be dramatically increased without an increase in the levelized cost of electricity if a national system of HVDC transmission was enabled. By making the network larger than a weather system, wind and solar could be used more reliably. It was estimated that this could reduce CO2 emissions by 80%. *MacDonald, Alexander E., Christopher TM Clack, Anneliese Alexander, Adam Dunbar, James Wilczak, and Yuanfu Xie. "Future cost-competitive electricity systems and their impact on US CO 2 emissions." Nature Climate Change 6, no. 5 (2016): 526. (b)*

8. Many reputable sources including ABB (a), The IEA (b), and The NREL have written about the many environmental and economical advantages that HVDC offers. (a) ABB, "Technical Advantages [Why HVDC]", *ABB,* site visited June 2019. https://new.abb.com/systems/hvdc/why-hvdc/technical-advantages, (b) Vaillancourt, Kathleen, *Electricity Transmission and Distribution,* April 2014. https://iea-etsap.org/E-TechDS/PDF/E12_el-t&d_KV_Apr2014_GSOK.pdf, (c) NREL, "Interconnections Seam Study" found that for every one dollar invested in national HVDC, there is a one dollar to two dollar net benefits through lower energy costs. Site visited August 2020 https://www.nrel.gov/analysis/seams.html.

9. A report in the Washington Post from 2016 highlights the parallels between the interstate system and a future national HVDC network. Both require (required) significant planning and investment and both are (were) important to the commercial and military wellbeing of the US. However, it is the authors' opinion that the development and maintenance of an HVDC network should be private. MacDonald, Alexander. "Save the climate and protect America: Build an 'underground energy interstate' now", *The Washington Post,* 2 Jun 2016. https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/06/02/save-the-climate-and-protect-america-build-an-underground-energy-interstate-now/?noredirect=on&utm_term=.2b78cf181353.

10. An Energy Information Administration (EIA) report from June 2016 lists 21 existing HVDC projects in the USA, five of which are remote generator interconnectors. They range from 427 to 845 miles in length. EIA, *Assessing HVDC Transmission for Impacts of Non-Dispatchable Generation.* Washington, DC: U.S. Department of Energy, June 2018. https://www.eia.gov/analysis/studies/electricity/hvdctransmission/pdf/transmission.pdf.

11. The Plains and Eastern transmission line is a $2.5bn project, covering over 700 miles and designed to transport wind power from Oklahoma through Arkansas to Tennessee. In 2018 the DoE ended its partnership with Clean Line due to challenges associated with different governing bodies and landowners in the states that the line would pass through. Editors of Electric Light & Power / POWERGRID International, "DOE, Clean Line end partnership over wind transmission project", *Electric Light & Power,* 26 Mar 2018. https://www.elp.com/articles/2018/03/doe-ends-partnership-with-clean-line-wind-transmission-project.html.

12. A report from the Idaho National Laboratory (INL) emphasizes the importance of designing fast-charging stations that don't increase pressure on the grid and are robust to future developments. The use of solar PV generation and onsite energy storage is key in the central design of the report. A complementary article, also from the INL in 2017 highlights the importance of stationary batteries for EV charging. The battery could act as a buffer between the grid and a load. (a) Francfort, Jim *et al, Considerations for Corridor and Community DC Fast Charging Complex System Design,* Idaho Falls, ID: Department of Energy, May 2017. https://avt.inl.gov/sites/default/files/pdf/reports/DCFCChargingComplexSystemDesign.pdf. (b) Hatch, Corey, "Idaho scientists help pave the way for faster-charging electric vehicles", *Idaho National Laboratory,* 23 Oct 2017. https://inl.gov/article/electric-vehicle-research/.

Our interstates could be our future energy system

Use the state-owned land alongside our interstates to generate renewable energy

13. This report looks at the average costs of vegetation control along roads in Michigan and Ohio. Adams, Theresa M., *Estimating cost per lane mile for routine highway operations and maintenance.* Midwest Regional University Transportation Center, Jan 2011. http://www.wistrans.org/mrutc/files/CPLM_Final.pdf.

14. A study commissioned by The Ray and carried out by researchers at the Webber Energy Group at UT Austin found that installation of solar panels at interstate interchanges and rest areas could generate significant amounts of power for the United States. Placing solar panels on exits alone is estimated to generate 36 TWh annually. Insufficient data on land available at rest areas prevented the calculation of energy generation potential for this land. (a) Beagle, Emily A., Richardson, Kelsey J., Rhodes, Joshua D., Webber, Michael E.. The Ray Solar Highway Project:

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15. A 2020 FERC report "Report on barriers and opportunities for high voltage transmission" found that "lease payments from infrastructure development in these corridors would be used to fund state energy efficiency initiatives and economic incentives for renewable energy development." https://cleanenergygrid.org/wp-content/uploads/2020/08/Report-to-Congress-on-High-Voltage-Transmission_17June2020-002.pdf.

16. The Ray, in partnership with the Webber Energy Group at UT Austin and Georgia Power, has demonstrated the ability to leverage the ROW land to generate renewable energy through the installation of solar panels. This project uses the land that is currently unused at exit 14 on the I-85 in Georgia. Cullen, Anna, "The Ray partners with the University of Texas, Austin on right of way solar research", *The Ray,* 18 Jun 2018. https://theray.org/2018/06/18/ray-partners-ut-austin-right-way-solar-research/.

17. The Dutch government has announced that it will hold a tender for a utility-scale solar project that will incorporate solar noise barriers that rely on a bifacial module (a panel that can absorb energy from both faces), for improved energy generation capacity. Bellini, Emiliano, "Dutch government launches tender for utility-scale solar noise barrier", *pv magazine,* 20 Aug 2018. https://www.pv-magazine.com/2018/08/20/dutch-government-launches-tender-for-utility-scale-solar-noise-barrier/.

18. Wattway is a company that has designed, developed and installed a patented PV road. They have a 66 m2 carpool area pilot in Narbonne (France). http://www.wattwaybycolas.com/en/.

19. A 2018 IRENA report found that onshore wind and solar PV are expected to consistently offer a less expensive source of new electricity than the least expensive fossil fuel alternative, even without financial assistance. These technologies are also expected to increasingly cost less than the marginal operating cost of existing coal fired power plants. IRENA, *Renewable Power Generation Costs* in 2018, Abu Dhabi: International Renewable Energy Agency, 2019. https://www.irena.org/publications/2019/May/Renewable-power-generation-costs-in-2018.

20. A brief published by ACORE has enumerated the many national security benefits of having renewable energy infrastructure. This includes considerations about supply chain, ease of deployment, grid resiliency, and cybersecurity. ACORE, *October 2018 Issue Brief: The Role of Renewable Energy in National Security,* American Council on Renewable Energy, 2018. https://acore.org/wp-content/uploads/2018/10/ACORE_Issue-Brief_-The-Role-of-Renewable-Energy-in-National-Security.pdf.

Use this renewable energy to charge EVs

21. A report from the Idaho National Laboratory (INL) emphasizes the importance of designing fast-charging stations that don't increase pressure on the grid and are robust to future developments. The use of solar PV generation and onsite energy storage are key in the central design of the report. A complementary article, also from the INL in 2017 highlights the importance of stationary batteries for EV charging. The battery could act as a buffer between the grid and a load. (a) Francfort, Jim *et al, Considerations for Corridor and Community DC Fast Charging Complex System Design,* Idaho Falls, ID: Department of Energy, May 2017. https://avt.inl.gov/sites/default/files/pdf/reports/DCFCChargingComplexSystemDesign.pdf. (b) Hatch, Corey, "Idaho scientists help pave the way for faster-charging electric vehicles", Idaho National Laboratory, 23 Oct 2017. https://inl.gov/article/electric-vehicle-research/.

22. At-home electricity typically costs $0.08–0.15/kWh, while Telsa superchargers have been recorded to cost $0.32–0.36/kWh in New York and California (Jan, 2019). (a) Smith, Margaret; Castellano, Jonathan, *Costs Associated with Non-Residential Electric Vehicle Supply Equipment,* US Department of Energy, Nov 2015. https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf. (b) Lambert, Fred "Tesla drastically increases Supercharger prices around the world (Updated)", electrek, 18 Jan 2019. https://electrek.co/2019/01/18/tesla-increases-supercharger-prices/.

23. The Idaho National Laboratory (INL) published a report in 2017 looking at considerations for DC fast-charging complexes. This work looks at possible deployment for such complexes in urban and rural environments and conducts cost analysis. Some implementations highlight the use of PV and battery storage to reduce pressure on the local grid. This was particularly important outside of urban areas (a). Work conducted at TU Delft shows how using direct PV to EV charging without conversion to AC could reduce conversion losses (b). (a) Francfort, Jim *et al, Considerations for Corridor and Community DC Fast Charging Complex System Design,* Idaho Falls, ID: Department of Energy, May 2017. https://avt.inl.gov/sites/default/files/pdf/reports/DCFCChargingComplexSystemDesign.pdf. (b) Mouli, Chardra. *Charging electric vehicles from solar energy; Power converter, charging algorithm and system design.* Diss. TU Delft. 2018. https://repository.tudelft.nl/islandora/object/uuid%3Adec62be4-d7cb-4345-a8ae-65152c78b80f.

24. In 2019 GRIDSERVE, a UK-based sustainable energy company, announced plans to develop more than 100 "Electric Forecourts" to deliver clean solar energy to ultrafast charging centers (speeds up to 500 kW), that will be subsidy-free. Centrica, a UK-based multinational energy company, announced a new solar-battery EV offering to offset the impact of electric vehicles on power demand. (a) GRIDSERVE, "100% Renewable Ultra Fast Charging", GRIDSERVE, Accessed Jun 2019. https://www.gridserve.com/electric-vehicle-charging, (b) Stoker, Liam, "GRIDSERVE unveils £1 billion 'Electric Forecourt' EV infrastructure programme", *Current±,* 29 Mar 2019. https://www.current-news.co.uk/news/gridserve-unveils-1-billion-electric-forecourt-ev-charging-programme, (c) Stoker, Liam, "Solar to play central role in new Centrica EV offering", *Solar Power Portal,* 28 May 2019. https://www.solarpowerportal.co.uk/news/solar_to_play_central_role_in_new_centrica_ev_offering.

Use our interstate system to build a national high-voltage direct-current (HVDC) grid

See references 7 and 8 above.

Everyone wins from the clean mobility revolution

25. The WHO has estimated 4.2 million premature deaths per year due to outdoor air pollution. WHO, "Air pollution", *World Health Organization,* accessed June 2019. https://www.who.int/airpollution/en/.

26. In 2018 an estimated 36,750 people died in motor vehicle crashes in the USA (a). Autonomous vehicles are expected to reduce the number of traffic accidents and fatalities by removing human error (b). (a) National Center for Statistics and Analysis, *Early estimate of motor*

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vehicle traffic fatalities for 2018, Washington D.C.: National Highway Traffic Safety Administration, June 2019. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812749, (b) EIA, *Autonomous Vehicles: Uncertainties and Energy Implications,* Washington D.C.: U.S. Department of Energy, May 2018. https://www.eia.gov/outlooks/aeo/pdf/AV.pdf.

The clean mobility revolution is happening in Georgia

27. Hanwha Q CELLS, a South Korean solar PV manufacturer, has completed construction on a 1.7 GW assembly plant, creating an estimated 500 jobs for the region. (a) Pickerel, Kelly, "Hanwha Q CELLS completes 1.7-GW panel assembly facility in Georgia" *Solar Power World,* 28 Feb 2019. https://www.solarpowerworldonline.com/2019/02/hanwha-q-cells-completes-1-7-gw-panel-assembly-facility-in-georgia/ (b) Georgia Department of Economic Development, "Solar cell manufacturer to create more than 500 jobs in Whitfield County", *Georgia USA,* 30 May 2018. https://www.georgia.org/newsroom/press-releases/solar-cell-manufacturer-to-create-more-than-500-jobs-in-whitfield-county.

28. The battery division of SK Innovation, a South Korean energy and petrochemical company, has recently started work on a battery factory in Jackson County, GA. The company is expecting to employ 2000 workers by 2025 (a). Officials in the Georgia Department of Economic Development believe that this project could be the start of a battery technology ecosystem that attracts suppliers to the region (b). (a) Trubey, Scott, "Massive Georgia battery plant to serve need for electric vehicles", *Atlanta Journal-Constitution,* 19 Mar 2019. https://www.ajc.com/business/economy/massive-georgia-battery-plant-serve-need-for-electric-vehicles/PNGkWFl0l2vOy3u4dZiDAK/. (b) Karkaria, Urvaksh, "Will Georgia land electric projects?", *Automotive News,* 10 June 2019, https://www.autonews.com/suppliers/will-georgia-land-electric-projects.

29. The vice president of technology at Silicon Ranch (a Tennessee-based solar farm) has stated that the reduction in lead times associated with having locally manufactured parts is good for business. Hsu, Andrea; Kelly, Mary Louise. "How Georgia Became a Surprising Bright Spot in the U.S. Solar Industry", *npr,* 24 June, 2019. https://www.npr.org/2019/06/24/733795962/how-georgia-became-a-surprising-bright-spot-in-the-u-s-solar-industry.

30. In 2018 Georgia Power announced plans to add 177 MW of new solar resources in partnership with Google, Target, Walmart and Johnson & Johnson. This program was designed to help the global businesses move towards their renewable energy targets and create growth in renewable energy sources in Georgia, while ensuring access to affordable and reliable energy for Georgia residents (a). Walmart is currently striving to become powered by 100% renewable energy by 2025, and recently worked with bill advocates to extend the maximum length of solar and wind contracts that rural utilities companies can enter with their customers. The length was extended from 10 years to 20 years (b). (a) Georgia Power, "Georgia Power to add 177 MW of solar resources for C&I REDI program", *PR Newswire,* 9 Apr 2018. https://www.prnewswire.com/news-releases/georgia-power-to-add-177-mw-of-solar-resources-for-ci-redi-program-300626410.html. (b) Golden, Sarah, "How Walmart boosted clean energy policy in Georgia", GreenBiz, 16 May 2019. https://www.greenbiz.com/article/how-walmart-boosted-clean-energy-policy-georgia.

31. Facebook has chosen to open a new data center in Georgia because of the access to affordable renewable energy (a). In conjunction with this, Silicon Ranch has committed to an investment in three solar projects in Early County, Georgia (b). This construction is expected to create 400 jobs. It's estimated that the projects will bring in $8 million in taxes, $5 million of which will go into the Early County school system (a). (a) Hsu, Andrea; Kelly, Mary Louise. "How Georgia Became a Surprising Bright Spot in the U.S. Solar Industry", *npr,* 24 June, 2019. https://www.npr.org/2019/06/24/733795962/how-georgia-became-a-surprising-bright-spot-in-the-u-s-solar-industry, (b) Wilson, Asia, "$150 million solar farm coming to Early Co., bringing 400 jobs", *WALBNEWS10,* 1 Mar 2019. https://www.walb.com/2019/03/02/million-solar-farm-coming-early-co-bringing-jobs/.